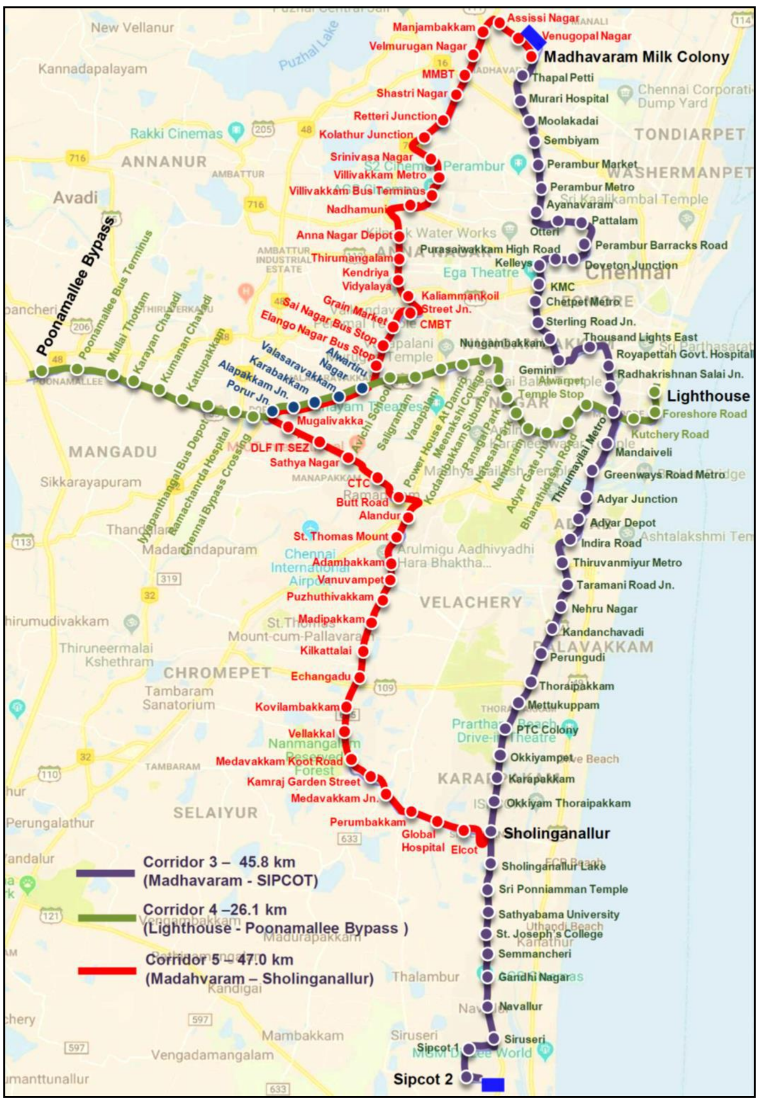
CHENNAI METRO RAIL LIMITED

Comprehensive Detailed Project Report for Chennai Metro Phase-II



DETAILED PROJECT REPORT

DECEMBER 2018

RITES
THE INFRASTRUCTURE PEOPLE
(A Government of India Enterprise)

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1 Standard Guage: 1435 MM

2 Route Length (Between Dead Ends)

Corridors	Elevated (Km)	Underground (Km)	Total Length (Km)
C-3 Madhavaram to SIPCOT	19.1	26.7	45.8
C-4 Lighthouse to Poonamallee Bypass	16.0	10.1	26.1
C-5 Madhavaram to Sholinganallur	41.2	5.8	47.0
		Total	**118.9**

3 Number of Stations

Corridors	Elevated Stations	Underground Stations	Total
C-3 Madhavaram to SIPCOT	20	30	50
C-4 Lighthouse to Poonamallee Bypass	18	12	30
C-5 Madhavaram to Sholinganallur	41 + 1 (At-Grade)	6	48
		Total	**128**

4 Traffic Forecast

Year	Max. PHPDT			Daily Boardings (in Lakh)				Daily PKM (in Lakh)			
	C3	C4	C5	C3	C4	C5	Total	C3	C4	C5	Total
2025	16,289	11,707	17,539	6.6	5.5	7.2	**19.2**	40.4	27.2	56.7	**124.3**
2035	22,115	18,944	24,528	10.1	9.3	13.2	**32.6**	49.3	44.2	88.3	**181.8**
2045	24,301	23,816	29,441	11.8	10.3	15.6	**37.7**	52.7	51.0	92.5	**196.3**
2055	27,361	29,940	35,714	13.6	11.4	18.5	**43.5**	56.4	58.9	96.8	**212.2**

5 Station Planning & Intermodal Integration

Six typical designs have been suggested for various station types and these will form basis for planning of all the 128 stations.

Type	Station Type	Size (sq m)	Levels	Construction Type
A	Elevated	140 X 21.95	2	Cantilever
B	Underground	190 X 21.80	2	Cut and Cover
C	Underground with Ext. Concourse	150 X 21.40	2	Cut and Cover
D	Underground	150 X 21.40	3	Cut and Cover
E	Elevated(split concourse)	140 X 32.35	-	RCC framed structure
F	Elevated(split concourse)	140 X 37.04	-	RCC framed structure

Parking at various Stations, Feeder Bus Services, Public Bicycle Sharing& Pedestrian facilities such as footpath etc. have also been proposed. The intermodal integration and passenger dispersal facilities have been planned for efficient passenger movement at all stations.

6 Intermodal Integration

Intermodal integration and dispersal facilities have been planned for efficient passenger movement. A total of 122, 164, 222 & 269 feeder buses and 809, 994, 1205 & 1397 public bi-cycles have been estimated for years 2025, 2035, 2045& 2055 respectively.

7 Speed

a) Design Speed : 80 kmph
b) Scheduled Speed : 32 kmph

8 Train Operation Plan

Train Operation	Items	Year 2025	2035	2045	2055
(1) Madhavaram - CMBT-Sholinganallur – Adyar - Madhavaram	Cars/ Train	3,6	3,6	6	6
	Headway in Sec.	514	514	514	514
	Trains/hr (3 Car, 6 Car)	7(4,3)	7(2,5)	7(0,7)	7(0,7)
(2) Madhavaram -Adyar-SIPCOT	Cars/ Train	3	3	3	6
	Headway in Sec.	600	600	600	600
	Trains/hr (3 Car, 6 Car)	6 (6,0)	6 (6,0)	6 (6,0)	6 (0,6)
(3) MMBT-CMBT-Sholinganallur	Cars/ Train	3,6	3,6	6	6
	Headway in Sec.	450	450	450	360
	Trains/hr (3 Car, 6 Car)	8(7,1)	8(3,5)	8(0,8)	10(0,10)
(4) Lighthouse - Poonamallee Bypasss	Cars/ Train	3	3,6	3,6	6
	Headway in Sec.	277	277	257	240
	Trains/hr (3 Car, 6 Car)	13(13,0)	13(6,7)	14(3,11)	15(0,15)

9 Fare Collection

Automatic Fare Collection System with recharging of Travel Cards using Cash, Debit/Credit Cards and Netbanking/web portal etc.

10 Rolling Stock

S. No.	Parameter	Rolling Stock
1	Basic Unit	3 Car basic unit 2 DMC and 1 TC. Every coach should be fully interchangeable with any other coach of same type.
2	Train Composition	3- Car: DMC + TC + DMC 6- Car: DMC + TC + MC + MC + TC + DMC Capable of GoA4 operation
3	Coach Dimensions	L= 22.6m, W=2.9m, H= 3.9m
4	Coach construction	Light weight Stainless Steel / Aluminum body
5	Axle load	≤16 T
6	Braking System	Regenerative Braking
7	Propulsion system	3 phase drive system with VVVF control
8	Type of traction supply	25kV AC OHE system

Rolling Stock Requirement:

Year	2025	2035	2045	2055
Total Coach Requirement	414	537	633	762

11 Power Supply System

a) Voltage: 25 KV OHE
b) Power Demand (MVA)

Name of RSS	Peak Demand- Normal (MVA)				Peak Demand – Emergency (MVA)			
	2025	2035	2045	2055	2025	2035	2045	2055
Manali GSS- Madhavaram RSS Chainage C3 0 to 5966 (5.966 km)								
Traction	3.51	4.00	4.25	5.60	4.88	5.78	6.38	7.97
Auxiliary	10.27	12.66	14.47	15.75	19.60	24.33	27.53	29.75
Total	13.78	16.66	18.72	21.35	24.48	30.10	33.91	37.72
GMR Vasavi GSS -Vasanthi RSS- C3 Chainage 5966 to 12362 (6.396 km)								
Traction	2.14	2.41	2.68	3.50	5.65	6.42	6.93	9.09
Auxiliary	9.33	11.67	13.07	14.00	19.60	24.33	27.53	29.75
Total	**11.47**	**14.08**	**15.75**	**17.50**	**25.25**	**30.74**	**34.46**	**38.84**

Name of RSS	Peak Demand- Normal (MVA)				Peak Demand – Emergency (MVA)			
	2025	2035	2045	2055	2025	2035	2045	2055
Mylapore GSS- YMCA RSS - C3- Chainage 12362- 19974 (7.612km)								
Traction	2.55	2.87	3.19	4.16	6.70	7.56	8.40	10.96
Auxiliary	9.33	11.67	13.07	14.00	18.67	23.33	26.13	28.00
Total	**11.88**	**14.54**	**16.26**	**18.16**	**25.37**	**30.90**	**34.53**	**38.96**
Tharamani GSS- Tharamani RSS - C3 - Chainage 19974- 32393 (12.419 km)								
Traction	4.15	4.69	5.21	6.79	6.70	7.56	8.40	10.96
Auxiliary	9.57	11.85	13.36	14.35	18.90	23.52	26.43	28.35
Total	**13.72**	**16.54**	**18.56**	**21.14**	**25.60**	**31.08**	**34.82**	**39.31**
Siruseri GSS – Siruseri RSS - C3 - Chainage 32393-44671 (12.278 km)								
Traction	2.20	2.33	2.44	4.05	6.35	7.02	7.65	10.84
Auxiliary	3.85	4.42	5.08	5.48	13.42	16.28	18.43	19.83
Total	**6.05**	**6.75**	**7.52**	**9.53**	**19.77**	**23.30**	**26.08**	**30.68**
Korattur GSS- Nadhamuni RSS - C5- Chainage 0-7186 (7.186 km)								
Traction	1.36	1.77	2.12	2.37	4.88	5.78	6.38	7.97
Auxiliary	3.97	4.84	5.51	5.95	14.23	17.49	19.98	21.70
Total	**5.33**	**6.61**	**7.64**	**8.32**	**19.11**	**23.27**	**26.35**	**29.67**
Thiruverkadu GSS – Mugalivakkam RSS - C5- Chainage 7186- 13366 (6.180km)								
Traction	2.46	3.24	3.90	4.42	6.34	8.36	10.05	11.39
Auxiliary	5.13	6.38	7.18	7.70	7.70	9.40	10.70	11.55
Total	**7.59**	**9.62**	**11.08**	**12.12**	**14.04**	**17.75**	**20.75**	**22.94**
Alandur GSS - St. Thomas RSS- C5 - Chainage 13366-23109 (9.743 km)								
Traction	3.88	5.11	6.15	6.97	8.59	11.33	13.62	15.44
Auxiliary	2.57	3.02	3.53	3.85	5.13	6.03	7.06	7.70
Total	**6.44**	**8.13**	**9.68**	**10.82**	**13.72**	**17.36**	**20.68**	**23.14**
Kadaperi GSS – Medavakkam RSS - C5- Chainage 23109-34947 (11.838 km)								
Traction	4.71	6.21	7.47	8.47	9.22	12.16	14.62	16.57
Auxiliary	2.57	3.02	3.53	3.85	5.13	6.03	7.06	7.70
Total	**7.28**	**9.23**	**11.00**	**12.32**	**14.35**	**18.19**	**21.68**	**24.27**
Mambakkam GSS-Perubakkam - C5- Chainage 34947-46272 (11.325 km)								
Traction	4.51	5.94	7.15	8.10	9.22	12.16	14.62	16.57
Auxiliary	2.57	3.02	3.53	3.85	5.13	6.03	7.06	7.70
Total	**7.07**	**8.96**	**10.68**	**11.95**	**14.35**	**18.19**	**21.68**	**24.27**
Kilpauk GSS - Panagal Park RSS – C4 - Chainage 0 to 7436 (7.691 km)								
Traction	2.45	3.62	4.40	5.36	8.39	12.41	15.10	18.38
Auxiliary	11.67	14.58	16.32	17.49	19.95	24.40	27.46	29.62
Total	**14.12**	**18.20**	**20.72**	**22.85**	**28.34**	**36.81**	**42.56**	**48.00**

Name of RSS	Peak Demand- Normal (MVA)				Peak Demand – Emergency (MVA)			
	2025	**2035**	**2045**	**2055**	**2025**	**2035**	**2045**	**2055**
Koyembedu GSS- Avicii School RSS – C4- Chainage 7436-25829 (18.38 km)								
Traction	5.94	8.79	10.70	13.02	8.39	12.41	15.10	18.38
Auxiliary	8.28	9.82	11.14	12.13	19.95	24.40	27.46	29.62
Total	**14.22**	**18.61**	**21.84**	**25.15**	**28.34**	**36.81**	**42.56**	**48.00**

c) SCADA System: Provided

12 Maintenance Depot

a) The Maintenance facilities for Corridor- 3 & 5 is proposed at Madhavaram Depot. The inspection and maintenance of the rakes of the two corridors can be done at Madhavaram Depot.

b) The Maintenance facilities for Corridor- 4 is proposed at Poonamallee Bypass Depot.

c) Minor Depot for Corridor-3 is proposed in SIPCOT with elevated stabling, inspection and washing facilities.

13 Signalling and Telecommunication

a) Type of Signalling: Communication based Train Control System (CBTC) with unattended train operation permitting an operational headway of 90 seconds.

b) Telecommunication: Integrated System with Optical Fibre Transmission System, SCADA, CCTV, Central Voice Recording System (CVRS) etc.

14 Total Estimated Cost (At December 2018 Prices) Without Taxes & Duties

Corridor-3 : Rs. 25,627 Crore
Corridor-4 : Rs. 13,076 Crore
Corridor-5 : Rs. 14,308 Crore
Total : Rs. 53,011 Crore

15 Total Estimated Cost (At December 2018 Prices) With Taxes & Duties

Corridor-3 : Rs.29,192 Crore
Corridor-4 : Rs. 14,761 Crore
Corridor-5 : Rs. 16,382 Crore
Total : Rs. 60,335 Crore

16 Completion Cost With Taxes & Duties

Total : Rs. 69,180 Crore (5% escalation)

17 Transit Oriented Development

Net cash flow from TOD cannot be estimated without considering market costs of land, approvals, development of public infrastructure etc. Quantification of these variables requires a detailed study which is beyond the scope of this DPR. Further, the share and form of TOD revenue which will flow into the Metro Project is a matter of policy to be decided by GoTN. However, for present analysis this is taken as 10% and the summary based on this is given below:

Particular	Total Revenues (in Rs. Crore)			
	2025	2035	2045	2054
Net Cash Flow from TOD	411	1155	2789	5816

18 Economic and Financial Indices

Construction Period: 6 years (starting from 2019)

Commencement of Commercial Operation: 2025-26

a) EIRR

Sensitivity	EIRR (%)
Basic EIRR	17.78
With increase in cost by 10%	16.47
With reduction in traffic materialization by 10%	16.90

b) FIRR

The FIRR for a project operation period of 30 years is given below:

Prices	FIRR
Constant Prices	4.01%
Current Prices	12.05%

EXECUTIVE SUMMARY

0.1 INTRODUCTION

Study Area for the Assignment is the administrative boundary of Chennai Metropolitan Area (CMA) covering Chennai city and parts of Tiruvallur and Kanchipuram districts with an area of 1189 sq. km. CMA comprises the City of Chennai, 16 Municipalities, 20 Town Panchayats and 214 Village Panchayats in 10 Panchayat Unions. As per Census 2011, the population of CMA and City area is 89.2 Lakh and 46.8 Lakh respectively. CMA and City areas have registered an annual growth rate of 2.4% and 0.8% in the decade from 2001-11.

Large-scale urbanization in IT/ITES and industrialization with rapid growth of vehicular population has laid severe stress on urban transport system in City. The City has about 48 lakh vehicles as per Tamil Nadu government vehicle statistics. The usage of private modes is increasing unabated mainly due to inadequate public transport facilities.

The Phase-I of Chennai Metro covers 54 km in two corridors - Washermenpet to Airport (23.085 Km), Chennai Central to St. Thomas Mount (21.96 Km) and extension from Washermanpet to Wimco Nagar (9 km) in Thiruvottriyur. A stretch of 10.7 km from Koyambedu to Alandur in Corridor 2 became operational from June 2015 and Little Mount to Airport (7.7 km) & Alandur to St. Thomas Mount (1.3 km) in Corridor 1 opened in September/October 2016. Further, sections from Thirumangalam to Nehru Park (8.0 km) in May 2017, Little Mount Station to AGDMS Station and Egmore to Chennai Central Station (7.3 km) in May 2018 are also under operations.

With a view of developing effective and efficient mass transit system in addition to the existing public transportation and Phase-I Metro rail system, a Feasibility Report for Phase II Corridors with a total length of 88.9 km was prepared by CMRL in 2015.

The Detailed Project Report for Chennai Metro Rail Phase-II Corridors for 107.55 km covering 3 corridors - C3, C4 and C5 was prepared in March 2017. Detailed Project Report for Extended C4 corridor (total length 26 km) was also prepared in October 2018. Govt. of Tamil Nadu through CMRL has engaged RITES Ltd. to prepare a comprehensive Detailed Project Report for complete Phase-II **(Figure 0.1).**

FIGURE 0.1: CHENNAI METRO PHASE-II CORRIDORS

0.2 EXISTING TRANSPORT SYSTEM

City level transportation demand is catered predominantly by Metropolitan Transport Corporation buses (MTC), Intermediate Public Transport System (IPT) in the form of shared services along major arterials and Commuter Rail System including elevated MRTS.

The Phase-I of Chennai Metro covers 54 km in two corridors - Washermenpet to Airport (23.085 Km), Chennai Central to St.Thomas Mount (21.96 Km) and extension from Washermanpet to Wimco Nagar (9 km) in Thiruvottriyur. A stretch of 10.7 km from Koyambedu to Alandur in Corridor 2 became operational from June 2015 and Little Mount to Airport (7.7 km) &Alandur to St. Thomas Mount (1.3 km) in Corridor 1 opened in September/October 2016. Further, sections from Thirumangalam to Nehru Park (8.0 km) in May 2017, Little Mount Station to AGDMS Station (7.3km) and Egmore to Chennai Central Station (7.3 km) in May 2018 are also under operations.

The MTC operates 830 routes with a fleet of about 3,720 buses in 2018. The MTC covers most of the CMA and even covers up to 50 km to places beyond CMA limit and carried over 50 lakh daily passengers.

0.3 TRAVEL DEMAND FORECAST

The travel demand model was made available to RITES by CMRL. Same basic set of assumptions including traffic zone system have been used for the demand forecasting for present study. The revision in Chennai Phase II metro network / stations in existing model have been carried out for horizon years.

Peak Hour Peak Direction Traffic (PHPDT) and daily boarding (including interchange passengers) for horizon years 2025, 2035, 2045 and 2055 for Phase-II corridors have been estimated and is presented in **Table 0.1.**

TABLE 0.1: TRAVEL DEMAND PROJECTIONS

Year	Max. PHPDT			Daily Boardings (in Lakh)			
	C3	C4	C5	C3	C4	C5	Total
2025	16,289	11,707	17,539	6.6	5.5	7.2	**19.2**
2035	22,115	18,944	24,528	10.1	9.3	13.2	**32.6**
2045	24,301	23,816	29,441	11.8	10.3	15.6	**37.7**
2055	27,361	29,940	35,714	13.6	11.4	18.5	**43.5**

The average trip length (in km) for various horizon years for Chennai Metro Rail Phase-II corridors is presented in **Table 0.2.**

TABLE 0.2: AVERAGE TRIP LENGTH

SN	Year	Trip Length (in km)		
		Corridor-3	Corridor-4	Corridor-5
1	2025	10.96	10.98	12.26
2	2035	11.34	11.24	12.29
3	2045	11.42	11.50	12.41
4	2055	11.42	11.77	12.41

0.4 SYSTEM & TECHNOLOGY SELECTION

Considering the PHPDT for design year and to maintain uniformity, it is recommended to adopt metro rail system for Chennai Metro Phase II.

0.5 CIVIL ENGINEERING

0.5.1 GEOMETRIC DESIGN PARAMETERS

TABLE 0.3: DESIGN PARAMETERS

Sn	Criteria	Dimension
1	Gauge	1435 mm
2	Design Speed	80Kmph
3	Maximum Axle Load	16T
4	Traction System	25 KV AC (OHE)

TABLE 0.4: HORIZONTAL CURVE PARAMETERS

Description	U/G Section	Elevated Section
Desirable Minimum Radius	300 m	200 m
Absolute minimum Radius	200 m	120 m
Minimum curve radius at stations	1000 m	
Maximum permissible cant (Ca)	110 mm*	
Maximum cant deficiency (Cd)	85 mm	
* The applied cant will be decided in relation to normal operating speeds at specific locations like stations/vicinity to stations.		

TABLE 0.5: TRACK CENTRE AND HEIGHT IN ELEVATED SECTION

Parameter	Minimum Track Centre	Minimum Rail Level above Ground Level
Mid-Section	4.00 m*	7.50 m**
Station w/o Scissor Cross-over	4.00 m	12.00 m

Parameter	Minimum Track Centre	Minimum Rail Level above Ground Level
Station with Scissor Cross-over	4.50 m	12.00 m

Note:
* Track centre in elevated section can be modified as per the choice of girder/superstructure. For Double U-girder minimum 4.90 m track centre will be provided.
** For I-girder and Box-girder, Minimum Rail Level above Ground Level shall be 8.50 m

TABLE 0.6: TRACK CENTRE AND DEPTH IN UNDERGROUND SECTION

Description	Minimum Track Centre	General Depth below Ground Level for 2 level stations	General Depth below Ground Level for 3 level stations
Running section by TBM	14.05 m	16.0 m	21.0 m
Running section by cut & cover except ramp	4.90 m	12.60 m	12.60 m
Stations by cut & cover and island platform	14.05 m	15.0 m	20.0
Stations by cut & cover and side platform	4.90 m	15.0 m	20.0
Stations by NATM	22.00 m	18.0 m	20.0

TABLE 0.7: GRADIENT PARAMETERS

Description	Desirable	Absolute Minimum
Gradient at Mid-Section	Upto2%	Upto 4% (compensated)
Gradient at Stations	Level	Upto 0.25%

TABLE 0.8: VERTICAL CURVE PARAMETERS

Parameter	Vertical Curve
Desirable Radius on Main line	2500 m
Absolute Minimum Radius on Main line	1500 m
Minimum Length of Vertical Curve	20 m

0.5.2 ENGINEERING SURVEY

Topographical Surveys for Chennai metro phase II Corridors were conducted based on differential GPS.

0.5.3 GEOTECHNICAL INVESTIGATIONS

In total, 237 Bore Holes (BHs) have been drilled for 30 m depth each, all along the length of proposed Metro alignment for Phase-II Corridors including depot locations. Strata parameters have been provided for tunneling. For all viaduct locations, since heavy loads are expected, shallow foundations are ruled out; either driven or bored cast in-situ piles preferably (bored ones) will have to be provided. For Depot Area, possibility of providing Open Foundation or Pile foundation has been explored. Since the proposed site is situated in seismic Zone III of the seismic zone map of India, suitable seismic coefficient commensurate to seismic Zone III (IS: 1893) should be adopted in the design of the structures.

0.5.4 ROUTE ALIGNMENT

0.5.4.1 Corridor-3: Madhavaram to SIPCOT

- Proposed alignment of Corridor-3 starts from Madhavaram Milk Colony as underground and heads in south direction upto SIPCOT. Total length of the corridor is 45.81 km including 19.09 km elevated and 26.72 km underground section. **(Table 0.9)**.
- **Switch Over Ramp**
  - Switch over Ramp (SWR) is required to provide transition from underground to elevated alignment after Tharamani Link road junction, on centre of Old Mahabalipuram Road (OMR) from Ch: 26124 m to Ch: 26543 m
- 50 stations have been proposed in Corridor-3 consisting of 20 elevated stations and 30underground stations.

TABLE 0.9: ALIGNMENT SUMMARY OF CORRIDOR 3

Alignment Type	From (m)	To (m)	Length (m)
Underground	-383	26124	26507
Switch over Ramp (-)8.0m to (+)7.5m	26124	26554	430
Elevated	26554	45430	18876
Total			**45813**

0.5.4.2 Corridor-4 : Lighthouse to Poonamallee Bypass

- Proposed alignment of Corridor-4 starts from Lighthouse as underground and heads in east direction upto Poonamallee Bypass. Total length of the corridor is 26.09 km including 16.01 km elevated and 10.07 km underground section. **(Table 0.10)**.
- **Switch Over Ramp**
  - Switch over Ramp (SWR) is required to provide transition from underground to elevated alignment after Meenakshi College, on centre of the Arcot Road from Ch: 9567 m to Ch: 10027 m.
- 30 stations have been proposed in Corridor-4 consisting of 18 elevated stations and 12 underground stations.

TABLE 0.10: ALIGNMENT SUMMARY OF CORRIDOR 4

Alignment Type	From(m)	To(m)	Length(m)
Underground	-255	9567	9822
Switch over Ramp (-)8.0m to (+)7.5m	9567	10027	460
Elevated	10027	25830	15803
Total			**26085**

0.5.4.3 Corridor-5: Madhavaram to Sholinganallur

- Proposed alignment of Corridor-5 starts from Madhavaram as underground and heads in south direction upto Sholinganallur. Total length of the corridor is 47.0 km including 41.17 km elevated and 5.83 km underground section. **(Table 0.11)**.
- **Switch Over Ramp**
  – Switch over Ramp (SWR) have been provided at three locations viz a viz. after Madhavaram station, second between Retteri junction & Kolathur Junction and third between Nathmuni & Anna Nagar Bus Depot.
- 48 stations have been proposed in Corridor-5 consisting of 41 elevated stations, 1 at-grade station and 6 underground stations.

TABLE 0.11: ALIGNMENT SUMMARY OF CORRIDOR 5

Alignment Type	From (m)	To (m)	Length (m)
Underground	-386	356	742
Switch over Ramp (-)8.0m to 0.0m	356	573	217
At-grade	573	1150	577
Elevated	1150	6653	5503
Switch over Ramp (+)7.5m to (-)8.0m	6653	7049	396
Underground	7049	11530	4481
Switch over Ramp (-)8.0m to (+)7.5m	11530	11920	390
Elevated	11920	46623	34703
Total			**47009**

0.5.5 UTILITY DIVERSION

TABLE 0.12: UTILITY RESPONSIBILITY DEPARTMENTS

SN	Organization/ Department	Utility Services
1	CMWSSB	Sewer Lines
2	CMWSSB	Water Lines
3	Aircel Optical Fibre Cables	Optical Fibre Cables
4	BSNL Optical Fibre Cables	Optical Fibre Cables

SN	Organization/ Department	Utility Services
5	Airtel Optical Fibre Cables	Optical Fibre Cables
6	Idea Optical Fibre Cables	Optical Fibre Cables
7	Reliance COM Optical Fibre Cables	Optical Fibre Cables
8	Jio Optical Fibre Cables	Optical Fibre Cables
9	Railtel Optical Fibre Cables	Optical Fibre Cables
10	Tata Optical Fibre Cables	Optical Fibre Cables
11	POWER GRID	Optical Fibre Cables
12	Vodafone Optical Fibre	Optical Fibre Cables and Copper Cables
13	TNEB	HT and LT Lines

0.5.6 LAND REQUIREMENT

The total cost of land including contingencies works out to be **Rs. 4469.03 Crore** for Corridor-3, **Rs. 3567.37 Crore** for Corridor-4 and **Rs. 2363.14 Crore** for Corridor-5.

TABLE 0.13: SUMMARY OF LAND REQUIREMENT (IN HA) FOR PHASE II CORRIDORS

Ownership	Purpose	Corridor 3, 4 & 5 (in Ha)		
		Permanent Land	Temporary Land	Structures (Floor area)
Central Govt	Alignment / Stations, ancillary buildings & Misc.	2.0377	0	0
	Total	**2.0377**	**0**	**0**
State Govt	Alignment / Stations, ancillary buildings & Misc. etc	8.5726	0	1.3656
	Depot	49.7	0	0.4008
	Parking cum PD	33.4268	0	0
	Casting Yard (Approx.)	0	120	0
	Total	**91.6994**	**120**	**1.7664**
Private	Alignment / Stations, ancillary buildings & Misc., RSS, etc	27.1931	0	39.3756
	Total	**27.1931**	**0**	**39.3756**
	Grand Total	**120.9302**	**120**	**41.142**

0.6 STATION PLANNING

0.6.1. Station Planning

The stations have been planned based on the following parameters:

a. Peak hour traffic load for each station.

b. 6 cars train.

c. The total evacuation time for the movement of all passengers in an emergency from platform level to the landing at the point of safety does not exceed 4.0 minutes for an enclosed station and 5.5 minutes for an open station (as per NBC 2016)

d. Compliance to the "Guidelines and space Standards for Barrier Free Built Environment for Disabled and Elderly persons" published by the Ministry of Urban Affairs and Employment India in 1998.

Typical designs have been suggested for various stations (**Table 0.14**) and these will form basis for planning of all the stations.

TABLE 0.14: TYPICAL DESIGNS

Type	Station Type	Size (sq m)	Levels	Construction Type
A	Elevated	140 X 21.95	2	Cantilever
B	Underground	190 X 21.80	2	Cut and Cover
C	Underground with Ext. Concourse	150 X 21.40	2	Cut and Cover
D	Underground	150 X 21.40	3	Cut and Cover
E	Elevated(split concourse)	140 X 32.35	-	RCC framed structure
F	Elevated(split concourse)	140 X 37.04	-	RCC framed structure

0.6.2. NMV and Pedestrian Facilities

Pedestrian facilities like continuous footpath of 2m wide, demarcation of pick and drop for PT/IPT, Zebra crossing at intersections, table top crossings, relocation of encroachments, strengthen of ROW have been proposed near the station influence areas for ease for pedestrian movement. For non-motorized vehicles, facilities like cycle tracks have been planned on the basis of land availability near the stationsfor seamless movement.

0.6.3. Accessibility for Differently-abled

The metro rail system should be user-friendly ensuring accessibility to persons with disabilities, people travelling with small children or are carrying luggage, as well as people with temporary mobility problems and the elderly persons. The standards are taken from 'Guidelines for Pedestrian Facilities' and 'NFPA Guidelines', 'Space Standards for Barrier Free Built Environment for differently-abled and Elderly Persons' and other standards.

0.6.4. Parking at Stations

Dedicated parking provision for commuters is one of the key factors determining success of the metro systems. Parking provisions along with priority to pedestrians through Foot Over Bridges and Bus feeder services will encourage more commuters to use the metro system who could safely park their vehicles at the nearest station, walk to the station or rely on feeder connectivity.

0.7 INTERMODAL INTEGRATION

The proposals have been formulated for facilitating traffic dispersal and circulation facilities based on the following considerations:

- Proper design of circulation area adjoining the station building to ensure rapid/ efficient dispersal of the passengers and avoiding conflicts between pedestrian and vehicular traffic.
- Footpaths in the metro station influence zone are proposed to be upgraded considering direct and easy connectivity, ease of movement and safety.
- Dedicated linkages like subways, skywalks, covered walkways etc. between MRTS, suburban railway and Metro which will reduce the passenger travel time and pedestrian load on the roads
- Circulation area with adequate parking space, designated space for pick-drop zones and feeder modes like Buses, IPTs and NMT.

In addition to improvement of pedestrian and intermodal facilities, Feeder services in the form of buses and public bicycle sharing system have been planned for Chennai Metro Phase II stations for providing last mile connectivity **(Table 0.15).**

TABLE 0.15: FEEDER BUSES AND PUBLIC BICYCLE REQUIREMENT

Corridor	2025	2035	2045	2055
Feeder Buses				
Corridor-3: Madhavaram to SIPCOT	50	70	95	120
Corridor-4: Lighthouse to Poonamallee Bypass	42	54	77	86
Corridor-5: Madhavaram to Sholinganallur	30	40	50	63
Total Feeder Buses	**122**	**164**	**222**	**269**
Public Bicycle				
Corridor-3: Madhavaram to SIPCOT	384	455	540	588
Corridor-4: Lighthouse to Poonamallee Bypass	237	316	406	519
Corridor-5: Madhavaram to Sholinganallur	188	223	259	290
Total Public Bicycle	**809**	**994**	**1205**	**1397**

0.8 TRAIN OPERATION PLAN

Train operation plan for Channai Metro Phase II corridors is based on the following:

- Running of services for 19 hours of a day (05:00hrs to 00:00 hrs) with a station dwell time of 30 seconds
- Scheduled speed of 32 kmph
- Make up time of 5-10% (on tangent track) with 8-12% coasting.
- Adequate services to ensure comfortable journey for commuters

The train operation plan **(Table 0.16)** is envisaged with the combination of 3 car and 6 car rake composition in the inception year 2025 and 6 car rake composition in the design year 2055. The infrastructure and train operation plan for Phase II corridors are proposed to be designed for 6 car rake composition for the design year.

Based on traffic demand, a circular train operation is envisaged between Corridor 3 and Corridor 5. Corridor 4 i.e. Light House to Poonamallee Bypass corridor is proposed to have independent train operation. The trains are proposed to run between following sections of the corridors:

- Madhavaram– Adyar – SIPCOT
- Circular Train operation from Madhavaram – CMBT – Sholinganallur – Adyar – Madhavaram
- MMBT- CMBT – Sholinganallur
- Independent train operation for Lighthouse - Poonamallee Bypass

TABLE 0.16 : TRAIN OPERATION PLAN FOR CHENNAI METRO PHASE II

Train Operation	Items	Year			
		2025	2035	2045	Design
(1) MMC (Madhavaram Milk Colony) -CMBT-Sholinganallur-Adyar-MMC	Cars/ Train	3,6	3,6	6	6
	Headway in Sec.	514	514	514	514
	Trains/hr (3 Car, 6 Car)	7(4,3)	7(2,5)	7(0,7)	7(0,7)
(2) MMC-Adyar-SIPCOT	Cars/ Train	3	3	3	6
	Headway in Sec.	600	600	600	600
	Trains/hr (3 Car, 6 Car)	6 (6,0)	6 (6,0)	6 (6,0)	6 (0,6)
(3) MMBT-CMBT-Sholinganallur	Cars/ Train	3,6	3,6	6	6
	Headway in Sec.	450	450	450	360
	Trains/hr (3 Car, 6 Car)	8(7,1)	8(3,5)	8(0,8)	10(0,10)

Train Operation	Items	Year			
		2025	2035	2045	Design
(4) Poonamallee Bypasss - Light House	Cars/ Train	3	3,6	3,6	6
	Headway in Sec.	277	277	257	240
	Trains/hr (3 Car, 6 Car)	13(13,0)	13(6,7)	14(3,11)	15(0,15)

The headway and capacity provided for different sections of three corridors is given in **Table 0.17.**

TABLE 0.17: HEADWAY AND CAPACITY PROVIDED FOR DIFFERENT SECTIONS

Corridor	Section	Items	2025	2035	2045	Design
Madhavaram (MMC) to SIPCOT	MMC- Adyar-Sholinganallur (1)+(2)	Cars/ Train	3,6	3,6	3,6	6
		Headway in Sec.,	277	277	277	277
		Trains/hr (3 Car, 6 Car)	13 (10,3)	13 (8,5)	13 (6,7)	13 (0,13)
		Capacity (@6p/m²)	12388	14008	15628	20488
		Capacity (@8p/m²)	15762	17820	19878	26052
		PHPDT	16289	22115	24301	27329
	Sholinganallur-SIPCOT (2)	Cars/ Train	3	3	3	6
		Headway in Sec.,	600	600	600	600
		Trains/hr (3 Car, 6 Car)	6(6,0)	6(6,0)	6(6,0)	6(0,6)
		Capacity (@6p/m²)	4596	4596	4596	9456
		Capacity (@8p/m²)	5850	5850	5850	12024
		PHPDT	2213	3566	4050	4500
Madhavaram (MMC) to Sholinganallur Corridor	MMC – MMBT (1)	Cars/ Train	3,6	3,6	6	6
		Headway in Sec.	514	514	514	514
		Trains/hr (3 Car, 6 Car)	7(4,3)	7(2,5)	7(0,7)	7(0,7)
		Capacity (@6p/m²)	7792	9412	11032	11032
		Capacity (@8p/m²)	9912	11970	14028	14028
		PHPDT	2838	4814	5081	7272
	MMBT-CMBT-Sholinganallur (1)+(3)	Cars/ Train	3,6	3,6	6	6
		Headway in Sec.	240	240	240	212
		Trains/hr (3 Car, 6 Car)	15 (11,4)	15 (5,10)	15 (0,15)	17 (0,17)
		Capacity (@6p/m²)	14730	19590	23640	26792
		Capacity (@8p/m²)	18741	24915	30060	34068
		PHPDT	17539	24528	29441	35714
Lighthouse to Poonamallee	Poonamallee Bypass to	Cars/ Train	3	3,6	3,6	6
		Headway in Sec.,	277	277	257	240

Corridor	Section	Items	2025	2035	2045	Design
Bypass	Lighthouse	Trains/hr (3 Car, 6 Car)	13 (13,0)	13 (6,7)	14 (3,11)	15 (0,15)
		Capacity (@6p/m^2)	9958	15628	19634	23640
		Capacity (@8p/m^2)	12675	19878	24969	30060
		PHPDT	11707	18944	23816	29940

Train operation plan is formulated such that traffic demand for majority of sections of corridor is met with the passenger loadings @6 passengers/m^2. However, in the sections where planned capacity is less than section load, capacity can be met by carrying standees @ 8 passengers/m^2 or higher which have been deliberately planned for optimum utilization of rolling stock. The total coach requirement for Phase II corridors is given in **Table 0.18.**

TABLE 0.18: COACH REQUIREMENT FOR DIFFERENT HORIZON YEARS

Year	2025	2035	2045	2055
Total Coach Requirement	414	537	633	762

0.9 SIGNALLING & TELECOMMUNICATION

0.9.1 Signaling System

Communication based Train Control (CBTC) Signaling system provides adequate safety level of CENELEC SIL-4 (Safety Integrity Level) and permits an operational headway of 90 seconds with continuous automatic train control. The CBTC technology is suitable for UTO (Unattended Train Operation) / DTO (Driverless Train Operation).

Considering the above, CBTC system with Unattended Train Operation (UTO) is recommended for phase II of Chennai Metro.

0.9.2 Telecommunication System

The proposed telecom system and transmission media will have following sub-systems:

- Optical Fiber Transmission System
- Telephone Exchange
- Mobile Radio Communication System
- Public Address System
- Centralized Clock System
- Passenger Information Display System
- Close Circuit Television
- Central Voice Recording System (CVRS) and
- Supervisory Control and Data Acquisition (SCADA) System

0.9.3 Platform Screen Doors

To ensure the safety of passengers, Half Height Platform Screen Doors is proposed to be provided at all elevated stations and Full Height Platform Screen Doors at all underground stations.

0.10 FARE COLLECTION SYSTEM

It is proposed to provide computer based automatic fare collection system (AFC) with contactless smart token/card type ticketing cheaper which offers lower life cycle costs.The proposed AFC system shall be interoperable with existing system. The existing AFC System Central Computer (CC) has a capacity to cater for upto 256 stations. The AFC system shall also have functionality of interface to existing CCHS (Central Clearing House System) which is capable of handling upto 32 operators and 10 million transactions with provision of integration with other transit (metro, bus etc.) and non-transit (parking, toll etc.) which may be planned in future in line with the state / national policy.

In addition, the proposed AFC system shall also be NFC (Near Field Communication) enabled. Facility of recharging of travel cards using Cash, Debit/Credit Cards and Netbanking/Web Portal shall also be available. AFC system shall also support offsite sales terminals also, wherein cards and tokens can be dispensed at locations outside metro premises.

0.11 ROLLING STOCK

Rolling stock proposed for Phase II corridors will be similar to that of Phase-I. The broad features are presented in **Table 0.19.**

TABLE 0.19: BROAD FEATURES OF ROLLING STOCK

S. No.	Parameter	Rolling Stock
1	Basic Unit	3 Car basic unit 2 DMC and 1 TC. Every coach should be fully interchangeable with any other coach of same type.
2	Train Composition	3- Car: DMC + TC + DMC 6- Car: DMC + TC + MC + MC + TC + DMC Capable of GoA4 operation
3	Coach Dimensions	L= 22.6m, W=2.9m, H= 3.9m
4	Coach construction	Light weight Stainless Steel / Aluminum body
5	Axle load	≤16 T
6	Braking System	Regenerative Braking
7	Propulsion system	3 phase drive system with VVVF control
8	Type of traction supply	25kV AC OHE system

0.12 POWER SUPPLY SYSTEM

Phase I of Chennai Metro has been operational with 25 kV AC overhead traction. Thus, in order to maintain the uniformity of the system, it is proposed that ***25 kV AC traction*** shall be adopted for Chennai Metro Phase II corridors. 25 kV AC traction system offers several advantages like lower losses and more regeneration and thus is energy efficient in comparison to 750 V DC Third Rail Traction system.

The power requirements of a metro system are determined by peak-hour power demand for traction and auxiliary applications. Broad estimation of auxiliary and traction power demand is made based on the following assumptions:

- Train operation with 6 car rakes with carrying capacity of 1576 passengers (standing @6 passengers/m²).
- Specific energy consumption of rolling stock – 70 KWh / 1000 GTKM
- Regeneration @ 30%
- At grade/ Elev. station load – initially 200kW, ultimate design 300 kW
- Underground station load – initially 1000 kW, ultimate design 1500Kw
- Poonamallee Depot auxiliary load – initially 1500kW, ultimate design 2000 KW
- Power factor of load – 0.9
- Transmission losses @ 5%
- Voltage and current harmonics with in utilities statutory limit

Keeping in view the above norms, projected power requirement for different horizon years is summarized in **Table 0.20.**

Table 0.20: POWER DEMAND ESTIMATION (MVA)

Corridore	Items	Years			
		2025	**2035**	**2045**	**2055**
Corridor-3: Madhavaram to SIPCOT	Traction	14.55	16.3	17.77	24.1
	Auxiliary	42.35	52.27	59.05	63.58
	Total	**56.9**	**68.57**	**76.82**	**87.68**
Corridor-4: Lighthouse to Poonamallee Bypass	Traction	8.39	12.41	15.10	18.38
	Auxiliary	19.95	24.4	27.46	29.62
	Total	**28.34**	**36.81**	**42.56**	**48.00**
Corridor-5: Madhavaram to Sholinganallur	Traction	17.61	23.12	27.77	31.31
	Auxiliary	16.80	20.27	23.28	25.20
	Total	**34.41**	**43.39**	**51.05**	**56.51**

0.12.1 SOURCES OF POWER SUPPLY

Chennai City has 230kV, 110kV, 33kV power transmission and distribution network to cater to various types of demand in the vicinity of the proposed corridor. Keeping in view of the reliability requirements and considering the complete length of corridors, twelve (12 nos) Receiving Substations (RSS) are proposed to avail power supply for traction as well as auxiliary services from the Tamil Nadu Transmission Corporation Limited grid sub-stations at 110kV voltage through transmission lines or cable feeders for proposed corridors. M/s TANGEDCO has confirmed the availability of supply vide letter no. CE/Plg&RC/SE/SS/EE1/AEE2/F.Metro Rail Coridor/D.417/16 dated 18.11.16.

The receiving substations (110/33/25 kV) planned for the power requirements of Phase II corridors with the respective feeding zones and the length of cables of from the Grid Substations is shown in **Table 0.21.**

TABLE 0.21 : SOURCES OF POWER SUPPLY

Grid sub-station	RSS of Metro Authority	Approx. Distance from GSS to RSS
Manali GSS (230/110kV)	Madhavaram RSS (110/33/25kV)	3.5 km
GMR Vasavi GSS (230/110 kV)	Vasanthi RSS (110/33/25kV)	2 km
Mylapore GSS (230/110 kV)	YMCA RSS (110/33/25kV)	1 km
Tharamani GSS (230/110 kV)	Tharamani RSS (110/33/25kV)	0.5 km
Siruseri GSS (230/110 kV)	Siruseri RSS (110/33/25kV)	2.0 km
Korattur GSS (230/110 kV)	Nadhamuni RSS (110/33/25kV)	1 km
Thiruverkadu GSS (230/110 kV)	Mugalivakkam RSS (110/33/25kV)	7 km
Alandur GSS (230/110 kV)	St. Thomas RSS (110/33/25kV)	1.5 km
Kadaperi GSS (230/110 kV)	Medavakkam RSS (110/33/25kV)	6 km
Mambakkam GSS (230/110 kV)	Perubakkam RSS (110/33/25kV)	5 km
Koyambedu GSS (230/110 kV)	CMBT RSS (110/33/25kV)	1 km
Kilpauk GSS (230/110 kV)	Kodambakkam RSS (110/33/25kV)	2 km

Receiving Sub stations (RSS) are proposed to be provided in phases. Initially, the traction and auxiliary power supply will be provided with nine (09 Nos.) RSS. These substations will cater to the power requirement of phase II corridors till year 2035. Thereafter, the remaining three RSS will handle power requirement along with other nine RSS provided during inception. Gas Insulated Substation (GIS) type substations, which offer the advantage of considerable saving in space requirement as well as reduced maintenance, are proposed for each Receiving cum Traction Substation and Auxiliary Substations of Phase II corridors.

0.12.2 AUXILIARY SUPPLY ARRANGEMENTS AND STANDBY POWER SUPPLY

Auxiliary sub-stations (ASS) are envisaged to be provided at each station for stepping down 33kV supply to 415V for auxiliary applications. The ASS will be located at mezzanine or platform level inside a room. The demand of power at each elevated station is expected to be about 200 kW in the initial years and is likely to reach 300 kW in the horizon year. Similarly, for the underground stations, the auxiliary load requirements have been assessed at 1000 kW for the initial years which is expected to increase to 1500 kW in the horizon year.

The proposed Auxiliary substation shall be Gas insulated type. This will reduce the maintenance requirements. Each elevated station shall be provided with an Auxiliary Substation with two 33kV/415V, 3-phase, 500 kVA dry type cast resin transformers and the associated HT & LT switchgear. In addition, provision shall be made for one DG set at each station for emergency loads. Two transformers (33kV/415V, 3-phase) of 3.2 MVA at each underground ASS for the underground stations are proposed to be installed (one transformer as standby).In addition, it is proposed to provide standby DG set of 250 kVA at all elevated stations and 2 x 910 KVA capacity at underground stations to cater to all emergency loads.

0.12.3 SOLAR ENERGY HARNESSING SYSTEM

Provision of a grid connected solar photovoltaic power plant utilizing all possible areas viz. roof top of stations/sheds and buildings is proposed. Based on the solar radiation intensity in Chennai, the peak solar power generation of Chennai Metro Phase II is expected to be about 50 kWp for the elevated stations and about 2000kWp for maintenance depot.

For solar energy harnessing system, CMRL shall sublet the rooftop to project developer who will be responsible for the solar PV installation. The power shall be purchased by CMRL on the basis of the unit rate specified by Power Purchase Agreement (PPA).

0.13 VENTILATION AND AIR CONDITIONING SYSTEM

0.13.1 ENVIRONMENT CONTROL SYSTEM

Large quantity of heat generated in underground stations cannot be extracted by simple ventilation, especially when outdoor air temperature and humidity is high. It is, therefore, essential to provide mechanical cooling in order to remove heat to maximum possible extent..

Proposals for Ventilation and Air-conditioning (VAC) system are as follows:

- Concourse & Platform public area Air-conditioning
- Technical & office rooms Air conditioning
- Ventilation of Ancillary spaces & plant rooms
- Smoke Management system
- VAC Electrical system
- VAC SCADA system

0.13.2 TUNNEL VENTILATION SYSTEM (TVS)

TVS is provided in a Subway system to carry out the following functions:

a) Train Pressure relief during normal operation
b) Ventilation during maintenance periods
c) Removal of smoke during emergency conditions
d) Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies.

0.14 MAINTENANCE DEPOT

The major maintenance depot for Corridor- 3 & 5 is proposed at Madhavaram. Since, circular train operation is proposed between Corridor-3 and Corridor-5 i.e. from Madhavaram – MMBT – CMBT- Sholinganallur – Adyar – Madhavaram, the inspection and maintenance of the rakes of the two corridors can be done at Madhavaram The depot will have infrastructure to maintain the rakes with necessary facilities viz stabling lines, scheduled inspection lines, workshop for overhaul, unscheduled maintenance including major repairs, wheel profiling, heavy interior/under frame/roof cleaning etc. for the rolling stock operational on the corridor as well as maintenance facilities for civil – track, buildings, water supply; electrical – traction, E&M; signaling & telecommunication; automatic fare collection etc. Minor Depot is proposed at SIPCOT with elevated stabling, inspection and washing facilities. The major maintenance depot for Corridor 4 i.e. from Lighthouse to Poonamallee Bypass is located at Poonamallee.

The planning of the maintenance facilities is done considering the rolling stock requirement which is calculated on the basis of the proposed train operation plan. The proposed arrangement for stabling and maintenance facilities for the Chennai metro Phase II corridors is given below in **Table 0.22**.

TABLE 0.22: MAINTENANCE DEPOT

Infrastructure	Madhavaram Depot	Sipcot Depot	Poonamllee Depot
Stabling Lines	37 lines of 6 car	19 lines of 6 car	24 lines of 6 car
Inspection Lines	6 lines of 6 car	3 lines of 6 car	3 lines of 6 car
Workshop Lines	6 lines of 6 car	Nil	4 lines of 6 car

0.15 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

0.15.1 ENVIRONMENTAL IMPACT ASSESSMENT

The negative impacts due to location of Phase II corridors include: Project Affected People (PAPs), Change of Land use, Loss of trees/forest and Utility/Drainage Problems. The impacts due to construction include: Soil erosion, pollution and health risk at construction site, traffic diversion and risk to existing buildings, excavated soil disposal problems, dust generation, increased water demand, impact due to supply of construction material. Anticipated Impacts due to operation are: noise pollution, water supply and sanitation at stations, traffic congestion issues and impact due to depots.

A lot of positive impacts are anticipated which include employment opportunities, benefits to economy; quick service and safety; reduced fuel consumption and reduction in air pollution.

Mitigation measures and management plan for Compensatory Afforestation, Construction Material, Labour Camp, Energy Management, Hazardous Waste, Housekeeping, Air Pollution Control, Noise and vibration Control, Traffic Diversion/Management, Soil Erosion Control, Muck Disposal, Draining of Water from Tunnel, Water Supply, Sanitation and Solid Waste, Rain water harvesting, Construction Waste, Depot are suggested. The total estimated environmental management cost for the project is about Rs. 4869.07 Lakh.

0.15.2 SOCIAL IMPACT ASSESSMENT

The objective of the study is (i) to prepare a draft inventory of structures, affected families and persons,(ii) to identify major social impacts and (iii)to prepare preliminary Resettlement Action Plan (RAP). The SIA which includes RAP has been prepared in Right to Fair Compensation and Transparency in land acquisition. The base line data have been collected from secondary sources such as the Census and the Statistical Hand Book and primary data are being collected through household survey conducted by RITES Social team during October and November 2016, May 2017 and November-December 2018.

The proposed project shall require acquisition of 120.9882 Ha in which 27.1931 Ha is private land and remaining 93.7951 Ha is Government land. Total 1309 properties will be affected out of which 104 are residential, 937 are commercial. There are 2865 affected families consisting 1924 PAFs shall be partially affected and remaining 941 families shall be fully affected. Out of the total partially affected families, 244 are residential and 1680 are commercial. Similarly, out of the total fully affected families 164 are residential and 777 are commercial.

Compensation for land acquisition, resettlement and rehabilitation has been considered as per Right to Fair Compensation and Transparency in land acquisition, Rehabilitation and Resettlement Act, 2013(RTFCTLARR Act).

CMRL is overall responsible for implementation of resettlement and rehabilitation component of the proposed corridor. CMRL will coordinate with all implementing agencies like PMC, NGO, R&R and Implementation Support Consultant and supervise their work and monitor the progress of the project. Social Management Unit (SMU) of CMRL shall look after land acquisition and rehabilitation activities of the project. The responsibility of NGO will be assisting SMU of CMRL in implementation of R&R activities. A Social Development Consultant will be appointed by CMRL to assist in the R&R implementation process. Grievances of PAPs will be first brought to the attention of field level staffs of CMRL. Grievances not redressed by the staffs (field level) will be brought to the Grievance Redressal Committee (GRC). The period for implementation of RAP has been taken as approx. two and half years. The tentative cost for implementation of Resettlement and Rehabilitation Plan is Rs.29130.0 Lakh.

0.16 DISASTER MANAGEMENT & SECURITY MEASURES

The main objectives of disaster management measures are as follows:

- Arrange for prompt evacuation of passengers
- Instill a sense of security among passengers
- Protect Metro Rail property
- Expedite restoration of train operation

An effective system needs to be in place under the provision of ‘Disaster Management Act, 2005’. Provisions at metro stations include Fire Detection and Suppression System, Environmental Control System (ECS), Tunnel Ventilation System, Track-way Exhaust System (TES), Power Supply System, DG Sets & UPS, Water Supply and Drainage System, Lights and other facilities which may be deemed necessary. In order to be prepared for any disaster, it is essential to train the concerned staff in situations such as fire, rescue of disabled trains, evacuation, etc. and mock drills need to be conducted. The measures will cover disasters both man-made and natural. The measures will be in consonance with practices suggested the disaster management authorities.

The three phases of security system followed include Prevention, Preparedness and Recovery. Various provisions like CCTV cameras, baggage scanners, metal detectors, bomb detection equipment, wireless sets, sniffer dogs and related facilities will be part of station security system.

0.17 PROJECT COST ESTIMATES

0.17.1 CAPITAL COST

Cost estimate for Chennai Metro Phase II corridors has been prepared covering civil, electrical, signaling and telecommunications works, rolling stock, environmental protection, rehabilitation, etc. at December' 2018 price level.

The construction cost of project at December' 2018 prices is estimated at **Rs. 43126 Crore**. The cost of land and R&R is estimated at **Rs. 9884 Crore**. The total cost of project including land and R&R, is estimated at **Rs. 53011 Crore**. The Central and State Taxes & duties amounts to **Rs. 7325 Crore**. Thus, the total cost of the project works out to be **Rs. 60335 Crore** at December' 2018 price level (**Table 0.23**).

TABLE 0.23: ABSTRACT OF COST ESTIMATE **Rs. in Crore**

SN	Item	Corridor-3	Corridor-4	Corridor 5	Total
1	Land	4469.03	2990.73	2133.20	9592.95
2	Alignment and Formation	4665.54	2070.31	2282.66	9018.51
3	Station Buildings incl. Civil works, EM works, ECS, TVS, Lift, escalators & Architectural Finishes etc	8717.58	3960.50	3546.62	16224.71
4	Depot including civil, EM, Machinery & plants, general works	607.62	225.54	0.00	833.16
5	P-Way for main line, depot and depot connectivity	541.60	305.72	445.74	1293.06
6	Traction & power supply for main line and depot incl. OHE, ASS, GIS etc.	966.58	530.05	737.84	2234.47
7	Signalling and Telecom. Incl. AFC, Platform screen doors, CCHS etc.	1469.05	837.51	1284.20	3590.76

SN	Item	Corridor-3	Corridor-4	Corridor 5	Total
8	Rolling Stock	1563.84	847.08	2085.12	4496.04
9a	Environment	17.60	8.33	22.76	48.69
9b	R & R incl. Hutments etc.	75.53	75.76	140.01	291.30
10	Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management	386.99	226.75	397.73	1011.47
11	Capital Expenditure on Security including civil and EM works	20.68	12.41	19.85	52.93
12	Staff Quarters and buildings including civil, electrical works and green building concept (Cost of OCC building is included in corridor-3 only)	154.43	49.45	86.73	290.61
13	Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land	382.23	181.47	218.19	781.89
14	Total of all items except Land and R&R	19493.73	9255.13	11127.44	39876.30
15	General Charges incl. Design charges, (Civil+EM works) @ 5% on all items except Land and R&R.	974.69	462.76	556.37	1993.81
16	Total of all items including G. Charges	20468.41	9717.89	11683.81	41870.11
17	Contingencies @ 3 % on all items except Land and R&R	614.05	291.54	350.51	1256.10
Total Cost including Contingencies & excluding Land and R&R Cost		21082.47	10009.42	12034.33	43126.21
Total Cost including Contingencies & including Land and R&R Cost		**25627.02**	**13075.91**	**14307.53**	**53010.47**
Central Taxes & Duties		1975.98	933.10	1150.57	4059.65
State Taxes & Duties		1589.04	752.43	923.63	3265.09
Total Taxes & Duties		**3565.02**	**1685.52**	**2074.20**	**7324.74**
Gross Total including Taxes & Duties		**29192.05**	**14761.43**	**16381.73**	**60335.21**

0.17.2 O&M ESTIMATE

The O&M cost in year 2025, 2035, 2045 and 2054 is estimated at **Rs. 1304 Crore, Rs. 5289 Crore, Rs. 25569 Crore** and **Rs. 12388 Crore** respectively.

0.18 TRANSIT ORIENTED DEVELOPMENT

National Transit Oriented Development (TOD) Policy provides guidelines on development along phase II corridors. TOD focuses on creation of high-density mixed land use development in the influence zone of transit stations, i.e. within the walking distance of (500-800 m) of transit station or along the corridor in case the station spacing is about 1km.

The present TOD study consist of Real Estate Market Study on the basis of which Real estate development potential for three asset classes i.e. Residential, Retail and Office has been determined.

Net cash flow from TOD cannot be estimated without considering market costs of land, approvals, development of public infrastructure etc. Quantification of these variables requires a detailed study which is beyond the scope of this DPR. Further, the share and form of TOD revenue which will flow into the Metro Project is a matter of policy to be decided by GoTN. However, for present analysis this is taken as 10% and the summary based on this is given in **Table 0.24.**

TABLE 0.24: NET CASH FLOW FROM TOD OF PHASE II CORRIDORS

Item	Total Revenues (Rs. Crore)				
	2019	2025	2035	2045	2054
Net Cash Flow from TOD	184	411	1155	2789	5816

0.19 FINANCIAL ANALYSIS

The Project is proposed to have a construction period of 6 years starting from the year 2019-20 but the payments are expected to spillover to seventh year as well. Hence capital expenditure is assumed to be in ratio of 5:15:20:20:20:15:5. The operation would start from the year 2025-26. Escalation is considered at 5% p.a. from Dec' 2018 onwards and no escalation has been considered in cost of land. The completion cost (without IDC) is calculated as Rs. 69180 Crore.

The revenue has been estimated for the fare-box revenue and non-fare-box revenue (i.e.) advertisement and commercial activities. The revenue estimate and Financial Analysis is done on fare structure suggested by CMRL. The fare is escalated by 7.5% annually.

Non-fare revenue under the heads of advertisement receipts, rentals from kiosks, parking receipts, cess on 4-wheeler sales, cess on companies, Film Shooting, Telecom Cable & Tower (License fees), is presented in **Table 0.26**.

TABLE 0.25: NON-FARE-BOXREVENUE

Revenue Stream	Total Revenues (Rs. in Crore)			
	2025	**2035**	**2045**	**2054**
Advertisement Receipts	73	123	210	326
Rentals from Kiosks	23	44	85	152
Parking Receipts	26	39	57	69
4-Wheeler sales and cess thereon	324	1,403	5,533	12,454
Cess on Companies/ firms (on no. of employees)	160	452	1,207	2,761
Film Shooting	1	2	4	6
Telecom Cable & Tower (License fees)	9	19	39	75
Total	**617**	**2,082**	**7,136**	**15,843**

0.19.1 FIRR ANALYSIS

The FIRR for a project operation period of 30 years is carried out as follows:

TABLE 0.26: PROJECT FIRR WITH 10% OF FARE BOX REVENUE AS NON-FARE BOX REVENUE

Prices	FIRR
Constant Prices	4.01%
Current Prices	12.05%

0.19.2 SENSITIVITY ANALYSIS

TABLE 0.27: PROJECT FIRR- SENSITIVITY ANALYSIS

Parameter	Change in Parameter	Constant Prices	Current Prices
Base Case		4.01%	12.05%
Ridership	5% decrease	3.67%	11.73%
	10% decrease	3.32%	11.40%
Capital Cost	5% increase	3.72%	11.73%
	10% increase	3.43%	11.43%

0.19.3 FINANCING PLAN

Financing Plan with ODA Loan

The capital contribution from GoTN, GoI and Loan from Bilateral/multilateral agency is assumed as given in **Table 0.29**.

TABLE 0.28: CONTRIBUTION FROM EACH SOURCE

Particulars	Option 1		Option 2	
	Share (in Rs. Crore)	%	Share (in Rs. Crore)	%
State Government				
State Taxes (SGST)	3838	5.43%	3838	5.43%
State Land and R&R	9672	13.68%	9672	13.68%
Construction Cost	0	0.00%	0	0.00%
IDC (@1.4%) by State Govt	592	0.84%	0	0.00%
Front End Fee by State Govt @ 0.1%	37	0.05%	0	0.00%
Sub Total (State Government)	**14138**	**20.000%**	**13510**	**19.04%**
Central Government				
Central Taxes (CGST)	4771	6.75%	4771	6.75%
Central Land and R&R	212	0.30%	212	0.30%
Construction Cost	8272	11.70%	0	0.00%
IDC (@1.4%) by Central Govt	878	1.24%	1710	2.42%
Front End Fee by Central Govt @0.1%	6	0.01%	51	0.07%
Sub Total (Central Government)	**14138**	**20.00%**	**6745**	**9.51%**
Bilateral / Multilateral Agency				
Construction Cost	42415	60.00%	50687	71.45%
Sub Total (Bilateral / Multilateral Agency)	**42415**	**60.00%**	**50687**	**71.45%**
Grand Total	**70692**	**100%**	**70941**	**100%**

The terms of Loan from Bilateral/ Multilateral Agency (General Terms, Fixed) are given in **Table 0.30**.

TABLE 0.29: ODA LOAN TERMS

S.No.	Parameter	Value
1	Annual Interest rate for Loan	1.40%
2	Front end fee	0.1%
3	Repayment Period	30 years
4	Moratorium Period	10 years
5	Payment Schedule	Yearly

The year-wise contribution from each source is as given in **Table 0.31** and **0.32** for Option 1 and Option 2.

TABLE 0.30: YEAR-WISE CONTRIBUTION FROM EACH SOURCE-OPTION 1, ODA LOAN (RS. CRORE)

Particulars	Year-wise Contribution							Total
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
State Government								
State Taxes (SGST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	0	0	0	0	0	0	0	0
IDC (@1.4%) by State Govt	15	74	126	126	126	94	31	592
Front End Fee by State Govt @ 0.1%	37	0	0	0	0	0	0	37
Sub Total (State Government)	**5053**	**5431**	**855**	**891**	**929**	**727**	**253**	**14138**
Central Government								
Central Taxes (CGST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	62	513	1143	1624	2130	1995	804	8272
IDC (@1.4%) by Central Govt	0	0	38	112	171	247	310	878
Front End Fee by Central Govt @0.1%	6	0	0	0	0	0	0	6
Sub Total (Central Government)	**379**	**1267**	**2087**	**2687**	**3300**	**3029**	**1390**	**14138**
Bilateral/Multilateral Agency								
Construction Cost	2121	6362	8483	8483	8483	6362	2121	42415
Sub Total (Bilateral/Multilateral Agency)	2121	6362	8483	8483	8483	6362	2121	42415
Total	**7553**	**13060**	**11424**	**12062**	**12712**	**10118**	**3763**	**70692**

TABLE 0.31: YEAR-WISE CONTRIBUTION FROM EACH SOURCE-OPTION 2, ODA LOAN (RS. CRORE)

Particulars	Year-wise Contribution							Total
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
State Government								
State Taxes (GST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	0	0	0	0	0	0	0	0

Particulars	Year-wise Contribution							Total
	2019	2020	2021	2022	2023	2024	2025	
IDC (@1.4%) by State Govt	0	0	0	0	0	0	0	0
Front End Fee by State Govt @ 0.1%	0	0	0	0	0	0	0	0
Sub Total (State Government)	**5001**	**5357**	**729**	**765**	**803**	**633**	**221**	**13510**
Central Government								
Central Taxes (Basic Customs Duty and GST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	0	0	0	0	0	0	0	0
IDC (@1.4%) by Central Govt	15	79	179	269	347	409	413	1710
Front End Fee by Central Govt @0.1%	51	0	0	0	0	0	0	51
Sub Total (Central Government)	**378**	**832**	**1085**	**1220**	**1346**	**1195**	**689**	**6745**
Bilateral/Multilateral Agency								
Construction Cost	2183	6876	9626	10107	10613	8358	2925	50687
Sub Total (Bilateral/Multilateral Agency)	**2183**	**6876**	**9626**	**10107**	**10613**	**8358**	**2925**	**50687**
TOTAL	**7562**	**13064**	**11440**	**12093**	**12762**	**10186**	**3835**	**70941**

Financing Plan with STEP Loan

Implications of STEP Loan (i.e., tied loan) on financing plan have been analyzed in this section. The capital contribution from GoTN, GoI and Bilateral / Multilateral Agency Step Loan is assumed in two different Options – Option 1 and Option 2 in **Table 0.33**.

TABLE 0.32: CONTRIBUTION FROM EACH SOURCE

Particulars	Option 1		Option 2	
	Share (in Rs. Crore)	%	Share (in Rs. Crore)	%
State Government				
State Taxes (GST)	3838	5.54%	3838	5.54%
State Land and R&R	9672	13.95%	9672	13.95%
Construction Cost	298	0.43%	0	0.00%
IDC (@0.1%) by State Govt	15	0.02%	0	0.00%
Front End Fee by State Govt @ 0.1%	42	0.06%	0	0.00%
Sub Total (State Government)	**13865**	**20.00%**	**13510**	**19.48%**

Particulars	Option 1		Option 2	
	Share (in Rs. Crore)	%	Share (in Rs. Crore)	%
Central Government				
Central Taxes (Basic Customs Duty and GST)	4771	6.88%	4771	6.88%
Central Land and R&R	212	0.31%	212	0.31%
Construction Cost	8794	12.69%	0	0.00%
IDC (@0.1%) by Central Govt	88	0.13%	122	0.18%
Front End Fee by Central Govt @0.1%	0	0.00%	51	0.07%
Sub Total (Central Government)	**13865**	**20.00%**	**5156**	**7.43%**
Bilateral/Multilateral Agency				
Construction Cost	41595	60.00%	50687	73.09%
Sub Total (Bilateral/Multilateral Agency)	**41595**	**60.00%**	**50687**	**73.09%**
TOTAL	**69325**	**100%**	**69353**	**100%**

The terms of loan from Bilateral/ Multilateral Agency (STEP Loan) are given in **Table 0.34**.

TABLE 0.33: STEP LOAN TERMS

S.No.	Parameter	STEP (Fixed-Standard)
1	Annual Interest rate for Loan	0.10%
2	Front end fee	0.1%
3	Repayment Period	40 years
4	Moratorium Period	10 years
5	Payment Schedule	Yearly

The year-wise Contribution from each source is as given in **Table 0.35** and 36 for option 1 and option 2 of step loan.

TABLE 0.34: YEAR-WISE CONTRIBUTION FROM EACH SOURCE - OPTION 1, STEP LOAN (RS. CRORE)

PARTICULARS	Year-wise contribution							TOTAL
	2019	2020	2021	2022	2023	2024	2025	
State Government								
State Taxes (GST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672

PARTICULARS	Year-wise contribution							TOTAL
	2019	2020	2021	2022	2023	2024	2025	
Construction Cost	15	45	60	60	60	45	15	298
IDC (@0.1%) by State Govt	0	1	2	3	4	4	1	15
Front End Fee by State Govt @ 0.1%	42	0	0	0	0	0	0	42
Sub Total (State Government)	**5058**	**5402**	**791**	**828**	**867**	**681**	**238**	**13865**
Central Government								
Central Taxes (Basic Customs Duty and GST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	88	592	1247	1729	2234	2074	830	8794
IDC (@0.1%) by Central Govt	1	4	9	13	17	20	23	88
Front End Fee by Central Govt @0.1%	0	0	0	0	0	0	0	0
Sub Total (Central Government)	**401**	**1349**	**2163**	**2693**	**3250**	**2881**	**1129**	**13865**
Bilateral/Multilateral Agency								
Construction Cost	2080	6239	8319	8319	8319	6239	2080	41595
Sub Total (Bilateral/Multilateral Agency)	**2080**	**6239**	**8319**	**8319**	**8319**	**6239**	**2080**	**41595**
TOTAL	**7538**	**12991**	**11272**	**11841**	**12436**	**9801**	**3446**	**69325**

TABLE 0.35:: YEAR-WISE CONTRIBUTION FROM EACH SOURCE - OPTION 2, STEP LOAN (RS. CRORE)

Particulars	Year-wise contribution							Total
	2019	2020	2021	2022	2023	2024	2025	
State Government								
State Taxes (GST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	0	0	0	0	0	0	0	0
IDC (@0.1%) by State Govt	0	0	0	0	0	0	0	0
Front End Fee by State Govt @ 0.1%	0	0	0	0	0	0	0	0
Sub Total (State Government)	**5001**	**5357**	**729**	**765**	**803**	**633**	**221**	**13510**
Central Government								
Central Taxes (Basic Customs Duty and GST)	205	647	906	951	999	787	275	4771

Particulars	Year-wise contribution							Total
	2019	2020	2021	2022	2023	2024	2025	
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	0	0	0	0	0	0	0	0
IDC (@0.1%) by Central Govt	1	6	13	19	25	29	30	122
Front End Fee by Central Govt @0.1%	51	0	0	0	0	0	0	51
Sub Total (Central Government)	**363**	**759**	**919**	**971**	**1024**	**816**	**305**	**5156**
Bilateral/Multilateral Agency								
Construction Cost	2183	6876	9626	10107	10613	8358	2925	50687
Sub Total (Bilateral/Multilateral Agency)	**2183**	**6876**	**9626**	**10107**	**10613**	**8358**	**2925**	**50687**
TOTAL	**7547**	**12991**	**11274**	**11843**	**12440**	**9806**	**3451**	**69353**

0.19.4 ALTERNATIVE MEANS OF FINANCING - EXPLORING PRIVATE PARTICIPATION

As per Metro Rail Policy 2017, private participation will be explored either for complete provisioning of metro rail or for some unbundled components such as Automatic Fare Collection System of metro rail.

It is known that, compared with public entities, private firms usually have higher costs of capital as well as profitability requirements that significantly affect the cost of infrastructure initiatives. Therefore, any PPP arrangement should, in principle, enhance value for money (VfM) through a combination of factors, including financing, operational efficiencies, superior risk management, greater implementing capacity, and enhanced service quality.

0.20 ECONOMIC ANALYSIS

The economic appraisal has been carried out within the broad framework of Social Cost – Benefit Analysis Technique. It is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the "with" and "without" project scenario. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices. This has been done to iron out distortions due to externalities and anomalies arising in real world pricing systems. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost / benefit and to calculate the economic viability of the project in terms of EIRR & ENPV.

The EIRR works out to 17.78% and ENPV @8% works out to Rs. 38,730 Crore. Sensitivity analysis of the EIRR with 5% to 15% cost overrun and reduction in traffic materialization has been carried out (**Table 0.25**).

TABLE 0.36: EIRR AND SENSITIVITY ANALYSIS

S. No.	Factor	Range		
		5%	10%	15%
1	Cost overruns due to delay or other factors	17.10%	16.47%	15.88%
2	Increase in Maintenance Cost	17.70%	17.63%	17.55%
3	Reduction in Ridership	17.34%	16.90%	16.46%
4	Reduction in benefits	16.99%	16.19%	15.37%
5	Combination of reduction in benefits and increase in cost	16.33%	14.97%	13.66%

0.21 IMPLEMENTATION PLAN

Effective institutional arrangements are needed to enable the metro project to be implemented without any loss of time and cost over-run. The Government of Tamil Nadu has created a Special Purpose Vehicle (SPV) for implementing the Chennai Metro Rail Project. This SPV named as “Chennai Metro Rail Limited” was incorporated on 03.12.2007 under the Companies Act. It has now been converted into a Joint Venture of Government of India and Government of Tamil Nadu with equal equity holding. Chennai Metro Rail Limited (CMRL)may be nominated for implementation of Phase-II Metro Project.

Implementation Schedule

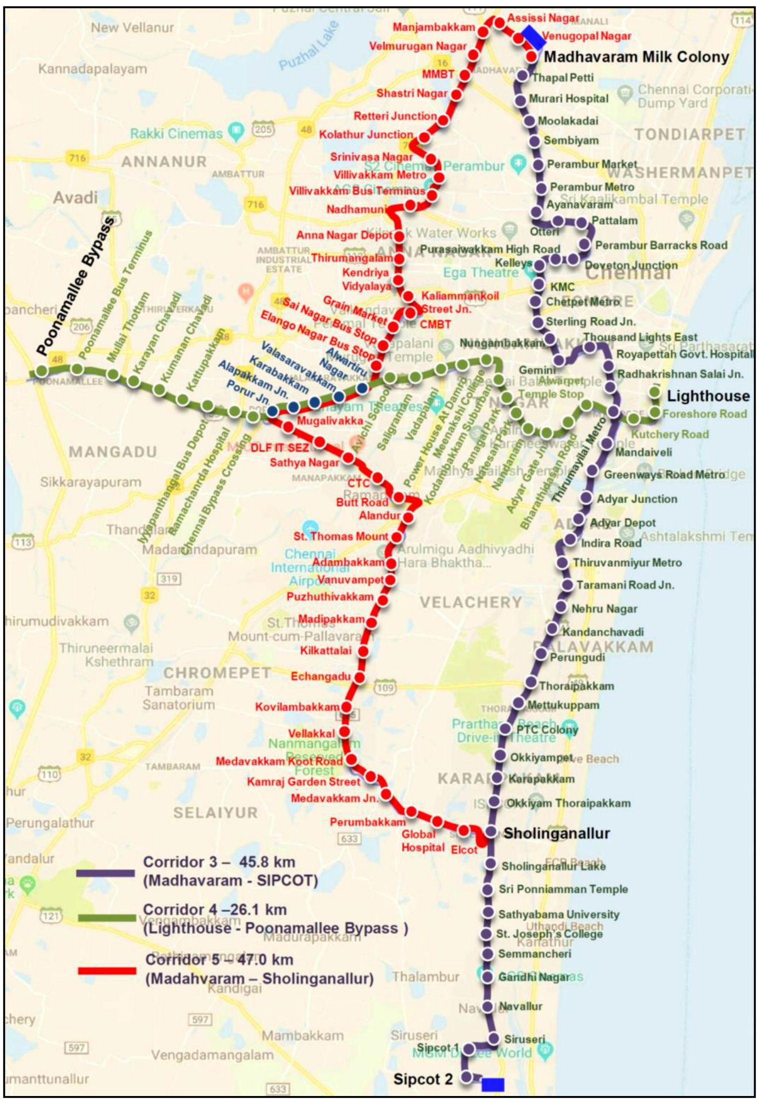
The possible dates of important milestones are given in **Figure 0.2.**

FIGURE 0.2: PROJECT IMPLEMENTATION SCHEDULE

	2018-2019	2019-2020				2020-2021				2021-2022				2022-2023				2023-2024				2024-25				2025-26	
MAIN ACTIVITIES	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun
APPROVAL OF DPR BY STATE GOVERNMENT	■																										
APPROVAL OF DPR BY CENTRAL GOVERNMENT		■	■																								
APPOINTMENT OF DDC	■	■																									
ARRANGEMENT OF FINANCE INCLUDING POSSIBLE PPP		■	■	■																							
APPOINTMENT OF GENERAL CONSULTANT		■	■																								
PACKAGING & INVITATION OF BIDS			■	■																							
LAND ACQUISITION	■	■	■	■	■																						
SHIFTING OF UTILITIES				■	■	■	■																				
DEPOT CONSTRUCTION						■	■	■	■	■	■	■	■														
VIADUCT CONSTRUCTION							■	■	■	■	■	■	■	■	■	■	■	■									
ELEVATED STATIONS							■	■	■	■	■	■	■	■	■	■	■	■									
GT SURVEY, BUILDING CONDITION SURVEY							■	■	■	■	■	■															
UG STATIONS											■	■	■	■	■	■	■	■	■	■	■	■					
TUNNELLING													■	■	■	■	■	■	■	■	■	■					
CONSTRUCTION OF CROSS PASSAGES																	■	■	■	■	■	■					
BASE SLAB LAYING																		■	■	■	■	■	■				
TRACK LINKING																		■	■	■	■	■	■	■			
OHE FIXING TESTING																			■	■	■	■	■	■	■		
S&T WORKS																		■	■	■	■	■	■	■	■		
TRIAL RUN TESTING																										■	■
CRS INSPECTION AND COMMISSIONING																											■

CHENNAI METRO RAIL LIMITED

Comprehensive Detailed Project Report for Chennai Metro Phase-II



DETAILED PROJECT REPORT

DECEMBER 2018

RITES
THE INFRASTRUCTURE PEOPLE
(A Government of India Enterprise)

RITES LTD.
A Government of India Enterprise
URBAN TRANSPORT DIVISION
RITES Bhawan
Plot No. 1, Sector 29, Gurgaon – 122001 (INDIA)
Tel: 0091-124-2571666, 2571648, Fax: 0091-124-2571638

1. PROFILE OF CITY

1.1 BACKGROUND

Chennai, the capital city of the Indian state of Tamil Nadu is located on the Coromandel Coast off the Bay of Bengal. It is one of the biggest industrial and commercial center of South India, and a major cultural, economic and educational centre. It is also known for its automobile industry. The City is divided into four broad regions: North, Central, South and West. The City is home to a growing number of information technology firms, financial companies and call centers.

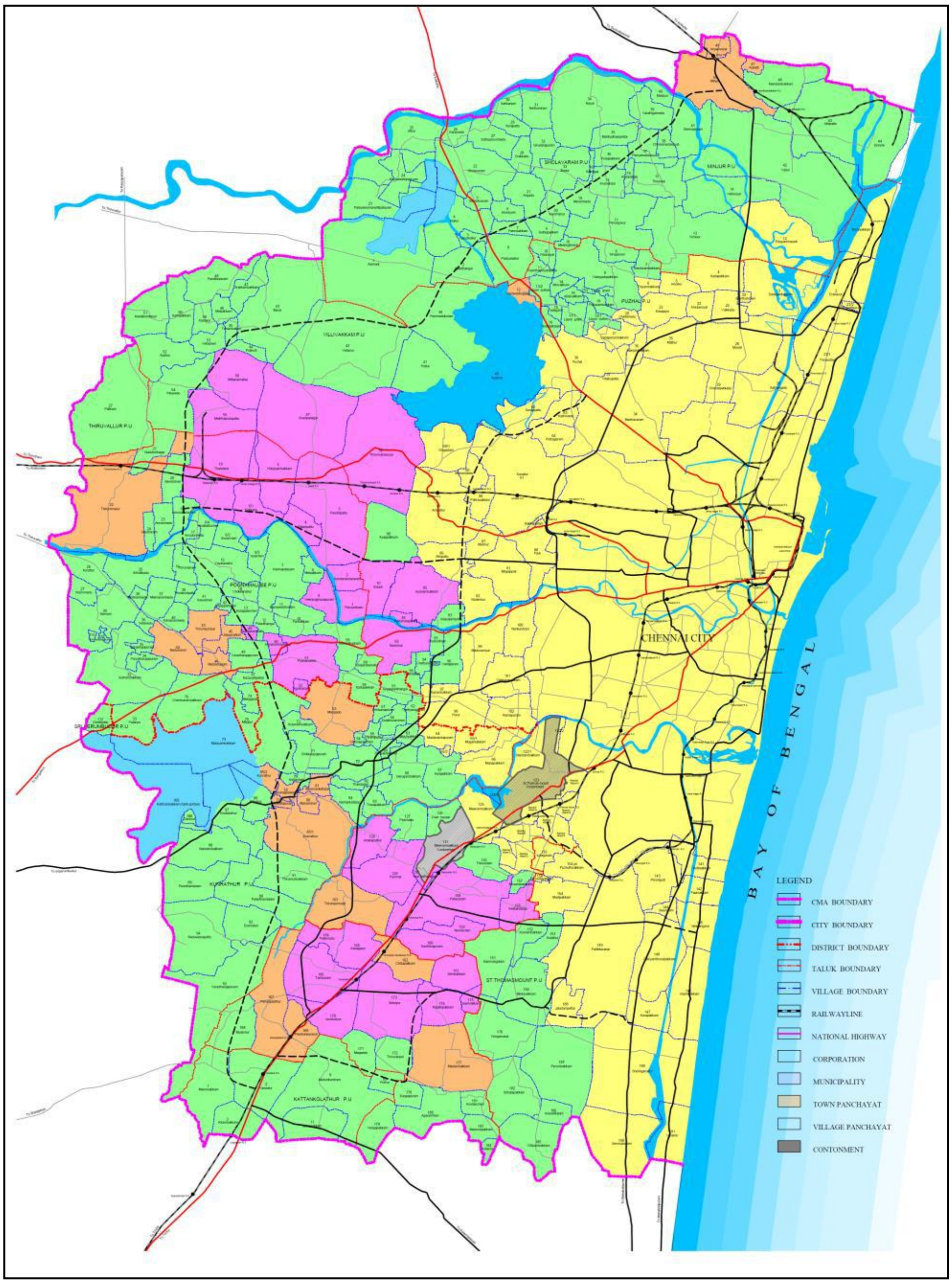
Large-scale urbanization in IT/ITES and industrialization with rapid growth of vehicular population has laid severe stress on urban transport system in city over the years. The city has a total of about 48 lakh vehicles as per Tamil Nadu government vehicle statistics. The usage of private modes is growing unabated mainly due to inadequate and inconvenient public transport facilities.

Various developmental activities in the Chennai Metropolitan Area (CMA – 1189 sq km) as presented in **Figure 1.1**, have attracted people to migrate from Tier-II cities and even from other states. The Census 2011 population of CMA is about 89 lakh. Chennai Master Plan 2026 has estimated a population of 125.82 lakh for Chennai Metropolitan Area (CMA) with a proposed Public and Private mode share of 70:30. The combined share of public transport buses and train has decreased from a considerable 54% in 1970 to 28.5% in 2014 with increased private transport trips.

The Phase-I of Chennai Metro covers 54 km in two corridors - Washermenpet to Airport (23.085 Km), Chennai Central to St. Thomas Mount (21.96 Km) and extension from Washermanpet to Wimco Nagar (9 km) in Thiruvottriyur. A stretch of 10.7 km from Koyambedu to Alandur in Corridor 2 became operational from June 2015 and Little Mount to Airport (7.7 km) & Alandur to St. Thomas Mount (1.3 km) in Corridor 1 opened in September/October 2016. Further, sections from Thirumangalam to Nehru Park (8.0 km) in May 2017, Little Mount Station to AGDMS Station and Egmore to Chennai Central Station (7.3 km) in May 2018 are also under operations.

With a view of developing effective and efficient mass transit system in addition to the existing public transportation and Phase-I Metro rail system, a Feasibility Report for Phase II Corridors with a total length of 88.9 km was prepared by CMRL in 2015.

FIGURE 1.1: CHENNAI METROPOLITAN AREA



The Detailed Project Report for Chennai Metro Rail Phase-II Corridors for 107.55 km covering 3 corridors - C3, C4 and C5 was prepared in March 2017. Detailed Project Report for Extended C4 corridor (total length 26 km) was also prepared in October 2018. Govt. of Tamil Nadu through CMRL has engaged RITES Ltd. to prepare a comprehensive Detailed Project Report for Chennai Metro Rail Phase-II with corridor details (**Figure 1.2**) as mentioned below:

- Corridor 3: Madhavaram Milk Colony to SIPCOT (45.8 km)
- Corridor 4: Lighthouse to Poonamalle Bypass (26.1 km)
- Corridor 5: Madhavaram Milk Colony to Sholinganallur (47.0 km)

FIGURE 1.2: CHENNAI METRO PHASE-II CORRIDORS

1.2 CHENNAI MASTER PLAN 2026

1.2.1 Chennai Second Master Plan 2026

The Master Plan 2026 was prepared in 2008 and amendments were incorporated in 2010. The proposed landuse of Chennai for an area of 1189 for the year 2026 is presented in **Table 1-1** and shown in **Figure 1.3.**

TABLE 1-1: PROPOSED LANDUSE AS PER CHENNAI SECOND MASTER PLAN 2026

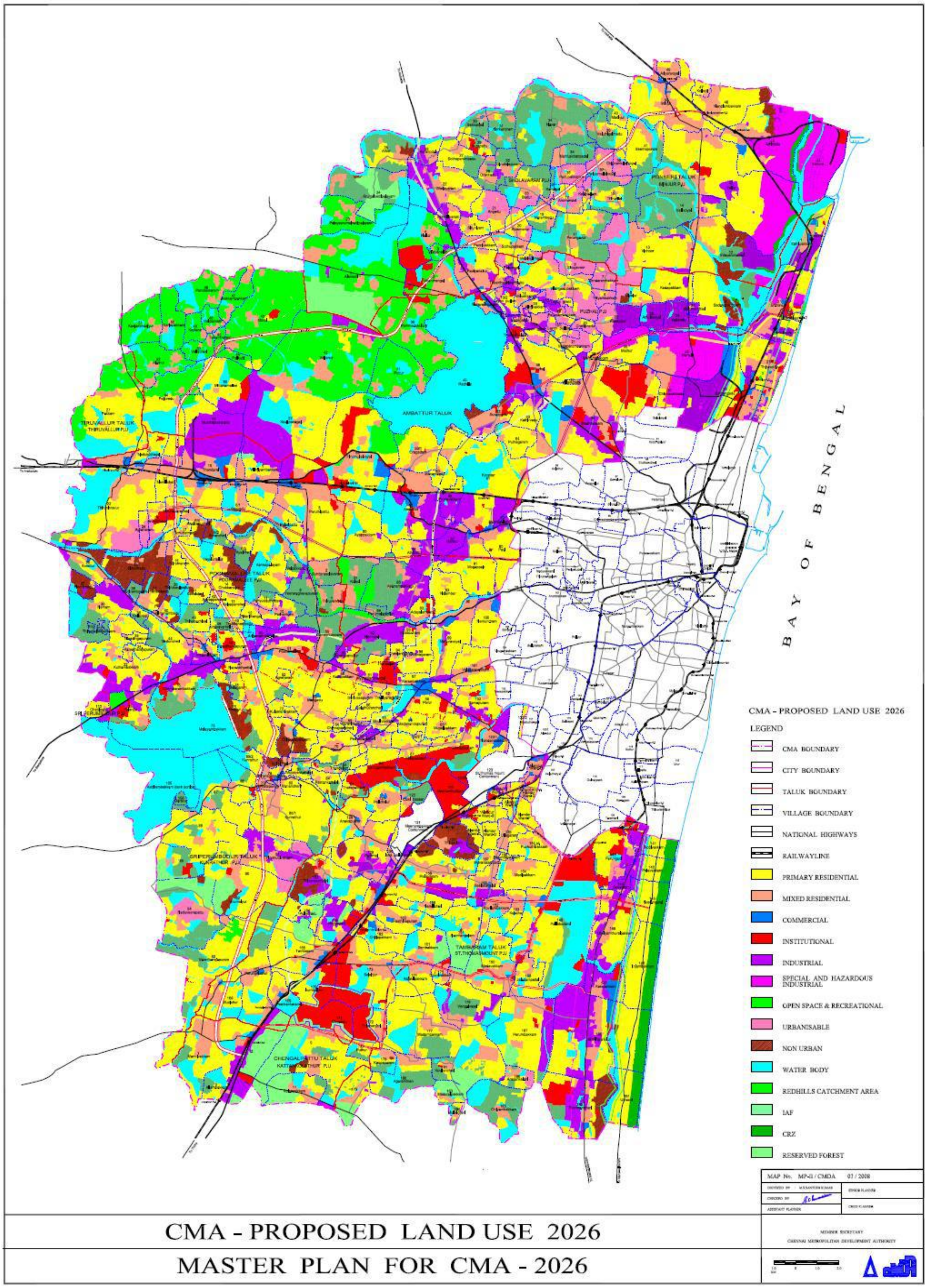
SN	Landuse	Chennai City		Rest of CMA	
		Extent (ha)	%	Extent (ha)	%
1	Primary Residential use zone	5916.35	33.6%	31090.68	30.7%
2	Mixed Residential use zone	2426.9	13.8%	13503.1	13.3%
3	Commercial use zone	714.24	4.1%	880.35	0.9%
4	Institutional use zone	2868.97	16.3%	3888.85	3.8%
5	Industrial use zone	691.83	3.9%	7274.33	7.2%
6	Special and haxardous Industrial use zone	130.67	0.7%	3416.08	3.4%
7	Open Space & Recreational use zone	1000.65	5.7%	392.86	0.4%
8	Agriculture use zone	-	-	7295.81	7.2%
9	Non Urban	113.31	0.6%	2332.92	2.3%
10	Urbanisable	-	-	2075.89	2.0%
11	Others (Roads, water bodies, hills, Redhills catchments area, forests etc.,)	3754.79	21.3%	28147.55	27.8%
	Total	**17617.70**	**100%**	**101298.42**	**100.0%**

Master Plan 2026 estimated a population of 125.82 for year 2026 and daily 207.60 lakh person trips with a modal split of 30:70 towards private and public transportation.

Total public transport trips of 145.32 lakh have been estimated necessitating the need for rail based mass transportation system in the city in order to achieve the proposed modal share of public transportation trips.

The Master Plan has recommended medium term and long term traffic & transport proposals upto the year 2026 with estimated costs of Rs. 47,812 Crore and Rs. 33,999 Crore respectively.

FIGURE 1.3: PROPOSED LANDUSE AS PER CHENNAI SECOND MASTER PLAN 2026



1.3 REVIEW OF PAST STUDIES

1.3.1 Comprehensive Traffic and Transportation Study (CTTS)

The Study carried out in 1992-95 and was revised in 2010 for Chennai Metropolitan Authority (CMA). As part of the CTTS study short, medium and long-term measures for improvement of road and transport infrastructure were identified and prioritised for investment purpose.

Since, the preparation of the CTTS report, CMDA made investments on number of projects in the urban transport sector, the largest one being on elevated railway (MRTS) along the Buckingham Canal.

Level of congestion on arterials and other major roads has increased eight-fold for the period 1984 to 2008. The average volume carried by the principal corridor of the city Anna Salai, is about 1.86 lakh PCUs per day (14,000 PCUs in peak hour) as against its capacity of 60,000 PCUs per day. A higher per capita trip rate with 1.60 is observed in 2008 as compared to 1.44 in 2005 study. The observed trip rate in 2008 is higher than the predicted trip rate (1.50) for 2011 from CTTS (1992 - 95).

The problems of public transport remain largely unsolved and the public transport system continues to be road based. Need has been felt to provide Mass Transit System (such as Metro) along the congested corridors to overcome the public transport needs.

1.3.2 Detailed Project Report for Development of Hybrid Monorail System

A detailed project report for development for hybrid monorail system in Chennai was undertaken for a length of 25 km comprising parts of Periyar EVR Salai and Anna Salai. The project cost was estimated at Rs. 947 Crore and it was proposed to be implemented over a period of 27 months.

1.3.3 Multi Modal Outer Ring Road Project

The Study indicates that the modalities of implementing 62 km long Outer Ring Road project as a multi-modal corridor with area development on either side to a depth of 25 metre at an approx. cost of Rs. 800 Crore in the public-private-partnership mode.

1.3.4 Feasibility Study for Chennai Metro 2003

A Feasibility Study was carried out in 2003 to select and prioritise the corridors for Chennai Metro. The following corridors were recommended for implementation:

Corridor 1: NH-45 (Airport)- Guindy- Sardar Patel Road- Cenotaph Road- Anna Salai – Gemini – Spencers - Tarapore Towers - Central Station - Broadway (Prakasam Road) – Old Jail road - Tiruvottiyur High Road (upto Tiruvottiyur)

Corridor 2: Along Poonamallai High Road (Corporation limits) - EVR Periyar Salai - Rajaji Road (North Beach Road) covering Koyambedu - Anna Nagar Arch - Aminjikarai – Kilpauk Medical College – Egmore - Central-Fort-Beach

Corridor 3: Ambathur Industrial Area (Mogapair) - Ring Road - Arcort road - Panagal Park - Theagaraya road - Eldams road - Luz Church Road - RK Mutt Road - Adyar Bridge - Lattice Bridge Road - Tiruvanmiyur

Corridor 4: Porur – Kodambakkam (Arcot Road) - Panagal Park - Thyagaraya road - Eldams road - Luz Church Road - Kutchery Road - Kamaraja Salai

Corridor 5: Ring Road

Corridor 6: Radhakrishnan Salai - Nugambakkam High Road- McNiccols Road – Kilpauk Medical College.

Corridor 7: Along NH 5 Road.

1.3.5 DPR of Chennai Metro Rail Phase-I: Washermenpet- Chennai Airport and Chennai Fort – St. Thomas Mount, 2007

The features of recommended system and engineering for Phase I are Standard Gauge (1435 mm); ballast less track, 750 V dc third rail traction, minimum headway 150 seconds, 4 car rake to be upgraded to 6 car rake; The details of two Phase-I corridors is presented in **Table 1-2.** Summary of daily passengers, average trip length and PKM per km for various years is presented in **Table 1-3.**

TABLE 1-2: DETAILS OF CORRIDORS IN CHENNAI METRO PHASE-I DPR

S.No.	Details	Corridor-1	Corridor-2	Total
		Washermanpet to Airport	Anna Nagar to St. Thomas Mount	
1	Underground Length (km)	14.3	9.7	24.0
2	Elevated Length (km)	8.7	12.3	21.0
	Total Route Length (km)	**23.0**	**22.0**	**45.0**
3	Underground Stations (Nos.)	10	9	19
4	Elevated Stations (Nos.)	6	7	13
	Total Stations (Nos.)	**16**	**16**	**32**

TABLE 1-3: TRANSPORT DEMAND SUMMARY IN CHENNAI METRO PHASE-I DPR

Year	Max. PHPDT		Daily Passengers		Daily Pass km/Km in lakh	
	C1	C2	C1	C2	C1	C2
2011	17611	18973	318532	254144	1.2	1.0
2016	24968	24324	403169	353297	1.5	1.3
2026	35757	36116	542444	521605	2.0	2.0

To enable the Chennai Metro rail project to be implemented without any loss of time and cost-over run, effective institutional arrangement in form of a SPV named 'Chennai Metro Rail Corporation Limited' had been proposed.

1.3.6 Feasibility Study for Chennai Metro Phase-II – Three Metro Corridors, 2015

The feasibility study was carried out in 2015 to analyse feasibility for proposed Phase-II metro rail with the following scope:

- Updation of primary transport network to include the proposed metro corridors
- Collection of all secondary information such as development plans and public transport routes
- Conduct limited primary traffic surveys on the three corridors
- Validation of CCTS (2008) model (morning peak) with the new (2014) traffic data on corridors
- The corridors proposed in this study with ridership projections **(Table 1-4)** for 2021, 2026 and 2035 is presented below:
    - C-3-Corridor 3 –Madhavaram to Siruseri (40.2km)
    - C-4-Corridor 4 Nerkundram-Luz (14km)
    - C-5-Corridor 5 Madhavaram to Shonlinganallur (34.7km)

TABLE 1-4: TRANSPORT DEMAND SUMMARY FOR PHASE II CORRIDORS IN FEASIBILITY STUDY

Year	Peak Hour Sectional Load (PPHPD)			Daily Ridership (in Millions)		
	C-3	C-4	C-5	C-3	C-4	C-5
2021	16,500	8,100	17,600	0.50	0.22	0.45
2026	21,500	10,800	21,650	0.67	0.29	0.59
2035	27,560	17,200	30,850	0.94	0.41	0.90

1.3.7 Mass Transport Plan in Chennai Metropolitan Region, 2015

Travel demand model was developed for Chennai Metropolitan Area to forecast travel for period of 30 years and suggest Mass Transit Master Plan for CMA for horizon years 2021, 2026, 2035 and 2045:

- Primary traffic and travel surveys were carried out
- Chennai Second Master Plan 2026 considered as base for forecasting landuse and other parameters for the study
- Potential Mass Transit Corridors around 250 km were identified
- Mass transit plan identified and prioritized based on ridership estimates
- Preliminary geometric feasibility carried out for the identified mass transit network
- Finalised Mass transit network include 6 metro rail corridors with a total length of 181.4 km and feasibility for Phase-II corridors was also established.

1.4 DPR of Chennai Metro Rail Phase-II, 2017

DPR for three Phase-II corridors was prepared by RITES in year 2017. The features of recommended system and engineering are Standard Gauge (1435 mm); ballast less track, 750 V dc third rail traction, minimum headway 225 seconds, 3 car rake to be upgraded to 6 car rake. The corridor details and travel demand summary are presented in **Table 1-5** and **Table 1-6** respectively.

TABLE 1-5: CORRIDORS DETAILS IN CHENNAI METRO PHASE-II DPR

Corridors	Length	No. of Stations
C3- Madhavaram to SIPCOT	45.81	50
C4- Lighthouse to CMBT	17.12	20
C5- Madhavaram to Sholinganallur	44.63	46
Total	**107.56**	**116**

TABLE 1-6: TRAVEL DEMAND SUMMARY IN CHENNAI METRO PHASE-II DPR

Year	Max. PHPDT			Daily Boarding (in Lakh)				Daily PKM (in Lakh)			
	C3	C4	C5	C3	C4	C5	Total	C3	C4	C5	Total
2024	15062	9004	17354	6.4	3.5	7.5	**17.3**	39.3	9.9	52.0	**101.2**
2026	16115	9754	18815	7.1	3.8	8.0	**18.9**	43.4	11.0	56.2	**110.6**
2035	19457	12461	24268	9.2	5.5	12.4	**27.1**	47.5	13.9	74.5	**135.9**
2045	23685	17436	27519	11.4	6.4	14.9	**32.7**	52.6	17.7	84.1	**154.4**

The total project cost including GST works out to be Rs 68,452 Crore at January 2017 price level. The construction period of 6 years (starting from 2018) has been considered with commencement of commercial operation in year 2024-25.

1.5 DPR for Extended Corridor-4 for Chennai Metro Rail Phase-II, 2018

The features of recommended system include Standard Gauge (1435 mm); ballast less track, 25 KV AC (OHE) traction system, minimum headway 240 seconds, 3 car rake to be upgraded to 6 car rake. The corridor details and travel demand summary are presented in **Table 1-7** and **Table 1-8** respectively**.**

TABLE 1-7: CORRIDORS DETAILS IN DPR FOR EXTENDED CORRIDOR-4

Corridor	Elevated	Underground	Total
C4- Lighthouse to Poonamallee Bypass(Km)	10.1	16.0	**26.1**
Total Stations (Nos)	18	12	**30**

TABLE 1-8: TRAVEL DEMAND SUMMARY IN DPR FOR EXTENDED CORRIDOR 4

Year	Max. PHPDT	Daily Boarding (Lakh)
2025	11707	5.5
2035	18944	9.3
2045	23816	10.3
2055	29940	11.4

The total cost of the project works out to be Rs 14564.51 Crore at July' 2018 price level. The construction period of 6 years (starting from 2019) is considered with commencement of commercial operation in year 2025-26.

1.6 SCOPE OF WORK

(i) Civil Works-Alignment

1. To carry out detailed topographic surveys along the suggested three corridors i.e. Corridor 3 - From Madhavaram to SIPCOT (45.8 km), Corridor 4 - From Lighthouse to Poonamallee Bypass (26.1 km) and Corridor 5 - From Madhavaram to Sholinganallur (47.0 km). The topographic survey would be conducted to establish the alignment, right of way, locations of stations, interchange points, maintenance depots and identification of land reservation requirements, building lines, number of properties affected, etc., along the metro Corridor. The corridors map is presented in **Figure 1.1.**
2. To conduct geotechnical investigations along the corridor alignment. Two Bore-hole/km will be sufficient for the purpose. If any abrupt change of strata is noticed, additional hole may be necessary.
3. To collect data about the existing underground/overhead utilities along the alignment from various agencies and identify such utilities likely to be affected permanently requiring diversion or temporarily during construction.
4. To examine integration / interchange requirements with existing corridors and other modes of the transport.
5. Identify locations for car maintenance depot(s) and concept Plan for the rolling stock Maintenance Depot.

6. Ascertain land acquisition requirements for the project. Govt. and Private Lands should be identified separately. R&R requirements based on State Government policy and as per new LA Act to be determined.
7. To review the impact of proposed road improvement works along the alignment and recommended changes, if any needed for proper integration.
8. Recommend the final alignment for the corridor after considering all aspects.
9. To prepare preliminary structural design for the viaduct as per standards of loading specified by Client, Consultants will however review and recommend if any changes are considered appropriate. Design should be in sufficient details to ascertain its adequacy and to estimate the cost reasonable accurate.

(ii) Stations

To identify station locations taking into account catchment area, adequacy of R.O.W, feasibility of entry/exit facilities, availability of parking areas, air funnel locations of stations in the vicinity of the airport and any other factor having impact on constructability and functioning of the station.

To prepare site-specific stations layouts to handle the projected traffic-stations will follow 'closed system' with complete access control through AFC. Lifts/escalators will be provided for the comfort of passengers especially physically challenged passengers. Stations may have single/double entry. Layout should provide adequate facilities for all operational, commercial & technical requirements.

1. As per availability of Right of Way, stations will be accommodated within R.O.W in exceptional cases, additional land requirements be indicated
2. Station layout should take security concerns into account.
3. Integration with other modes of transport at interchange stations should be provided for adequately.
4. Requirements of public information system, passenger amenities, signage etc should be considered to enable the realistic cost estimation.
5. Requirements of water supply and drainage arrangements
6. If any commercial development is proposed at stations, the same should be included in layouts.

(iii) Train Operation Plan

To prepare the Train operating plan to manage the projected ridership and recommend its phased implementation. Based on the Train operation plan, requirement of rolling stock will be worked out. Design parameters will be finalized in consultation with Client.

(iv) Traction & Power Supply

Consultant shall propose suitable Traction & Power supply system i.e. overhead AC traction systems to serve the Train operation Plan effectively. Consultant shall also provide the sufficient details for power supply arrangements.

(v) Signaling

Consultants shall propose suitable signaling system i.e. CBTC to serve the Train operation Plan effectively. The recommended system has to be cost-effective.

(vi) Rolling Stock

Consultant shall recommend suitable Rolling Stock requirements with optimal life-cycle cost.

(vii) Communication

Consultant shall recommend appropriate Communication System to serve all the operational requirements of the system.

(viii) Tunnel Ventilation System

Consultant shall propose suitable tunnel ventilation system

(ix) Environment/Social Impact Assessment

Consultants shall carryout preliminary Environmental Impact (EIA) study along the suggested corridors and propose Environment Management Plan (EMP) for construction and operation phase. Study must devote special attention to impact on traffic during construction, any adverse impact on the adjacent properties, business in the area and the impact on general quality of life in the project influence area. The Socio-economic impact in the area must be realistically assessed and suitable mitigation measures recommended.

(x) Cost -Estimates

Consultants shall prepare block cost-estimates for all the project elements including taxes and duties. The details in support of cost-estimates will need to be furnished. The completion cost will be worked out based on phasing of expenditure during construction and appropriate escalation factor.

(xi) Economic Analysis

The Consultants shall carry out Economic Analysis for the project to work out the EIRR.

(xii) Financial Analysis

Consultants shall prepare detailed financial analysis to work out the FIRR based on project clash flows. For the purpose of financial analysis, Consultants shall assess realistic O&M expenditure i.e. Staff, Energy Repair & maintenance. The capital expenditure on additional assets for capacity augmentation, replacement costs for assets etc, will have to be assessed. Fare box revenue will be worked out based on ridership forecast and proposed fare structure. Revenue from other sources viz. advertisement, real estate and other commercial activities will be considered as applicable. Consultants will also carry out sensitivity analysis for cost over-run and/or variations in revenue stream.

1.7 COMPOSITION OF REPORT

This 'Comprehensive Detailed Project Report' consists of following chapters covering:

Chapter 1: Profile of the City

Chapter 2: Existing Transport System

Chapter 3: Travel Characteristics and Demand Estimates

Chapter 4: System and Technology Selection covering traction system etc.

Chapter 5: Civil engineering covering alignment planning, geometric design parameters, geotechnical investigations, utilities and land requirements

Chapter 6: Station planning

Chapter 7: Intermodal integration

Chapter 8: Train operation plan

Chapter 9: Signaling and Telecommunication

Chapter 10: Fare Collection System

Chapter 11: Rolling Stock and requirement

Chapter 12: Power supply requirements, sources of power supply, substations and related infrastructure facilities

Chapter 13: Ventilation and Air Conditioning Systems

Chapter 14: Maintenance depot facilities, rolling stock maintenance and depot layouts

Chapter 15: Environmental & Social Impact Assessment with repair and resettlement plans

Chapter 16: Disaster Management and Security Measures

Chapter 17: Detailed Project Cost Estimates including capital and O&M costs

Chapter 18: Transit Oriented Development along the metro corridors and revenue potential

Chapter 19: Financial Analysis and Non-Fare Box Revenue

Chapter 20: Economic Analysis

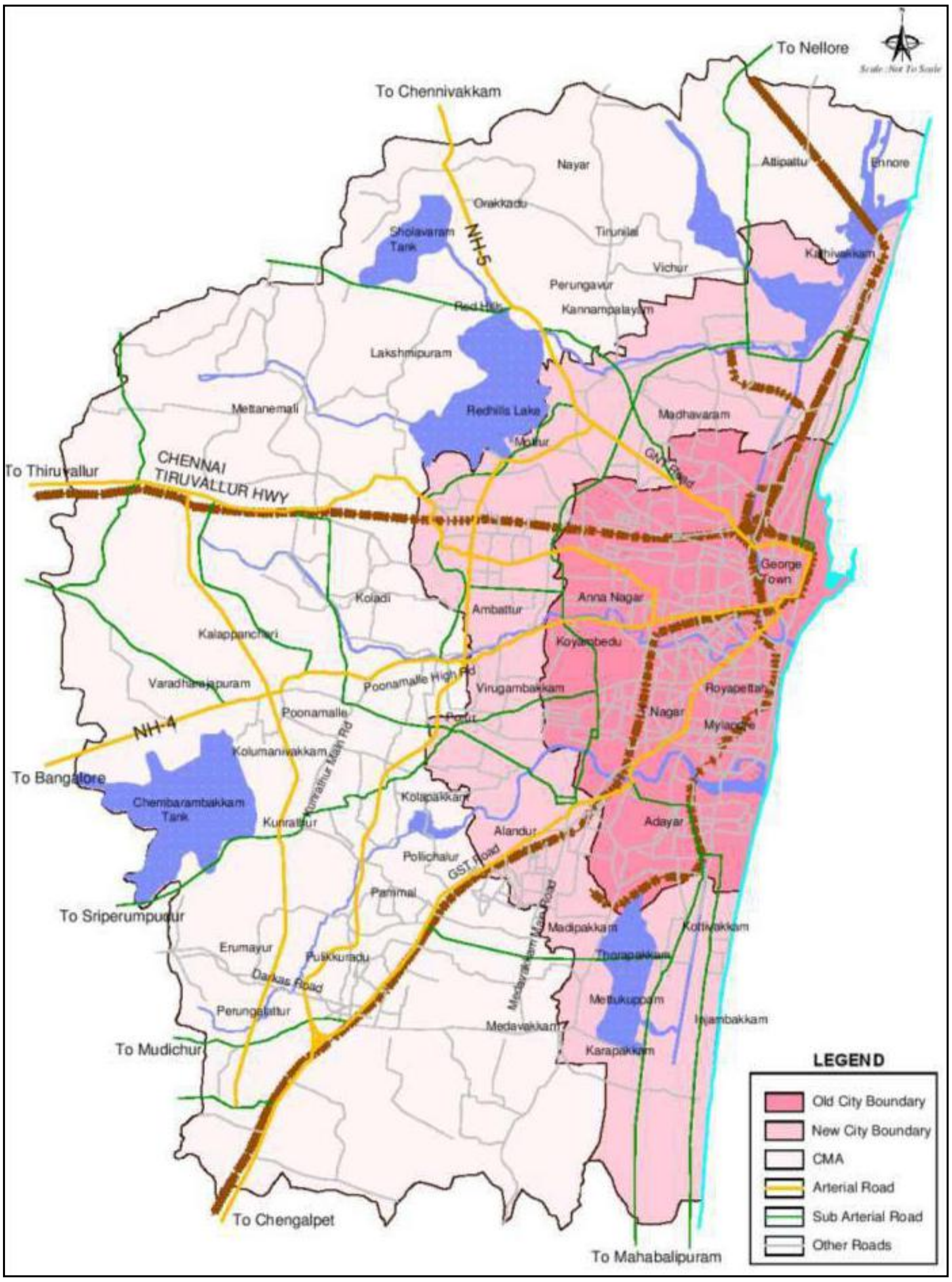
Chapter 21: Implementation Plan

2. EXISTING TRANSPORT SYSTEM

2.1 EXISTING TRANSPORTATION SYSTEMS

The City has regional connectivity with other major cities with National & State Highways and major roads. City level transportation demands are catered by Metropolitan Transport Corporation (MTC) buses, Phase-I Metro Rail System (Partly under operation and implementation) and Commuter Rail System including elevated MRTS. The network map of the city is presented in **Figure 2.1.**

FIGURE 2.1: TRANSPORT NETWORK IN CHENNAI



2.1.1 Existing Transport System Characteristics

❖ **Road Network**

The CMA has approximately 1,320 km of major roads over an area of 1189 sq. km. The radial pattern road network converges at George Town. Chennai is connected to other cities by four major National Highways (NH) originating in the City. The City is expanding majorly along the Old Mahabalipuram Road and the Grand Southern Trunk Road in the South and towards Ambattur, Koyambedu, Sriperumbudur in the West.

❖ **Intra-City Bus Transport**

The MTC operates 830 routes with a fleet of about 3,720 buses in 2018. The MTC covers most of the CMA and even covers up to 50 km to places beyond CMA limit and carried over 50 lakh daily passengers.

❖ **Intermediate Public Transport**

Intermediate Public Transport (IPT) fills the gap between public and private transport systems in the city. The IPT modes currently operating in the city include Auto-rickshaws, Call Taxis and Share auto/ Share Taxis. Share auto and share taxis are one of the predominant mode of transport in Chennai serving major arterials in the city along existing bus routes. The services are provided by three wheelers and four wheeler shared transport like Tata Magic etc.

❖ **Phase-I Metro Rail System**

The Phase-I of Chennai Metro covers 54 km in two corridors - Washermenpet to Airport (23.09 Km), Chennai Central to St. Thomas Mount (21.96 Km) and extension from Washermenpet to Wimco Nagar (9 km) in Thiruvottriyur. A stretch of 10.7 km from Koyambedu to Alandur in Corridor 2 became operational from June 2015 and Little Mount to Airport (7.7 km) & Alandur to St. Thomas Mount (1.3 km) in Corridor 1 opened in September/October 2016. Further, sections from Thirumangalam to Nehru Park (8.0 km) in May 2017, Little Mount Station to AGDMS Station and Egmore to Chennai Central Station (7.3 km) in May 2018 are also under operations. The Phase-I Metro System is presented in **Figure 2.2.**

❖ **Commuter Rail Network**

The commuter rail system in CMA, operated by the Southern Railways, consists of following three broad gauge lines including Chennai Beach- Tambaram line running south-west, Chennai Central- Tiruvallur line running east-west and Chennai Central-Gummidipoondi line running north-south.

Besides, a Mass Rapid Transit System (MRTS) operates on Chennai Beach - Velachery section for a length of about 20 km. The commuter rail network together contributes to about 17.5 lakh daily passengers.

FIGURE 2.2: CHENNAI METRO PHASE-I

❖ **Airport**

The Chennai International Airport (MAA) is the fourth busiest airport in India in terms of passenger traffic after Delhi, Mumbai and Kolkata and third busiest in terms of cargo handling.

2.2 GROWTH OF MOTOR VEHICLES

Tamil Nadu RTO classifies registered vehicles into two categories namely Transport & Non-Transport vehicles. As per RTO records, the registered transport vehicles & non-transport vehicles have grown by 1.28% & 7.06% per annum respectively over the years 2010-16. As of 01st April, 2018 the city has a total of 53.94 lakh vehicles with 2.44 lakh and 51.51 lakh Transport & Non-transport vehicles respectively as per Tamil Nadu government vehicle statistics as presented in **Table 2-1.**

TABLE 2-1: REGISTERED VEHICLES IN CHENNAI, 2018

Transport		Non-Transport	
Public (STU)	5569	Motor Cycle	2783689
Private	6	Scooter	780714
Autorickshaw	82889	Moped	690408
Ordinary Taxi	567	Motor Car	856270
Motor Cab (SP+AIP)	34275	Jeep	9900
Maxi Cab (SP+AIP)	19935	Tricycle Auto	2795
Omni Bus (SP+AIP)	166	Tractor	4641
Private Service Vehicle	1583	Three Wheeler	8706
School Bus	2759	Four Wheeler	2587
Ambulance & Fire Fighter	2088	Road Roller	227
Lorries	34008	Others	10572
National Permit Lorries	6801	**Total Transport**	**243904**
Tractor and Trailor	1661	**Total Non-Transport**	**5150509**
Light Commercial Vehicles	48572	**Grand Total**	**5394413**
Articulated Vehicles	3025		

Source: www.tn.gov.in, Tamil Nadu RTO Statistics

2.3 ROAD NETWORK & TRAFFIC CHARACTERISTICS

2.4.1 Carriageway & Footpath Characteristics

Road network inventory carried out for about 415 km along the Phase-II corridors in 2016-17 shows that two lane and intermediate lanes contribute under 13%, three lanes about 35%, four lanes about 27% and remaining 25% of six lanes. It has also been observed that about 67% of roads have footpath availability.

2.4.2 Speed and Delay Analysis

It has been observed from speed and delay surveys that the average journey and running speed in CMA are 17 kmph and 20 kmph respectively during peak hours.

2.4.3 Traffic Volume Characteristics at Midblock Locations

Traffic volume surveys were carried out in the city along major arterials. The daily traffic volume and traffic composition are presented respectively in **Table 2-2** and **Table 2-3.**

TABLE 2-2: DAILY TRAFFIC VOLUME AT MIDBLOCK LOCATIONS

Sno.	Name of Location	Total Vehicles	Total PCUs
1	Jeppiaar Engineering Collage Nr. Satya Bhama University	42460	35769
2	TCS Bus Stop Nr. Nissi Ladies Hostel	76180	70508
3	Adyar Road Nr. Globus Mall, Telephone Exchange	61424	51662
4	Sardar Patel Road (Nr. Punjab National Bank)	63523	55191
5	Inner Ring Rd. Nr. Fashion Meets Food	72459	55277
6	Butt Road Bus Stop LM (Nr St Helen Higher Sec School)	68191	56763
7	Nr. Kathipara Bus Stop	62859	46156
8	Poonamallee Bypass Ring Road	70802	103955
9	Thirumazhisai Vellore Chennai Road	59706	86453
10	Nandam Bakkam (Nr. Chennai Trade Center)	131556	103688
11	Alwarthirunagar Arcot Rd.	81454	69856
12	Near Sridev kuppam Main Rd. Arcot Rd.	71901	61758
13	SRCM Mount Poonamalle High Road	85618	76418
14	On Moggapair Road Nr. Ramani Driving School	15403	11638
15	North Main Road (Schizopherenia Research Foundation)	14188	11717
16	Padi Nr. Wheels Factory	22629	20115
17	Thiru Nagar (Nr. Singaram Pillary Higher Sec School)	34731	27006
18	Near Gopal Nagar	20119	15756
19	Milk Colony Road	12563	10894
20	Moolakadai-Perambur Road (Nr.Brinda Theatre)	34218	27817
21	Anderson Road Nr. Good Medical	34929	27233
22	CSI Bain School Nr. Kilpauk Road	30977	23274
23	Nr. Income Tax Office	65269	53150
24	White Road Nr. SBI ATM	23435	17450
25	Nr. Isabel's Hospital	22406	16068
26	Gandhi Beach Nr. Light House	55573	45370
27	Thayagaraya Road Nr. Soundarapandiana Police Station	23429	20825
28	On Venkat Narayan Road Nr. Kochar Building	21954	18592
29	Indira Nagar, Nr. Kun Honda Service Station	18430	16071
30	TT Krishnamchari Road Nr. Alwar Pet Bus Stop	38312	30366
31	Medawakkam Primary Health Center	24486	24592
32	Raja Manner Salai Nr. Best Bakery	63934	45705
33	Chinmaya Nagar Nr. Chennai Central Co-operative Bank	46737	38694

Sno.	Name of Location	Total Vehicles	Total PCUs
34	NR. Saligramam Bus Terminus	19553	13103
35	Red Hills Road (Nr. Amman Textile)	23145	18951
36	Vellacherry- Tambaram Main Road Nr. Airtel Comfort Express Zone	16976	17793
37	Indira Nagar 2nd Avenue	18741	14115
38	Paper Mills Road (Nr. IDBI ATM, Christian Church Misionary)	15922	15280
39	Valluvar Kottam High Road (Nr. Sree Valu Military Hotel)	43698	36202
40	Indira Nagar 2nd Avenue Nr. Water Tank	13254	11471
41	Kattupakkam	44154	46925
42	Kunrathur Road Near Amman Kovil	35963	35583
43	Kalarai Bus Stop Poonamallee Avadi High Rd.	48535	47775
44	ECR Link Road Nr. BSNL Office	15746	14751
45	Global Hospital Nr Global Bus stop	42580	35145
46	Mettukuppam Road (Billroth College of Nursing)	5482	4987
47	Madhavaram Redhills Road (Nr. St Antony Hospital)	20449	18189
48	Nerkundram Road (Nr. Krishna Matriculation School)	5126	4972

Among various locations surveyed, Nandam Bakkam (Nr. Chennai Trade Center) has maximum daily traffic at 131556 vehicles (103688 PCU). The daily composition of reveals that share of passenger vehicles is high compared to goods and slow moving vehicles.

TABLE 2-3: DAILY TRAFFIC COMPOSITION AT MID-BLOCK LOCATIONS

SN	Location of Mid-Block	Composition (%)						
		Total Fast Moving Passengers					Total Goods	Total Slow
		Car	Jeep/ Van	2-whlr	Auto	Total Buses		
1	Jeppiaar Engineering Collage Nr. Satya Bhama University	35.5	53.0	3.4	0.8	3.6	3.4	0.2
2	ECR Link Road Nr. BSNL Office	36.4	41.0	5.2	8.1	6.5	1.9	1.0
3	Global Hospital Nr Global Bus stop	23.9	59.5	5.6	1.6	5.5	3.6	0.3
4	TCS Bus Stop Nr. Nissi Ladies Hostel	33.3	45.2	4.1	5.6	5.9	5.5	0.3
5	Adyar Road Nr. Globus Mall, Telephone Exchange	35.5	49.8	7.0	1.4	3.7	2.5	0.1
6	Sardar Patel Road (Nr. Punjab National Bank)	42.5	43.6	6.0	0.9	3.6	3.2	0.2
7	Inner Ring Rd. Nr. Fashion Meets Food	33.0	57.2	4.2	0.3	1.2	3.4	0.6
8	Butt Road Bus Stop LM (Nr St Helen Higher Sec School)	30.1	54.4	4.8	2.2	1.5	6.3	0.7
9	Nr. Kathipara Bus Stop	26.3	62.2	6.1	1.7	1.6	1.6	0.3
10	Nandam Bakkam (Nr. Chennai Trade Center)	28.1	58.3	5.6	2.0	1.5	4.0	0.4
11	Mettukuppam Road (Billroth College of Nursing)	20.4	56.1	4.0	0.6	1.4	14.0	3.5
12	Madhavaram Redhills Road (Nr. St Antony Hospital)	10.3	56.6	9.6	10.6	3.9	7.2	1.7
13	Nerkundram Road (Nr. Krishna Matriculation School)	25.4	42.1	4.8	0.6	2.4	17.2	7.5
14	On Moggapair Road Nr. Ramani Driving School	28.5	57.9	6.1	1.5	2.0	3.1	0.9
15	North Main Road (Schizopherenia Research Foundation)	29.2	49.3	10.7	0.4	3.9	3.4	3.1
16	Padi Nr. Wheels Factory	20.0	55.8	5.5	3.4	3.1	10.0	2.3

SN	Location of Mid-Block	Composition (%)						
		Total Fast Moving Passengers					Total Goods	Total Slow
		Car	Jeep/ Van	2-whlr	Auto	Total Buses		
17	Thiru Nagar (Nr. Singaram Pillary Higher Sec School)	25.1	57.0	10.3	3.0	2.5	1.2	0.9
18	Near Gopal Nagar	16.9	53.8	14.4	1.2	1.1	7.9	4.6
19	Milk Colony Road	9.0	61.2	6.5	9.7	4.2	8.5	0.9
20	Moolakadai-Perambur Road (Nr.Brinda Theatre)	24.8	46.5	6.7	8.6	2.0	4.2	7.1
21	Anderson Road Nr. Good Medical	25.4	56.8	10.0	1.5	1.8	3.9	0.6
22	CSI Bain School Nr. Kilpauk Road	22.2	56.9	14.2	1.5	0.4	3.9	0.9
23	Nr. Income Tax Office	39.5	42.9	9.4	4.1	1.5	1.3	1.4
24	White Road Nr. SBI ATM	38.0	50.7	8.0	0.0	0.2	1.0	2.1
25	Nr. Isabel's Hospital	18.3	60.8	15.7	1.5	0.3	2.9	0.4
26	Gandhi Beach Nr. Light House	26.7	56.0	9.6	0.2	3.6	3.8	0.1
27	Thayagaraya Road Nr. Soundarapandiana Police Station	29.2	41.6	17.3	5.3	4.3	1.2	1.0
28	On Venkat Narayan Road Nr. Kochar Building	32.9	42.4	18.8	0.4	1.9	2.0	1.5
29	Indira Nagar, Nr. Kun Honda Service Station	34.1	44.1	13.8	0.6	2.3	4.0	1.3
30	TT Krishnamchari Road Nr. Alwar Pet Bus Stop	41.3	50.1	3.9	0.1	1.3	2.1	1.2
31	Medawakkam Primary Health Center	21.1	48.3	8.7	1.8	3.0	16.7	0.4
32	Raja Manner Salai Nr. Best Bakery	21.5	63.7	8.2	0.2	0.7	4.3	1.5
33	Chinmaya Nagar Nr. Chennai Central Co-operative Bank	21.9	50.6	14.2	4.1	1.7	6.3	1.2
34	NR. Saligramam Bus Terminus	16.5	66.7	9.1	0.3	0.4	2.6	4.4
35	Red Hills Road (Nr. Amman Textile)	14.2	53.4	13.8	1.4	3.4	8.6	5.2
36	Vellacherry- Tambaram Main Road Nr. Airtel Comfort Express Zone	27.4	44.0	5.1	4.4	10.5	7.1	1.5
37	Indira Nagar 2nd Avenue	29.6	51.5	16.3	0.0	0.1	1.6	0.9
38	Paper Mills Road (Nr. IDBI ATM, Christian Church Misionary)	22.7	39.6	22.8	3.2	6.2	0.5	5.0
39	Valluvar Kottam High Road (Nr. Sree Valu Military Hotel)	32.5	51.2	9.8	0.2	3.5	2.3	0.6
40	Indira Nagar 2nd Avenue Nr. Water Tank	33.2	40.0	20.2	0.8	1.4	3.1	1.3
41	Alwarthirunagar Arcot Rd.	24.0	54.1	7.8	4.4	3.9	5.2	0.6
42	Near Sridev kuppam Main Rd. Arcot Rd.	23.7	54.1	7.9	4.5	3.8	5.4	0.6
43	Srcm Mount Poonamalle High Road	29.6	51.2	4.7	3.3	3.9	7.0	0.3
44	Kattupakkam	24.2	34.9	13.6	8.3	6.8	11.8	0.3
45	Kunrathur Road Neae Amman Kovil	26.8	45.2	8.8	7.1	2.5	9.4	0.4
46	Kalarai Bus Stop Poonamallee Avadi High Rd.	21.2	45.9	10.9	11.8	6.7	2.7	0.8
47	Poonamallee By Pass Ring Road	31.0	24.8	3.7	3.6	15.2	21.5	0.2
48	Thirumazhisai Vellore Chennai Road	29.3	26.1	4.2	4.0	16.3	19.9	0.2

2.4.4 Traffic Volume Characteristics at Intersections

The intensity of traffic at intersections along phase II corrdors is presented in **Table 2-4.** It can be seen that Ramavaram Signal intersection handles the maximum daily traffic at 175,412 vehicles (143,805 PCUs) while the lowest daily traffic is observed at Kanmal Nagar Jn. (Nr. Madhavaram EOC Hospital) with 23,596 vehicles (20,170 PCUs).

TABLE 2-4: DAILY TRAFFIC VOLUME AT INTERSECTION LOCATIONS

Loc.no.	Name of Location	Total Vehicles	Total PCU's
1	Devraj Nagar	98106	113220
2	Meddavakkam Koot Road Junction	89822	69894
3	Eachangadu Junction	109620	84957
4	Army Officer Training Academy	112355	93314
5	Vanuvam Pettai Signal	120746	124047
6	Pallikarnai Junction	132713	108232
7	Nr.SRP Tools	102475	92198
8	Greenways Road	123354	100579
9	Sabari Salai (Nr. UTI Bus Stop)	51881	55356
10	Dr Kamakshi Hospital	156412	170356
11	Vadaplani	110666	122497
12	Dr.Ambedkar Road	91269	74702
13	Perungudi Junction	111906	120460
14	Ramavaram Signal	175412	143805
15	Bharathi Dasan Colony	65122	50672
16	Alwarthirunagar	87226	72823
17	Tidel Park	137377	147428
18	Koyambed Market Junction	172999	149832
19	Nerkundram Junction	91282	88611
20	Mogappair	82667	67019
21	Thiru Manglam Junction	97186	89602
22	Retteri Junction	115026	106490
23	Velluar Kottom	129924	105127
24	Kanmal Nagar (Nr. Madhavaram EOC Hospital)	23596	20170
25	Otteri Junction	43143	36622
26	Pattalam	54822	56785
27	Nehru Park	97068	75386
28	Spur Tank Road Nr. KRM Tower	131442	133659
29	Mylapore junction	89139	85208
30	Nandanam Extn. Nr. Thevar Statue	125407	127435
31	Virugum Bakkam Junction (Container Depot)	74097	75355
32	Anna Nagar Junction Nr. Govt. Peripheral Hospital	53996	54405
33	Alapakkam Main Road Jn.	66422	55039
34	Porur Junction	127338	110583
35	Poonamallee High Road Jn.	72808	64838
36	Avadi Road Jn.	58338	57637
37	Sennerkuppam Jn.	116239	140309
38	ORR At Grade Jn.	99270	148691

2.4.4 IPT/PT Passenger Boarding/Alighting & OD Surveys

It is observed from **Table 2-5** that PT/IPT stop at Alandur Metro Station towards Airport caters to the maximum number of 14,738 passengers daily. It can be inferred from the table that Karaiyan Chavadi (towards Vadapalani), IMOT Hospital (towards Guindy), Kodambakkam Power house (towards Vadapalani), Chetpet near TSO Tower (towards Chetpet) and Chetpet near Agellen Service Pvt ltd (towards Chinmaya Vidhyalaya) are some of the busiest PT/IPT stops in Chennai.

TABLE 2-5: DISTRIBUTION OF PASSENGERS AT PT/IPT STOPS

Stop No	Name of Location	Direction	Total Boarding	Total Alighting	Total (B+A)	Peak Time	Peak Hour Boarding	Peak Hour Alighting	Peak Hour (B+A)
1	Thappal Pettai	To Moolakadai	1253	585	1838	1545 - 1645	131	98	229
2	Moolakadai	To Perambur	1386	1105	2491	1000 - 1100	184	186	370
3	ESI Hospital	To Purushawakkam	1311	844	2155	1000 - 1100	134	118	252
4	ESI Hospital	To Aynawaram	1054	926	1980	0745 - 0845	97	93	190
5	Thousand lights	To Tynampet	2398	2093	4491	1815 - 1915	392	204	596
6	St Merry College	To Nungabakkam	1213	854	2067	1545 - 1645	281	74	355
7	DMS	To Chennai Central	3051	2875	5926	0845 - 0945	669	690	1359
8	DMS	To Saidapet	3856	3268	7124	0945 - 1045	312	370	682
9	Gemini Circle flyover	To Marina Beach	3621	3425	7046	0830 - 0930	361	584	945
10	Gemini Circle flyover	To Chetpet	1455	1681	3136	1815 - 1915	242	247	489
11	Ajantha	To Mandewali	1341	1387	2728	0915 - 1015	165	247	412
12	Luz Corner	To Tynampet	2770	2247	5017	0900 - 1000	275	239	514
13	Luz Corner	To Adyar	2646	1644	4290	1815 - 1915	300	254	554
14	Mylapore Water Tank	To Adyar	2915	2852	5767	1715 - 1815	340	414	754
15	Mylapore Water Tank	To Royapettah	3775	2520	6295	1830 - 1930	436	342	778
16	Mandewali	To Adyar	1598	1323	2921	1830 - 1930	167	109	276
17	Rani Miyammai	To Mandewali	1195	1096	2291	1745 - 1845	200	164	364
18	Andhra Mahila Sabha	To Mandewali	2801	2402	5203	1145 - 1245	334	305	639
19	Satya Studio	To Adyar	2878	2080	4958	0800 - 0900	351	164	515
20	Adyar Nr. Indian bank	To Mandewali	2036	1510	3546	1900 - 2000	159	231	390
21	Adyar Nr. Fortis Hospital	To Mandewali	1364	708	2072	1000 - 1100	134	63	197
22	Malar Hospital Nr IP Pump	To Thiruvanmiyur	4711	5416	10127	1715 - 1815	444	465	909
23	Jayanthi	To Adyar	3904	1471	5375	1745 - 1845	388	116	504
24	Tidel Park	To Shollinganallur	3603	1749	5352	1930 - 2030	561	357	918
25	SRP Tools	To Anna University	1302	1644	2946	1715 - 1815	136	183	319
26	SRP Tools	To Shollinganallur	2304	2362	4666	1730 - 1830	278	293	571
27	Perungudi	To Semmancherry	2462	1934	4396	1200 - 1300	247	177	424
28	Perungudi	To Tidel Park	1568	1574	3142	1100 - 1200	196	110	306

Stop No	Name of Location	Direction	Total Boarding	Total Alighting	Total (B+A)	Peak Time	Peak Hour Boarding	Peak Hour Alighting	Peak Hour (B+A)
29	Karapakkam	To Shollinganallur	1821	1948	3769	0945 - 1045	247	221	468
30	Karapakkam	To Tidel Park	1461	1232	2693	0930 - 1030	161	139	300
31	Sathyabhama University	To Semmancherry	1022	1464	2486	1615 - 1715	74	183	257
32	Sathyabhama University	To Devraj Nagar	1231	996	2227	1715 - 1815	164	217	381
33	Global Hospital	To Medavakkam	712	645	1357	1615 - 1715	90	83	173
34	Global Hospital	To Shollinganallur	1131	1017	2148	1845 - 1945	182	172	354
35	Vellakal	To Medavakkam	928	908	1836	0800 - 0900	181	67	248
36	Kovilampakkam	To Pallikarnai	1040	1046	2086	0900 - 1000	154	78	232
37	Butt Road	To Nandambakkam	1753	1766	3519	1645 - 1745	236	222	458
38	Kathipara	To Adyar	279	366	645	1900 - 2000	56	36	92
39	Nandambakkam CTC	To Ramvaram Signal	1084	1158	2242	1845 - 1945	145	118	263
40	Nandambakkam CTC	To Guindy	2042	1541	3583	0945 - 1045	179	162	341
41	Collector Nagar	To Ambattur	1479	1874	3353	1615 - 1715	158	269	427
42	Collector Nagar	To Thirumanglam	707	471	1178	1645 - 1745	78	93	171
43	Thirumanglam	To Anna Nagar	2008	2021	4029	1830 - 1930	210	303	513
44	Thirumanglam	To Ambattur	2199	2019	4218	1830 - 1930	434	277	711
45	Retteri	To Senthil Nagar	4020	2441	6461	0900 - 1000	449	279	728
46	Retteri	To Perambur	4004	2586	6590	0815 - 0915	543	213	756
47	Rampuram Bharti Salai	To Ramvaram junction	154	55	209	0830 - 0930	48	11	59
48	IGP	To Anna University	1250	1028	2278	1845 - 1945	197	79	276
49	IGP	To Shollinganallur	1416	1313	2729	1900 - 2000	244	144	388
50	Medavakkam	To Shollinganallur	4270	1420	5690	1815 - 1915	582	127	709
51	Medavakkam	To Tambaram	2951	4835	7786	1700 - 1800	338	537	875
52	Medavakkam	To Shollinganallur	2132	886	3018	1615 - 1715	341	169	510
53	Thoraipakkam	To Anna University	2690	2404	5094	1845 - 1945	315	291	606
54	Thoraipakkam	To Shollinganallur	2803	1727	4530	1815 - 1915	360	138	498
55	Jain College	To Shollinganallur	3190	2666	5856	1615 - 1715	390	204	594
56	Jain College	To Anna University	2466	2779	5245	1030 - 1130	444	230	674
57	Royapettah Govt Hospital	To Mylapore	2161	2692	4853	0845 - 0945	237	417	654
58	Adyar Hotel Gate	To CIT Colony	520	405	925	0815 - 0915	76	85	161
59	TTK Rd	To Adyar Gate Rd	553	352	905	1815 - 1915	65	39	104
60	T. Nagar Pondy Bazar	To Tynampet	597	724	1321	0930 - 1030	41	102	143
61	On Venkat Narayan Rd	To T. Nagar	376	345	721	1530 - 1630	35	43	78
62	Otteri Junction	To Pattalam	4042	4014	8056	0800 - 0900	499	471	970
63	Otteri Junction	To Aynawaram	1812	1875	3687	1715 - 1815	176	222	398
64	Otteri Junction Nr. Masjid	To Aynawaram	1529	1417	2946	1700 - 1800	155	149	304
65	Pariyar Nagar	To Gemini Cirlce	729	671	1400	0800 - 0900	91	78	169
66	Pariyar Nagar	To Kodambakkam	2411	1913	4324	1730 - 1830	239	185	424

Stop No	Name of Location	Direction	Total Boarding	Total Alighting	Total (B+A)	Peak Time	Peak Hour Boarding	Peak Hour Alighting	Peak Hour (B+A)
67	Venuvam Pettai	To Medavakkam	791	706	1497	1815 - 1915	96	94	190
68	Venuvam Pettai	To Guindy	853	883	1736	1815 - 1915	123	122	245
69	Alandur Metro Station	To Airport	7797	6941	14738	1615 - 1715	776	789	1565
70	Alandur Metro Station	To Kathipara	2833	3001	5834	1830 - 1930	382	319	701
71	Avichi School	To Porur	1978	1302	3280	0900 - 1000	213	121	334
72	Karaiyan Chavadi	To Porur	1537	1026	2563	1730 - 1830	200	114	314
73	Karaiyan Chavadi	To Vadapalani	5367	4411	9778	0800 - 0900	896	654	1550
74	Madipakkam	To Alandur	2148	2014	4162	0800 - 0900	289	269	558
75	Madipakkam	To Kovilamvakkam	1675	1179	2854	1915 - 2015	215	141	356
76	UTI Bank	To Alandur	1777	869	2646	0845 - 0945	200	91	291
77	IMOT Hospital	To Bharat Nagar	2332	2345	4677	1745 - 1845	246	218	464
78	IMOT Hospital	To Guindy	3366	3884	7250	0845 - 0945	529	786	1315
79	Nerkundram	To Koyambedu	3107	2789	5896	1100 - 1200	683	595	1278
80	Koyambedu Nr. Theater	To Parrys Corner	2157	1919	4076	0830 - 0930	491	377	868
81	Peripheral Hospital	To Villivakkam	711	751	1462	0745 - 0845	115	97	212
82	Peripheral Hospital	To Anna Nagar	949	905	1854	0830 - 0930	122	71	193
83	Natesha Nagar	To Virugambakkam	738	536	1274	0815 - 0915	74	45	119
84	Sai Nagar	To Koyambedu	1066	1197	2263	0745 - 0845	121	121	242
85	Kodambakkam Power house	To Vadapalani	4821	3056	7877	1730 - 1830	600	443	1043
86	Kodambakkam Power house	To Gemini	1625	987	2612	1200 - 1300	233	98	331
87	Chetpet Nr. Agellen Service Pvt ltd	To Chinmaya Vidhalya	3634	4796	8430	1715 - 1815	583	708	1291
88	Chetpet Nr TSO Tower	To Chetpet	4209	4297	8506	1945 - 2045	458	484	942
89	Murugan Temple	To Kodambakkam	4093	2240	6333	0815 - 0915	434	194	628
90	AVM Bus Stop	To Virugambakkam	1948	1149	3097	1700 - 1800	258	122	380
91	Pattalam	To Purushawakkam	2086	1171	3257	0945 - 1045	292	145	437
92	Panagal Park	To Tynampet	2471	3105	5576	1745 - 1845	194	379	573
93	Alandur Nr. Bus Depot	To Airport	336	282	618	0815 - 0915	40	36	76
94	Alandur Nr. Bus Depot	To Guindy	276	193	469	0845 - 0945	34	25	59
95	Moolakadai	To Perambur	835	416	1251	0745 - 0845	79	80	159
96	Collector Nagar	To CMBT	485	227	712	1845 - 1945	90	32	122
97	Retteri	To Perambur	2581	1923	4504	0800 - 0900	282	180	462
98	Kesavardini	Towards Porur	1146	1046	2192	1800-1900	165	92	257
99	Kesavardini	Towards Alwarthirunagar	1231	681	1912	1730-1830	135	55	190
100	Kattupakkam	Towards Poonamallee	674	755	1429	1730-1830	74	124	198
101	Kattupakkam	Towards SRMC	808	749	1557	1800-1900	76	79	155

Stop No	Name of Location	Direction	Total Boarding	Total Alighting	Total (B+A)	Peak Time	Peak Hour Boarding	Peak Hour Alighting	Peak Hour (B+A)
102	Kalarai	Towards Kattupakkam	794	758	1552	0900-1000	91	85	176
103	Kalarai	Towards Poonamallee	978	894	1872	1745-1845	82	85	167
104	Thirumazhisai	Towards Poonamallee	1368	1063	2431	1730-1830	122	133	255
105	Thirumazhisai	Towards Sempermpakkam	586	442	1028	0815-0915	54	61	115
	Grand Total		**210911**	**179483**	**390395**				

It is observed from the OD surveys conducted that the share of service purpose trips is 56.3%, followed by educational trips which contribute to 12.9% as presented in Error! Not a valid bookmark self-reference.**.** The business trips and social trips contribute 15.9% & 5.1% respectively.

TABLE 2-6: DISTRIBUTION OF PT/IPT PASSENGERS BY TRIP PURPOSE

Trip Purpose	Service	Business	Education	Social	Others	Total
PT/IPT Passengers	219861	62017	50360	19717	38440	390395
Composition (%)	**56.3**	**15.9**	**12.9**	**5.1**	**9.8**	**100.0**

2.4 EXISTING PEDESTRIAN & ENCROACHMENT CHARACTERISTICS

On-street parking and encroachment of road space by vendors have been observed on all major roads in the City which reduces the efficiency of road carriageway leading to congestion. The existing traffic characteristics are presented in **Figure 2.3.**

FIGURE 2.3: EXISTING ROAD CHARACTERISTICS

Purasaiwakkam High Road

Nungambakkam High Road near Gemini Jn.

 Sholinganallur Junction	 Echangadu Signal near Kilkattalai
 Thalapalpetti - Moolakadai Road (4L Undivided)	 Nungambakkam High Road (4L Divided)
 Usman Road at Panagal Park	 Arcot Road (4L Divided)
 Arcot Road – Near Vadapalani	 Near Porur Junction

2.5 ISSUES AND PROSPECTS

Large-scale urbanization and rapid growth of vehicles population has laid severe stress on urban transport system in city. The sharing of limited right of way by a variety of modes and other utility services has resulted in traffic congestion, accidents, inadequate parking area and environment deterioration.

The usage of private modes is growing unabated mainly due to inadequate and inconvenient public transport facilities with poor level of service.

The Phase 1 of Chennai metro covers 54 km in three corridors including Extension. Presently a total metro network of about 35 km is operational in the city. With a view of augmenting the mass transit system in addition to the existing public transportation and Phase-I Metro rail system, the Government of Tamil Nadu has decided to expand the existing metro rail network in Phase- II.

3. TRAVEL DEMAND FORECAST

3.1 BACKGROUND

Detailed traffic and household surveys (23,400 household samples) were carried out as part of Metro Rail Master Plan study covering Chennai Metropolitan Area (CMA). The distribution of household size, income level and vehicular ownership are presented in **Tables 3.1, 3.2** and **3.3** respectively.

TABLE 3.1: DISTRIBUTION OF HOUSEHOLD SIZE

S. No.	HH Size	%
1	Less than 2	6.0
2	3	25.0
3	4	42.0
4	5	23.0
5	6 and above	5.0
	Total	**100.0**

TABLE 3.2: DISTRIBUTION OF INCOME LEVEL

Income Level	Range	%
A	5000 and less	4.3
B	5000-10000	16.9
C	10000-20000	38.4
D	20000-30000	26.9
E	30000-40000	11.2
F	40000-50000	1.6
G	>50000	0.8
	Total	**100.0**

TABLE 3.3: DISTRIBUTION OF VEHICLE OWNERSHIP

Vehicle per Household	%
0	32.3
1	55.4
2	10.4
3 and above	2.0
Total	**100.0**

Average Trip length (km) and distribution of modal share across different modes of transport is presented in **Tables 3.4** and **3.5.** The average trip length has increased over the years as the city is growing along the outskirts. Share of public transport has been decreasing over the years with increase in private mode trips.

TABLE 3.4: DISTRIBUTION OF AVERAGE TRIP LENGTH

S. No.	Mode	Average Trip Length (km)
1	Walk	1.95
2	Bicycle	3.63
3	IPT (Auto Rickshaw / Shared Auto)	4.94
4	Two wheelers	9.23
5	Car/Van	9.52
6	Bus	12.11
7	Train	12.97

TABLE 3.5: DISTRIBUTION OF MODE SHARE

S. No.	Mode	%
1	Bus	23.5
2	Train	5.0
3	Car/Taxi	7.0
4	Fast two wheelers	27.0
5	Auto Rickshaw	6.0
6	Bicycle	5.5
7	Cycle rickshaw & others	0.0
8	Walk	26.0
	Total	100.0

3.2 TRAFFIC ANALYSIS ZONES

The traffic zone system and transport network as followed in the earlier study has been adopted for present assignment also. A total of 275 internal zones inside CMA area and 15 external zones have been considered. The zone map is presented in **Figure 3.1**.

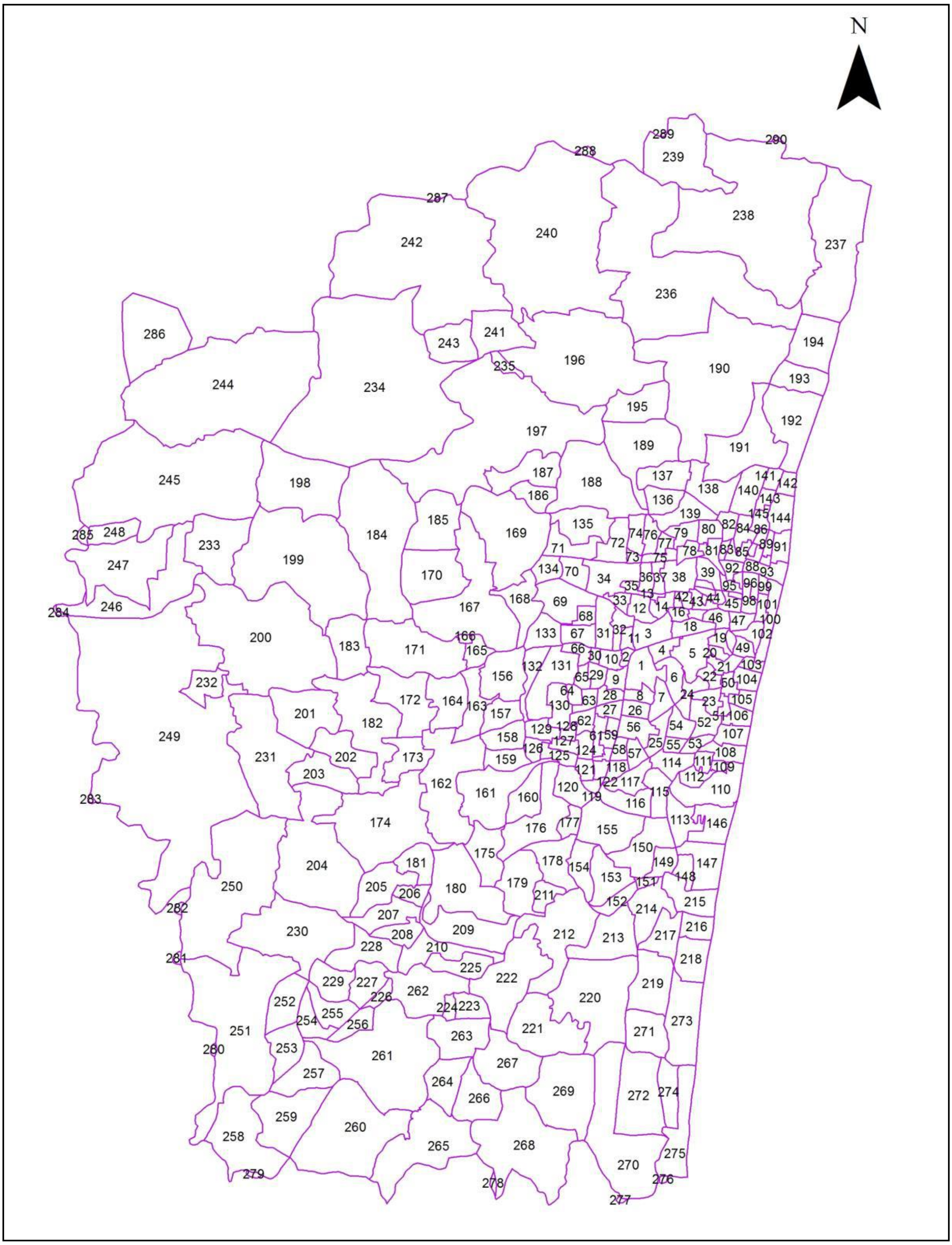
3.3 DEVELOPMENT OF TRAVEL DEMAND MODEL

3.3.1 Travel Demand Modelling

An urban transport model was developed as part of Feasibility Study for travel demand assessment and to arrive at influential mass rapid transit corridors. The methodology adopted for travel demand forecast is presented in **Figure 3.2.**

For present assignment, Cube Voyager Software has been used for the updation of model. The modes that have been modelled include two- Wheeler, Private Car, Taxi, three-Wheeler and shared three-Wheeler, Public Transport. The highway (road) network considered all the key arterials, sub arterials and collectors (1047 km).

FIGURE 3.1: TRAFFIC ANALYSIS ZONES



The transit system considered the existing public transport system in all its forms i.e. bus, suburban rail and MRTS with its routes, frequency, fare structure, etc. bus routes- 897 routes, share auto routes- 8 routes, three commuter rail routes and one MRTS route). The model inputs for network are presented in **Table 3.6.**

TABLE 3.6: TRANSIT SYSTEM CONSIDERED FOR TRAVEL DEMAND MODELLING

SN	Parameters	Type/Value
1	Software	CUBE
2	Network	2033 links & 1763 nodes
3	Bus Routes	897 bus routes
4	Mass Transit Routes	3 Suburban / 2 Monorail / 1 MRTS / 2 Metro Phase-I routes
5	Modes	Two wheeler, Car, Taxi, Three Wheeler and Share Autos and Public Transport modes
6	Population	2011 census and as per second master plan 2026

Source: Feasibility Study for Phase-II, July 2015

Vehicle Occupancy: The average occupancy adopted for the modes are given in **Table 3.7**.

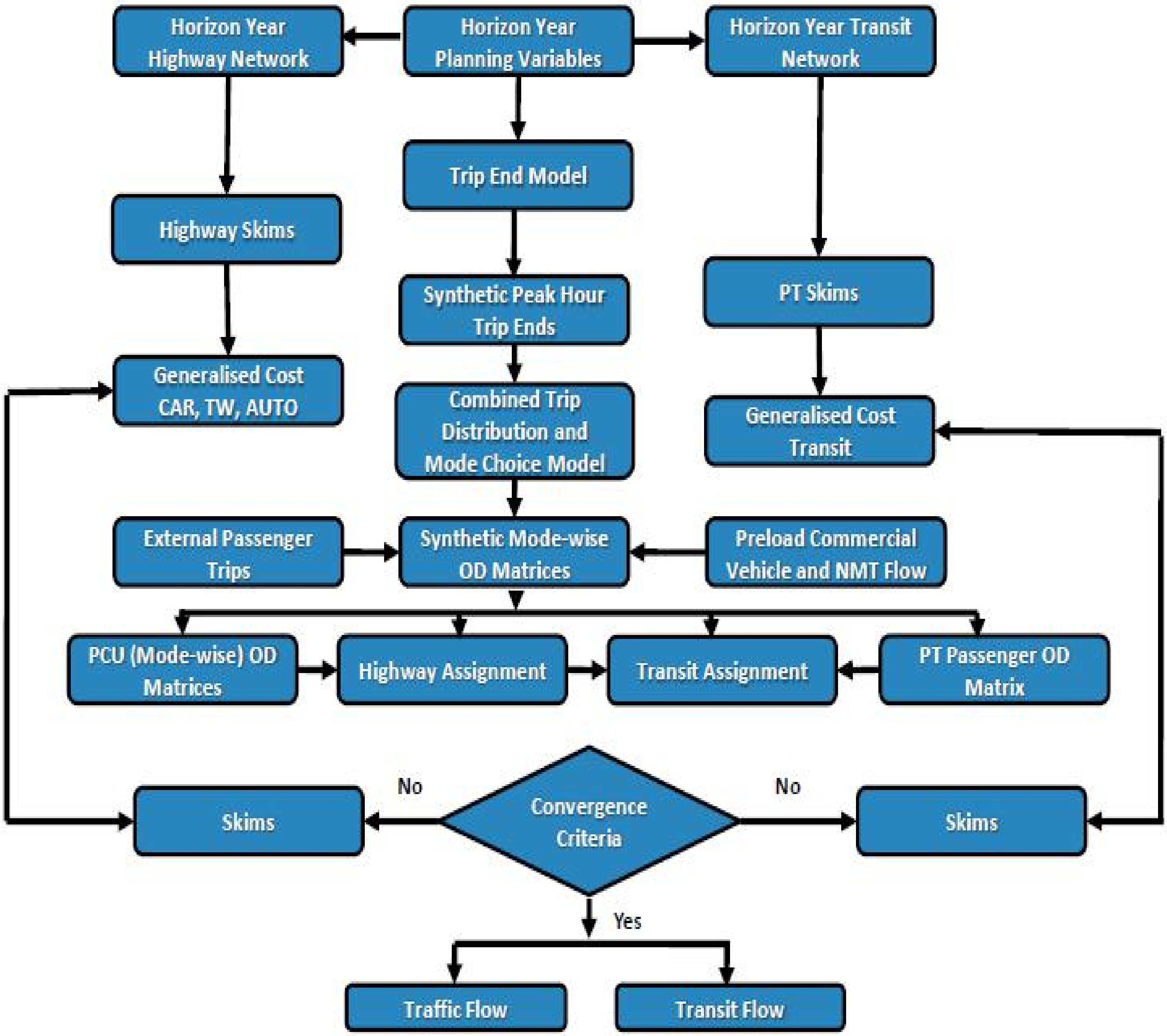
TABLE 3.7: AVERAGE VEHICLE OCCUPANCY

SN	Modes	Occupancy
1	Two Wheeler	1.2
2	Car/Jeep/Van (Private)	2.0
3	Car/Jeep/Van (Taxi)	2.5
4	Auto Rickshaws	2.0
5	Bus	67.0

Travel Demand Forecast Assumptions: The following forecast assumptions were used in the model. These assumptions are arrived at with the help of primary or secondary data concurrence with the expert opinion of our Economist. The various assumptions in the forecast model are:

- The projection has been done for the year 2025, 2035 and 2045.
- The transport proposals already in the implementation stage or been committed has been included in the forecast years.
- Per capita trip rate: Motorized trips will grow from 1.18 in the base year to 1.45 by year 2035.
- Operating speed of the metro system is considered as 32 kmph
- The bus fare considered is the weighted average of Ordinary, Express, Deluxe and Volvo buses.
- The headways of 5 minutes, 3.5 minutes and 2.5 minutes have been considered in travel demand model for 2025, 2035 and 2045
- The per capita trip rates of 1.41 and 1.45 have been estimated for different horizon years of 2025 and 2035 respectively.

FIGURE 3.2: METHODOLOGY FOR TRAVEL DEMAND FORECAST



3.3.2 Planning Parameters for Horizon Years

The base year population is estimated based on the 2011 Census and the anticipated population in the CMA as per the second Master Plan. The estimated population and employment for the year 2015 is presented in **Table 3.8**.

TABLE 3.8: POPULATION AND EMPLOYMENT FOR BASE YEAR

Forecast Input Variables	2011	2015	Annual Growth Rate
Population	88.2	95.7	2.8%
Employment	37.4	41.9	4.0%

The planning parameters for horizon years including population and employment in CMA for the horizon years 2021, 2026 and 2035 as estimated in Feasibility Report are presented in **Table 3.9.**

TABLE 3.9: POPULATION AND EMPLOYMENT FOR HORIZON YEARS

Year	Population (lakh)	Employment (lakh)
2021	110.76	51.05
2025	122.65	58.23
2026	125.82	60.18
2035	148.60	68.81

3.3.3 Trip Production and Attraction

Trip Generation modeling aims at predicting the total number of trips generated by and attracted to each zone of the study area. The summary of Production and Attraction (P&A) figures for various horizon years is presented in **Table 3.10**.

TABLE 3.10: PEAK HOUR PRODUCTION & ATTRACTION

TAZ	Productions	Attractions
2021	11,86,289	11,63,687
2025	13,39,065	13,11,771
2026	13,80,239	13,51,648
2035	17,05,679	16,70,984

3.3.4 Summary of Ridership from Feasibility Study

The Feasibility Study had proposed three metro corridors for Phase-II for a total length of 88.9 km with a total of 77 stations. The Feasibility Study had estimated ridership for the proposed three corridors for various horizon years. The study estimated PHPDT of 27560, 17200 and 30850 for Corridors 3, 4 and 5 respectively with a total daily ridership of 22.5 lakh passengers in horizon year 2035 in Phase-II.

3.4 REVISED RIDERSHIP ASSESSMENT FOR PHASE II NETWORK

3.4.1 Revision of Network in Cube

This revision of corridors necessitated an update in metro network in the travel demand model developed as a part of feasibility report for obtaining revised ridership figures for the updated network.

The travel demand model developed as a part of Feasibility Study has been provided to RITES Ltd. by CMRL. The revision in Chennai Phase II metro network / stations in existing model have been carried out for horizon years.

The traffic zone system and transport network followed in the Feasibility Report, 2015 has been adopted. RITES has considered the model for horizon years 2021, 2026, 2035 and 2045 without making changes to the basic set of assumptions as followed in Feasibility Report.

The parameters involved in the model development are traffic assessment zones, population, employment and transport systems (with their accessibility, speed & capacity) of the study area. However, further updates made in model include revision of metro network from 107.5 km to 119 km and its coding in PT routes with associated changes.

3.4.2 Revision of Network in Cube

Phase-II corridors along with coded road/metro network considered for travel demand updation is presented in **Figure 3.3**. After detailed discussions and studying various alignment options considering possible intermodal integration during the course of the study, the metro network has been revised for 119 km with 128 stations. The revised Corridors of Phase-II is presented in **Table 3.11.**

TABLE 3.11: DETAILS OF PROPOSED CORRIDORS FOR PHASE-II

Corridor	Name	Length (Km)	Stations
Corridor 3	Madhavaram to SIPCOT	45.8	50
Corridor 4	Lighthouse to Poonamallee Bypass	26.1	30
Corridor 5	Madhavaram to Sholinganallur	47.0	48
	Total	**118.9**	**128**

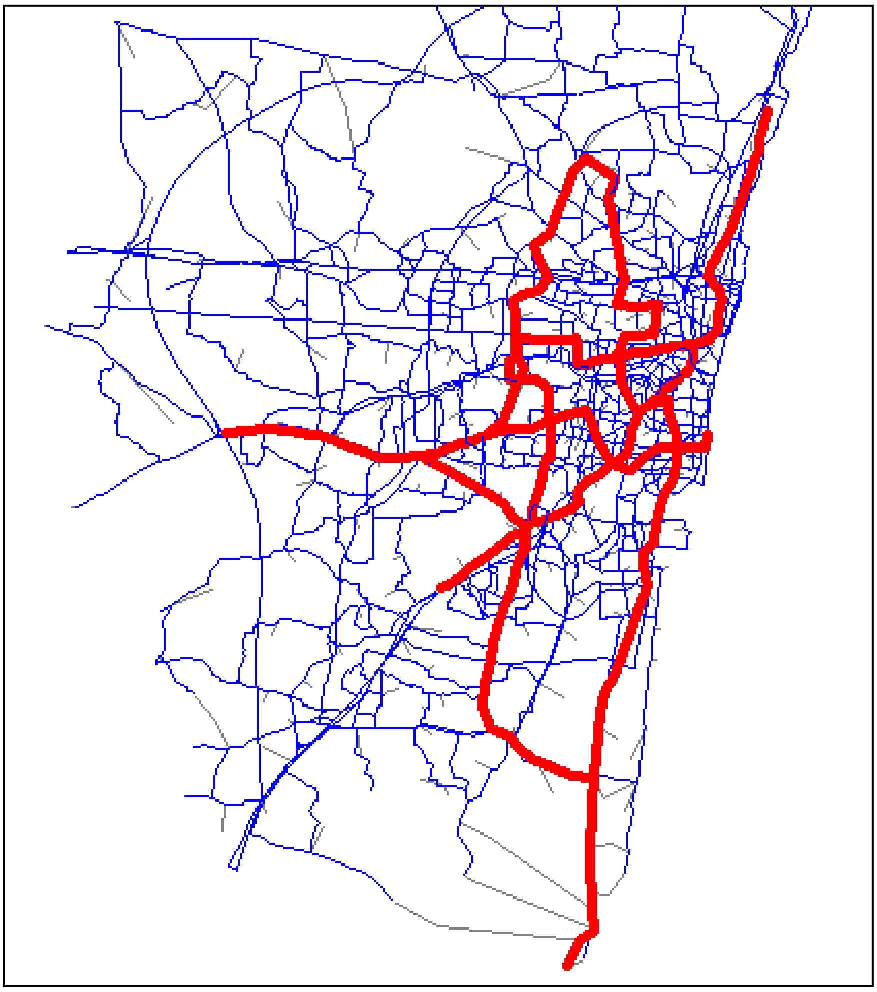
3.4.3 Planning Parameters & Peak Hour Production & Attraction for 2045

Production & Attraction (P&A) figures for 2021, 2026 and 2035 have been considered from Feasibility Study 2015. For year 2045 growth of 1% in the core city area and 1.5% in other zones of CMA are assumed and accordingly Production & Attraction (P&A) figures are worked out for 2045. The figures are presented in **Table 3.12.**

TABLE 3.12: POPULATION, EMPLOYMENT AND PEAK HOUR P&A FOR 2045

SN	Parameters	Figures
1	Population (lakh)	170.91
2	Employment (lakh)	76.01
3	Peak Hour Trip Productions (P)	18,83,851
4	Peak Hour Trip Attractions (A)	18,45,419

FIGURE 3.3: CUBE NETWORK & PHASE-II METRO CORRIDORS



3.4.4 Maximum Peak Hour Peak Direction Traffic (PHPDT), Daily Boarding and Passenger KM (PKM)

Peak Hour Peak Direction Traffic (PHPDT) and daily boarding (including interchange passengers) for horizon years 2025, 2035, 2045 and 2055 for Phase-II corridors have been estimated and is presented in **Table 3.13.** The ridership figures for 2025 and 2055 are estimated on the basis of growth rates between 2026 to 2035 and 2035 to 2045 respectively.

TABLE 3.13: TRAVEL DEMAND PROJECTIONS

Year	Max. PHPDT			Daily Boardings (in Lakh)				Daily PKM (in Lakh)			
	C3	C4	C5	C3	C4	C5	Total	C3	C4	C5	Total
2025	16,289	11,707	17,539	6.6	5.5	7.2	**19.2**	40.4	27.2	56.7	**124.3**
2035	22,115	18,944	24,528	10.1	9.3	13.2	**32.6**	49.3	44.2	88.3	**181.8**
2045	24,301	23,816	29,441	11.8	10.3	15.6	**37.7**	52.7	51.0	92.5	**196.3**
2055	27,361	29,940	35,714	13.6	11.4	18.5	**43.5**	56.4	58.9	96.8	**212.2**

3.4.5 Peak Hour Sectional Loads

The trips made between two adjacent stations of Phase-II corridors have been worked out for the horizon years of 2025, 2035, 2045 and 2055. The section loads for the horizon years are presented in **Table 3.14.**

TABLE 3.14: PEAK HOUR SECTION LOADS FOR PHASE-II CORRIDORS

From	To	2025		2035		2045		2055	
		Dir1	Dir2	Dir1	Dir2	Dir1	Dir2	Dir1	Dir2
C3 : Madhavaram to SIPCOT									
Madhavaram Milk Colony	Thapalpetti	2,184	1,023	2,771	1532	3,477	1760	4364	2021
Thapalpetti	Murari Hospital	2,445	1,199	2,884	2367	4,020	2581	5691	2824
Murari Hospital	Moolakadai	2,877	1,346	3,434	2572	4,675	2797	6469	3050
Moolakadai	Sembiyam	4,991	2,488	5,747	3773	7,455	3974	9792	4193
Sembiyam	Perambur Market	7,541	3,391	9,422	4783	12,991	5172	18129	5612
Perambur Market	Perambur Metro	9,692	4,293	12,511	5710	16,248	6427	21514	7301
Perambur Metro	Ayanavaram	10,468	4,509	13,096	5829	16,599	6518	21040	7288
Ayanavaram	Otteri	6,692	2,164	7,596	3881	9,557	4475	12032	5145
Otteri	Pattalam	5,963	2,077	6,698	3862	8,337	4613	10387	5502
Pattalam	Perambur Barracks Road	6,698	2,465	8,282	4195	9,729	5048	11507	6069
Perambur Barracks Road	Doveton Junction	7,220	2,967	8,939	4772	10,237	5932	11800	7391
Doveton Junction	Purasaiwakkam High Road	6,233	2,364	6,959	3672	8,177	4497	9679	5527
Purasaiwakkam High Road	Kelleys	7,420	3,518	8,757	5421	9,873	6295	11211	7327
Kelleys	KMC	9,436	5,549	11,948	7518	13,743	8488	15903	9617
KMC	Chetpet Metro	12,108	7,736	15,272	9488	17,966	10240	21226	11063
Chetpet Metro	Sterling Road Junction	10,489	6,548	12,786	7726	15,024	8156	17759	8606
Sterling Road Junction	Nungambakkam	10,288	6,514	13,103	7740	15,518	8155	18469	8589
Nungambakkam	Gemini	9,952	6,187	12,566	7475	14,817	7799	17553	8120
Gemini	Thousand Lights	9,400	5,658	11,675	6987	13,576	7241	15830	7485
Thousand Lights	Royapettah Govt. Hospital	9,195	5,394	11,281	6806	13,074	6940	15325	6991
Royapettah Govt. Hospital	Radhakrishnan Salai Jn	9,590	5,324	11,949	6903	13,812	7038	16114	7089
Radhakrishnan Salai Jn	Thirumayilai Metro	9,751	5,480	12,257	7127	14,148	7270	16482	7323
Thirumayilai Metro	Mandaiveli	10,964	6,201	14,565	7356	16,905	7463	19775	7477
Mandaiveli	Greenways Road Metro	15,136	8,622	21,161	10231	23,761	10869	26882	11511
Greenways Road Metro	Adyar Junction	16,289	9,452	22,115	10699	24,301	11227	27329	11698
Adyar Junction	Adyar Depot	11,766	5,740	14,088	7253	15,720	7754	18158	8196
Adyar Depot	Indira Nagar	8,985	3,992	10,165	5543	11,605	6085	13845	6587
Indira Nagar	Thiruvanmiyur Metro	8,738	3,801	9,801	5431	11,200	6011	13396	6565
Thiruvanmiyur Metro	Taramani Link Road	6,750	2,742	7,823	3904	9,485	4271	12129	4584
Taramani Link Road	Nehru Nagar	6,091	2,528	7,389	3815	9,273	4252	12268	4671
Nehru Nagar	Kandanchavadi	5,694	2,233	6,877	3539	8,680	4055	11584	4583
Kandanchavadi	Perungudi	5,535	2,270	7,148	3393	9,354	3828	12907	4232

From	To	2025		2035		2045		2055	
		Dir1	Dir2	Dir1	Dir2	Dir1	Dir2	Dir1	Dir2
Perungudi	Thoraipakkam	6,096	2,596	8,963	4688	11,254	5214	14943	5771
Thoraipakkam	Mettukuppam	5,840	2,425	8,466	4708	10,702	5082	13967	5418
Mettukuppam	PTC Colony	4,414	2,931	6,381	5715	7,536	5986	9010	6172
PTC Colony	Okkiyampet	4,598	2,257	7,204	3753	8,071	3965	9184	4104
Okkiyampet	Karapakkam	2,997	1,780	4,676	2526	5,321	2832	5973	3133
Karapakkam	Okkiyam Thoraipakkam	2,943	1,364	4,774	1746	5,307	1802	5808	1804
Okkiyam Thoraipakkam	Sholinganallur	2,489	1,232	3,889	1511	4,426	1932	4935	2557
Sholinganallur	Sholinganallur Lake	2,213	1,760	3,566	2256	4,050	2789	4500	3543
Sholinganallur Lake	Sri Ponniamman Temple	1,587	1,294	2,716	2464	3,009	2615	3246	2833
Sri Ponniamman Temple	Sathyabhama University	1,102	1,620	2,360	2806	2,684	2854	2955	2925
Sathyabhama University	St. Joseph's College	1,215	1,619	2,326	2801	2,660	2884	2944	3004
St. Joseph's College	Semmancheri	1,217	1,938	2,321	3180	2,665	3283	2962	3420
Semmancheri	Gandhi Nagar	451	378	655	489	803	592	943	741
Gandhi Nagar	Navallur	599	446	776	598	907	717	1027	879
Navallur	Siruseri	884	703	1,035	900	1,208	1071	1377	1296
Siruseri	SIPCOT 1	950	827	1,068	1021	1,232	1210	1392	1433
SIPCOT 1	SIPCOT 2	101	102	124	156	165	184	219	217
C4 : Lighthouse To Poonamallee Bypass									
Light House	Foreshore Road	852	908	1,719	1,662	1,854	2,077	2000	2595
Foreshore Road	Kutchery Road	538	705	988	1,192	1,056	1,546	1128	2007
Kutchery Road	Thrumayilai MRTS	854	940	1,445	1,494	1,480	1,865	1516	2329
Thrumayilai MRTS	Alwarpet	1,834	1,596	2,329	2,740	2,340	3,225	2351	3796
Alwarpet	Bharathidasan Road	2,809	2,209	3,792	3,582	3,919	4,099	4051	4692
Bharathidasan Road	Adyar Gate Junction	3,428	2,652	4,832	4,278	4,941	4,706	5053	5177
Adyar Gate Junction	Nandanam	6,340	5,071	9,447	8,820	9,685	9,418	9928	10056
Nandanam	Natesan Park	8,100	6,611	10,918	12,283	11,257	13,332	11607	14469
Natesan Park	Panagal Park	8,604	6,973	11,735	13,149	12,132	13,892	12541	14678
Panagal Park	Kodambakkam Suburban	9,181	9,904	12,216	18,394	12,543	19,811	12879	21338
Kodambakkam Suburban	Meenakshi College	7,133	7,843	8,839	15,622	8,976	17,662	9114	19967
Meenakshi College	Powerhouse At Damro	6,488	7,537	7,349	14,806	7,624	17,211	7910	20008
Powerhouse At Damro	Vadapalani	5,683	6,720	5,881	13,395	6,141	15,773	6413	18573
Vadapalani	Saligramam	5,918	6,630	7,028	13,344	7,448	15,990	7893	19162
Saligramam	Avichi School	5,718	5,864	6,906	12,046	7,466	14,765	8071	18097
Avichi School	Alwarthiru Nagar	5,282	5,385	6,583	11,563	7,214	14,266	7904	17601
Alwarthiru Nagar	Valasaravakkam	5,916	5,982	7,193	12,112	7,786	14,781	8427	18039
Valasaravakkam	Karambakkam	5,872	6,128	7,214	12,338	7,839	15,058	8518	18377
Karambakkam	Alapakkam Junction	5,807	6,000	7,359	11,780	8,070	14,861	8850	18749
Alapakkam Junction	Porur Junction	6,256	6,409	7,704	12,190	8,500	14,990	9379	18432
Porur Junction	Chennai Bypass Crossing	8,631	11,707	11,108	18,944	12,004	23,816	12973	29940
Chennai Bypass Crossing	Ramachanrda Hospital	6,976	8,155	9,665	15,611	10,714	20,482	11877	26873

From	To	2025		2035		2045		2055	
		Dir1	Dir2	Dir1	Dir2	Dir1	Dir2	Dir1	Dir2
Ramachanrda Hospital	Iyyapanthangal Bus Depot	7,087	8,234	10,029	14,996	11,155	19,308	12407	24861
Iyyapanthangal Bus Depot	Kattupakkam	8,135	9,019	12,441	18,034	13,698	22,215	15082	27366
Kattupakkam	Kumanan Chavadi	6,509	7,449	10,159	15,300	11,322	18,859	12618	23247
Kumanan Chavadi	Karayan Chavadi	6,392	7,620	11,372	14,409	11,964	17,342	12587	20873
Karayan Chavadi	Mullai Thottam	5,570	5,225	14,997	11,379	15,689	14,727	16413	19059
Mullai Thottam	Poonamallee Bus Terminus	4,321	3,873	13,277	7,190	13,736	12,246	14210	16457
Poonamallee Bus Terminus	Poonamallee Bypass	4,371	3,823	8,394	3,873	8,437	3,900	8480	3926
C5 : Madhavaram to Sholinganallur									
Madhavaram Milk Colony	Venugopal Nagar	2,536	1,380	4,814	1706	5,081	3411	5363	6820
Venugopal Nagar	Assissi Nagar	2,554	1,357	4,652	1617	4,910	3070	5182	5872
Assissi Nagar	Manjambakkam	2,413	1,154	3,149	2137	3,517	3550	3942	6269
Manjambakkam	Velumurugan Nagar	2,147	1,060	2,416	1864	2,770	3155	3183	5697
Velumurugan Nagar	MMBT	2,838	1,586	4,158	3113	4,564	4563	5023	7272
MMBT	Shastri Nagar	3,809	2,196	4,841	3637	5,843	4744	7237	6502
Shastri Nagar	Retteri Jn.	6,376	3,778	9,477	6122	11,555	7670	14269	9946
Retteri Jn.	Kolathur Jn.	9,340	4,909	13,966	7542	16,530	9227	19782	11650
Kolathur Jn.	Srinivasa Nagar	10,794	5,485	16,569	8483	20,091	10126	24649	12489
Srinivasa Nagar	Villivakkam Metro	12,388	6,234	18,904	9553	22,742	11147	27657	13450
Villivakkam Metro	Villivakkam Bus Terminus	12,291	6,837	19,132	10545	23,299	12104	28666	14308
Villivakkam Bus Terminus	Nathamuni	14,618	8,873	23,155	14714	27,819	16188	33742	18138
Nathamuni	Anna Nagar Depot	16,234	10,101	23,895	15735	28,589	17225	34515	19190
Anna Nagar Depot	Thirumangalam	16,146	11,266	23,055	17534	29,119	18,357	35083	19533
Thirumangalam	Kendriya Vidyalaya	16,692	12,998	23,147	21006	28,047	22637	32396	24786
Kendriya Vidyalaya	Kaliammankoil Street Jn.	16,880	12,833	23,769	20480	28,358	21963	34171	23947
Kaliammankoil Street Jn.	CMBT	17,539	13,890	24,528	20969	29,441	22288	35714	24079
CMBT	Grain Market	15,335	11,998	22,298	15525	25,472	16181	29413	17263
Grain Market	Sai Nagar Bus Stop	14,878	11,542	21,071	14090	24,419	15347	28718	16593
Sai Nagar Bus Stop	Elango nagar Bus Stop	14,214	11,083	20,447	13226	23,964	14389	28636	15532
Elango nagar Bus Stop	Alwartirunagar	12,355	8,771	17,211	10232	20,067	11830	23943	13926
Alwartirunagar	Valasaravakkam	11,986	8,765	16,757	10319	19,562	11939	23474	14063
Valasaravakkam	Karabakkam	9,831	6,644	13,697	7104	16,206	8472	19810	10331
Karabakkam	Alapakkam Junction	9,212	6,231	12,522	6642	15,027	7670	18773	8973
Alapakkam Junction	Porur Jn.	9,765	6,947	16,033	7027	21,536	8369	27023	10150
Porur Jn.	Mugalivakkam	10,726	8,089	18,848	9057	24,250	10153	29628	11615
Mugalivakkam	DLF IT SEZ	10,751	7,949	18,976	8772	24,187	9677	29117	10865
DLF IT SEZ	Sathya Nagar	11,309	8,224	21,440	8921	26,323	9572	30688	10455
Sathya Nagar	CTC	11,569	8,832	21,735	9702	26,960	10735	31792	12169
CTC	Butt Road	12,349	9,765	23,501	11881	29,149	12435	34503	12901

From	To	2025		2035		2045		2055	
		Dir1	Dir2	Dir1	Dir2	Dir1	Dir2	Dir1	Dir2
Butt Road	Alandur	11,620	8,146	21,508	10273	27,015	11047	32223	11948
Alandur	St. Thomas Mount	8,904	8,087	14,683	10498	15,641	11259	16829	12146
St. Thomas Mount	Adambakkam	6,182	6,093	10,461	8455	11,202	9308	12191	10308
Adambakkam	Vanuvampet	5,514	5,199	8,950	6589	9,592	7474	10505	8538
Vanuvampet	Puzhuthivakkam	5,596	5,068	9,113	6344	9,813	7242	10804	8331
Puzhuthivakkam	Madipakkam	4,985	3,928	8,123	4780	8,247	5807	8364	7205
Madipakkam	Kilkattalai	5,280	3,677	8,684	4559	8,867	5353	9049	6365
Kilkattalai	Echangadu	3,965	5,254	6,232	8460	6,447	9663	6691	11108
Echangadu	Kovilambakkam	3,717	3,781	6,476	5823	6,913	6657	7458	7696
Kovilambakkam	Vellakkal	3,042	2,548	5,231	3349	5,373	3644	5556	4027
Vellakkal	Medavakkam Koot Road	3,044	2,228	5,301	2741	5,439	2971	5614	3280
Medavakkam Koot Road	Kamaraj garden Street	2,495	1,574	3,445	1780	3,749	1782	4181	1821
Kamaraj garden Street	Medavakkam Jn.	2,142	1,276	2,837	1411	2,995	1441	3248	1558
Medavakkam Jn.	Perumbakkam	2,353	1,147	3,267	1629	3,465	1644	3760	1710
Perumbakkam	Global Hospital	2,358	1,142	3,277	1629	3,460	1642	3688	1700
Global Hospital	ELCOT	2,021	884	3,498	1999	3,550	2308	3629	2750
ELCOT	Soholinganallur	2,093	574	3,747	596	3,754	767	3761	987

3.4.6 Peak Hour Station Loads

The peak hour station loads in terms of two way platforms boarding & alighting (B&A) on Phase-II Corridors for horizon years 2025, 2035, 2045 and 2055 are presented in **Table 3.15.**

TABLE 3.15: PEAK HOUR STATION LOADS FOR PHASE-II CORRIDORS

Station Names	2025		2035		2045		2055	
	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*
C3 : Madhavaram To Sipcot								
Madhavaram Milk Colony	2184	1023	2771	1532	3477	1760	4364	2021
Thapalpetti	593	508	980	1702	1473	1752	2327	1803
Murari Hospital	530	245	676	331	821	382	997	444
Moolakadai	2257	1285	2595	1483	3179	1576	3894	1713
Sembiyam	2881	1234	4191	1526	6190	1852	9175	2258
Perambur Market	2404	1155	3454	1292	3741	1739	4051	2355
Perambur Metro	1197	637	1554	1088	2256	1997	3315	3776
Ayanavaram	2899	4330	3412	6963	3662	8661	3935	10800
Otteri	477	1119	840	1719	907	2265	984	2986
Pattalam	1394	1047	3068	1817	3257	2300	3469	2915
Perambur Barracks Road	883	863	1478	1399	1553	1929	1632	2662
Doveton Junction	973	1357	1563	2443	2010	2635	2587	2843
Purasaiwakkam High Road	1842	1809	2840	2791	3103	3205	3436	3705

Station Names	2025		2035		2045		2055	
	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*
Kelleys	2260	2275	3464	2372	4182	2506	5049	2647
KMC	3823	3338	5010	3655	6193	3720	7664	3787
Chetpet Metro	1439	1870	2543	3267	3003	3861	3563	4574
Sterling Road Junction	1180	1347	1764	1461	2027	1533	2335	1608
Nungambakkam	582	591	803	1075	1005	1350	1260	1707
Gemini	732	755	806	1209	903	1587	1013	2100
Thousand Lights	511	452	698	911	1367	1568	2701	2712
Royapettah Govt. Hospital	1108	643	1615	1045	1902	1262	2251	1561
Radhakrishnan Salai Jn	422	417	1025	941	1123	1018	1240	1105
Thirumayilai Metro	2670	2178	5145	3066	5911	3347	6813	3675
Mandaiveli	5401	3650	7920	4199	8450	5000	9030	5955
Greenways Road Metro	2901	2578	5162	4675	5530	5349	6379	6119
Adyar Junction	4446	5257	4618	9199	4667	9774	4717	10387
Adyar Depot	2178	3211	2415	4628	2513	4959	2620	5323
Indira Nagar	514	570	718	969	790	1121	871	1299
Thiruvanmiyur Metro	1637	2566	2507	2958	3031	3006	3770	3056
Taramani Link Road	637	1082	902	1246	1202	1396	1642	1589
Nehru Nagar	720	822	1159	1396	1266	1661	1386	1982
Kandanchavadi	426	622	1130	713	1744	843	2695	1021
Perungudi	1869	1634	3738	3217	4003	3489	4337	3840
Thoraipakkam	2206	2291	2917	3435	3459	3879	3764	4386
Mettukuppam	864	2796	1868	4959	2316	6385	2671	8382
PTC Colony	2087	1229	4724	1939	4928	2372	5144	2902
Okkiyampet	1627	2751	3324	4626	3727	5344	3961	6200
Karapakkam	1248	886	2426	1546	2795	1779	3227	2062
Okkiyam Thoraipakkam	906	1228	1815	2466	1951	2962	2098	3724
Sholinganallur	877	1681	1441	2509	1631	2864	1849	3270
Sholinganallur Lake	1431	1591	2209	3267	2642	3509	3230	3774
Sri Ponniamman Temple	540	1351	1748	2445	2025	2588	2360	2743
Sathyabama University	335	221	357	386	395	449	436	527
St. Joseph's College	260	577	276	660	337	731	413	810
Semmancheri	1865	1071	3060	2036	3233	2404	3502	2841
Gandhi Nagar	422	342	495	483	578	599	693	747
Navallur	501	473	585	628	663	717	752	819
Siruseri	305	363	385	473	510	624	715	837
SIPCOT 1	946	1070	1196	1275	1475	1516	1848	1805
SIPCOT 2	102	101	156	124	184	165	216	220
C4 : Lighthouse To Poonamallee Bypass								
Light House	852	908	1719	1662	1854	2077	2000	2595
Foreshore Road	278	388	692	952	764	1031	843	1117
Kutchery Road	414	334	582	427	624	519	675	665

Station Names	2025		2035		2045		2055	
	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*
Thrumayilai MRTS	1644	1322	2120	2483	2202	2702	2288	2940
Alwarpet	1043	683	1579	957	1726	1020	1887	1108
Bharathidasan Road	817	638	1522	1178	1633	1218	1786	1262
Adyar Gate Junction	3134	2642	5091	5019	5265	5233	5444	5458
Nandanam	4280	4052	5197	7189	5363	7704	5536	8266
Natesan Park	1092	951	1886	1935	2327	2013	3017	2098
Panagal Park	4821	7178	7470	12234	7516	13023	7563	13877
Kodambakkam Suburban	3183	3163	4437	5042	4555	5973	4690	7286
Meenakshi College	1140	1495	1986	2659	2137	3038	2368	3568
Powerhouse At Damro	1044	1045	1803	1861	1876	1921	1954	1985
Vadapalani	2304	1964	4609	3410	4827	3737	5061	4105
Saligramam	2471	1902	4293	3117	4762	3518	5283	4016
Avichi School	1160	1112	2550	2389	2662	2416	2785	2443
Alwarthiru Nagar	1489	1452	2600	2539	2818	2761	3070	3003
Valasaravakkam	110	298	209	414	357	580	638	814
Karambakkam	1234	1166	2566	1863	3022	2594	3568	3887
Alapakkam Junction	676	643	737	803	1143	841	2775	881
Porur Junction	2934	5836	4873	8223	5069	10390	5273	13151
Chennai Bypass Crossing	4162	2204	4761	2871	4975	2932	5229	2995
Ramachanrda Hospital	650	610	1839	859	2594	979	3760	1119
Iyyapanthangal Bus Depot	1145	893	2515	3141	2818	3182	3855	3224
Kattupakkam	1949	2001	3559	3107	4209	3230	4994	3357
Kumanan Chavadi	1233	1494	4149	2044	4882	2723	5895	3717
Karayan Chavadi	5202	3597	10984	4329	11230	4890	11482	5700
Mullai Thottam	2256	2175	5730	3261	5770	5243	5813	11932
Poonamallee Bus Terminus	2066	1909	5274	6840	10355	7308	13916	7809
Poonamallee Bypass	3823	4371	3873	8394	3900	8437	3926	8480
C5 : Madhavaram To Sholinganallur								
Madhavaram Milk Colony	2536	1380	4814	1706	5081	3411	5363	6820
Venugopal Nagar	307	266	371	444	674	503	1341	573
Assissi Nagar	572	510	707	2731	968	2841	1325	2963
Manjambakkam	401	573	617	1077	803	1153	1057	1244
Velumurugan Nagar	912	747	2048	1555	2200	1815	2384	2119
MMBT	1201	840	1386	1228	2400	1303	4367	1383
Shastri Nagar	2823	1838	5043	2892	6162	3376	7531	3943
Retteri Jn.	3482	1649	5698	2629	6350	2932	7079	3270
Kolathur Jn.	1750	872	3149	1486	4234	1572	5696	1669
Srinivasa Nagar	2074	1229	3288	2024	3706	2076	4177	2130
Villivakkam Metro	2832	3532	6327	7090	7915	8315	9904	9752
Villivakkam Bus Terminus	3070	2779	5285	5432	6090	5654	7131	5885

Station Names	2025		2035		2045		2055	
	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*	Total Board*	Total Alight*
Nathamuni	2762	2374	3033	3315	3538	3806	4137	4416
Anna Nagar Depot	3240	4493	7058	9697	9218	9820	10171	9946
Thirumangalam	1847	3033	4144	7523	4538	9889	5080	13020
Kendriya Vidyalaya	1559	1206	2927	1779	3170	2186	5436	2822
Kaliammankoil Street Jn.	2194	2592	4153	3884	5262	4503	6710	5299
CMBT	5940	6252	13449	10234	14320	12183	15249	14734
Grain Market	1014	1015	2319	2110	2673	2893	3227	3252
Sai Nagar Bus Stop	698	903	1227	989	1574	1070	2141	1161
Elango Nagar Bus Stop	3357	2904	4322	4564	4595	5933	4910	7997
Alwartirunagar	594	957	703	1245	995	1609	1498	2104
Valasaravakkam	3136	3170	5385	5230	6091	5980	6906	6839
Karabakkam	672	878	823	1536	1377	1753	2321	2001
Alapakkam Junction	1944	2107	5723	2596	8824	3014	10681	3608
Porur Jn.	3860	4041	7427	6643	7900	6969	8452	7312
Mugalivakkam	447	282	808	394	1038	625	1355	1116
DLF IT SEZ	1350	1067	4274	1959	4553	2313	4886	2904
Sathya Nagar	794	1142	1172	1659	1551	2077	2058	2669
CTC	1306	1459	2771	3184	3786	3297	5403	3424
Butt Road	2059	1169	2214	2599	2298	3045	2400	3728
Alandur	1085	3742	1362	8410	1428	13014	1832	17425
St. Thomas Mount	2485	3213	3169	5348	3320	5808	3513	6313
Adambakkam	1172	946	2253	1897	2393	2169	2579	2496
Vanuvampet	553	340	815	407	978	525	1184	678
Puzhuthivakkam	1471	942	2008	1434	2109	2241	2216	3530
Madipakkam	1054	508	1743	962	2244	1169	2949	1424
Kilkattalai	365	3257	474	6827	651	7380	894	7996
Echangadu	2401	1176	5231	2350	6279	2807	7543	3364
Kovilambakkam	1533	975	3478	2250	4262	2788	5223	3456
Vellakkal	760	438	1650	972	1870	1130	2120	1314
Medavakkam Koot Road	1220	1115	1932	2827	2395	2897	2995	2970
Kamaraj garden Street	536	591	636	875	730	1142	839	1509
Medavakkam Jn.	1152	812	1691	1478	1994	1727	2396	2036
Perumbakkam	300	290	425	415	990	993	2323	2385
Global Hospital	975	1054	2129	2279	2173	2748	2218	3327
ELCOT	766	384	2771	1119	3195	1450	3684	1789
Sholinganallur	574	2093	596	3747	767	3754	987	3761

* Two way boarding (B) / alighting (A) on platforms

3.4.7 Trip Length Frequency Distribution

The station to station OD matrices are extracted from the travel demand model for the horizon years. Based on the inter station distance, the distribution of trips is estimated for the given range of distances based on fare bands. The trip length distribution for various horizon years for Chennai Metro Phase-II corridors is given in **Table 3.16**.

TABLE 3.16: TRIP LENGTH FREQUENCY DISTRIBUTION

Distance in km	(Trips in %)											
	2025			2035			2045			2055		
	C3	C4	C5	C3	C4	C5	C3	C4	C5	C3	C4	C5
0-2	8.7	9.4	7.8	10.1	9.5	4.2	10.0	9.6	4.2	10.0	9.6	4.2
2--4	14.5	13.3	10.7	13.9	13.1	12.5	13.7	13.0	13.8	13.4	12.9	13.6
4--6	15.6	15.4	10.4	13.7	15.3	11.9	11.9	14.9	13.0	12.3	14.1	13.2
6--12	24.9	27.4	28.1	24.9	28.5	29.8	27.4	27.1	28.6	27.1	25.8	28.3
12--18	17.8	14.9	20.4	14.4	13.4	19.1	14.9	13.9	18.1	14.9	14.3	17.8
18-24	9.3	10.0	11.3	13.9	8.4	12.4	12.2	9.0	8.9	12.2	9.6	9.2
>24	9.2	9.6	11.3	9.1	11.7	10.1	9.8	12.4	13.3	10.2	13.7	13.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

3.4.8 Average Trip Length

The average trip length (in km) for various horizon years for Chennai Metro Rail Phase-II corridors is presented in **Table 3.17.**

TABLE 3.17: AVERAGE TRIP LENGTH (KM)

SN	Year	Trip Length (in km)		
		Corridor-3	Corridor-4	Corridor-5
1	2025	10.96	10.98	12.26
2	2035	11.34	11.24	12.29
3	2045	11.42	11.50	12.41
4	2055	11.42	11.77	12.41

3.5 RIDERSHIP REALISATION

The estimated PHPDT and daily ridership figures will rely on the proposed developments as envisaged in Master Plan of Chennai and realization of other planned transport infrastructure projects. The PHPDTs of Chennai Metro Rail Phase-II corridors is impacted by the presence of various interchange points like Phase-I Metro Stations, Suburban Railway Station and Bus Terminal options available for the metro commuters resulting in larger trip lengths.

Metro system however, will serve the city much beyond 2055. Ridership realisation however depends on a number of factors including the type/ intensity/ direction of development, various policies of the government and a number of unforeseen issues that could appear during next 20-30 years. The system will start operating with initial ridership estimated and the capacity will be increased depending on the ridership growth.

4. SYSTEM & TECHNOLOGY SELECTION

4.1 BACKGROUND

Selection of a particular mass transit system for a city largely depends on the characteristics of the city and its metropolitan area, projection of traffic demand for travel and availability of suitable right-of-way (ROW). Mass Transit System is selected and planned to provide comfortable, safe, reliable and fast/high frequency connectivity across the cityscapes.

Urban transport requirements of Chennai have been evaluated based on expected traffic demand and medium capacity metro rail system is proposed as the most suitable system depending upon requirements of the city.

4.2 TECHNOLOGY

Metro rail system is the most prevalent mass transit system adopted worldwide. In India, MRTS is operational in various cities viz. Delhi, Chennai, Kolkata, Mumbai, Bangalore, Kochi, Jaipur etc. It is a grade separated system with exclusive right of way characterized by short distances of stations spaced at about 1 km and modern state of the art rolling stock having high acceleration and deceleration with maximum speed of 80-120 kmph. Sharpest curve of 120m radius is permitted for MRTS. The system can be designed to meet PHPDT from 10,000 to up to 80,000 depending upon type of systems and infrastructure adopted such as rolling stock, train set configurations, signaling system, stations platform length etc. Considering the city specific characteristics, traffic demand, availability of right of way, **medium capacity metro rail system with 6 car train composition can be adopted for the proposed corridors of Chennai**. Capacities indicated for 6 car trains have been calculated by considering 1.5 minutes (90 seconds) headway which is achievable with advanced signalling system i.e. CBTC technology. However, because of track geometry, radius of curvature and gradients etc. along track alignment, headway of 90 seconds may not be practically achievable for metro systems.

4.3 SYSTEM SPECIFICATION

Following system specification parameters are considered for Phase-II corridors. The rationale for choosing the particular technological parameter has been discussed in detail in the respective chapters.

TABLE 4.1: SYSTEM SPECIFICATION PARAMETERS

Parameters		System Specification
Traffic Handling capacity (PHPDT)		10000-80000
Alignment and Gauge	Minimum radius of curvature	Min. for elevated = 120m Min. for UG = 200m
	Gradient	4%
	Gauge	Standard gauge (1435 mm)
Traction System		25 kV AC Overhead Catenary
Signaling System		Communication Based Train Control (CBTC) System as per IEEE 1474.1
Telecommunication System		IP GE based
PSD		Half Height PSD for elevated stations and Full Height PSD for Underground stations
Rolling Stock	Coach Width	2.9 m wide coaches
	Basic Unit	3 Car basic unit 2DMC and 1 TC. Every coach should be fully interchangeable with any other coach of same type.
	Train Composition	3- Car: DMC+TC+DMC 6 –Car: DMC +TC +MC + MC + TC + DMC Capable of GoA4 operation
	Coach construction	Light weight stainless steel/Aluminum body
	Axle load	≤16 T
	Braking System	Regenerative Braking
	Propulsion system	3 phase drive system with VVVF control
	Performance Characteristics	Max. speed : **90 kmph** Max. Acceleration :**1.0 m/s^2** Max. Deceleration : **1.1 m/s^2 (Normal brake)** More than **1.3 m/s^2 (Emergency brake**

5. CIVIL ENGINEERING

5.1 PERMANENT WAY

5.1.1 Gauge

Almost all metro rail systems in the country including Phase I of Chennai Metro is being constructed on Standard Gauge (1435mm). Accordingly, it is proposed to adopt Standard Gauge (1435mm) for Chennai Metro Phase II corridors.

5.2 TRACK STRUCTURE

5.2.1 General

Track on Metro Systems is required to cater peculiar requirements as under: -

- Highest standards for safety of passengers and property.
- High reliability to minimize failures as Low as Possible.
- Low Axle loads of approx.16MT and low GMT.
- Very High Frequency of train operations on alignment having sharp curves and gradients.
- Frequent braking and acceleration at stations typically located @1 km distance.
- Minimum noise and vibrations.
- Maximum comfort to passengers.

Above working scenario leads to requirement of very high degree of safety and reliability but with very small window for inspections, maintenance and renewal of track assets. In view of above, the track structure selected for Metro system should have long life and high degree of reliability to reduce the maintenance and renewal efforts.

5.2.2 Rail Section and Grade

In view of sharp curves, steep gradients, frequent braking, requirement of less noise & vibration, rails on main lines should have high degree of wear resistance. To reduce maintenance and renewal efforts, Head Hardened (HH) rails of grade 1080 are proposed for main lines. Presently, HH rails are not manufactured in India and with regard to imported rails, two broad choices are available with regard to rail section i.e. 54 KG UIC and 60 Kg UIC section. Though the axle load and GMT of Metro rolling stocks are less and on criteria of axle load alone, 54 Kg UIC section shall be sufficient but keeping in view the difficulties in inspection, maintenance and renewal of rails, 60 KG UIC section is recommended, which will also have longer life than 54 Kg rail section. It is understood that SAIL, Bhilai is developing facilities for 60 KG HH rails for Indian Railways and it is expected that in near future, indigenous 60 KG 1080 HH rails shall be available.

Thus, for main lines, 60KG UIC HH rails of grade 1080 are proposed. For other than main lines and Depot lines, 60 kg rails of grade 880 (without Head hardening) are proposed. These rails are being manufactured indigenously. The rails for main lines and depot lines should also conform to the technical specifications laid down by Indian Railways in IRS-T- 12-2009. The rails should have cant of 1 in 20 and wheel profile of rolling stock should be compatible with rail profile.

5.2.3 Formation (Ballastless and Ballasted)

In views of peculiar working scenario outlined in preceding paras, ballastless track is proposed for elevated and underground stretches. **Figure 5.1** shows the plinth type ballastless track structure on viaducts.

At Depot, following track structure is proposed to serve specific usage:-

- Ballast less for Washing Line
- Steel pedestal for inspection lines
- Embedded Rail type inside Workshop
- Conventional Ballasted track for Stabling and other line

5.2.4 Fastening System for Ballasted Track

In Feb 2015, Govt. of India, Ministry of Railways- Nodal Ministry entrusted with technical planning of Metro Systems, has issued “Procedure for Safety certification and Technical clearance of Metro System”. Part-A, Annexure C-2 of the said document covers “Performance criteria of fastening system for ballesstless track on Metro Railways/MRTS System”. Ministry of Railways has already approved certain fastening systems complying the requisite performance criteria.

Further, scope for introduction of “new fastening system” has been made vailable (for those not approved by Ministry of Railways) with the proviso that the details of such fastening systems shall be made available to MoR and the same will be kept under observation by MoR for a period of two years under service conditions in association with Metro Railways/MRTS system.

5.2.5 Turnouts and Scissor Crossover

It is proposed to lay following types of turnouts on considerations of maintainability and riding comfort;

- On main lines of Elevated section with 4.9m track centre (Double U-girder), crossovers of 1 in 9 type turnout with lead radius of 300m and speed potential on divergent track as 45 km/h.
- On main lines of Underground section with 14.05 track centre, Scissor cross-over of 1 in 9 type turnout with lead radius of 190m and speed potential on divergent track as 35 km/h.
- On Depot lines, 1 in 7 type turnout with a lead radius of 190m and speed potential on divergent track as 35 km/h.

5.2.6 Welding

To minimize noise and vibrations, track joints should be welded by Flash Butt Welding Technique and Alumino-Thermit Welding may be done only for those joints which cannot be welded by Flash Butt Welding Technique.

FIGURE 5.1: TYPICAL CROSS SECTION OF BALLASTLESS TRACK ON VIADUCT

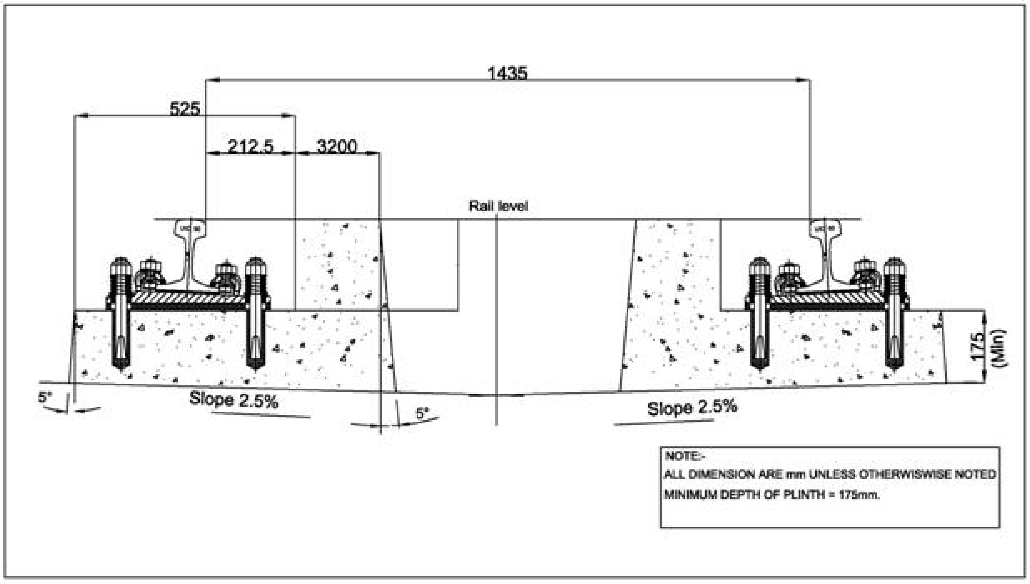


FIGURE 5.2: 1 IN 9 TYPE TURN-OUT (300M LEAD RADIUS)

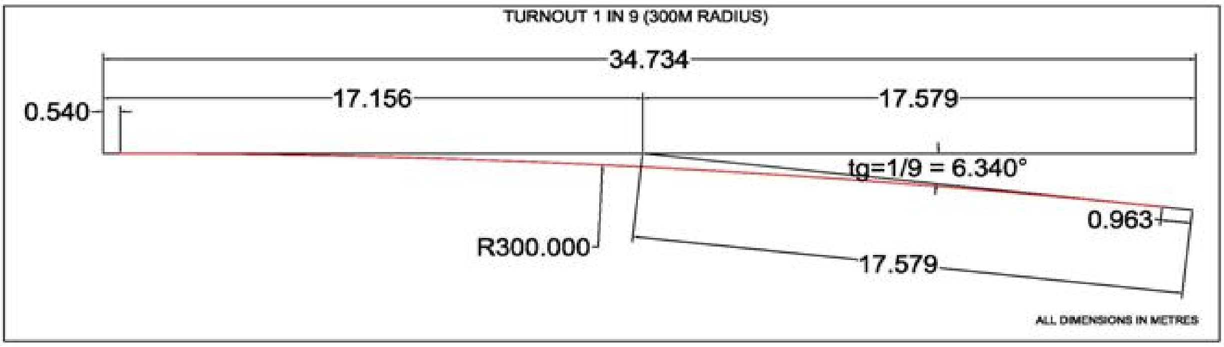


FIGURE 5.3: 1 IN 9 TYPE TURN-OUT (190M LEAD RADIUS)

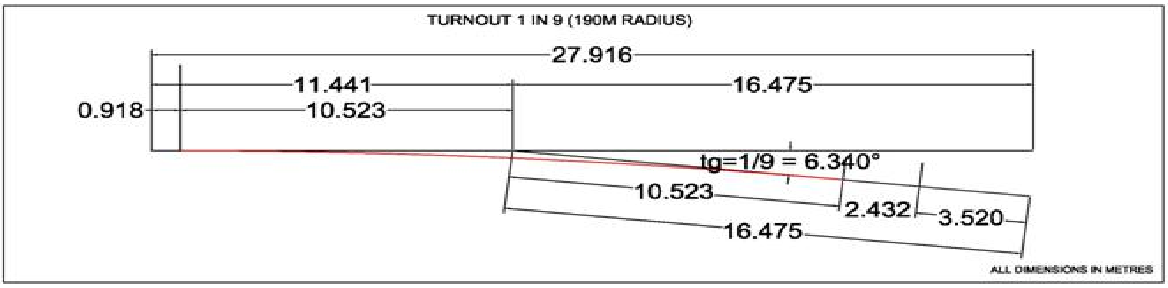


FIGURE 5.4: 1 IN 7 TYPE TURN-OUT (190M LEAD RADIUS)

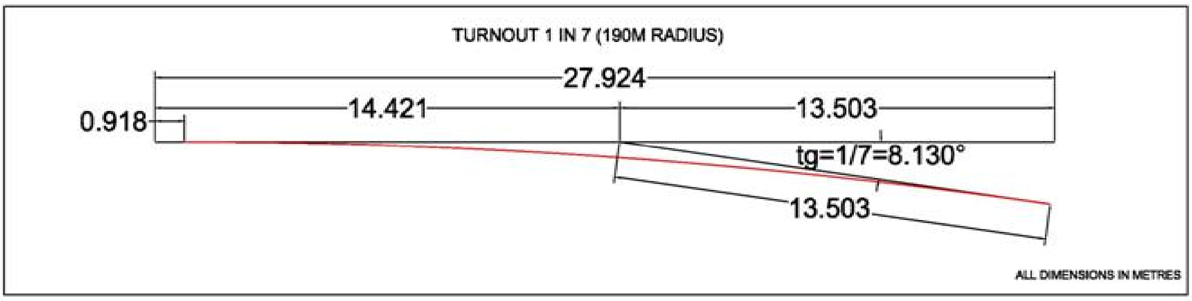


FIGURE 5.5: SCISSOR CROSS-OVER WITH 1 IN 9 TYPE TURN-OUT (190M LEAD RADIUS) ON MAIN LINES OF UNDERGROUND SECTION WITH 14.05 TRACK CENTRE

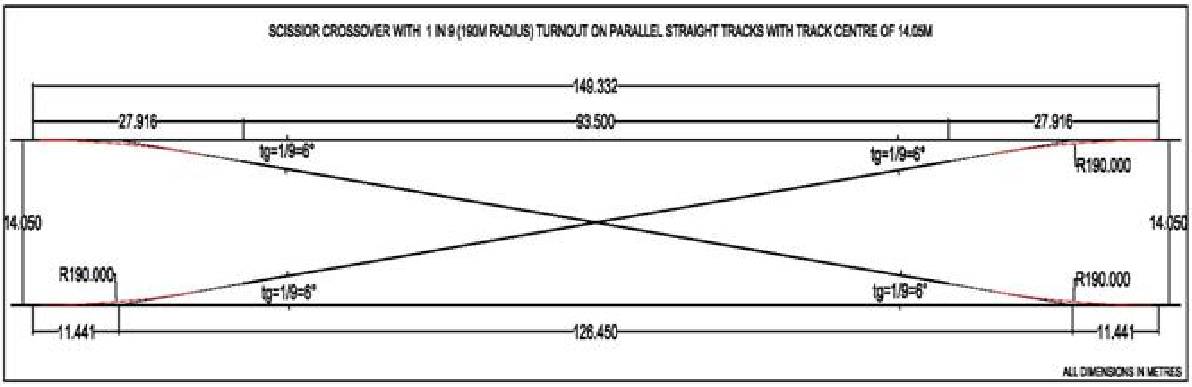
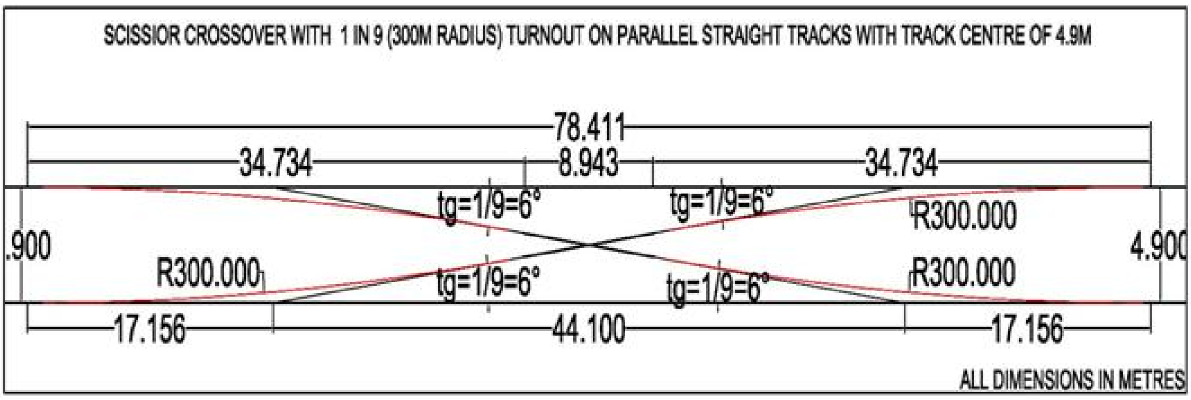


FIGURE 5.6: SCISSOR CROSS-OVER WITH 1 IN 9 TYPE TURN-OUT (300M LEAD RADIUS) ON MAIN LINES OF ELEVATED SECTION WITH 4.9M TRACK CENTRE



5.3 GEOMETRIC DESIGN PRINCIPLES

5.3.1 Principles for Metro Corridor Planning

i) To remain on CL of the existing road or Government premises/land to the extent feasible.

ii) To utilize the existing road Right of Way (ROW) to the maximum extent in order to minimise the land acquisition and also length of diversions.

iii) To avoid dismantling of existing structures/buildings etc. to the extent feasible.

iv) To avoid private built up areas, villages, habitation and religious structures etc. to the extent feasible.

v) To provide adequate clearance from existing Railway/ Highway structures.

vi) To satisfy the requirements of sound economic engineering practices

vii) To rationalise the location of proposed stations and underground ramps

5.3.2 Geometric Design Parameters

5.3.2.1 Alignment Considerations: As far as possible-

- Tangent alignment has been maximized.
- Flattest possible curves have been proposed.
- Number of curves has been minimized.
- Maximum possible transition lengths, commensurate to operating speed have been proposed.
- Elevated alignment has been maximized.
- Number of gradients has been minimized.
- Flattest possible vertical curve have been proposed.
- Cants of appropriate values, commensurate to operating speed at specific locations have been proposed to counter the effect of centrifugal force.
- Vertical curves & Transition curves of Horizontal Alignment do not overlap.

5.3.2.2 General Criteria

TABLE 5.1: DESIGN CRITERIA

SN	CRITERIA	DIMENSION
1	Gauge	1435 mm
2	Design Speed	80 kmph
3	Maximum Axle Load	16T
4	Electric Power Collection	25 KV AC (OHE)

5.3.2.3 Horizontal Alignment

A) Circular Curves

Larger radii shall be used whenever possible to improve riding quality. The minimum radius of curvature for mainline track shall be governed by the design speeds and by the limits for *cant* but shall not be less than 120m.

TABLE 5.2: HORIZONTAL CURVE PARAMETERS

Description	U/G Section	Elevated Section
Desirable Minimum Radius	300 m	200 m
Absolute minimum Radius	200 m	120 m
Minimum curve radius at stations	1000 m	
Maximum permissible cant (Ca)	110 mm*	
Maximum cant deficiency (Cd)	85 mm	
* The applied cant will be decided in relation to normal operating speeds at specific locations like stations/vicinity to stations.		

B) Reverse Curves

The use of reverse curves is discouraged but where necessary, the two curves have been separated by minimum 25 m. If provision of 25 m straight length is restricted by physical constraints, the two curves have provided without any straight in between.

C) Transition Curves

It is necessary to provide transition curves at both ends of the circular curves for smooth transition from straight section to curved section and vice-versa. **Table 5.3** shows required Length of transitions for Horizontal curves.

TABLE 5.3: LENGTH OF TRANSITIONS OF HORIZONTAL CURVES

Minimum Length	0.44 *actual cant (in mm) 0.44 * cant deficiency (in mm) whichever is higher
Desirable Length	0.72 *actual cant (in mm) 0.72 * cant deficiency (in mm) whichever is higher
Minimum Straight between two transition curves	25 m or NIL
Minimum horizontal curve length between two transition curves	25 m
No Overlap is allowed between transition curves and vertical curves	

5.3.2.4 Vertical Alignment

A) Elevated Section

As per para 2.12.2 of IRC : SP-73, "*Minimum 5.50 m vertical clearance shall be provided from all points of the carriageway of project Highways to the nearest surface of the overpass structure*". However, suitable margin is kept for future raising of road by resurfacing etc (min. 5.65m). Rail level will also depend upon the type and detailed design of pier cap and super-structure elements.

Rail levels at elevated station locations have been proposed by providing minimum vertical clearance and con-course of 3.50 m. Structural design of con-course floor slabs and viaduct will also govern the final rail level. **Table 5.4** shows required Track centres and height for elevated station.

TABLE 5.4: REQUIREMENT OF TRACK CENTRE AND HEIGHT IN ELEVATED SECTION

Parameter	Minimum Track Centre	Minimum Rail Level above Ground Level
Mid-Section	4.00 m*	7.50 m**
Station w/o Scissor Cross-over	4.00 m	12.00 m
Station with Scissor Cross-over	4.50 m	12.00 m

Note:
* Track centre in elevated section can be modified as per the choice of girder/superstructure. For Double U-girder minimum 4.90 m track centre will be provided.
** For I-girder and Box-girder, Minimum Rail Level above Ground Level shall be 8.50 m

B) Underground Section

Rail level at mid-section tunnels has been proposed with a view to provide minimum cover of tunnel diameter 'D' to the foundation of structures located above. At stations, depth of rail below the ground level shall accommodate station concourse also.

TABLE 5.5: TRACK CENTRE AND DEPTH IN UNDERGROUND SECTION

Description	Minimum Track Centre	General Depth below Ground Level for 2 level stations	General Depth below Ground Level for 3 level stations
Running section by TBM	14.05 m	16.0 m	21.0 m
Running section by cut & cover except ramp	4.90 m	12.60 m	12.60 m
Stations by cut & cover and island platform	14.05 m	15.0 m	20.0
Stations by cut & cover and side platform	4.90 m	15.0 m	20.0
Stations by NATM	22.00 m	18.0 m	20.0

5.3.2.5 Gradients

A) Mid-Section

The grade on the mid-sections shall not be generally steeper than 2.0%. However, there are a few situations, where steeper gradients are unavoidable, such as:

- Switch over ramp between underground and elevated sections where a grade of up to 4% (compensated) may be adopted to minimise the length of ramp.
- Where the existing road gradient is more than 2% as the elevated section is kept parallel to the road surface to minimise the rail level (to reduce the pier height).

Suitable longitudinal grades with drains at the low point are proposed for assuring proper drainage.

B) Stations

The stations shall preferably be on level stretch with suitable provision for drainage by way of cross slope and slope of longitudinal drains. However, maximum grade shall not exceed 1 in 400. There shall be no change of grade on turnouts on ballastless track.

C) Depot

For connectivity to track depot, maximum 4% (compensated) gradient is proposed. For other portions of depot, gradient as flat as possible with adequate track drainage shall be designed to suit the actual ground slope. All shop tracks shall be at level. Sidings shall be level or shall fall away from the main line connection at a gradient not exceeding 0.25%. There shall be no change of grade within 30 m of any points and crossing on ballasted track. **Table 5.6** shows gradient parameters.

TABLE 5.6: GRADIENT PARAMETERS

Description	Desirable	Absolute Minimum
Gradient at Mid-Section	Upto 2%	Upto 4% (compensated)
Gradient at Stations	Level	Upto 0.25%

5.3.2.6 Vertical Curves

Vertical curves are provided when change in gradient exceeds 0.4%. However, it is recommended that all changes in grade shall be connected by a circular curve or by a parabolic curve.

It is ensured that vertical curves and transition curves of horizontal alignment do not overlap. Minimum radius and length of vertical curves are tabulated in **Table 5.7**.

TABLE 5.7: VERTICAL CURVE PARAMETERS

Parameter	Vertical Curve
Desirable Radius on Main line	2500 m
Absolute Minimum Radius on Main line	1500 m
Minimum Length of Vertical Curve	20 m

5.3.3 Design Speed

The maximum sectional speed will be 80 km/h, subject to further restriction by radius of horizontal curves, cant and cant deficiency. The parameters of radius of horizontal curve, cant and permitted speed are summarized in **Table 5.8.**

TABLE 5.8: RADIUS, CANT AND PERMITTED SPEED

Radius	Actual Cant (Ca)	Permitted Speed
(m)	(mm)	(km/h)
5000	10	80
4000	13	80
3500	15	80
3000	17	80
2500	20	80
2000	25	80
1750	30	80
1500	35	80
1200	45	80
1000	50	80
800	65	80
600	85	80
500	100	80
450	105	80
400	105	80
350	110	75
300	110	70
200	110	55
175	110	50
150	110	45
120	110	40

5.4 CORRIDOR SELECTION

5.4.1 Chennai Metro Phase-I

The Phase-I of Chennai Metro covers 54 km in two corridors - Washermenpet to Airport (23.085 Km), Chennai Central to St. Thomas Mount (21.96 Km) and extension from Washermanpet to Wimco Nagar (9 km) in Thiruvottriyur. A stretch of 10.7 km from Koyambedu to Alandur in Corridor 2 became operational from June 2015 and Little Mount to Airport (7.7 km) & Alandur to St. Thomas Mount (1.3 km) in Corridor 1 opened in September/October 2016. Further, sections from Thirumangalam to Nehru Park (8.0 km) in May 2017, Little Mount Station to AGDMS Station (7.3km) and Egmore to Chennai Central Station (7.3 km) in May 2018 are also under operations.

5.4.2 Comprehensive Transportation Study (CTS)

Based on the Studies undertaken by Chennai Metropolitan Development Authority viz. Chennai Comprehensive Transportation Study and based on the corridors already identified in the Detailed Project Report for Phase-I of Chennai Metro Rail Project, the Delhi Metro Rail Corporation has proposed three corridors for taking up under Phase-II. i.e. Corridor 3 – From Madhavaram to Lighthouse (17 Km), Corridor 4 - From Koyambedu to Injambakkam (27 Km) and Corridor 5 – From Madhavaram to Perumbakkam (32 Km).

Corridor 3 – Madhavaram - Perambur - Ayanavaram – Purasaiwalkam - Nugambakkam High Road - Gemini - Radhakrishnan Salai - Lighthouse (17 Km)

Corridor 4 – Koyambedu - Saligramam – Vadapalani - Kodambakkam - Panagal Park - Nandanam - Luz - Mandeveli - Adyar - Besant Nagar - Tiruvanmiyur - Kottivakkam - Injambakkam (27 Km)

Corridor 5 - Madhavaram- Kolathur- Villivakkam- Anna Nagar West- Mugappir- Madurvoyal- Valsarawakkam- Trade Centre- OTA- Adambakkam- Madipakkam- Kikattalai- Edavakkam- Perumbakkam (32 Km).

5.4.3 Feasibility Study for Phase-II Corridors of Chennai Metro

Corridor 3: Madhavaram to Siruseri along Old Mahabalipuram Road (OMR)

Madhavaram to Siruseri (via Puraswalkam, Luz, Adayar, Metukuppam, Varapakam, Navallur etc) of length 40.2 km and has 34 stations and follows the Mahabalipuram Road from Thiruvanmiyur till Sholinganallur. It caters many commercial establishments located at Mylapore, Luz, Gemini, Koyambedu, T-Nagar, Madhavaram and Nandambakkam area. It goes along institutional locations and several major hospitals.

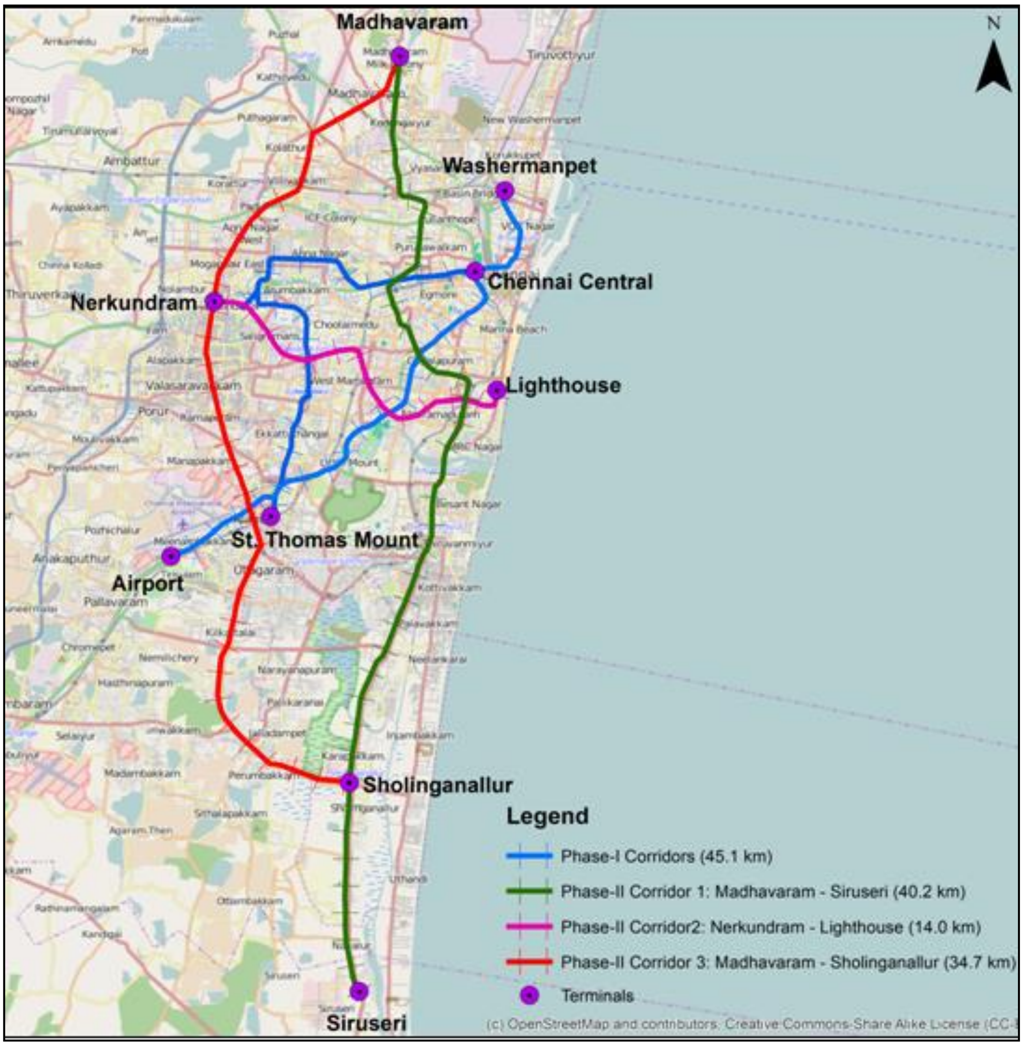
Corridor 4: Nerkundram to Lighthouse

Nerkundrum to light house (via Vadapalani, Nandanam, LUZ etc) of length 14 km consisting of 13 stations. Nerkundram station which is on Corridor 5 facilitates transfer of passengers from North-South alignment to East-West alignment for seamless connectivity across the length and breadth of city and Luz being interchange station between Corridors 3 and 4. It crosses the Phase-I at Vadapalani and Nandanam stations.

Corridor 5: Madhavaram to Sholinganallur

Madhavaram to Shonlinganallur (via Villivakam, Anna nagar west, Nerkundrum, Valasaravakkam, Nandambakkam, OTA, Adambakkam, Kovilambakkam, Medavakkam etc) of length 34.7 km consisting of 30 stations having common origin at Madhavaram as that of corridor 3. It is connected with corridor 4 at Nerkundrum and corridor 3 at Sholinganallur which is the end of corridor 5. It is connected to Phase-I of metro at OTA station which caters peoples from Chennai International Airport.

FIGURE 5.7: PHASE-I & PHASE-II CORRIDORS AS PER FEASIBILITY REPORT



Land has been identified at two locations along the Corridors for metro rail depots.

i. Madhavaram (Talco Industries near Thapalpetti & Madhavaram Aavin Milk Booth Quarters)
ii. SIPCOT (Land available in Siruseri area)

5.4.4 Chennai Metro Phase-II

With a view of developing effective and efficient mass transit system in addition to the existing public transportation and Phase-I Metro rail system, the Government of Tamil Nadu has decided to implement 3 corridors as a part of Phase-II Metro rail network and engaged RITES Ltd. to prepare a Detailed Project Report for Chennai Metro Rail Phase-II Corridors.

Phase-II DPR corridors were based on better connectivity with other existing modes of transport like Phase-1 metro corridors, Sub-urban railways, Bus terminus etc. in the city as well as with better service to commericial and residential area, Enhanced Ridership, minimizing risk of building damage & land acquisition, Enhanced Multimodal Integration at important nodes etc.

RITES has submitted DPR for Phase-II in October'2017. The Phase-II corridors as per DPR are presented below in **TABLE 5.9.**

TABLE 5.9: CHENNAI METRO PHASE-II CORRIDORS AS PER DPR, 2017

Corridor	Name	Length (Km)	Stations
Corridor 3	Madhavaram to SIPCOT	45.81	50
Corridor 4	CMBT to Lighthouse	17.12	20
Corridor 5	Madhavaram to Sholinganallur	44.63	46
	Total	107.56	116

5.4.5 Extension of Corridor-4

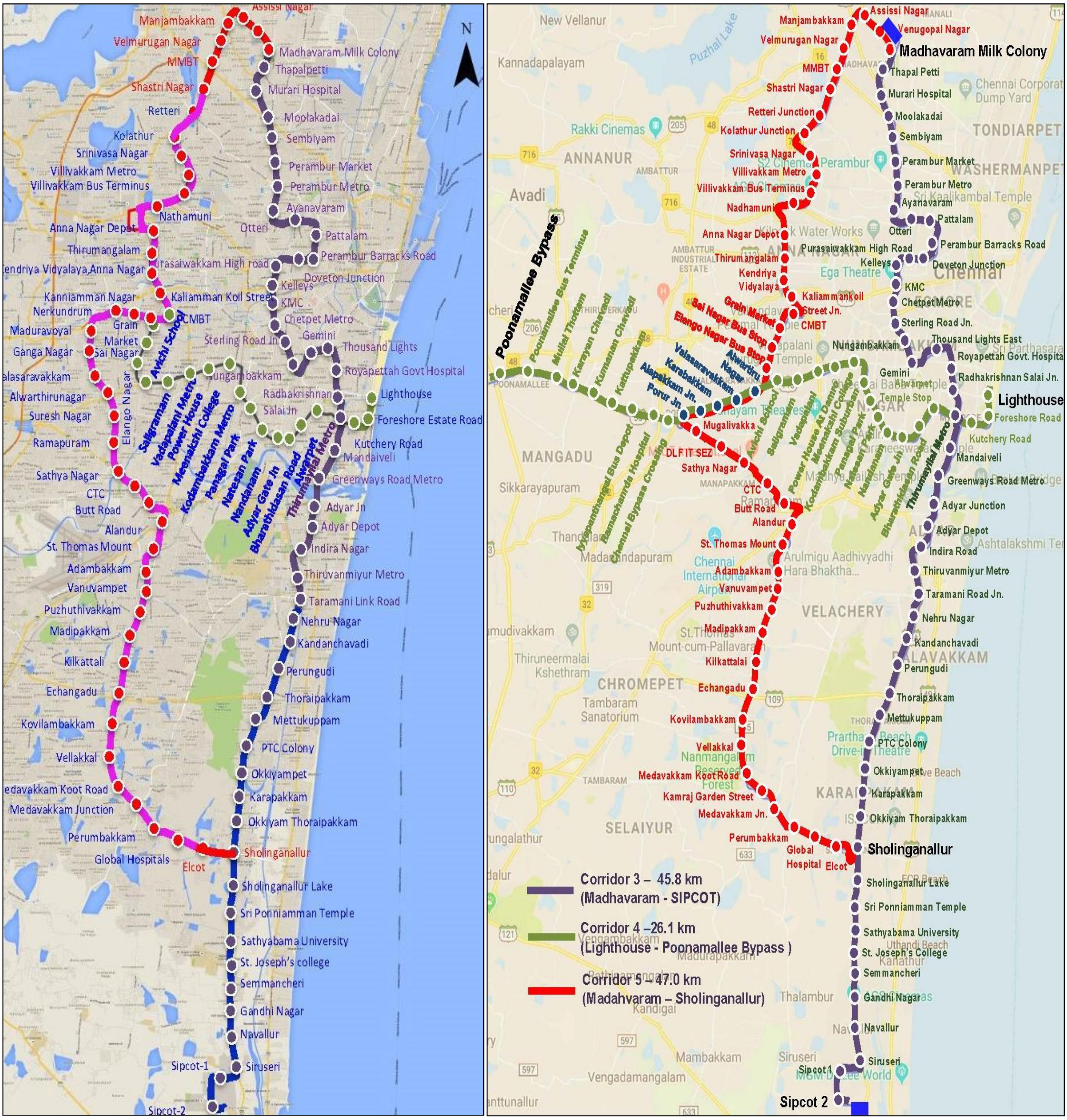
In Phase-II DPR, Corridor-4 was planned from Light House to CMBT with a total length of 16.5 Km covering Foreshore Road, Thirumaylai, Nandanam, Kodambakkam, Vadapalini, Saligramam, Elangonagar, Sai Nagar etc. Corridor was completely underground. Government of Tamil Nadu through CMRL has now desired to study the extension of Corridor-4 from Avichi School to Ponnamallee. Corridor-4, now, follows same route from Light house upto Avichi School. It further continues on the Arcot Road and covers Alwathirunagar, Porur Junction, Chennai Bypass Road, Iyappanthangal Bus

Terminus, KumananChavadi, Poonamallee Bus Terminus & Outer Ring Road. The corridor terminates at Outer Ring Road cloverleaf with Depot situated on one side of the Poonammallee Bypass Road.

TABLE 5.10: SUMMARY OF CORRIDOR-4

Corridor	Name	Length (Km)	Stations
Corridor 4	CMBT to Lighthouse	26.10	30

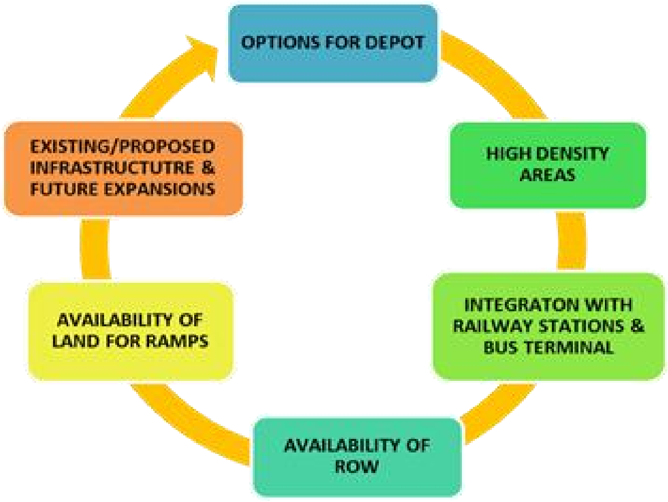
FIGURE 5.8: CHENNAI PHASE-II CORRIDORS BEFORE & AFTER C-4 EXTENSION



5.4.6 Alignment Options Parameters

The consultant studied the various alignment options for the priority MRTS corridors based on the planning parameters shown in **Figure 5.9.**

FIGURE 5.9: ALIGNMENT OPTIONS PARAMETERS



5.4.7 Selection of Corridors

Corridors recommended in various reports were studied for preparation of comprehensive DPR. Following modifications are made for the better connectivity with other existing modes of transport like Phase-1 metro corridors, Sub-urban railways, Bus terminus etc. in the city as well as with better service to commericial and residential area.

- Phase 2 Network Length increased from 107.56 km to 118.9 km
- Enhanced Ridership
- Following major roads, minimizing risk of building damage & land acquisition
- Enhanced Multimodal Integration at important nodes
- Improved connectivity Arcot road & Mount Poonamallee road
- Connects commercial hubs like Purasaiwalkam.
- Connects with Express Avenue / Royapettah Hospital

Type	Corridor 3 (Madhavaram – SIPCOT)	Corridor 4 (CMBT – Light house)	Corridor 5 (Madhavaram – Sholinganallur)
Metro-Metro	Madhavaram, KMC, Thirumayilai, Shollinganallur	Alwathirunagar, Valasaravakkam, Karabakkam, Alapakkam Junction, Porur Junction, Vadapalani, Nandanam, Thirumayilai	Madhavaram, Thirumangalam, CMBT, Alwathirunagar, Valasaravakkam, Karabakkam, Alapakkam Junction, Porur Junction, Alandur, St. Thomas Mount, Sholinganallur
Metro-Bus	Ayanavaram, Mandaveli, Adyar	CMBT	MMBT, Villivakkam, CMBT
Metro-Suburban Rail	Perambur, Chetpet	Kodambakkam	Villivakkam, St. Thomas Mount
Metro-MRTS	Thirumayilai, Thiruvanmiyur	Thirumayilai	St. Thomas Mount

5.5 ENGINEERING SURVEY

5.5.1 Topographical Surveys

- Before starting the detailed topographical survey work, a team of expert in the field of alignment design and survey has conducted reconnaissance survey to familiarize with the area and selection of control points along the proposed Metro Route.
- Topographical survey of the Corridor 3, 4 & 5 have been carried out to collect all manmade and natural features like roads, building, drain, railway line telephone/electric pole etc., falling in the proposed metro corridor for better and accurate planning of the metro alignment.
- Topographical survey was carried out in detail covering all the activities which are mentioned in Terms of Reference of the Contract using modern surveying instrument like GPS, Total Station and Auto/Digital Level. Survey Drawings were prepared in AutoCAD format.
- Topographical survey has been carried out in following six steps:
    - Establishment of Horizontal Control Points using DGPS
    - Densification of Horizontal Control Points using Total station
    - Establishment of Vertical Control Points
    - Detailed survey of corridor
    - Preparation of drawings.
    - Site verification of features.

5.5.2 Geotechnical Investigations

Geotechnical investigation was carried out with the following objectives:

- To determine the required strength characteristics of the underlying soil/rock strata to design the foundation of the structure proposed to be constructed at various locations.
- To determine the subsurface profile of the underlying strata.

Geotechnical Investigations Report separately submitted includes the field investigation, the laboratory test results of the soil samples to evaluate the soil parameters and recommendations with regard to competency of strata for the design of foundations of proposed structures.

Scope of Investigations

Field Investigation at the site were planned to determine the required strength characteristics of the underlying soil/rock to design the foundations of the proposed structure to be constructed. The Geotechnical investigation work includes:

a) Drilling of 150mm diameter boreholes in all kind of soil including gravels and cobbles, & 76 mm dia. drilling in Weathered Rock, Soft Rock & Hard Rock. Although Majority of the boreholes have been drilled upto 30 m depth below the ground level, some boreholes have been terminated at shallower depth after completing atleast 3 m drilling in Hard Rock. These bore holes have been drilled at an interval of about 500m c/c distance along the alignment or at change of strata.

b) Conducting Standard Penetration test (SPT) at every 3.0 m interval upto Borehole termination depth.

c) Collection of disturbed & undisturbed soil samples as per IS: 2132, IS: 1892.

d) Following laboratory tests were conducted on collected soil samples:

SN	PARTICULARS OF PROPERTIES	RELEVANT IS CODE	DISTURBED SAMPLES	UNDISTURBED SAMPLES
1	Sieve Analysis	IS 2720 (part IV)	✓	✓
2	Natural Moisture Content	IS 2720 (part II)		✓
3	Bulk/Dry Density	IS 2720 (part II)		✓
4	Specific Gravity	IS 2720 (part III)		✓
5	Atterberg's Limit	IS 2720 (part V)	✓	✓
6	Direct Shear test	IS 2720 (part XIII)		✓
7	Triaxial Shear Test	IS 2720 (part XI)		✓

e) Following laboratory tests were conducted on selected Rock samples:

SN	PARTICULARS OF PROPERTIES	RELEVANT IS CODE	ROCK CORE SAMPLES
1	Water Absorption	IS 1330	√
2	Porosity	IS 1330	√
3	Specific Gravity	IS 1330	√
4	Uniaxial Compressive Strength	IS 8764	√
5	Point load Index	IS 8764	√

In total, 237 Bore Holes (BHs) have been drilled for 30 m depth each, all along the length of proposed Metro alignment. 91 No. of BHs have been drilled upto a maximum 30 m depth each for Corridor-III. These bore holes have been drilled from MMC Gate to Sipcot. 52 No. of BHs have been drilled each upto a maximum of 30 m depth for Corridor-IV. These bore holes have been drilled from Poonamallee Bypass to Light House including Depot location. 94 No. of

BHs have been drilled upto a maximum 30 m depth each for Corridor-V. These bore holes have been drilled from Madhavaram Depot to Sholinganallur including Depot Areas.

Standard Penetration Test (SPT) was conducted in the boreholes at every 3.0 m interval and change of strata as per specifications. Standard split spoon sampler attached to lower end of drill rods was driven in the boreholes by means of standard hammer of 63.50 kg falling freely from a height of 75 cm. The sampler was driven 45 cm as per specifications and number of blows required for each 15 cm penetration was recorded. The number of blows for the first 15 cm penetration was not taken into account as it is considered seating drive. The number of blows for next 30 cm penetration was designated as SPT 'N' value. Wherever the total penetration was less than 45 cm, the number of blows & the depth penetrated is incorporated in respective bore logs. Disturbed Soil samples obtained from standard split spoon sampler were collected in polythene bags of suitable size. These samples were properly sealed, labeled, recorded and carefully transported to laboratory for testing

Undisturbed Soil Samples (UDS) were collected from the boreholes at every 3.0 m interval & change of strata as per sampling specifications, in thin walled sampling tubes of 100 mm dia. and 450 mm length. These sampling tubes after retrieval from the boreholes were properly waxed and sealed at both ends. These were carefully labeled and transported to the laboratory for testing. UDS wherever could not recover due to presence of hard strata or slipped during lifting, were duly marked in the respective bore logs.

Depth of ground water table was checked/ measured in all bore holes.

Recommendations

- The load carrying capacities of piles are based on empirical correlation's and to be confirmed by conducting **pile load test as per IS: 2911 (Part 4)** on test piles before execution of working piles.
- Since the proposed site is situated in seismic **Zone III** of the seismic zone map of India, suitable seismic coefficient commensurate to seismic Zone III (IS: 1893) should be adopted in the design of the structures.

5.6 ROUTE ALIGNMENT

5.6.1 Corridor – 3: Madhavaram (MMC-Milk Colony) to SIPCOT

5.6.1.1 Alignment Description

Considering centre line of Madhavaam Milk Colony Station as 0.00m, this corridor is 45813 m long starting from -795 m and running upto 45430 m. This corridor starts as Underground stretch followed by Switch Over Ramp (SOR), and finally again as elevated stretch.

TABLE 5.11: ALIGNMENT DESCRIPTION

Alignment Type	From (m)	To (m)	Length (m)
Underground	-383	26124	26507
Switch over Ramp (-)8.0m to (+)7.5m	26124	26554	430
Elevated	26554	45430	18876
Total			**45813**

Alignment of Corridor -3 is described in detail in following sub sections:-

I) Madhavaram Milk Colony to Taramani Link Road Junction
II) Switch Over Ramp from Underground to Elevated
III) Nehru Nagar to SIPCOT

I) Madhavaram Milk Colony to Taramani Link Road Junction

- The proposed alignment of Corridor-3 starts from Madhavaram Milk Colony as underground and heads in South direction.
- Total length of the section is about 26.72 Km and is completely underground. Total of 30 stations have been proposed in this section.

FIGURE 5.10: STARTING POINT OF CORRIDOR 3 & 5

- The corridor runs underneath Moolakadai flyover, passes through dense commercial area of Revati and crosses Railway tracks at Perambur Railway station with clear cushion of 15.4m between tunnel top and ground level. **(Figure 5.11)**.

FIGURE 5.11: ALIGNEMNT CROSSING RAILWAY TRACKS AT PERAMBUR

- The alignment passes through under-construction metro station of Phase-I at KMC Medical College. The Rail level of phase-I metro line is at -17.1m below ground level (Ch: 3200m) at the crossing point. Accordingly, the Rail level proposed for corridor-3 at this location is -29.6m below ground level **(Figure 5.12)**.

FIGURE 5.12: ALIGNEMNT CROSSING PHASE-I METRO LINE NEAR KMC

- The alignment passes below Royapettah High road and reaches Luz road junction. Here, metro alignment of corridor-3 and corridor -4 crosses one below the other. The proposed station at this junction for Corridor 3 is planned at the centre of the road junction and at a distance of 74m for Corridor 4. The rail levels for corridor 4 are proposed at -22m below ground level and for corridor-3 Rail level is proposed at depth of -15m below the ground level, thus keeping a level difference of 7m between tracks of two corricors. With this arrangement, the Rail tracks for Corridor-4 passes below the proposed station of Corridor-3 **(Figure 5.13).**

FIGURE 5.13: INTEGRATION OF CORRIDOR 3 & 4 AT THIRUMAYILAI

II) Switch Over Ramp from Underground section to Elevated section:

- The aligment after passing below MRTS lines at Thiruvanmiyur station, comes on centre of Old Mahabalipuram Road (OMR). The corridor is integrated with MRTS by proposing a UG metro station, namely, Tidel Park parallel to Thiruvanmiyur MRTS station.
- The alignment then, runs along OMR. The switch over ramp is proposed on the centre line of existing road, between the underground station at Tharamani Link road junction and elevated station as Nehru Nagar near Kandhan Chavadi Bus stop, i.e. from Chainage 26,124 m to 26,543 m with RL rising from (-)8.0 m to (+)7.5 m. The existing ROW at this location varies from 37m to 32m. The width of proposed 419m long ramp shall be 12m – 13m. Hence, road shall be widened to accommodate the proposed ramp within the ROW.

III) Nehru Nagar to SIPCOT:

- The alignment in this section runs elevated along the centre of the Old Mahabalipuram Road from Kandhan Chavadi Bus stop southwards and terminates at SIPCOT. Total length of the section is about 19.1 Km and total 20 elevated stations have been proposed in this section.
- Corridor 3 integrates with corridor 5 at Sholinganallur Road junction. Both the corridors are elevated at this location. The station is proposed accommodating 4 tracks, two for each corridor. The four tracks are planned such as to accommodate stabling of 6 rakes **(Figure 5.16).**
- The metro section proposed in this section is double elevated in integration with elevated road proposed on OMR throughout the section. Conceptual drawings of Double elevated metro cum elevated road have been prepared (placed at **Figure 5.14 & 5.15**) after detailed discussions and agreements between CMRL, TNRDC and their consultants.

- The agreed cross sections of double elevated metro cum elevated road at 2 & 3 levels are shown in **Figure 5.14 & 5.15**

FIGURE 5.14: AGREED CROSS SECTION OF DOUBLE ELEVATED METRO CUM ELEVATED ROAD – 2 LEVEL

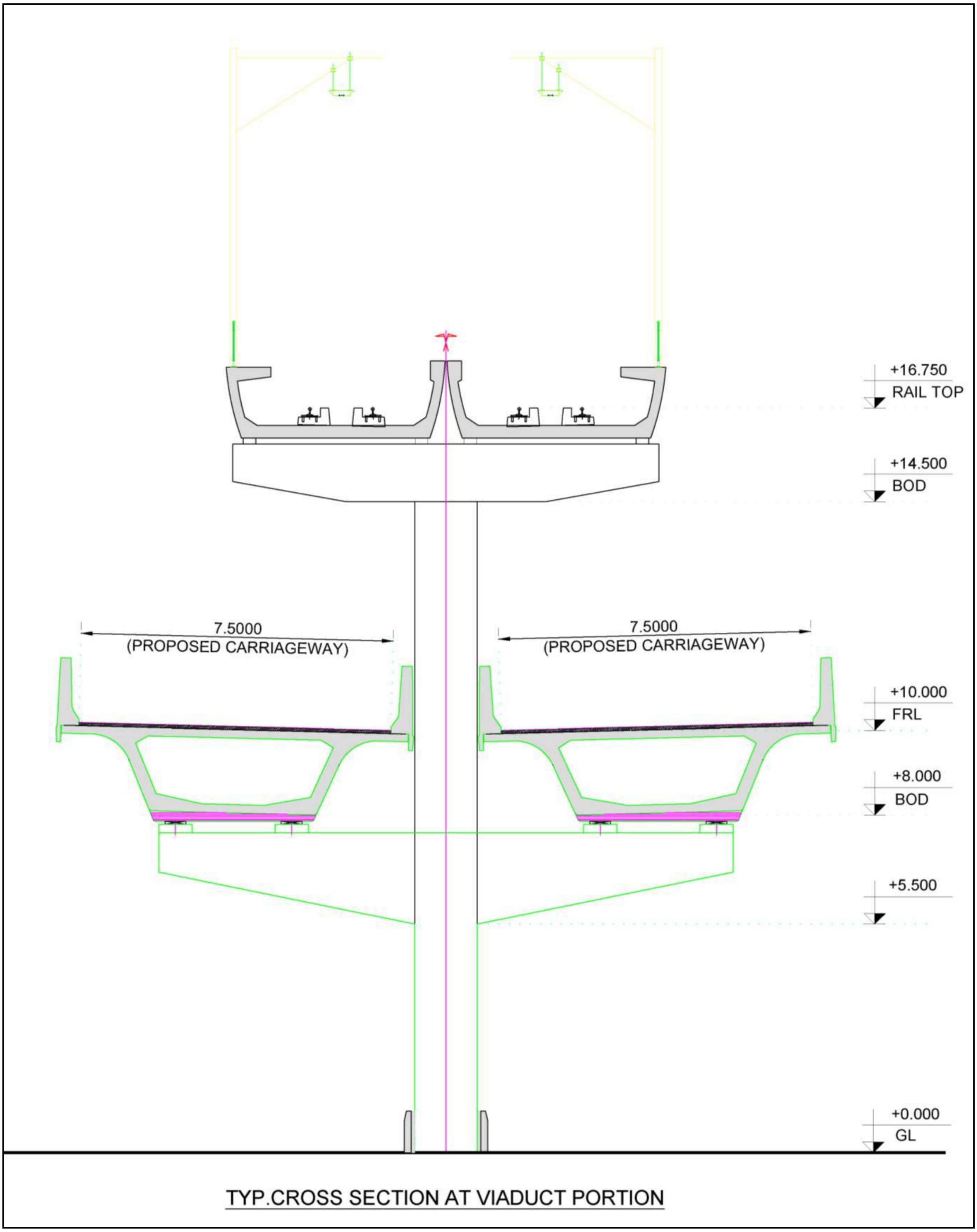


FIGURE 5.15: AGREED CROSS SECTION OF DOUBLE ELEVATED METRO CUM ELEVATED ROAD – 3 LEVEL

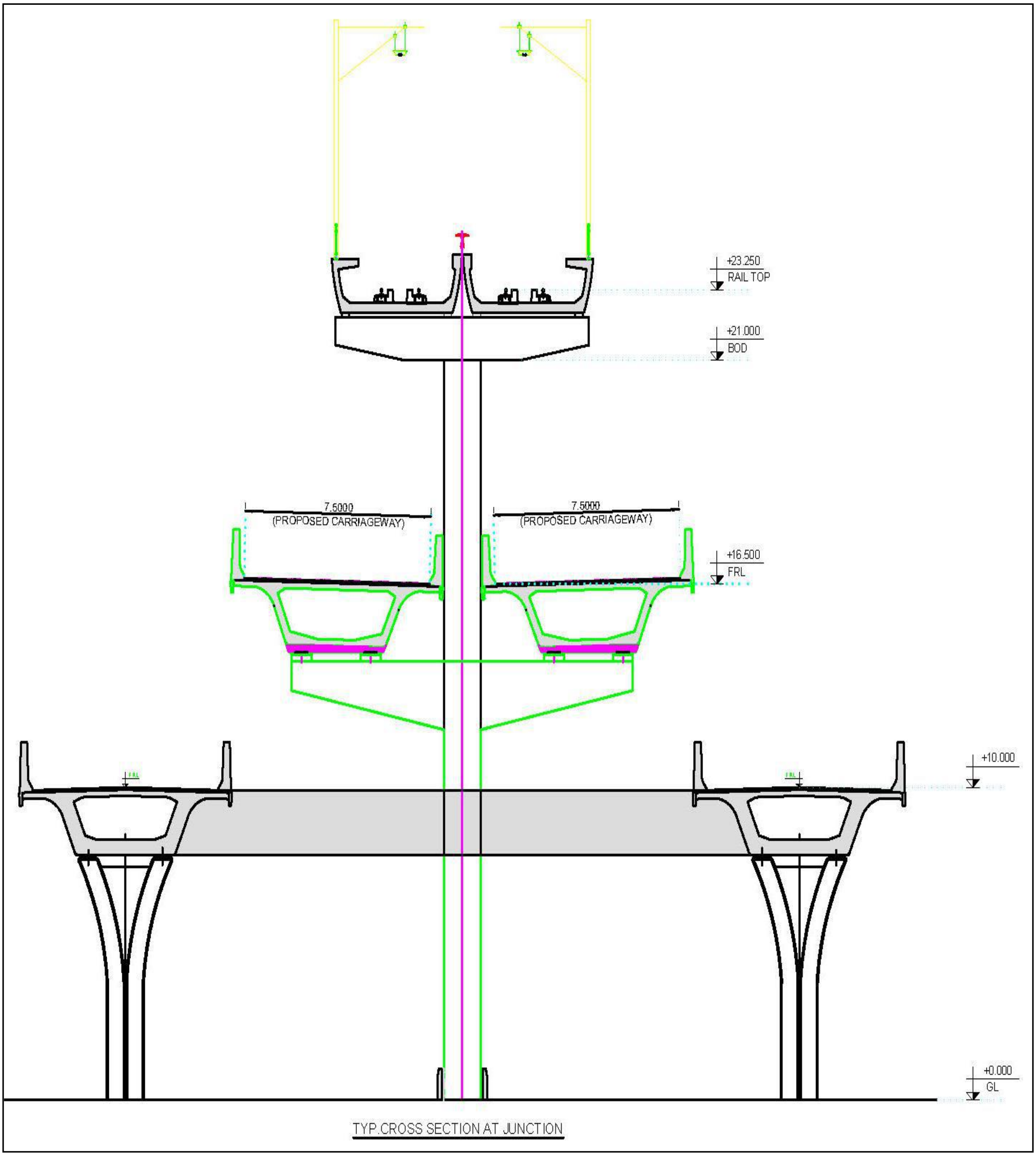


FIGURE 5.16: INTEGRATION OF CORRIDOR 3 & 5 AT SHOLINGANALLUR

- The alignment terminates at SIPCOT area with the proposal of two elevated stations in this location, namely, SIPCOT 1 & SIPCOT 2.
- The terminal station is proposed with extended stabling lines to accommodate 6 rakes including two rakes at platform side.
- The minor depot with stabling, inspection & washing facilities is proposed at the end of this corridor. This minor depot is proposed in 6.3 Ha. private land and shall be constructed elevated with 4.5 Ha. covered area. The underneath land shall be used for parking cum property development **(Figure 5.17)**.

FIGURE 5.17: TERMINAL STATION AT SIPCOT

5.6.1.2 Reference Point

For the planning convenience, the zero point of corridor is considered at the centre line of the proposed Madhavaram Milk Colony. The chainage along the alignment increases in Southern direction. All elevations are from Mean Sea Level (MSL).

5.6.1.3 Terminal stations of Corridor-3

i. Madhavaram Milk Colony Metro Station (North side terminal station)

The North side station on the Metro corridor is Madhavaam Milk Colony Metro Station. The station is proposed underground and rail level has been kept -15.00 m (minimum) below the ground level. Proposed metro station is a common station for Corridor 3 & 5.

Depot connections have been planned through this station for corridor 3. Two nos. underground stabling lines on both corridors are proposed to accommodate total eight rakes including at stabling at platforms.

ii. SIPCOT 2 Metro Station (South side Terminal Station)

South side Terminal of the corridor will be SIPCOT 2 Metro Station. The station is proposed elevated and rail level has been kept 14.00 m (minimum) above the ground level. It will serve the nearby private commercial areas of SIPCOT.

Reversal/stabling facility has also been planned beyond this Metro station. The entry to minor depot in southern SIPCOT land (6.3 Ha) has also been planned after the station.

5.6.1.4 Horizontal Curvature

Although the topology of Chennai is not very undulating and the terrain type is plain, yet the existing road has frequent horizontal curves to negotiate the densely built up areas. The proposed alignment also negotiates frequent horizontal curves to follow the existing road median. At some places there are sharp turns and curves along the road and this necessitates provision of sharp curves on metro alignment also.

Total 116 nos. horizontal curves have been provided on the entire length of the alignment of Corridor 3. The minimum radius of curves is 210m in underground section and 125 m in elevated section at identified terminal locations. About 52.24% alignment is on straight & about 47.76% of alignment is on curves. The abstract and details of curves are indicated in **Table 5.12** and **Table 5.13** respectively.

FIGURE 5.18: PROPOSED PHASE-II METRO CORRIDOR-3

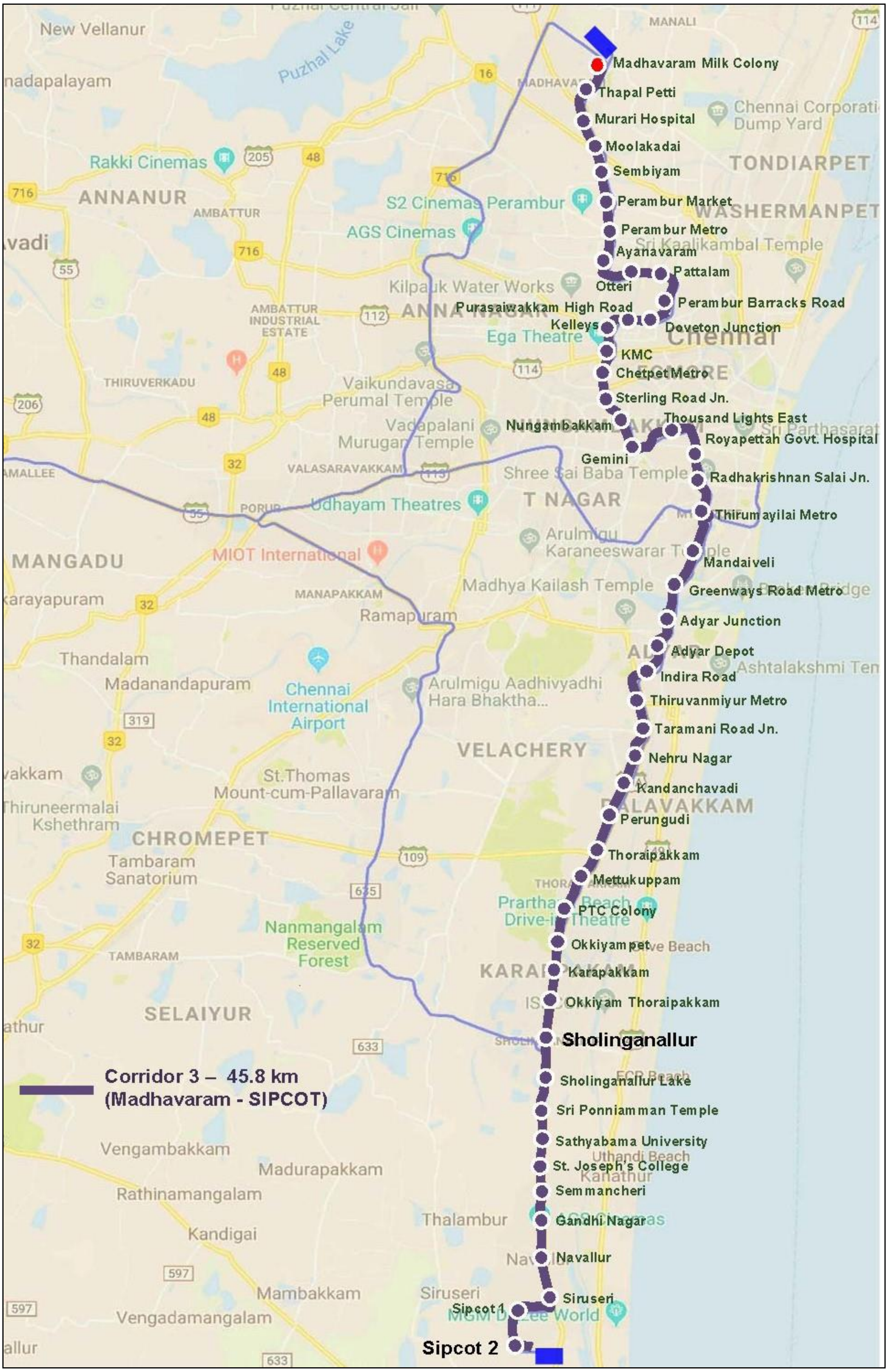


TABLE 5.12: ABSTRACT OF HORIZONTAL CURVES OF CORRIDOR-3

S. No.	Curve Radius	No. of Occurrences	Length	Percentage
1	≤150	2	213.82	0.97
2	>150 <300	44	9014.39	40.83
3	≥300 ≤ 500	19	3821.94	17.31
4	>500 ≤ 800	14	2359.46	10.69
5	>800 ≤ 1000	15	3541.72	16.04
6	>1000	22	3127.71	14.17
7	**Total**	**116**	**22079.05**	**100.00**

TABLE 5.13: DETAILS OF HORIZONTAL CURVES OF CORRIDOR-3

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
1	-745.06	-508.80	Right	145	73	21	36.36	50	50	133.99	136.26	236.26	--
2	380.04	617.83	Right	210	51	8	27.96	50	50	125.92	137.79	237.79	888.84
3	617.95	902.47	Left	-210	63	35	26.16	50	50	156.48	184.52	284.52	Nil
4	1063.87	1248.03	Left	-210	36	21	43.2	50	50	94.61	84.17	184.17	161.40
5	1359.11	1503.69	Right	240	22	20	40.2	50	50	72.99	44.58	144.58	111.08
6	1503.94	1865.31	Left	-1011	19	8	9.24	22	22	182.30	317.37	361.37	Nil
7	1943.96	2065.00	Right	3000	2	4	17.4	10	10	60.53	101.04	121.04	78.64
8	2182.96	2361.87	Left	-450	16	33	7.92	46	46	89.97	86.91	178.91	117.96
9	2556.43	2830.55	Right	210	61	5	7.8	50	50	149.35	174.12	274.12	194.56
10	2831.39	3042.90	Left	-210	35	31	27.84	80	80	108.35	51.50	211.50	Nil
11	3589.42	3778.84	Left	-500	13	24	38.52	70	70	95.04	49.43	189.43	546.52
12	3951.06	4187.27	Right	210	42	22	13.08	80	80	122.36	76.20	236.20	172.22
13	4389.70	4568.17	Left	-400	18	34	58.08	46	46	89.88	86.47	178.47	202.44
14	4615.24	4735.44	Left	-450	9	15	54	46	46	60.20	28.20	120.20	47.07
15	4790.97	4891.25	Right	800	5	1	12	30	30	50.17	40.28	100.28	55.53
16	5086.60	5249.66	Right	600	9	30	9.72	60	60	81.67	43.05	163.05	195.35
17	5367.04	5550.27	Right	500	12	34	59.88	70	70	91.90	43.24	183.24	117.38
18	6061.00	6555.29	Left	-210	121	7	50.52	50	50	398.70	394.29	494.29	510.73
19	6713.95	6794.69	Right	1500	2	8	37.68	22	22	40.38	36.74	80.74	158.65
20	7171.23	7315.03	Right	250	21	17	41.64	50	50	72.53	43.80	143.80	376.54

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
21	7534.36	7654.83	Left	-1000	4	32	5.64	35	35	60.26	50.47	120.47	219.34
22	7947.30	8428.72	Right	210	117	25	18.84	50	50	373.28	381.41	481.41	292.47
23	8472.23	8625.67	Left	-210	28	7	54.12	50	50	77.90	53.44	153.44	43.52
24	9045.42	9277.86	Right	210	49	27	49.32	50	50	122.65	132.44	232.44	419.75
25	9322.60	9454.94	Right	300	15	25	58.08	50	50	66.47	32.33	132.33	44.74
26	9647.19	9831.94	Right	220	35	3	15.84	50	50	94.71	84.76	184.76	192.25
27	9934.01	10087.61	Left	-400	15	14	40.2	46	46	77.15	61.60	153.60	102.07
28	10238.85	10388.12	Right	210	27	3	2.88	50	50	75.69	49.27	149.27	151.23
29	10388.41	10766.16	Left	-210	89	15	8.64	50	50	233.38	277.75	377.75	Nil
30	11005.11	11242.39	Left	-210	51	3	19.08	50	50	125.61	137.29	237.29	238.95
31	11277.55	11437.05	Right	210	29	31	22.8	50	50	81.15	59.50	159.50	35.15
32	11606.12	11909.11	Right	210	69	0	46.8	50	50	169.73	202.99	302.99	169.08
33	11909.22	12291.97	Left	-210	90	28	17.4	50	50	238.40	282.75	382.75	Nil
34	12449.43	12568.18	Right	600	7	18	39.6	40	40	59.44	38.74	118.74	157.46
35	12598.36	12718.20	Left	-600	7	22	22.44	40	40	59.99	39.85	119.85	30.18
36	12789.06	12939.93	Left	-300	19	9	19.8	50	50	75.97	50.87	150.87	70.85
37	12940.40	13131.60	Right	210	38	18	43.56	50	50	98.54	91.19	191.19	Nil
38	13281.94	13611.15	Left	-210	76	6	17.28	50	50	189.98	229.21	329.21	150.34
39	13636.07	13834.02	Right	210	40	12	56.16	50	50	102.36	97.95	197.95	24.92
40	13834.32	14133.52	Right	1011	15	23	27.6	23	23	150.47	253.20	299.20	Nil
41	14135.12	14268.01	Right	600	7	12	11.88	56	56	66.51	20.89	132.89	1.60
42	14362.89	14512.07	Left	-300	18	33	48.24	50	50	75.10	49.18	149.18	94.88
43	14670.88	15076.05	Left	-210	96	32	30.48	50	50	262.51	305.18	405.18	158.81
44	15426.46	15590.20	Right	250	26	2	25.44	50	50	82.96	63.74	163.74	350.41
45	15799.31	15922.93	Left	-600	7	18	10.44	45	45	61.88	33.62	123.62	209.10
46	16144.31	16632.64	Right	210	119	21	13.68	50	50	386.61	388.33	488.33	221.38
47	16892.74	17069.62	Left	-300	24	8	8.16	50	50	89.47	76.88	176.88	260.10
48	17175.67	17333.33	Left	-210	29	13	18.48	50	50	80.16	57.65	157.65	106.06
49	17426.55	17596.03	Right	210	32	21	17.64	50	50	86.54	69.47	169.47	93.23
50	17885.10	18040.94	Left	-210	28	31	24.24	50	50	79.18	55.84	155.84	289.07
51	18075.58	18443.26	Right	300	54	33	48.24	80	80	196.42	207.68	367.68	34.64
52	18571.84	18715.74	Left	-210	25	22	13.08	50	50	72.85	43.89	143.89	128.58
53	19038.78	19252.11	Right	220	34	25	55.2	80	80	109.12	53.32	213.32	323.05
54	19377.74	19546.98	Left	-400	13	17	43.44	75	75	84.90	19.24	169.24	125.63

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
55	19666.61	19719.32	Left	-1000	1	27	12.6	22	22	26.36	8.71	52.71	119.63
56	20053.54	20237.68	Right	210	36	21	18	50	50	94.60	84.14	184.14	334.22
57	20267.77	20407.62	Left	-250	20	21	11.16	50	50	70.48	39.85	139.85	30.09
58	20438.60	20590.12	Left	-240	24	8	26.88	50	50	76.61	51.52	151.52	30.98
59	20590.21	20789.88	Right	210	40	30	1.8	50	50	103.34	99.67	199.67	Nil
60	21017.97	21151.45	Left	-600	8	33	12.6	40	40	66.84	53.48	133.48	228.09
61	21262.01	21470.13	Left	-225	32	22	24.24	80	80	106.16	48.12	208.12	110.56
62	21845.91	21976.13	Right	350	13	4	32.52	50	50	65.32	30.22	130.22	375.78
63	22290.72	22419.60	Left	-230	19	23	25.08	50	50	64.90	28.88	128.88	314.58
64	22419.95	22665.45	Right	210	53	12	7.92	50	50	130.72	145.50	245.50	Nil
65	22665.55	22870.40	Left	-210	37	31	49.44	66	66	105.34	72.85	204.85	Nil
66	22922.22	22976.02	Left	-2000	0	34	49.8	20	20	26.90	13.80	53.80	51.82
67	23510.68	23788.33	Right	210	62	3	50.4	50	50	151.75	177.65	277.65	534.67
68	24089.29	24453.23	Left	-210	85	23	30.12	50	50	220.10	263.94	363.94	300.96
69	25408.65	25580.65	Right	500	12	30	0.72	60	60	86.26	52.00	172.00	955.42
70	25842.55	26105.99	Right	274	42	19	19.56	60	60	136.86	143.43	263.43	261.91
71	26106.07	26256.14	Left	-204.7	25	7	24.24	60	60	75.92	30.07	150.07	Nil
72	26461.85	26525.18	Left	-2000	1	8	34.44	20	20	31.67	23.33	63.33	205.71
73	26978.16	27101.68	Right	400	11	3	41.4	46	46	61.90	31.52	123.52	452.98
74	27135.73	27229.95	Left	-800	4	21	20.52	30	30	47.13	34.22	94.22	34.05
75	27263.73	27367.09	Right	1000	3	33	13	35	35	51.70	33.36	103.36	33.78
76	27425.48	27577.60	Left	-1000	6	25	25.32	35	35	76.13	82.12	152.12	58.39
77	27635.49	27847.91	Right	1500	7	12	21.24	20	20	106.34	172.41	212.41	57.90
78	28136.35	28364.39	Left	-3000	3	34	56.64	20	20	114.06	188.04	228.04	288.44
79	29099.56	29192.36	Left	-1000	4	6	6.12	20	20	46.42	52.80	92.80	735.17
80	29452.16	29534.10	Right	800	3	25	51.6	30	30	40.98	21.93	81.93	259.80
81	29691.82	29747.63	Right	3000	0	27	52.56	15	15	27.91	25.81	55.81	157.72
82	29853.93	30063.46	Right	300	24	26	30.84	80	80	105.96	49.53	209.53	106.30
83	30239.52	30463.07	Left	-300	33	5	2.76	50	50	114.37	123.55	223.55	176.07
84	30594.96	30767.31	Right	600	12	22	54.12	40	40	86.45	92.35	172.35	131.89
85	30872.55	30926.67	Left	-2000	1	4	17.4	15	15	27.06	24.13	54.13	105.24
86	31157.32	31210.53	Left	-2000	1	3	14.76	15	15	26.61	23.21	53.21	230.64
87	31434.05	32151.90	Left	-2300	17	13	49.08	20	20	361.63	677.85	717.85	223.52
88	32671.71	32755.50	Right	1500	2	15	40.32	20	20	41.90	43.79	83.79	519.81

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
89	32811.72	32891.83	Left	-1500	2	10	28.56	20	20	40.06	40.11	80.11	56.22
90	33116.47	33189.21	Right	3000	1	3	39.6	15	15	36.37	42.74	72.74	224.64
91	33604.36	33662.76	Left	-3000	0	29	39.84	15	15	29.20	28.40	58.40	415.15
92	33799.27	33867.14	Right	2000	1	18	19.08	15	15	33.94	37.87	67.87	136.51
93	34398.12	34524.05	Left	-1000	5	17	40.92	30	30	63.00	65.93	125.93	530.98
94	35617.35	35687.50	Left	-2500	1	5	8.88	20	20	35.08	30.15	70.15	1093.30
95	35836.76	35963.61	Right	1000	5	19	32.88	30	30	63.47	66.86	126.86	149.26
96	36006.70	36165.41	Left	-1000	7	13	22.44	30	30	79.45	98.71	158.71	43.09
97	36449.88	36708.35	Right	1000	13	3	9.36	30	30	129.74	198.48	258.48	284.47
98	36811.74	36958.74	Left	-400	13	32	2.4	50	50	73.77	47.00	147.00	103.38
99	37510.15	37607.48	Left	-1000	3	30	46.08	30	30	48.68	37.33	97.33	551.41
100	37786.99	38044.20	Right	1011	13	15	48.6	20	20	129.15	217.21	257.21	179.51
101	38044.26	38185.66	Left	-780	7	15	55.44	40	40	70.78	61.40	141.40	Nil
102	38407.24	38520.52	Right	1000	4	27	42.12	30	30	56.66	53.28	113.28	221.59
103	38627.21	38856.33	Left	-1011	11	26	30.12	22	22	114.93	185.12	229.12	106.69
104	38952.07	39116.58	Right	1000	7	25	20.64	30	30	82.36	104.51	164.51	95.74
105	39257.30	39371.58	Left	-1000	4	29	39.84	30	30	57.17	54.28	114.28	140.73
106	39451.36	39660.15	Right	1011	10	21	3.24	22	22	104.66	164.79	208.79	79.77
107	39763.35	40004.20	Left	-800	14	0	49.32	45	45	120.93	150.85	240.85	103.21
108	40345.70	40495.34	Right	700	8	5	31.2	50	50	74.91	49.64	149.64	341.50
109	40907.22	41013.31	Left	-800	5	15	56.88	30	30	53.07	46.09	106.09	411.88
110	41075.15	41151.61	Right	1000	3	4	15.96	22	22	38.23	32.45	76.45	61.85
111	41210.57	41711.01	Left	-1900	14	17	29.76	20	20	251.51	460.43	500.43	58.97
112	42071.47	42208.19	Right	1000	6	3	54.36	30	30	68.41	76.71	136.71	360.47
113	42660.94	42945.32	Right	155	86	22	54.84	50	50	171.78	184.38	284.38	452.75
114	42992.56	43168.86	Right	500	12	6	18.36	70	70	88.39	36.30	176.30	47.25
115	43646.63	43939.97	Left	-155	89	34	14.16	50	50	180.52	193.34	293.34	477.77
116	44740.80	44986.42	Left	-125	89	24	3.24	50	50	150.08	145.63	245.63	800.82

5.6.1.5 Gradients

While designing vertical alignment, efforts have been made to avoid frequent gradients. The number of gradients has been kept to minimum, however, due to ground profile, difference in rail level of viaduct over mid section and station location, horizontal alignment and switch over ramps, gradients are inevitable.

Efforts have been made to provide the gradients as flat as possible, subject to ground profile.

A total 116 number of change of gradients has been provided in the entire Corridor. Flattest gradient is level provided for 38% of the alignment. Steepest gradient is 4% (compensated) provided for Switch Over Ramp near Tidel Park. The abstract and details of gradients are given in **Table 5.14 and 5.15** respectively.

TABLE 5.14: ABSTRACT OF GRADIENTS OF CORRIDOR-3

S. No.	Description	No.s of Occurrences	Length (m)	Percentage
1	Level (0%)	52	17466.95	37.79
2	>0% to 1%	50	19805.46	42.85
3	>1% to 2%	14	7678.50	16.61
4	>2% to 3%	1	546.50	1.18
5	>3%	1	728.00	1.57
	TOTAL	**118**	**46225**	**100.00**

TABLE 5.15: DETAILS OF GRADIENTS OF CORRIDOR-3

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
1	-795	-770	25	4.35	4.35	0.00	Level
2	-770	-224	547	4.35	-6.70	-2.02	Fall
3	-224	370	594	-6.70	-6.70	0.00	Level
4	370	837	467	-6.70	-8.70	-0.43	Fall
5	837	1129	292	-8.70	-8.70	0.00	Level
6	1129	1344	215	-8.70	-10.33	-0.76	Fall
7	1344	1575	231	-10.33	-9.13	0.52	Rise
8	1575	1825	250	-9.13	-9.13	0.00	Level
9	1825	2080	255	-9.13	-10.54	-0.55	Fall
10	2080	2300	220	-10.54	-9.44	0.50	Rise
11	2300	2522	222	-9.44	-9.44	0.00	Level
12	2522	2926	404	-9.44	-11.50	-0.51	Fall
13	2926	3147	221	-11.50	-9.65	0.84	Rise
14	3147	3546	399	-9.65	-9.65	0.00	Level
15	3546	3819	273	-9.65	-11.02	-0.50	Fall
16	3819	4092	273	-11.02	-9.63	0.51	Rise

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
17	4092	4451	359	-9.63	-9.63	0.00	Level
18	4451	4906	455	-9.63	-17.50	-1.73	Fall
19	4906	5162	256	-17.50	-17.50	0.00	Level
20	5162	5841	679	-17.50	-10.33	1.06	Rise
21	5841	6127	286	-10.33	-10.33	0.00	Level
22	6127	6441	314	-10.33	-13.34	-0.96	Fall
23	6441	6754	313	-13.34	-11.77	0.50	Rise
24	6754	7237	483	-11.77	-11.77	0.00	Level
25	7237	7482	245	-11.77	-13.01	-0.51	Fall
26	7482	7727	245	-13.01	-11.78	0.50	Rise
27	7727	8013	286	-11.78	-11.78	0.00	Level
28	8013	8287	274	-11.78	-13.75	-0.72	Fall
29	8287	8560	273	-13.75	-12.38	0.50	Rise
30	8560	8846	286	-12.38	-12.38	0.00	Level
31	8846	9388	542	-12.38	-9.90	0.46	Rise
32	9388	9712	324	-9.90	-9.90	0.00	Level
33	9712	9869	157	-9.90	-11.27	-0.87	Fall
34	9869	10025	156	-11.27	-10.49	0.50	Rise
35	10025	10315	290	-10.49	-10.49	0.00	Level
36	10315	10700	385	-10.49	-16.19	-1.48	Fall
37	10700	10950	250	-16.19	-16.19	0.00	Level
38	10950	11358	408	-16.19	-23.75	-1.85	Fall
39	11358	11676	318	-23.75	-23.75	0.00	Level
40	11676	12222	546	-23.75	-16.26	1.37	Rise
41	12222	12509	287	-16.26	-16.26	0.00	Level
42	12509	13061	552	-16.26	-9.07	1.30	Rise
43	13061	13350	289	-9.07	-9.07	0.00	Level
44	13350	13765	415	-9.07	-14.60	-1.33	Fall
45	13765	14059	294	-14.60	-14.60	0.00	Level
46	14059	14283	224	-14.60	-15.72	-0.50	Fall
47	14283	14447	164	-15.72	-14.66	0.65	Rise

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
48	14447	14740	293	-14.66	-14.66	0.00	Level
49	14740	15520	780	-14.66	-23.75	-1.17	Fall
50	15520	15773	253	-23.75	-23.75	0.00	Level
51	15773	16560	787	-23.75	-15.40	1.06	Rise
52	16560	16820	260	-15.40	-15.40	0.00	Level
53	16820	17660	840	-15.40	-11.87	0.42	Rise
54	17660	17951	291	-11.87	-11.87	0.00	Level
55	17951	18301	350	-11.87	-13.62	-0.50	Fall
56	18301	18650	349	-13.62	-10.88	0.79	Rise
57	18650	18936	286	-10.88	-10.88	0.00	Level
58	18936	19293	357	-10.88	-14.25	-0.94	Fall
59	19293	19650	357	-14.25	-12.47	0.50	Rise
60	19650	20120	470	-12.47	-12.47	0.00	Level
61	20120	20423	303	-12.47	-14.00	-0.50	Fall
62	20423	20720	297	-14.00	-12.30	0.57	Rise
63	20720	21075	355	-12.30	-12.30	0.00	Level
64	21075	21375	300	-12.30	-17.58	-1.76	Fall
65	21375	21911	536	-17.58	-17.58	0.00	Level
66	21911	22110	199	-17.58	-18.00	-0.21	Fall
67	22110	22355	245	-18.00	-18.00	0.00	Level
68	22355	22994	639	-18.00	-10.48	1.18	Rise
69	22994	23411	418	-10.48	-10.48	0.00	Level
70	23411	23640	229	-10.48	-12.75	-0.99	Fall
71	23640	23869	229	-12.75	-11.60	0.50	Rise
72	23869	24155	286	-11.60	-11.60	0.00	Level
73	24155	24600	445	-11.60	-11.00	0.13	Rise
74	24600	25260	660	-11.00	-11.00	0.00	Level
75	25260	25597	337	-11.00	-11.20	-0.06	Rise
76	25597	25932	335	-11.20	-11.20	0.00	Level
77	25932	26660	728	-11.20	15.80	3.71	Rise
78	26660	26895	235	15.80	15.80	0.00	Level

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
79	26895	27620	725	15.80	28.50	1.75	Fall
80	27620	27862	242	28.50	28.50	0.00	Level
81	27862	28453	591	28.50	21.70	-1.15	Rise
82	28453	28653	200	21.70	21.70	0.00	Level
83	28653	29437	784	21.70	27.60	0.75	Fall
84	29437	29763	326	27.60	27.60	0.00	Level
85	29763	30398	635	27.60	21.80	-0.91	Rise
86	30398	30690	292	21.80	21.80	0.00	Level
87	30690	31000	310	21.80	21.90	0.03	Fall
88	31000	31633	633	21.90	21.90	0.00	Level
89	31633	32293	660	21.90	21.20	-0.11	Rise
90	32293	32493	200	21.20	21.20	0.00	Fall
91	32493	32705	212	21.20	21.70	0.24	Level
92	32705	33158	453	21.70	21.00	-0.15	Rise
93	33158	33365	207	21.00	21.00	0.00	Level
94	33365	33973	608	21.00	21.30	0.05	Rise
95	33973	34173	200	21.30	21.30	0.00	Level
96	34173	34590	417	21.30	28.80	1.80	Fall
97	34590	35240	650	28.80	28.80	0.00	Level
98	35240	36120	880	28.80	22.55	-0.71	Fall
99	36120	36335	215	22.55	22.55	0.00	Level
100	36335	36893	558	22.55	22.20	-0.06	Fall
101	36893	37153	260	22.20	22.20	0.00	Level
102	37153	37819	666	22.20	21.90	-0.05	Rise
103	37819	38100	281	21.90	21.90	0.00	Level
104	38100	38612	512	21.90	22.30	0.08	Rise
105	38612	38872	260	22.30	22.30	0.00	Rise
106	38872	39025	153	22.30	23.00	0.46	Level
107	39025	39436	411	23.00	24.10	0.27	Rise
108	39436	39675	239	24.10	24.10	0.00	Level
109	39675	39925	250	24.10	25.35	0.50	Fall

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
110	39925	40887	962	25.35	25.35	0.00	Level
111	40887	41335	449	25.35	24.50	-0.19	Fall
112	41335	41535	200	24.50	24.50	0.00	Level
113	41535	42437	902	24.50	23.10	-0.16	Fall
114	42437	42637	200	23.10	23.10	0.00	Level
115	42637	43477	840	23.10	19.60	-0.42	Fall
116	43477	43712	235	19.60	19.60	0.00	Level
117	43712	44477	765	19.60	18.10	-0.20	Fall
118	44477	45430	953	18.10	18.10	0.00	Level

5.6.1.6 Break-up of Alignment Length

Break-up of alignment length for Corridor-3 is given in **Table 5.16**.

TABLE 5.16: BREAK-UP OF ALIGNMENT LENGTH FOR CORRIDOR-3

S. No.	Description	Chainage (KM)		Length (m)	Method of Construction / Structure Type
		From	To		
1	Underground	-383	26340	26723	TBM/Cut & cover/NATM
2	Elevated	26340	45430	19090	Box/I/U- Shape Girder
Total Length				**45813**	

5.6.2 Corridor-4: Light House to Poonamallee

5.6.2.1 Alignment Description

Considering centre line of Light House Station as 20.00m, this corridor is 26085 m long starting from -255 m and running upto25830 m. This corridor starts as Underground stretch followed by Switch Over Ramp (SOR), and finally again as elevated stretch. The corridor is summarised as under in **Table 5.17.**

TABLE 5.17: ALIGNMENT DESCRIPTION

Alignment Type	From(m)	To(m)	Length(m)
Underground	-255.412	9567.281	9822.693
Switch over Ramp (-)8.0m to (+)7.5m	9567.281	10027.102	459.821
Elevated	10027.102	25829.793	15802.691
Total			**26085.205**

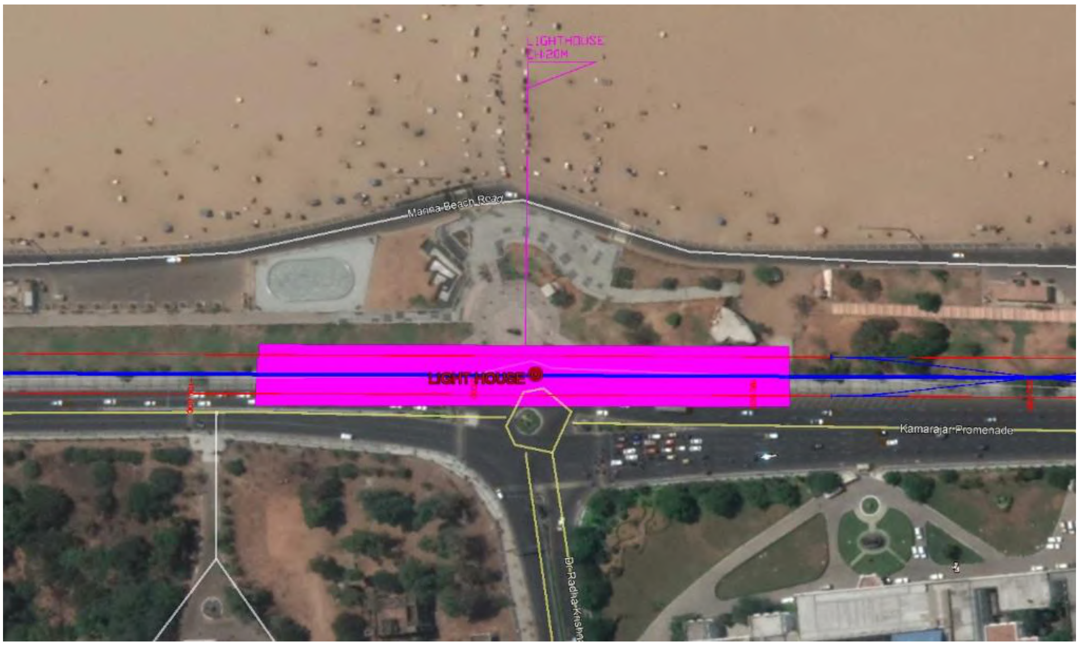
The Alignment of Corridor -4 is described in detail in following sub sections: -

I) Light House to Meenakshi College
II) Switch Over Ramp from Underground to Elevated
III) Power House to Poonamallee Bypass

I) Light House to Meenakshi College

- The proposed alignment starts from Light House as underground and heads in West direction. Total length of the section is about 9.823 Km and is completely underground.12 underground stations have been proposed in this section.**Figure 5.19** shows proposed Light House station location.

FIGURE 5.19: PROPOSED LIGHT HOUSE STATION LOCATION



- Foreshore road stationwith all ancialiary buildings and entry/exits has been proposed within the right edge of existing Foreshore road.

  The alignment of Corridor-4 is crossing below the Corridor-3 alignment. Thirumaylai station for corridor-4 is proposed at third level below the ground. The rail levels for corridor 4 are proposed at -22m below ground level and for corridor-3 Rail level is proposed at depth of -15m below the ground level, thus keeping a level difference of 7m between tracks of two corricors. With this arrangement, the Rail tracks for Corridor-4 passes below the proposed station of Corridor-3. Both the stations are planned with passenger integration **(Figure 5.20)**

FIGURE 5.20: INTEGRATION OF CORRIDOR 3 & 4 AT THIRUMAYILAI

- Corridor 4 is crossing Phase-1 Corridor-1 near existing Nanadanam station which is about 16m deep from of the existing road level. Proposed level of Nandanam Station in Phase-2 has been planned at 30m depth with 8m cushion between the existing tunnel of the Corridor 1, due care will have to be ensured during construction near at this location. The depth of rail level of this station has been kept around 30m from the existing road level and the length of the station is 150m.

FIGURE 5.21: INTEGRATION OF CORRIDOR-4 WITH PHASE-1 CORRIDOR AT NANDANAM

- Alignment at Kodambakkam Metro has been proposed parallel to the existing railway station. Passenger integration has to be planned with existing station at this location. This area is very congested, so the location of the planned station has been selected in such a way that it requires minimum land and properties.

FIGURE 5.22: KODAMBAKKAM STATION

The depth of rail level of this station has been kept around 20m from the existing road level and the length of the station is 150m. The details of land and properties required for construction of this station are shown in the alignment plan.

- Meenakshi college station has been proposed at 12m below the ground to keep the Swich over ramp (from underground to elevated) location closer to the station. The station is proposed in 1000m curve to follow the road curvature and to keep the ramp in centre of the road.

II) Switch Over Ramp from Underground section to Elevated section:

- The aligment after passing below Railway lines at Kodabakkam station, comes on centre of Arcotroad. The switch over ramp is proposed on the centre line of existing road, between the underground station atMeenakshi College and elevated station as Power House, i.e. from Chainage 9567.281 m to 10027.102 m with RL rising from (-)8.0m to (+)7.5m. The width of proposed 459.8 m long ramp shall be 12m – 13m. Hence, road shall be widened to accommodate the proposed ramp within the ROW.

III) Power House to Poonamallee Bypass:

- The alignment in this section runs elevated along the centre of the Arcot road from Power Housewestwards and terminates at Poonamallee bypass. Total length of the section is about 15.803 Km and is completely elevated.18 elevated stations have been proposed in this section.

- After the switch over ramp, the first elevated station is proposed as Power House. The station is proposed with RL 13m with normal vertical clearance of 5.5m from ground level.

FIGURE 5.23: VADAPALINI STATION

After power house station, the alignment is further ramped up upto RL 25m at Vadapalini junction. The metro station proposed in corridor-4 at this location is crossing over existing VadapaliniMetro cum flyover on 100 feet road. Passenger integration between these two stations has been planned.

- Corridor-4 & 5 run on common alignment between Alwathirunagar&Porur Junction section. Both the corridors are proposed to run elevated at different level with common pier arrangement. In this arrangement, Corridor-5 is proposed to run above corridor-4. Four stations namely, Alwathirunagar, Valasaravakkam, Karabakkam & Alapakkam Junction shall be common to both the corridors with common concourse with platforms at different levels. Porur junction stations shall be separate at different locations for both the corridors.

- Alignment crosses Porur junction flyover, Chennai bypass, Poonamalle flyover & Outer ring road at double height with minimum vertical clearance of 5.5m from finished road road of grade separaters.

- The terminal station is proposed with extended stabling lines to accommodate 4 rakes including two rakes at platform side.

- Depot entry & exits are proposed separately from the terminal station.

FIGURE 5.24: COMMON SECTION OF CORRDOR-4 & 5 BETWEEN ALWATHIRUNAGAR & PORUR JUNCTION

5.6.2.2 Reference Point

For the planning convenience, the zero point of the Corridor is considered at the 20m before centre line of the proposed Light House station. The chainage along the alignment increases in western direction. All elevations are from Mean Sea Level (MSL).

5.6.2.3 Terminal stations

iii. Light House (East side terminal station)

The east side station on the Metro corridor is Light House Station. The station is proposed underground and rail level has been kept -15.00 m (minimum) below the ground level.

iv. Poonamallee Bypass (West side Terminal Station)

The west side Terminal of the corridor will be Poonamallee bypass Station. The station is proposed elevated and rail level has been kept 18.0 m (minimum) above the ground level.

Reversal/stabling facility has also been planned beyond this Metro station. The entry to depot has also been planned at this station.

5.6.2.4 Horizontal Curvature

Total 73 nos. horizontal curves have been provided on the entire length of the alignment of Corridor 4. The minimum radius of curves is 210m in underground section and 122.5 m in elevated section. About 58.7% alignment is on straight & about 41.3% of alignment is on curves. The abstract and details of curves are indicated in **TABLE 5.18 & TABLE 5.19** respectively.

TABLE 5.18: ABSTRACT OF HORZ. CURVES OF CORRIDOR-4

S. No.	Curve Radius	No. of Occurrences	Length	Percentage
1	≤150	6	855.74	7.95
2	>150 <300	15	3322.36	30.87
3	≥300 ≤ 500	16	2363.47	21.96
4	>500 ≤ 800	8	1140.02	10.59
5	>800 ≤ 1000	9	1038.48	9.65
6	>1000	19	2041.57	18.97
7	**Total**	**73**	**10761.64**	**100.00**

FIGURE 5.25: PROPOSED PHASE-II METRO CORRIDOR-4

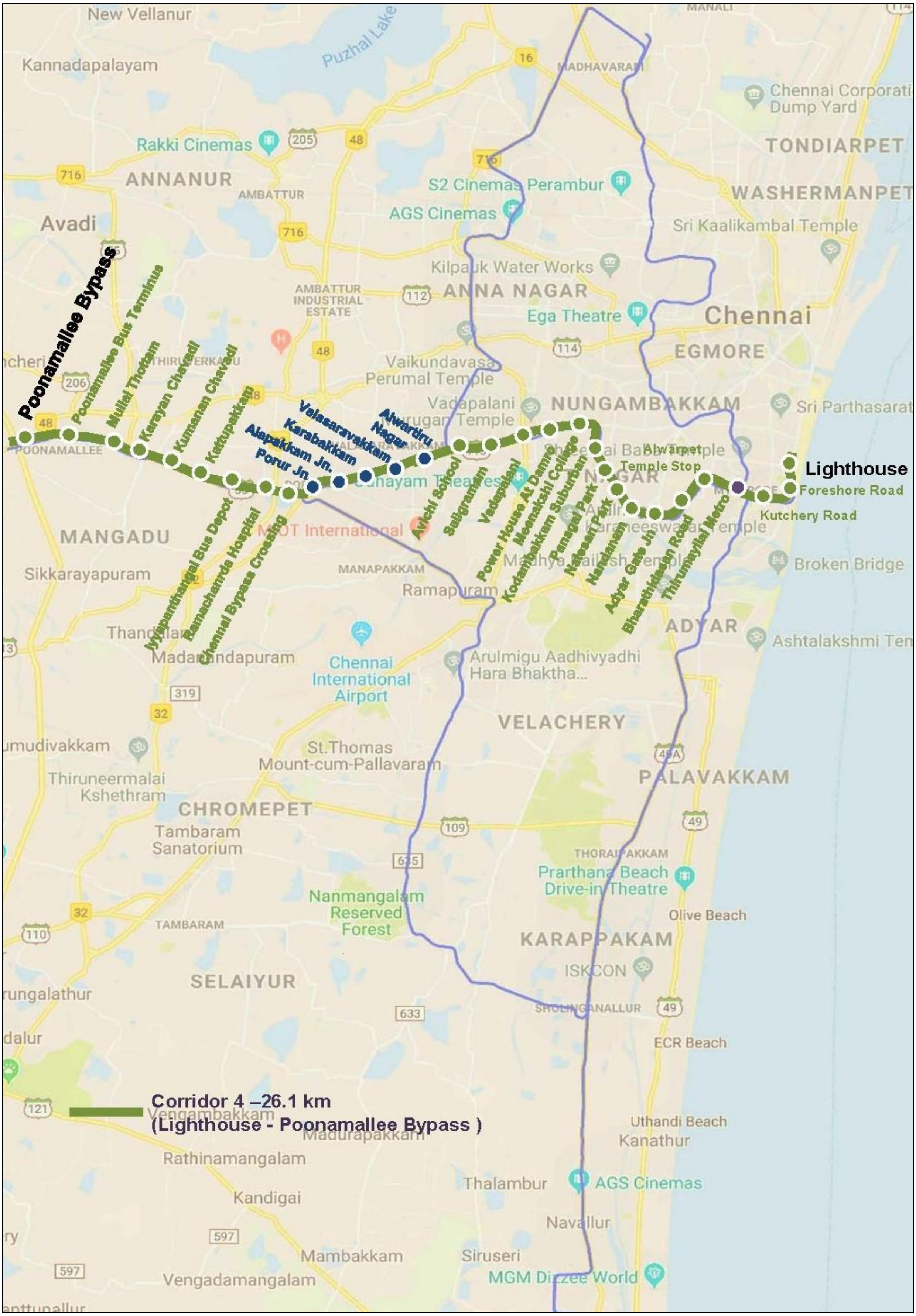


TABLE 5.19: DETAILS OF HORIZONTAL CURVES OF CORRIDOR-4

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
1	336.23	528.39	Left	-210	38	28	18.12	50	50	99.09	92.17	192.17	--
2	528.40	711.34	Right	210	36	9	38.88	50	50	93.93	82.93	182.93	Nil
3	932.04	1340.55	Right	210	97	29	24.72	50	50	266.36	308.52	408.52	220.70
4	1959.26	2100.78	Right	300	17	17	3.84	50	50	71.17	41.52	141.52	618.71
5	2345.68	2488.64	Left	-300	17	27	4.68	50	50	71.90	42.96	142.96	244.90
6	2734.05	2906.40	Left	-300	23	13	12.36	50	50	87.10	72.35	172.35	245.42
7	3018.50	3197.04	Right	210	35	2	31.2	50	50	91.50	78.55	178.55	112.09
8	3408.54	3749.15	Left	-210	79	10	18.48	50	50	199.40	240.61	340.61	211.49
9	4514.69	4679.08	Left	-1000	8	9	44.28	20	20	82.32	124.39	164.39	765.54
10	4757.41	5067.13	Right	210	70	30	51.12	50	50	174.75	209.72	309.72	78.33
11	5338.57	5457.91	Left	-600	7	20	36.24	40	40	59.73	39.34	119.34	271.44
12	5539.11	5681.96	Right	600	9	29	30.48	40	40	71.56	62.85	142.85	81.20
13	5883.32	6104.90	Right	210	46	29	3.12	50	50	116.10	121.57	221.57	201.36
14	6983.60	7075.16	Right	1500	2	33	10.08	15	15	45.79	61.56	91.56	878.70
15	7593.58	7666.92	Left	-1500	2	1	17.04	20	20	36.67	33.33	73.33	518.42
16	7961.02	8185.31	Right	250	39	33	49.32	50	50	116.00	124.29	224.29	294.11
17	8612.63	9091.09	Left	-240	102	10	17.04	50	50	323.43	378.46	478.46	427.32
18	9159.83	9421.73	Left	-1500	9	8	32.28	20	20	131.21	221.90	261.90	68.75
19	9724.23	9809.34	Left	-1050	3	0	9.36	30	30	42.56	25.11	85.11	302.50
20	10130.37	10233.92	Left	-1250	3	29	41.28	20	20	51.80	63.56	103.56	321.02

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
21	10395.16	10468.23	Right	3000	1	3	47.52	15	15	36.53	43.06	73.06	161.24
22	10602.87	10694.04	Left	-1000	3	18	5.76	30	30	45.59	31.16	91.16	134.65
23	10694.17	10836.14	Right	400	13	6	8.28	50	50	71.21	41.97	141.97	Nil
24	11247.79	11405.68	Left	-600	9	29	35.16	55	55	79.09	47.89	157.89	411.65
25	11502.11	11584.87	Right	2000	1	28	30.72	20	20	41.38	42.76	82.76	96.43
26	11837.52	11927.73	Right	1000	3	16	12	30	30	45.12	30.22	90.22	252.65
27	11956.45	12038.98	Left	-1550	2	11	2.4	20	20	41.27	42.52	82.52	28.72
28	12039.23	12174.58	Right	300	16	10	49.08	50	50	68.01	35.35	135.35	Nil
29	12760.98	12896.78	Left	-134	36	24	36	50	50	69.65	35.79	135.79	586.40
30	12896.92	13032.44	Right	149	32	31	50.88	50	50	69.16	35.52	135.52	Nil
31	13304.72	13369.96	Right	2100	1	8	25.08	20	20	32.62	25.24	65.24	272.28
32	13409.44	13536.81	Left	-250	17	26	8.16	50	50	64.05	27.37	127.37	39.48
33	13676.86	13803.93	Left	-225	19	22	24.96	50	50	63.99	27.07	127.07	140.04
34	13829.90	13960.51	Right	300	15	14	3.48	50	50	65.59	30.61	130.61	25.97
35	14207.01	14341.92	Left	-300	16	7	33.24	50	50	67.78	34.91	134.91	246.50
36	14342.01	14471.47	Right	185	24	21	47.88	50	50	65.46	29.46	129.46	Nil
37	14612.32	14743.50	Right	235	19	28	22.44	50	50	66.06	31.18	131.18	140.85
38	14823.57	15011.20	Left	-400	20	10	17.04	46	46	94.60	95.63	187.63	80.07
39	15320.30	15594.51	Left	-1010	13	30	41.04	30	30	137.71	214.22	274.22	309.10
40	15782.97	15932.24	Right	300	18	34	24.6	50	50	75.15	49.27	149.27	188.46
41	16113.79	16320.72	Right	1200	8	29	41.28	22	22	103.65	162.94	206.94	181.55

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
42	16320.77	16551.50	Left	-1091.5	10	19	16.68	30	30	115.65	170.73	230.73	Nil
43	16551.55	16650.29	Right	800	4	33	8.28	30	30	49.39	38.74	98.74	Nil
44	16821.20	16980.98	Left	-500	13	5	27.6	45	45	80.16	69.78	159.78	170.91
45	17069.50	17175.62	Left	-130	29	5	3.48	40	40	53.91	26.13	106.13	88.51
46	17311.87	17518.84	Right	122.5	78	3	15.12	40	40	119.79	126.97	206.97	136.24
47	17699.34	17852.26	Left	-200	29	17	25.44	50	50	77.75	52.92	152.92	180.51
48	18169.98	18266.70	Right	2000	2	6	54.72	20	20	48.37	56.72	96.72	317.72
49	18389.67	18521.22	Right	700	7	17	37.32	40	40	65.85	51.55	131.55	122.96
50	19065.46	19124.06	Right	3500	0	25	29.64	15	15	29.30	28.59	58.59	544.25
51	19280.61	19349.22	Left	-2000	1	14	0.24	20	20	34.31	28.61	68.61	156.55
52	19450.41	19680.88	Right	700	15	6	18	45	45	115.79	140.47	230.47	101.19
53	19909.09	19993.18	Left	-2000	1	30	3.6	20	20	42.05	44.10	84.10	228.21
54	20560.57	20637.74	Right	1000	2	35	30.84	25	25	38.59	27.16	77.16	567.39
55	21051.20	21155.65	Left	-2000	2	15	3.6	20	20	52.23	64.45	104.45	413.46
56	21323.88	21415.12	Right	2000	2	1	22.08	20	20	45.63	51.24	91.24	168.22
57	21519.42	21594.16	Left	-1000	3	0	43.2	22	22	37.38	30.75	74.75	104.30
58	21739.76	21874.61	Left	-125	38	31	59.16	50	50	69.39	34.85	134.85	145.59
59	21874.84	22011.32	Right	142	34	32	0.24	50	50	69.83	36.48	136.48	Nil
60	22071.42	22165.71	Right	2000	2	4	27.12	20	20	47.15	54.29	94.29	60.10
61	22273.12	22392.68	Right	800	6	14	42	30	30	59.83	59.56	119.56	107.41
62	22619.39	22759.02	Right	700	8	5	30.12	40	40	69.90	59.63	139.63	226.72

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
63	22782.17	22875.71	Left	-1000	3	22	57.36	30	30	46.78	33.54	93.54	23.15
64	22912.38	23031.71	Left	-500	10	8	27.96	30	30	59.79	59.33	119.33	36.67
65	23082.03	23168.88	Right	1500	2	6	6.84	30	30	43.43	26.86	86.86	50.31
66	23228.74	23426.85	Left	-360	23	20	30.12	50	50	100.17	98.10	198.10	59.86
67	23617.21	23784.02	Right	300	26	4	28.56	30	30	84.65	106.81	166.81	190.36
68	23805.77	23931.32	Left	-300	14	15	15.48	50	50	63.01	25.55	125.55	21.75
69	24036.03	24102.52	Right	1000	2	3	9.72	30	30	33.25	6.49	66.49	104.71
70	24185.64	24301.76	Left	-310	13	5	2.76	45	45	58.24	26.12	116.12	83.12
71	24438.06	24555.61	Left	-180	23	3	11.16	45	45	59.36	27.55	117.55	136.30
72	24688.69	24829.90	Right	400	13	27	55.44	45	45	70.86	51.21	141.21	133.08
73	24880.46	24987.02	Left	-1000	4	13	51.6	30	30	53.30	46.55	106.55	50.56

5.6.2.4 Gradients

A total 80 number of change of gradients has been provided in the entire Corridor. Flattest gradient is level provided for 39% of the alignment. Steepest gradient is 3.6% provided for Switch Over Ramps near Meenaksi College. The abstract and details of gradients are given in **TABLE 5.20 & TABLE 5.21** respectively.

TABLE 5.20: ABSTRACT OF GRADIENTS OF CORRIDOR-4

S. No.	Description	Nos. of Occurrences	Length (m)	% Length
1	Level (0%)	34	10232	39.22
2	>0% to 1%	14	5524	21.18
3	>1% to 2%	17	5530	21.20
4	>2% to 3%	12	3391	13.00
5	>3%	3	1408	5.40
	TOTAL	**80**	**26085**	**100.00**

TABLE 5.21: DETAILS OF GRADIENTS OF CORRIDOR-4

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
1	-255	406	662	-10.44	-10.44	0.00	Level
2	406	643	237	-10.44	-8.26	0.92	Rise
3	643	999	357	-8.26	-8.26	0.00	Level
4	999	1357	357	-8.26	-10.05	-0.50	Fall
5	1357	1639	282	-10.05	-8.60	0.51	Rise
6	1639	1889	250	-8.60	-8.60	0.00	Level
7	1889	2328	439	-8.60	-18.46	-2.25	Fall
8	2328	2689	361	-18.46	-18.46	0.00	Level
9	2689	3132	443	-18.46	-11.12	1.66	Rise
10	3132	3474	342	-11.12	-11.12	0.00	Level
11	3474	3851	377	-11.12	-9.87	0.33	Rise
12	3851	4266	415	-9.87	-9.87	0.00	Level
13	4266	5077	811	-9.87	-15.60	-0.71	Fall
14	5077	5282	205	-15.60	-15.60	0.00	Level
15	5282	6039	757	-15.60	-23.93	-1.10	Fall
16	6039	6293	254	-23.93	-23.93	0.00	Level
17	6293	6706	413	-23.93	-13.58	2.51	Rise
18	6706	6942	236	-13.58	-13.58	0.00	Level
19	6942	7331	389	-13.58	-8.11	1.41	Rise
20	7331	7541	210	-8.11	-8.11	0.00	Level
21	7541	8348	807	-8.11	-13.40	-0.66	Fall

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
22	8348	8850	502	-13.40	-13.40	0.00	Level
23	8850	9125	275	-13.40	-3.78	3.50	Rise
24	9125	9450	325	-3.78	-3.78	0.00	Level
25	9450	10181	731	-3.78	22.54	3.60	Rise
26	10181	10498	317	22.54	22.54	0.00	Level
27	10498	10900	402	22.54	36.61	3.50	Rise
28	10900	11217	317	36.61	36.61	0.00	Level
29	11217	11614	397	36.61	25.53	-2.79	Fall
30	11614	11823	209	25.53	25.53	0.00	Level
31	11823	12106	283	25.53	20.20	-1.88	Fall
32	12106	12312	206	20.20	20.18	-0.01	Fall
33	12312	12591	279	20.18	25.56	1.93	Rise
34	12591	12830	239	25.56	25.56	0.00	Level
35	12830	13058	229	25.56	21.04	-1.98	Fall
36	13058	13171	113	21.04	21.04	0.00	Fall
37	13171	13473	302	21.04	26.48	1.80	Rise
38	13473	13740	267	26.48	26.47	0.00	Fall
39	13740	14018	278	26.47	21.57	-1.77	Fall
40	14018	14106	88	21.57	21.56	0.00	Fall
41	14106	14407	301	21.56	27.29	1.90	Rise
42	14407	14678	271	27.29	27.30	0.00	Rise
43	14678	14945	267	27.30	21.95	-2.00	Fall
44	14945	15306	361	21.95	22.23	0.08	Rise
45	15306	15613	307	22.23	27.75	1.80	Rise
46	15613	15857	244	27.75	27.74	-0.01	Fall
47	15857	16080	222	27.74	23.39	-1.95	Fall
48	16080	16271	192	23.39	28.00	2.40	Rise
49	16271	16667	396	28.00	28.00	0.00	Level
50	16667	17123	456	28.00	33.68	1.25	Rise
51	17123	17540	417	33.68	33.68	0.00	Level
52	17540	17870	330	33.68	35.68	0.61	Rise
53	17870	18218	348	35.68	35.68	0.00	Level
54	18218	18833	615	35.68	31.27	-0.72	Fall
55	18833	19140	307	31.27	31.27	0.00	Rise
56	19140	19378	238	31.27	27.69	-1.50	Fall
57	19378	19600	222	27.69	32.26	2.06	Rise
58	19600	19851	251	32.26	32.26	0.00	Rise
59	19851	20064	214	32.26	27.99	-2.00	Fall
60	20064	20493	429	27.99	27.99	0.00	Fall
61	20493	20760	267	27.99	33.32	2.00	Rise
62	20760	20960	200	33.32	33.33	0.00	Rise

S. No.	Chainage		Length	Rail Level		Gradient %	Remarks
	From	To		From	To		
63	20960	21197	238	33.33	28.58	-2.00	Fall
64	21197	21288	90	28.58	28.58	0.00	Fall
65	21288	21557	269	28.58	33.97	2.00	Rise
66	21557	21808	251	33.97	33.97	0.00	Rise
67	21808	22026	218	33.97	29.88	-1.88	Fall
68	22026	22182	156	29.88	29.91	0.02	Rise
69	22182	22450	268	29.91	35.55	2.10	Rise
70	22450	22687	238	35.55	35.54	-0.01	Fall
71	22687	22894	206	35.54	31.29	-2.06	Fall
72	22894	23067	174	31.29	31.29	0.00	Fall
73	23067	23325	257	31.29	36.09	1.86	Rise
74	23325	23597	272	36.09	36.09	0.00	Fall
75	23597	23869	272	36.09	32.50	-1.32	Fall
76	23869	23946	77	32.50	32.50	0.00	Level
77	23946	24244	298	32.50	37.55	1.69	Rise
78	24244	24496	252	37.55	37.56	0.00	Rise
79	24496	24999	504	37.56	42.12	0.91	Rise
80	24999	25830	831	42.12	42.12	0.00	Level

5.6.2.4 Break-up of Alignment Length

Break-up of alignment length for Corridor-4 is given in **TABLE 5.22**.

TABLE 5.22: BREAK-UP OF ALIGNMENT LENGTH FOR CORRIDOR-4

S. No.	Description	Chainage (KM)		Length (m)	Method of Construction / Structure Type
		From	To		
1	Underground	-255.412	9815.743	10071.155	TBM/Cut & cover/NATM
2	Elevated	9815.743	25829.793	16014.050	Box/I/U- Shape Girder
Total Length				**26085.205**	

5.6.3 Corridor-5: Madhavaram (MMC) to Sholinganallur

5.6.3.1 Alignment Description

In the Phase-II DPR 2017, the alignment of C-5 was mostly underground. In view of the recent developments, the corridor has been reviewed during various stakeholder's meetings and slightly modified from CMP/Alternative Analysis Report and 2017 DPR proposals. Now, the alignment of C-5 is mostly elevated with only underground section between Kolathur Junction and Nathamuni. The major factors for C-5 modifications are: -

- Road widening of Kaliamann Koil Street and Medavakkam Main Road.

- Corridor-4 has been extended from Meenakshi College to Poonamallee Bypass with elevated section. The alignment of C-5 has also been modified via Kaliamann Koil Street and it runs alongwith with Corridor-4 from Alwathirunagar to Porur Junction on Arcot Road and further takes Mount Poonamallee High Road towards Sathya Nagar ensuring better connectivity.
- Reduction of underground section has led to reduction of Capital costs.

The corridor starts with Madhavaram at 0.00m and terminates at Sholinganallur at 46272m. The corridor is summarised in **Table 5.23** and presented in **Figure 5.35**.

TABLE 5.23: ALIGNMENT DESCRIPTION OF CORRIDOR - 5

Alignment Type	From	To	Length
	(m)	(m)	(m)
Underground	-386	356	742
Switch over Ramp (-)8.0m to 0.0m	356	573	217
At-grade	573	1150	577
Elevated	1150	6653	5503
Switch over Ramp (+)7.5m to (-)8.0m	6653	7049	396
Underground	7049	11530	4481
Switch over Ramp (-)8.0m to (+)7.5m	11530	11920	390
Elevated	11920	46623	34703
Total			**47009**

Alignment of Corridor -5 is described in detail in following sub sections: -

I) Madhavaram Milk Colony to Retteri

II) Switch Over Ramp from Elevated to Underground

III) Kolathur Junction to Nathamuni

IV) Switch Over Ramp from Underground to Elevated

V) Anna Nagar to Sholinganallur

I) MMC to Retteri

- The proposed alignment of Corridor-5 starts from Madhavaram Milk Colony as underground and heads in East direction towards Jawaharlal Nehru Road. Total length of the section is about 7.225 Km.
- The first station is underground and is common station for Corridor 3 & 5. The corridor then ramps out to ground level with at-grade station as Venugopal Nagar. The alignment then comes on centre of Jawaharlal Nehru Road and runs elevated upto Retteri. The Retteri station is proposed double elevated in between the two flyovers on either side of the ROW.

- MMBT station is proposed as mid-terminal station with facility of stabling of two rakes. The either ends of the station is proposed with scissor cross-overs. Total 8 stations (1 UG, 1 at-grade and 6 elevated) have been proposed in this section.

FIGURE 5.26: STARTING POINT OF CORRIDOR 3 & 5

II) Switch Over Ramp from Elevated section to Underground section:

- In Phase II DPR 2017, the ramp was proposed between Shastri Nagar & Retteri junction and underground Retteri junction station was planned on left side of the road (Shastri Nagar to Kolathur junction direction) opposite to the existing flyover. Now, second flyover is being constructed on the left side of the road. There shall now be two flyovers on either side of the ROW and at-grade 4-lane carriageway in between. Thus, the ramp is now proposed between double height Retteri Junction stationand shallow depth Kolathur Junction station from Chainage 6653 m to 7049 m with RL dropping from (+)7.5 m to (-)8.0 m. The road is sufficiently wide to accommodate the proposed ramp within the ROW.

III) Retteri Junction to Nathamuni:

- The alignment in this section runs underground below the dense residential areas. It is also integrated with Bus terminals and Railway systems.

- Total length of the section is about 4.876 Km and is completely underground. Total 5 underground stations have been proposed in this section.

- The alignment runs below dense area of Kolathur & Srinivasa Nagar and crosses Railway tracks at Villivakkam Railway station station with clear cushion of 15.5m between tunnel top and ground level (**Figure 5.27**).

FIGURE 5.27: ALIGNMENT CROSSING RAILWAY TRACKS AT VILIVAKKAM METRO

IV) Switch Over Ramp from Underground section to Elevated section:

- The switch over ramp to bring the alignment from underground to elevated is proposed in the vacant private land after Nathamuni station. The metro alignment becomes elevated short of sub-urban railway track from coming from Villivakkam connecting ICF. The ramp is so proposed that there shall be least interference with existing road and rail. The ramp portion with diaphragm runs from Chainage 11530 m to 11920 m with RL rising from (-)8.0 m to (+)7.5 m. The total area required is 0.5 Ha. approx. considering 12-13 m wide ramp.

FIGURE 5.28: RAMP LOCATION AFTER NATHAMUNI STATION NEAR PADI CLOVER LEAF

V) Anna nagar to Sholinganallur:

- The alignment in this section runs elevated along the centre of 100 ft road upto CMBT passing double elevated over existing flyover near Thirumangalam and Koyembedu flyover.

FIGURE 5.29: ALIGNMENT NEAR KOYEMBEDU CLOVER LEAVES

- Also, there is flyover underconstruction after Koyembedu flyover towards CMBT. The alignment is therefore, proposed to be double elevated on one side of the road. The alignment then takes u-turn towards other side of the existing Metro station. the proposed CMBT station is integrated with Phase-1 station. The alignment takes Kaliamann Koil Street from Koyembedu South Jn. Station to Alwathirunagar via CMBT. Kaliamann Koil Street is being widened in this section from 8-10m to 24-27m.Therefore the alignment is proposed as elevated in this section.

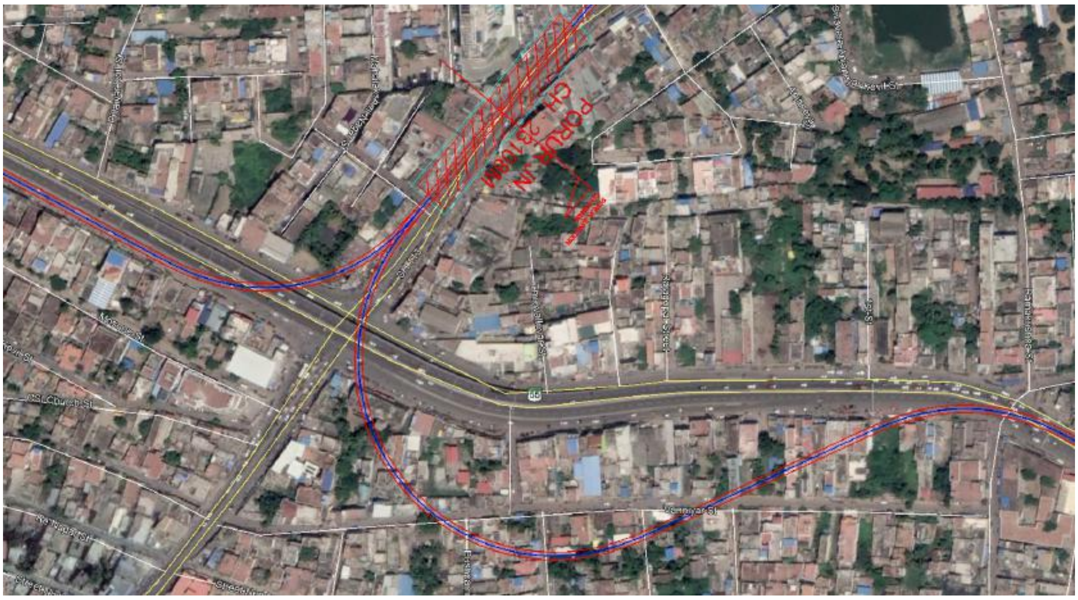
- The corridor further takes right on Arcot road upto short of Porur Junction flyover. At the junction of Kaliamann Koil Street and Arcot road, the alignment takes sharp right turn towards Porur junction. Hence, land acquisition shall be required in Rajeshwari Colony as a condition precedent.

FIGURE 5.30: LAND ACQUISITION AT THE JUNCTION OF KALIAMANN KOIL STREET & ARCOT ROAD

- Further, as explained in previous sections of Corridor-4, the alignment is common for Corridor-4 & Corridor-5 in the section from Alwathirunagar to Porur Junction flyover. Both corridors are proposed elevated at different levels one top of the other sharing common sub-structure. The land acquisition shall be required in taking sharp curve from Kaliamann Koil Street to Arcot road.

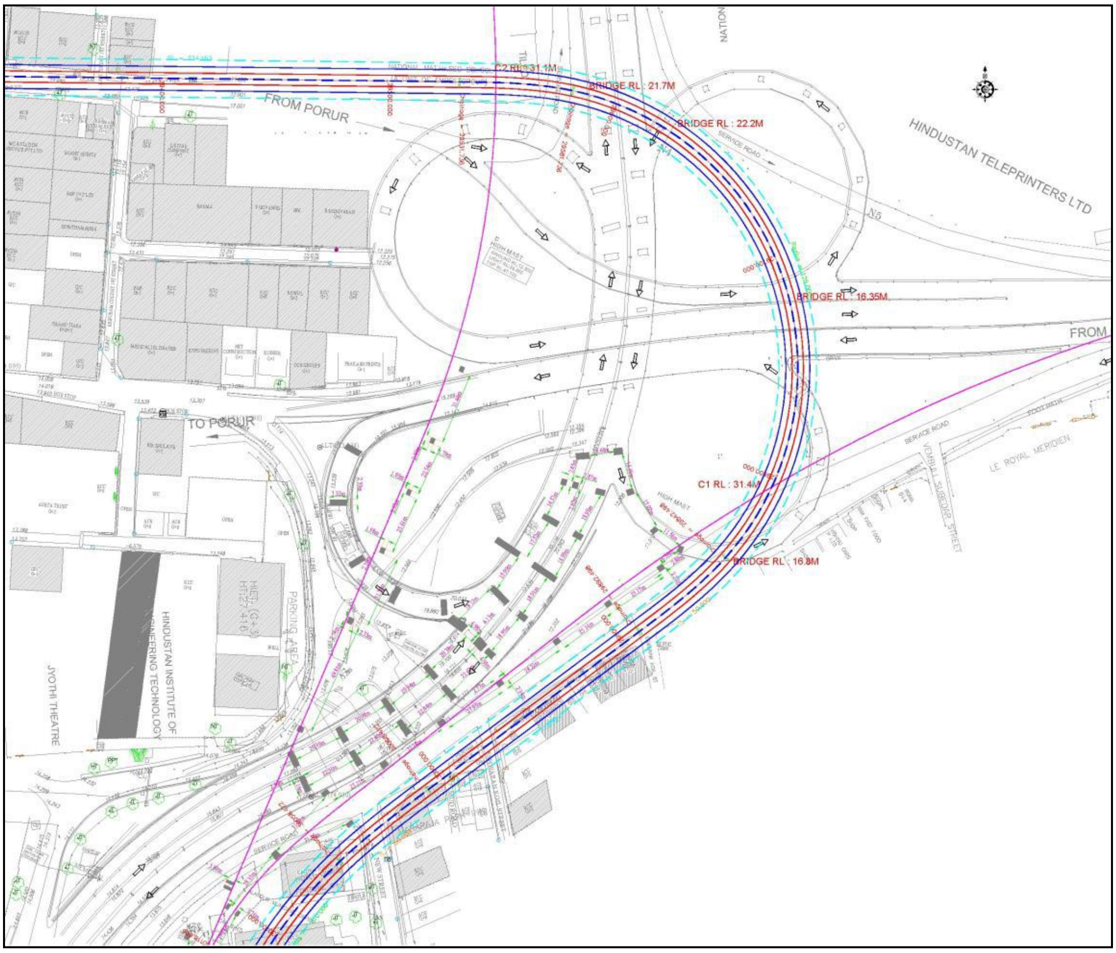
- The corridor then turns left sharply on Mount Poonamallee road towards Sathya Nagar beyond which it follows earlier alignment upto St. Wesley Church. The land acquisition shall be required in taking sharp curve from Arcot road to Mount Poonamalle road near Porur Junction.

FIGURE 5.31: LAND ACQUISITION PORUR JUNCTION



- The alignment is further modified and passes over elevated corridor-1 & 2 of Phase-1 at Alandur metro station near Kathipara cloverleaf Junction. The elevation of the proposed Corridor-5 is 40.4m which is within permissible elevation of Air funnel zone as shared by CMRL. The station is proposed on left side of existing station in land reserved for Metro.

FIGURE 5.32: ALIGNMENT NEAR KATHIPARA JUNCTION

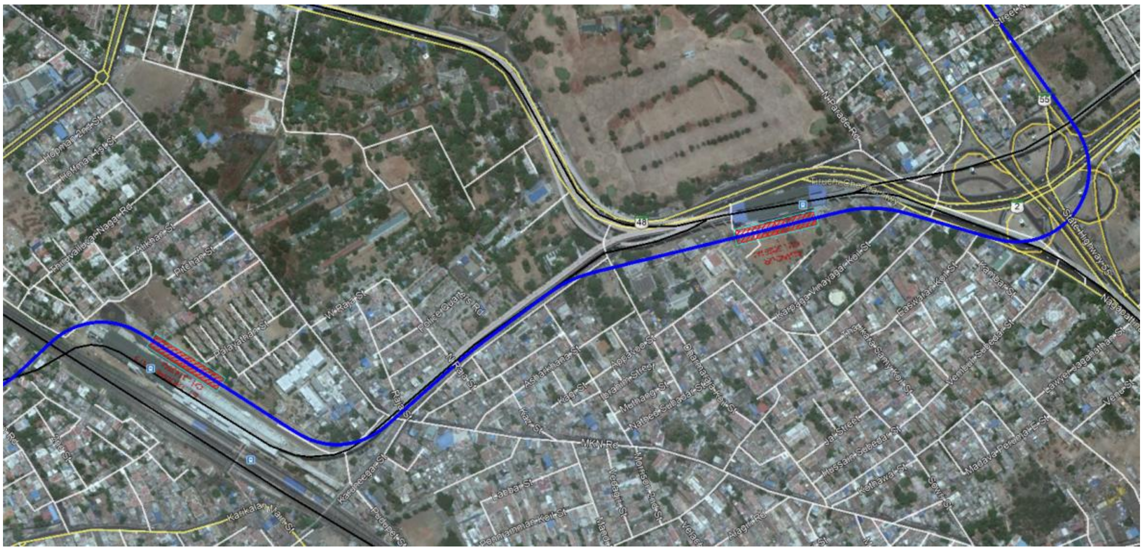


- The alignment then follows Phase-1 corridor from Alandur to Inner ring road via St. Thomas Mount. The alignment is proposed as double elevated in this section. From St. Thomas Mount station upto existing MRTS corridor near Adambakkam, the corridor follows same alignment as that of proposed MRTS. It is proposed that substructure for MRTS and elevated corridor-5 in this section may be constructed together with common / alternative pier arrangement to minimize land acquisition.

- Further, upto Adambakkam crossing the alignment shall continue double height on one side (left) to accommodate piers on shoulder of service road.

- The alignment then turns right on Medavakkam main road and follows centre line of the road upto HLC Elcot. From Medavakkam main road upto Vellakallu, the road is being widened upto 24-27m. hence, the alignment is proposed as elevated in this section.

FIGURE 5.33: INTEGRATION OF CORRIDOR-5 AT ALANDUR & ST. THOMAS MOUNT



- A double height viaduct elevated road is being constructed on Echangadu, Medavakkam Koot road to Medavakkam Bus depot junction. The alignment is therefore proposed on right side on shoulder of service road away from service road. The land shall be required for part of the viaduct beyond ROW.
- Further, the alignment terminates at Sholinganallur forming a ring arrangement at the terminal station between Corridor-3 & Corridor-5 as described in description of Corridor-5.
- Total length of the section is about 34.907 Km and is completely elevated.
- Tota 35 elevated stations have been proposed in this section.

5.6.3.2 Reference Point for Corridor-5

- For the planning convenience, the zero point of the Corridor is considered at the centre line of the proposed Madhavaram Milk Colony Metro station. The chainage along the alignment increases in Southern direction. All elevations are from Mean Sea Level (MSL).

5.6.3.3 Terminals of Corridor-5

i. Madhavaram Milk Colony Metro Station (North terminal station)

The Northernmost station on the Metro corridor-5 is Madhavaram Milk Colony. The station is proposed underground and rail level has been kept (-) 15.00m (minimum) below the ground level. Reversal facilities have also been planned at this station.

Entry to the proposed depot has also been planned after the station through at-grade station of Venugopal Nagar.

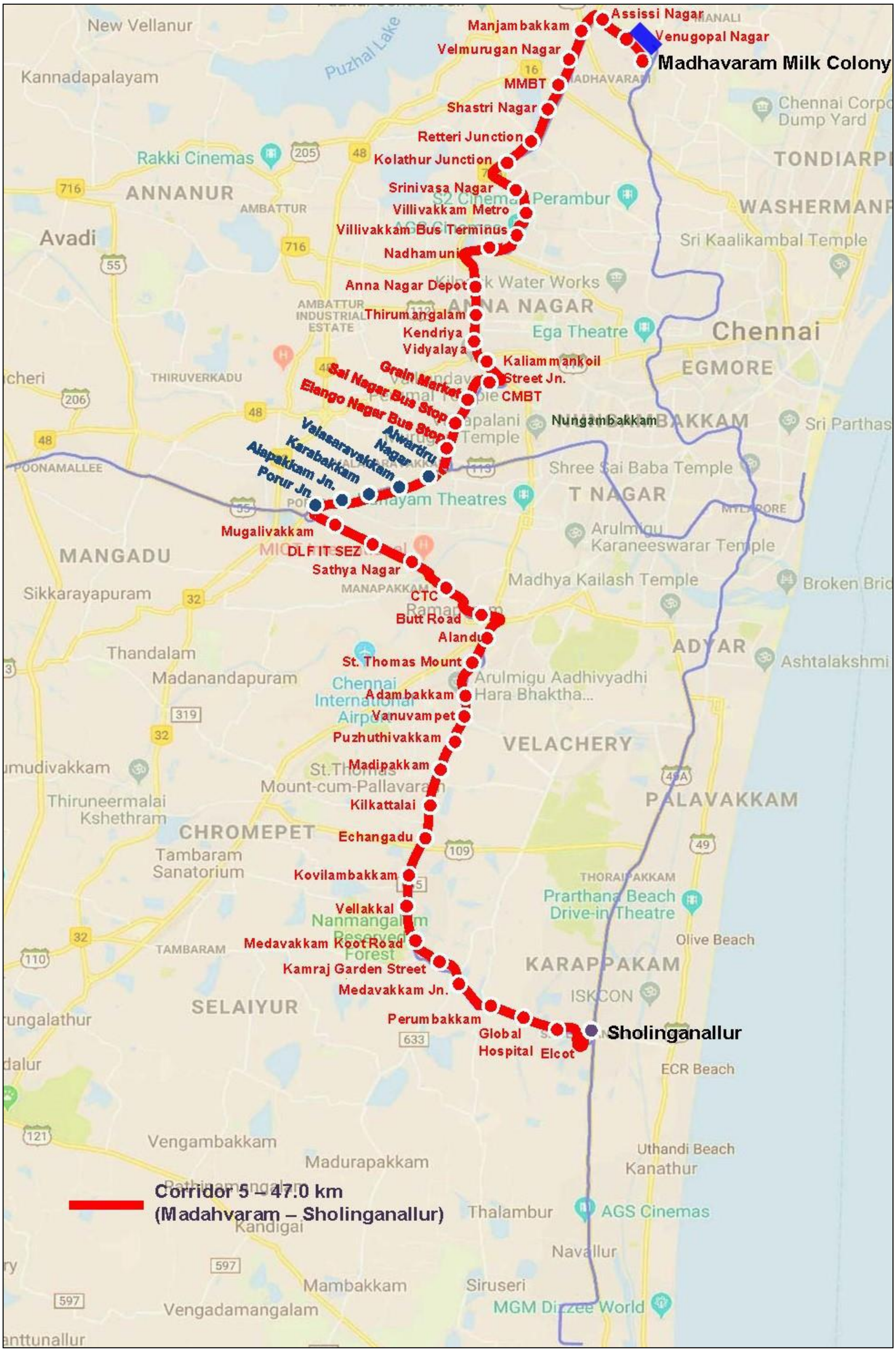
ii. Sholinganallur Metro Station (South terminal station)

Southern Terminal of the corridor will be Sholinganallur Metro Station. The station is proposed elevated and is common to corridors 3 & 5. Rail level has been kept 24 m (minimum) above the ground level.

Reversal/stabling facility has also been planned beyond this Station. Two elevated stabling lines for one rake each has also been proposed beyond Sholinganallur alongwith two rakes on station platform itself.

FIGURE 5.34: INTEGRATION OF CORRIDOR 3 & 5 AT SHOLINGANALLUR

FIGURE 5.35: PROPOSED METRO CORRIDOR-5



5.6.3.4 Horizontal Curvature

A total of 111 curves have been provided on the entire length of the alignment of Corridor 5. The minimum radius of curves is 210 m in underground section and 125 m in elevated section at identified terminal locations. About 59.9% of the length of the alignment is on straight and remaining 40.1% is on curves. The abstract and details of curves are indicated in **Tables 5.24** and **Table 5.25** respectively.

TABLE 5.24: ABSTRACT OF HORIZONTAL CURVES OF CORRIDOR-5

S. No.	Curve Radius	No. of Occurrences	Length	Percentage
1	≤150	23	5058.53	26.83
2	>150 <300	24	4937.58	26.19
3	≥300 ≤ 500	23	3754.94	19.92
4	>500 ≤ 800	14	1958.73	10.39
5	>800 ≤ 1000	5	732.89	3.89
6	>1000	22	2409.67	12.78
7	**Total**	**111**	**18852.32**	**100.00**

TABLE 5.25: DETAILS OF HORIZONTAL CURVES OF CORRIDOR-5

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
1	157.90	483.16	Left	-210	75	3	36	50	50	186.80	225.26	325.26	--
2	1165.47	1279.07	Left	-1000	4	18	4	35	35	56.82	43.60	113.60	682.31
3	1343.75	1457.34	Right	1000	4	18	4	35	35	56.82	43.59	113.59	64.68
4	2108.59	2379.02	Left	-120	105	8	41	50	50	183.19	170.43	270.43	651.25
5	2552.54	2615.93	Left	-3000	0	33	10	15	15	31.70	33.39	63.39	173.52
6	3637.21	3800.25	Left	-700	9	9	4	50	50	81.66	63.04	163.04	1021.28
7	3800.42	3966.43	Right	600	10	4	20	60	60	83.16	46.00	166.00	Nil
8	4657.39	4811.01	Right	600	8	33	46	60	60	76.93	33.63	153.63	690.96
9	4811.87	4964.69	Left	-600	8	30	54	60	60	76.52	32.82	152.82	Nil
10	6097.67	6345.06	Right	300	37	24	56	50	50	127.53	147.39	247.39	1132.98
11	7440.65	7930.80	Left	-210	120	3	9	50	50	390.24	390.15	490.15	1095.58
12	8645.86	8911.97	Right	250	49	18	53	50	50	140.51	166.12	266.12	715.06
13	9197.75	9430.04	Right	210	49	26	29	50	50	122.56	132.30	232.30	285.78
14	9692.11	9844.18	Left	-400	15	6	48	46	46	76.37	60.06	152.06	262.07
15	9882.75	10017.39	Left	-400	12	24	53	46	46	67.52	42.64	134.64	38.58
16	10324.08	10798.66	Right	210	115	30	11	50	50	360.82	374.58	474.58	306.70
17	10798.74	11010.79	Left	-210	44	7	30	50	50	110.49	112.05	212.05	Nil
18	11401.42	11694.60	Left	-210	66	12	20	50	50	162.60	193.18	293.18	390.63

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
19	11769.86	12062.62	Left	-210	66	8	26	50	50	162.30	192.76	292.76	75.25
20	12120.75	12278.90	Right	125	49	20	31	50	50	83.07	58.15	158.15	58.12
21	12894.63	12953.71	Right	20000	0	4	25	15	15	29.54	29.08	59.08	615.74
22	13967.09	14074.39	Left	-800	5	19	16	30	30	53.68	47.30	107.30	1013.38
23	14227.65	14362.31	Left	-300	16	6	4	50	50	67.66	34.67	134.67	153.26
24	14362.41	14500.32	Right	400	13	5	42	46	46	69.18	45.90	137.90	Nil
25	14706.52	14844.73	Left	-125	40	15	18	50	50	71.30	38.21	138.21	206.21
26	15286.84	15455.75	Left	-600	11	29	45	45	45	84.69	78.91	168.91	442.11
27	15534.28	15936.80	Right	125	161	20	44	50	50	801.12	302.52	402.52	78.53
28	16267.81	16478.18	Left	-125	73	18	11	50	50	118.95	110.37	210.37	331.01
29	16571.54	16639.74	Left	-3000	0	33	5	20	20	34.10	28.20	68.20	93.37
30	16927.56	16995.39	Right	3500	0	27	57	20	20	33.91	27.83	67.83	287.82
31	17133.06	17208.13	Right	3000	1	1	50	20	20	37.53	35.07	75.07	137.68
32	17423.90	17549.11	Left	-2000	3	0	18	20	20	62.62	85.21	125.21	215.77
33	18203.24	18456.18	Left	-450	25	30	7	50	50	128.27	152.94	252.94	654.14
34	18665.27	18846.80	Left	-400	19	14	42	46	46	91.46	89.53	181.53	209.08
35	18846.92	19131.78	Right	125	107	23	27	50	50	197.06	184.86	284.86	Nil
36	19274.61	19401.69	Left	-250	17	23	44	50	50	63.91	27.08	127.08	142.83
37	19541.88	19668.96	Left	-225	19	22	25	50	50	63.99	27.07	127.07	140.19
38	19694.93	19825.54	Right	300	15	14	3	50	50	65.59	30.61	130.61	25.97
39	20072.04	20206.95	Left	-300	16	7	33	50	50	67.78	34.91	134.91	246.50
40	20207.04	20336.50	Right	185	24	21	48	50	50	65.46	29.46	129.46	Nil
41	20477.35	20608.52	Right	235	19	28	22	50	50	66.06	31.18	131.18	140.85
42	20688.59	20876.23	Left	-400	20	10	17	46	46	94.60	95.63	187.63	80.07
43	21185.32	21459.54	Left	-1010	13	30	41	30	30	137.71	214.21	274.21	309.10
44	21648.00	21797.27	Right	300	18	34	25	50	50	75.15	49.27	149.27	188.46
45	21978.82	22185.75	Right	1200	8	29	41	22	22	103.65	162.94	206.94	181.55
46	22185.80	22416.53	Left	-1091.5	10	19	17	30	30	115.65	170.73	230.73	Nil
47	22416.58	22515.32	Right	800	4	33	8	30	30	49.39	38.74	98.74	Nil
48	22686.23	22846.01	Left	-500	13	5	28	45	45	80.16	69.78	159.78	170.91
49	22934.52	23040.65	Left	-130	29	5	3	40	40	53.91	26.13	106.13	88.51
50	23181.34	23568.68	Left	-125	154	22	21	50	50	583.88	287.34	387.34	140.69
51	23690.91	23859.29	Right	125	54	9	12	50	50	89.44	68.38	168.38	122.23
52	25445.17	25502.80	Right	12000	0	7	17	15	15	28.82	27.63	57.63	1585.88
53	26136.24	26208.09	Left	-15000	0	7	49	15	15	35.93	41.86	71.86	633.44
54	26751.47	26903.66	Left	-400	15	7	26	46	46	76.44	60.19	152.19	543.37
55	26935.05	27084.04	Right	130	43	22	26	50	50	77.32	48.99	148.99	31.40
56	27260.92	27411.07	Left	-200	28	24	46	50	50	76.27	50.15	150.15	176.88
57	27988.07	28191.04	Right	300	29	7	32	50	50	103.27	102.97	202.97	576.99
58	28501.65	28631.11	Right	150	30	12	40	50	50	65.85	29.46	129.46	310.61
59	28658.57	28905.46	Left	-125	90	8	42	50	50	151.35	146.89	246.89	27.46

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
60	29226.83	29297.53	Right	1500	1	30	49	22	22	35.35	26.70	70.70	321.36
61	29531.69	29892.45	Right	125	142	15	48	50	50	395.05	260.76	360.76	234.16
62	30008.37	30168.55	Left	-210	30	2	4	50	50	81.51	60.18	160.18	115.92
63	30565.66	30699.70	Left	-210	22	33	17	50	50	67.68	34.04	134.04	397.11
64	30781.18	30898.44	Left	-1000	4	35	45	30	30	58.66	57.25	117.25	81.48
65	31016.72	31228.78	Right	125	74	10	14	50	50	120.28	112.07	212.07	118.28
66	31505.33	31722.24	Left	-125	76	18	6	50	50	124.17	116.91	216.91	276.55
67	31748.01	31889.12	Right	175	29	29	43	50	50	71.76	41.12	141.12	25.77
68	31930.17	32104.40	Left	-350	20	12	5	50	50	87.83	74.23	174.23	41.04
69	32225.86	32371.60	Left	-280	19	21	10	50	50	73.40	45.74	145.74	121.46
70	32515.11	32669.57	Right	350	17	3	36	50	50	77.66	54.46	154.46	143.50
71	32833.39	32983.10	Right	210	27	7	18	50	50	75.92	49.71	149.71	163.83
72	33244.54	33373.50	Right	595	8	3	2	45	45	64.56	38.96	128.96	261.44
73	33373.72	33518.55	Left	-220	24	24	55	50	50	73.26	44.83	144.83	Nil
74	33554.36	33712.78	Right	250	24	30	19	50	50	80.16	58.42	158.42	35.81
75	33751.38	33920.98	Left	-500	14	9	52	45	45	85.15	79.61	169.61	38.60
76	34201.80	34286.44	Right	2000	1	30	38	20	20	42.32	44.64	84.64	280.81
77	34448.89	34518.41	Right	2000	1	15	3	20	20	34.76	29.53	69.53	162.45
78	34749.28	34816.70	Left	-1200	2	9	19	20	20	33.72	27.43	67.43	230.86
79	35085.34	35293.95	Left	-1000	10	8	25	30	30	104.55	148.62	208.62	268.63
80	35339.00	35451.59	Left	-3000	1	27	38	20	20	56.30	72.59	112.59	45.05
81	35603.93	35721.29	Left	-500	8	10	23	45	45	58.75	27.36	117.36	152.35
82	35981.48	36102.98	Right	800	5	30	5	40	40	60.79	41.51	121.51	260.19
83	36214.31	36399.22	Right	5000	1	31	56	20	20	92.46	144.91	184.91	111.32
84	36430.91	36610.74	Right	1000	8	21	1	30	30	90.06	119.83	179.83	31.69
85	36926.73	37139.08	Right	400	19	24	8	75	75	106.95	62.34	212.34	316.00
86	37285.13	37426.94	Left	-150	35	2	8	50	50	72.59	41.80	141.80	146.06
87	37603.98	37696.30	Right	1500	2	27	16	20	20	46.17	52.32	92.32	177.04
88	37927.67	38063.87	Right	483	10	8	0	50	50	68.23	36.21	136.21	231.37
89	38063.98	38247.70	Left	-535	15	13	58	40	40	92.31	103.71	183.71	Nil
90	38273.14	38381.76	Left	-550	7	5	7	40	40	54.36	28.62	108.62	25.44
91	38418.24	38578.41	Right	300	21	1	23	50	50	80.77	60.17	160.17	36.48
92	38713.32	38791.96	Left	-800	4	1	56	22	22	39.33	34.64	78.64	134.91
93	38932.72	39065.05	Left	-200	23	21	5	50	50	66.85	32.33	132.33	140.76
94	39282.24	39429.55	Right	2000	3	23	6	20	20	73.68	107.31	147.31	217.19
95	39506.89	39643.07	Right	3000	2	11	7	15	15	68.10	106.18	136.18	77.34
96	39801.18	39937.97	Left	-400	13	0	6	46	46	68.61	44.79	136.79	158.10
97	40083.49	40297.02	Left	-125	74	34	21	50	50	121.45	113.53	213.53	145.52
98	40297.03	40452.01	Right	125	48	4	14	50	50	81.15	54.98	154.98	Nil
99	40739.17	40968.72	Left	-290	35	16	57	50	50	117.87	129.55	229.55	287.16
100	41285.97	41492.04	Right	125	71	19	13	50	50	115.61	106.06	206.06	317.26

Curve No	Chainage		Direction	Radius	Intersection Angle			Transition Length		Tangent Length	Curve Length	Total Curve Length	Straight Between
	From	To			D	M	S	In	Out				
101	41783.55	41914.67	Left	-200	23	8	31	50	50	66.22	31.12	131.12	291.51
102	42426.56	42590.93	Left	-125	52	15	11	50	50	86.92	64.37	164.37	511.89
103	42750.04	42817.94	Right	2000	1	18	20	15	15	33.95	37.90	67.90	159.10
104	43023.88	43183.07	Right	200	31	9	55	50	50	81.13	59.19	159.19	205.94
105	43183.10	43318.38	Left	-380	12	30	47	50	50	67.85	35.28	135.28	Nil
106	43781.42	43857.46	Left	-3000	1	2	29	20	20	38.02	36.03	76.03	463.04
107	44527.07	44755.45	Left	-700	14	21	36	50	50	114.69	128.38	228.38	669.62
108	45228.48	45326.95	Left	-800	4	32	29	30	30	49.26	38.47	98.47	473.03
109	45326.98	45560.07	Right	125	83	33	9	50	50	138.12	133.09	233.09	Nil
110	45560.14	45764.84	Left	-125	70	32	35	50	50	114.57	104.70	204.70	Nil
111	45765.18	46063.72	Left	-139.5	102	2	43	50	50	198.42	198.54	298.54	Nil

5.6.3.5 Gradients

While designing vertical alignment, efforts have been made to avoid frequent gradients. The number of gradients has been kept to minimum, however, due to ground profile, difference in rail level of viaduct over mid section and station location, horizontal alignment and switch over ramps, gradients are inevitable. Efforts have been made to provide the gradients as flat as possible, subject to ground profile.

A total 150 number of change of gradients has been provided in the entire Corridor. Flattest gradient is level provided for 38.9% of the alignment. Steepest gradient is 4% (compensated) provided for Switch Over Ramp near Tidel Park. The abstract and details of gradients are given in **Tables 5.26** and **5.27** respectively.

TABLE 5.26: ABSTRACT OF GRADIENTS OF CORRIDOR-5

S. No.	Description	No.s of Occurrences	Length (m)	Percentage
1	Level (0%)	57	18288	38.90
2	>0% to 1%	15	4852	10.32
3	>1% to 2%	55	17090	36.36
4	>2% to 3%	15	4070	8.66
5	>3%	8	2708	5.76
	TOTAL	**150**	**47008**	**100.00**

TABLE 5.27: DETAILS OF GRADIENTS OF CORRIDOR-5

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
1	-386	133	518	-6.70	-6.70	0.00	Level
2	133	578	445	-6.70	8.19	3.34	Rise
3	578	1148	570	8.19	8.19	0.00	Level
4	1148	1476	329	8.19	15.41	2.20	Rise
5	1476	1689	213	15.41	20.63	2.45	Rise
6	1689	1889	200	20.63	20.63	0.00	Level
7	1889	2193	303	20.63	17.48	-1.04	Fall
8	2193	2533	340	17.48	23.30	1.71	Rise
9	2533	2791	258	23.30	23.30	0.00	Level
10	2791	3044	253	23.30	18.29	-1.98	Fall
11	3044	3164	121	18.29	18.28	-0.01	Fall
12	3164	3391	227	18.28	22.76	1.98	Rise
13	3391	3591	200	22.76	22.76	0.00	Level
14	3591	3722	131	22.76	20.83	-1.48	Fall
15	3722	3886	165	20.83	23.31	1.51	Rise
16	3886	4507	620	23.31	23.31	0.00	Level
17	4507	4734	227	23.31	19.19	-1.81	Fall
18	4734	4888	154	19.19	19.19	0.00	Level
19	4888	5068	180	19.19	22.74	1.97	Rise
20	5068	5268	200	22.74	22.74	0.00	Level
21	5268	5518	250	22.74	18.80	-1.57	Fall
22	5518	5908	390	18.80	30.33	2.96	Rise
23	5908	6276	368	30.33	30.33	0.00	Level
24	6276	6372	97	30.33	27.94	-2.46	Fall
25	6372	6761	388	27.94	12.41	-4.00	Fall
26	6761	7051	290	12.41	1.68	-3.70	Fall
27	7051	7316	265	1.68	1.68	0.00	Level
28	7316	7565	249	1.68	-6.29	-3.20	Fall
29	7565	8205	640	-6.29	-6.98	-0.11	Fall
30	8205	8398	193	-6.98	-5.98	0.52	Rise
31	8398	8636	238	-5.98	-5.98	0.00	Level
32	8636	9367	732	-5.98	-13.00	-0.96	Fall
33	9367	9766	399	-13.00	-13.00	0.00	Level
34	9766	10154	388	-13.00	-5.62	1.90	Rise
35	10154	10388	234	-5.62	-5.62	0.00	Level
36	10388	10533	145	-5.62	-6.34	-0.50	Fall
37	10533	10933	400	-6.34	-3.60	0.69	Rise
38	10933	11371	438	-3.60	-3.60	0.00	Level
39	11371	12093	722	-3.60	23.67	3.78	Rise
40	12093	12704	611	23.67	23.67	0.00	Level
41	12704	12871	167	23.67	18.54	-3.06	Fall

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
42	12871	12981	110	18.54	18.55	0.01	Rise
43	12981	13251	270	18.55	28.00	3.50	Rise
44	13251	13466	215	28.00	28.00	0.00	Level
45	13466	13819	353	28.00	20.95	-2.00	Fall
46	13819	14027	208	20.95	24.95	1.92	Rise
47	14027	14293	266	24.95	24.95	0.00	Level
48	14293	14547	254	24.95	28.75	1.50	Rise
49	14547	15015	469	28.75	28.75	0.00	Level
50	15015	15147	131	28.75	26.75	-1.52	Fall
51	15147	15677	530	26.75	26.75	0.00	Level
52	15677	15876	200	26.75	28.16	0.70	Rise
53	15876	16112	236	28.16	28.16	0.00	Level
54	16112	16402	290	28.16	21.83	-2.18	Fall
55	16402	16608	206	21.83	24.34	1.22	Rise
56	16608	16962	354	24.34	24.34	0.00	Level
57	16962	17239	277	24.34	19.29	-1.82	Fall
58	17239	17513	274	19.29	24.25	1.81	Rise
59	17513	17719	206	24.25	24.25	0.00	Level
60	17719	17898	179	24.25	20.69	-1.99	Fall
61	17898	18152	255	20.69	20.69	0.00	Level
62	18152	18388	236	20.69	25.36	1.98	Rise
63	18388	18617	228	25.36	25.36	0.00	Level
64	18617	18911	294	25.36	30.31	1.68	Rise
65	18911	19044	133	30.31	30.31	0.00	Level
66	19044	19338	294	30.31	35.48	1.76	Rise
67	19338	19606	267	35.48	35.48	0.00	Level
68	19606	19883	278	35.48	30.58	-1.76	Fall
69	19883	19965	82	30.58	30.58	0.00	Level
70	19965	20272	306	30.58	36.39	1.90	Rise
71	20272	20543	271	36.39	36.39	0.00	Level
72	20543	20812	269	36.39	30.97	-2.02	Fall
73	20812	21135	323	30.97	31.24	0.09	Rise
74	21135	21413	278	31.24	36.75	1.98	Rise
75	21413	21630	217	36.75	36.75	0.00	Level
76	21630	21881	251	36.75	32.75	-1.60	Fall
77	21881	22146	266	32.75	37.00	1.60	Rise
78	22146	22462	316	37.00	37.00	0.00	Level
79	22462	22659	197	37.00	33.32	-1.87	Fall
80	22659	22988	329	33.32	38.68	1.63	Rise
81	22988	23301	314	38.68	38.68	0.00	Level
82	23301	23997	696	38.68	24.91	-1.98	Fall
83	23997	24209	212	24.91	29.03	1.95	Rise

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
84	24209	24509	300	29.03	29.03	0.00	Level
85	24509	24837	328	29.03	22.53	-1.98	Fall
86	24837	25225	388	22.53	22.53	0.00	Level
87	25225	25420	195	22.53	26.44	2.00	Rise
88	25420	25672	252	26.44	26.44	0.00	Level
89	25672	26013	341	26.44	19.64	-1.99	Fall
90	26013	26239	226	19.64	19.64	0.00	Level
91	26239	26511	271	19.64	25.02	1.98	Rise
92	26511	26711	200	25.02	25.02	0.00	Level
93	26711	26922	211	25.02	20.81	-2.00	Fall
94	26922	27332	411	20.81	18.84	-0.48	Fall
95	27332	27703	371	18.84	26.91	2.18	Rise
96	27703	27919	216	26.91	26.91	0.00	Level
97	27919	28123	204	26.91	22.40	-2.21	Fall
98	28123	28388	265	22.40	22.82	0.16	Rise
99	28388	28840	452	22.82	31.80	1.99	Rise
100	28840	29082	242	31.80	31.80	0.00	Level
101	29082	29515	432	31.80	40.40	1.99	Rise
102	29515	29828	313	40.40	40.40	0.00	Level
103	29828	30103	275	40.40	35.41	-1.81	Fall
104	30103	30377	274	35.41	35.41	0.00	Level
105	30377	30552	176	35.41	29.30	-3.48	Fall
106	30552	30929	377	29.30	21.53	-2.06	Fall
107	30929	31091	162	21.53	21.53	0.00	Level
108	31091	31332	241	21.53	28.35	2.83	Rise
109	31332	31571	239	28.35	28.35	0.00	Level
110	31571	32300	729	28.35	26.65	-0.23	Fall
111	32300	33310	1010	26.65	26.65	0.00	Level
112	33310	33633	323	26.65	19.50	-2.21	Fall
113	33633	33862	228	19.50	23.00	1.53	Rise
114	33862	34238	376	23.00	23.00	0.00	Level
115	34238	34536	299	23.00	19.33	-1.23	Fall
116	34536	34624	88	19.33	19.74	0.46	Rise
117	34624	34848	224	19.74	24.21	2.00	Rise
118	34848	35048	200	24.21	24.21	0.00	Level
119	35048	35323	275	24.21	18.58	-2.04	Fall
120	35323	35542	218	18.58	18.56	-0.01	Fall
121	35542	35746	204	18.56	22.63	1.99	Rise
122	35746	35946	200	22.63	22.63	0.00	Level
123	35946	36268	322	22.63	16.88	-1.78	Fall
124	36268	36674	406	16.88	24.91	1.98	Rise
125	36674	37018	345	24.91	24.91	0.00	Level

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
126	37018	37357	338	24.91	20.12	-1.42	Fall
127	37357	37662	305	20.12	23.83	1.22	Rise
128	37662	37891	229	23.83	23.83	0.00	Level
129	37891	38122	231	23.83	19.81	-1.74	Fall
130	38122	38401	279	19.81	21.40	0.57	Rise
131	38401	38752	351	21.40	28.41	2.00	Rise
132	38752	39002	250	28.41	28.41	0.00	Level
133	39002	39332	330	28.41	23.06	-1.63	Fall
134	39332	39867	535	23.06	33.53	1.96	Rise
135	39867	40147	279	33.53	33.53	0.00	Level
136	40147	40898	752	33.53	42.33	1.17	Rise
137	40898	41156	258	42.33	42.33	0.00	Level
138	41156	41849	693	42.33	29.90	-1.79	Fall
139	41849	42246	397	29.90	29.90	0.00	Level
140	42246	42511	265	29.90	22.46	-2.81	Fall
141	42511	42782	271	22.46	22.46	0.00	Level
142	42782	43347	565	22.46	13.38	-1.61	Fall
143	43347	43535	188	13.38	16.97	1.91	Rise
144	43535	43735	200	16.97	16.97	0.00	Level
145	43735	43967	232	16.97	12.33	-2.00	Fall
146	43967	44454	487	12.33	12.33	0.00	Level
147	44454	44688	234	12.33	17.00	2.00	Rise
148	44688	45405	717	17.00	17.00	0.00	Level
149	45405	45995	590	17.00	28.80	2.00	Rise
150	45995	46623	627	28.80	28.80	0.00	Level

5.6.3.6 Break-up of Alignment Length

Break-up of alignment length for Corridor-5 is given in **Table 5.28**.

TABLE 5.28: BREAK-UP OF ALIGNMENT LENGTH FOR CORRIDOR-5

S. No.	Description	Chainage (KM)		Length (m)	Method of Construction / Structure Type
		From	To		
1	Underground	-385.6	573.0	958.6	TBM/Cut & cover/NATM
2	At-grade	573.0	1150.0	577.0	Ballastless track
2	Elevated	1150.0	6839.0	5689.0	Box/I/U- Shape Girder
3	Underground	6839.0	11715.0	4876.0	TBM/Cut & cover/NATM
4	Elevated	11715.0	46622.6	34907.6	Box/I/U- Shape Girder
Total Length				**47008.2**	

5.7 DEPOTS

- Major depot for Coridors 3 & 5 is proposed at north of the corridors in Government land of Madhavaram Milk colony.
- Major depot for Coridors 4 is proposed at east end of the corridor in HR&CE land near Poonamallee Bypass.
- The proposed land requirement for major depot in Madhavaram is 57.2 Ha. Out of 57.2 Ha. Land, depot facilities requires 27.8 Ha. Land and remaining land shall be used for property development. About 17.4 Hectares land has been proposed to be acquired for major Depot for corridor-4 out of which depot construction requires 15.3 Hectares land and remaining land shall be reserved for staff quarters etc.
- Minor depot for stabling, inspection and washing facilities is proposed in southern end of Corridor-3 in SIPCOT. The minor depot is proposed in private land of 6.3 Ha. and shall be constructed elevated in covered area of 4.5 Ha.
- The area underneath shall be used for parking facilities and property development.
- Depot connectivity (entry/exit) from main lines are provided with following lengths:

Corridor	Corr - 3	Corr - 4	Corr - 5
Length (m)	412	485	500

5.8 STATIONS

- Stations have been located so as to serve major passenger catchment areas and to enable convenient integration with other modes of transport.
- Stations vary in complexity along the route and have been located by an interactive process influenced by ridership forecasts, availability of open land, interchange requirements with other modes of transport, construction feasibility, inter station distance, alignment, utilities, road and pedestrian requirements, future infrastructural developments and joint site visits & consultations with CMRL.
- Possibility of Parking space at all the stations has also been explored.
- List of stations along with their chainage and interstation distances (ISD) for Corridor-3, Corridor-4 and Corridor-5 are given in **Tables 5.29, 5.30** and **5.31** respectively**.**

TABLE 5.29: LIST OF STATIONS FOR CORRIDOR-3

S.No.	Station Name	Chainage (m)	Inter-station distance (m)	Proposed RL (m)	Elevation Diff. (m)	Station Type
1	MADHAVARAM MILK COLONY	0		-6.7	-15.11	UG (190x44.6) 2L
2	THAPALPETTI	980	980	-8.7	-15.17	UG (150x21.4) 2L with extended concourse
3	MURARI HOSPITAL	1700	720	-9.13	-15.11	UG (190x21.8) 2L
4	MOOLAKADAI	2461	761	-9.44	-15.71	UG (190x21.8) 2L
5	SEMBIYAM	3421	960	-9.65	-15.08	UG (190x21.8) 2L
6	PERAMBUR MARKET	4282	861	-9.63	-15.42	UG (190x21.8) 2L
7	PERAMBUR METRO	5009	727	-17.5	-22.83	UG (150x21.4) ML
8	AYANAVARAM	5966	957	-10.33	-15.13	UG (190x21.8) 2L
9	OTTERI	7076	1110	-11.77	-15.18	UG (190x21.8) 2L
10	PATTALAM	7852	776	-11.78	-15.28	UG (190x21.8) 2L
11	PERAMBUR BARRACKS ROAD	8721	869	-12.38	-15.47	UG (190x21.8) 2L
12	DOVETON JUNCTION	9550	829	-9.9	-15.25	UG (190x21.8) 2L
13	PURASAIWAKKAM HIGH ROAD	10164	614	-10.49	-15.06	UG (150x21.4) 2L with extended concourse
14	KELLEYS	10841	677	-16.19	-21.44	UG (150x21.4) 3L
15	KMC	11524	683	-23.75	-29.61	UG (150x21.4) ML
16	CHETPET METRO	12362	838	-16.26	-22.45	UG (150x21.4) ML
17	STERLING ROAD JN	13207	845	-9.07	-15.37	UG (150x21.4) 2L with extended concourse
18	NUNGAMBAKKAM	13954	747	-14.6	-21.26	UG (150x21.4) ML
19	GEMINI	14596	642	-14.66	-21.36	UG (150x21.4) ML
20	THOUSAND LIGHTS	15667	1071	-23.75	-29.84	UG (150x21.4) ML
21	ROYAPETTAH GOVT. HOSPITAL	16708	1041	-15.4	-20.77	UG (150x21.4) ML
22	RADHAKRISHNAN SALAI JN	17790	1082	-11.87	-16.68	UG (190x21.8) 2L
23	THIRUMAYILAI METRO	18811	1021	-10.88	-15.01	UG (150x21.4) ML
24	MANDAIVELI	19974	1163	-12.47	-15.01	UG (150x21.4) 2L with extended concourse
25	GREENWAYS ROAD METRO	20893	919	-12.3	-15.21	UG (190x21.8) 2L
26	ADYAR JN.	22216	1323	-18	-22.10	UG (150x21.4) ML
27	ADYAR DEPOT	23286	1070	-10.48	-15.18	UG (190x21.8) 2L
28	INDIRA NAGAR	23994	708	-11.6	-15.32	UG (190x21.8) 2L
29	THIRUVANMIYUR METRO	24725	731	-11	-15.37	UG (190x21.8) 2L
30	TARAMANI ROAD JN	25718	993	-11.2	-15.02	UG (190x21.8) 2L
31	NEHRU NAGAR	26795	1077	16.76	12.64	Elevated (140x32.35)
32	KANDANCHAVADI	27757	962	28.5	23.88	Elevated (140x37.04)
33	PERUNGUDI	28553	796	21.7	17.09	Elevated (140x32.35)
34	THORAIPAKKAM	29604	1051	27.6	23.48	Elevated (140x32.35)
35	METTUKUPPAM	30535	931	21.8	17.60	Elevated (140x32.35)
36	PTC COLONY	31533	998	21.9	17.21	Elevated (140x32.35)
37	OKKIYAMPET	32393	860	21.2	17.21	Elevated (140x32.35)
38	KARAPAKKAM	33265	872	21	16.98	Elevated (140x32.35)
39	OKKIYAM THORAIPAKKAM	34073	808	21.3	16.87	Elevated (140x32.35)

S.No.	Station Name	Chainage (m)	Inter-station distance (m)	Proposed RL (m)	Elevation Diff. (m)	Station Type
40	SHOLINGANALLUR	35044	971	28.8	23.67	Elevated (140x60.0)
41	SHOLINGANALLUR LAKE	36235	1191	22.55	16.99	Elevated (140x32.35)
42	SRI PONNIAMMAN TEMPLE	37053	818	22.2	16.89	Elevated (140x32.35)
43	SATHYABAMA UNIVERSITY	37919	866	21.9	16.96	Elevated (140x32.35)
44	ST. JOSEPH'S COLLEGE	38746	827	22.3	17.75	Elevated (140x32.35)
45	SEMMANCHERI	39551	805	24.1	17.32	Elevated (140x32.35)
46	GANDHI NAGAR	40702	1151	25.35	17.45	Elevated (140x32.35)
47	NAVALLUR	41435	733	24.5	16.85	Elevated (140x32.35)
48	SIRUSERI	42537	1102	23.1	16.87	Elevated (140x37.04)
49	SIPCOT 1	43606	1069	19.6	14.04	Elevated (140x21.95)
50	SIPCOT 2	44671	1065	18.1	13.26	Elevated (140x21.95)

TABLE 5.30: LIST OF STATIONS FOR CORRIDOR-4

S. No.	Station Name	Chainage (m)	Inter-station distance (m)	Rail Levels (m)	Elevation Diff. (m)	Station Type
1	LIGHT HOUSE	20		-10.44	-15.276	UG (190x21.8) 2L
2	FORESHORE ESTATE ROAD	806	786	-8.26	-15.009	UG (190x21.8) 2L
3	KUTCHERY ROAD	1764	958	-8.6	-15.779	UG (190x21.8) 2L
4	THIRUMAYILAI METRO	2564	800	-18.46	-22.745	UG (190x21.8) 2L
5	ALWARPET	3302	738	-11.12	-15.364	UG (190x21.8) 2L
6	BHARATHIDASAN ROAD	4141	839	-9.87	-15.266	UG (190x21.8) 2L
7	ADYAR GATE JUNCTION	5177	1036	-15.6	-20.937	UG (150x21.4) 3L
8	NANDANAM	6188	1011	-23.93	-30.062	UG (150x21.4) ML
9	NATESAN PARK	6813	625	-13.58	-20.798	UG (150x21.4) 3L
10	PANAGAL PARK	7436	623	-8.11	-15.068	UG (150x21.4) 2L with extended concourse
11	KODAMBAKKAM METRO	8453	1017	-13.4	-21.279	UG (150x21.4) ML
12	MEENAKSHI COLLEGE	9275	822	-3.775	-12.324	UG (190x21.8) 2L
13	POWER HOUSE	10315	1040	22.541	12.981	Elevated (140x21.95)
14	VADAPALANI	11078	763	36.611	25.397	Elevated (140x21.95) 3L
15	SALIGRAMAM	11743	665	25.53	14.412	Elevated (140x21.95)
16	AVICHI SCHOOL	12691	948	25.563	14.15	Elevated (140x21.95)
17	ALWARTHIRU NAGAR	13607	916	26.475	14.388	Elevated (140x21.95)
18	VALASARAVAKKAM	14541	934	27.296	13.974	Elevated (140x21.95)
19	KARABAKKAM	15665	1124	27.746	14.105	Elevated (140x21.95)
20	ALAPAKKAM JUNCTION	16426	761	28	13.655	Elevated (140x21.95)
21	PORUR JUNCTION	17244	818	33.681	18.174	Elevated (140x21.95) 2L
22	CHENNAI BYPASS CROSSING	18054	810	35.681	18.142	Elevated (140x21.95) 2L
23	RAMCHANDRA HOSPITAL	18977	923	31.27	13.981	Elevated (140x21.95)

S. No.	Station Name	Chainage (m)	Inter-station distance (m)	Rail Levels (m)	Elevation Diff. (m)	Station Type
24	IYAPPANTHANGAL BUS DEPOT	19751	774	32.259	14.07	Elevated (140x21.95)
25	KATTUPAKKAM	20860	1109	33.327	14.083	Elevated (140x21.95)
26	KUMANAN CHAVADI	21670	810	33.971	14.105	Elevated (140x21.95)
27	KARYAN CHAVADI	22550	880	35.545	14.474	Elevated (140x21.95)
28	MULLAI THOTTAM	23497	947	36.089	14.339	Elevated (140x21.95)
29	POONAMALLEE BUS TERMINUS	24370	873	37.551	14.444	Elevated (140x21.95)
30	POONAMALLEE BYPASS	25440	1070	42.115	18.16	Elevated (140x21.95) 2L

TABLE 5.31: LIST OF STATIONS FOR CORRIDOR-5

SN	STATION NAME	CHAINAGE (M)	INTER-STATION DISTANCE (M)	RAIL LEVEL (M)	ELEVATION DIFFERENCE (M)	ELEVATED/UG
1	MADHAVARAM MILK COLONY	0		-6.70	-15.27	UG (190x44.6) 2L
2	VENUGOPAL NAGAR	868	868	8.19	-0.07	At Grade (140x33.95)
3	ASSISSI NAGAR	1789	921	21.00	14.49	Elevated (140x21.95)
4	MANJAMBAKKAM	2691	902	23.30	14.34	Elevated (140x21.95)
5	VELUMURUGAN NAGAR	3491	800	22.76	14.05	Elevated (140x21.95)
6	MMBT	4307	816	23.31	15.61	Elevated (140x21.95)
7	SHASTRI NAGAR	5168	861	22.74	14.49	Elevated (140x21.95)
8	RETTERI JN.	6028	860	30.33	18.20	Elevated (140x32.35) 2L
9	KOLATHUR JN.	7186	1158	1.68	-8.33	UG (190x21.8) 2L
10	SRINIVASA NAGAR	8518	1332	-5.98	-14.91	UG (190x21.8) 2L
11	VILLIVAKKAM METRO	9505	987	-13.00	-21.46	UG (150x21.4) ML
12	VILLIVAKKAM BUS TERMINUS	10254	749	-5.62	-15.02	UG (150x21.4) 2L with extended concourse
13	NATHAMUNI	11106	852	-3.60	-15.27	UG (190x21.8) 2L
14	ANNA NAGAR DEPOT	12349	1243	23.67	14.72	Elevated (140x21.95)
15	THIRUMANGALAM	13366	1017	28.00	18.04	Elevated (140x32.35) 2L
16	KENDRIYA VIDYALAYA	14158	792	24.95	14.14	Elevated (140x21.95)
17	KALIAMMANKOIL STREET JN.	14915	757	28.75	19.00	Elevated (140x21.95) 2L
18	CMBT	16007	1849	28.16	18.49	Elevated (140x21.95) 2L
19	GRAIN MARKET	16855	848	24.34	14.63	Elevated (140x21.95)
20	SAI NAGAR BUS STOP	17619	764	24.25	14.13	Elevated (140x21.95)
21	ELANGO NAGAR BUS STOP	18517	898	25.36	14.05	Elevated (140x21.95)
22	ALWARTIRUNAGAR	19472	955	35.48	23.55	Elevated (140x21.95) 2L common with C4
23	VALASARAVAKKAM	20407	935	36.39	23.63	Elevated (140x21.95) 2L common with C4
24	KARABAKKAM	21530	1123	36.75	23.07	Elevated (140x21.95) 2L common with C4
25	ALAPAKKAM JUNCTION	22291	761	37.00	22.72	Elevated (140x21.95) 2L

SN	STATION NAME	CHAINAGE (M)	INTER-STATION DISTANCE (M)	RAIL LEVEL (M)	ELEVATION DIFFERENCE (M)	ELEVATED/UG
						common with C4
26	PORUR JN.	23109	818	38.68	23.03	Elevated (140x21.95) 2L common with C4
27	MUGALIVAKKAM	24309	1200	29.03	14.22	Elevated (140x21.95)
28	DLF IT SEZ	25573	1264	26.44	14.22	Elevated (140x21.95)
29	SATHYA NAGAR	26611	1038	25.02	14.76	Elevated (140x21.95)
30	CTC	27809	1198	26.91	14.33	Elevated (140x21.95)
31	BUTT ROAD	28982	1173	31.80	14.77	Elevated (140x21.95)
32	ALANDUR	30262	1280	35.41	20.73	Elevated (140x21.95) 2L
33	ST. THOMAS MOUNT	31435	1173	28.35	18.57	Elevated (140x21.95) 2L
34	ADAMBAKKAM	32442	1007	26.65	19.14	Elevated (140x21.95) 2L
35	VANUVAMPET	33159	717	26.65	19.78	Elevated (140x21.95) 2L
36	PUZHUTHIVAKKAM	34017	858	23.00	14.95	Elevated (140x21.95)
37	MADIPAKKAM	34947	930	24.21	14.07	Elevated (140x21.95)
38	KILKATTALAI	35846	899	22.63	14.49	Elevated (140x21.95)
39	ECHANGADU	36774	928	24.91	18.20	Elevated (140x32.35) 2L
40	KOVILAMBAKKAM	37791	1017	23.83	14.64	Elevated (140x21.95)
41	VELLAKKAL	38863	1072	28.41	14.30	Elevated (140x21.95)
42	MEDAVAKKAM KOOT ROAD	40010	1147	33.53	18.78	Elevated (140x32.35) 2L
43	KAMARAJ GARDEN STREET	41056	1046	42.33	23.23	Elevated (140x32.35) 2L
44	MEDAVAKKAM JN.	41985	929	29.90	15.08	Elevated (140x21.95)
45	PERUMBAKKAM	42661	676	22.46	14.76	Elevated (140x21.95)
46	GLOBAL HOSPITAL	43635	974	16.97	13.99	Elevated (140x21.95)
47	ELCOT	44850	1215	17.00	13.96	Elevated (140x21.95)
48	SHOLINGANALLUR	46272	1422	28.80	24.03	Elevated (140x60.0) 2L

FIGURE 5.36: PROPOSED CORRIDORS OF CHENNAI METRO PHASE-II

5.9 CONSTRUCTION METHODOLOGY

Construction of elevated, underground alignment involves following type of constructions: -

- Sub-structure - Columns on Open/Pile foundations with pier cap at top of columns. Alternatively, Portal arrangement is provided at certain locations.
- Superstructure by segmental construction of whole unit construction. Box segments are most common type of segmental construction. I-Girder and U-girder are most common type of non-segmental construction methods where the structural element for whole span length is pre-cast and launched in position.
- Underground alignment by means of tunnels made through Tunnel Boring Machine / open cut and cover method/ NATM method.
- Underground stations by means of cut and cover method or NATM method.
- Earth retaining structures like diaphragm walls, sheet piles, secant piles etc.

5.9.1 Cast in-situ and Pre-Cast Construction

A) Cast in-situ construction

In cast in-situ construction method, structure is cast at its final location of use. This involves erection of temporary shuttering, scaffolding and support system for casting the structure. The temporary supports and shuttering is removed when the concrete is set and structure attains the strength to bear its dead weight and other loads. This method involves longer construction time and interference to road users for longer period. This method is restricted to casting of substructure - open foundation, pile, pile caps, columns; station structure; earth retaining structures.

B) Pre - cast construction

In this method, structural segments are pre-casted in casting yards, pre-stressed and then transported to the location of use and launched by means of suitable launching arrangement. The structural elements for superstructure i.e. box segments, I-Girders, U-girders and sometimes pile caps are casted by pre-cast technique. Pre-cast construction may be segmental or non-segmental type.

Casting yard is required for casting of precast structural segments and other precast units like U-girder, I-Girder etc. The construction depot has arrangement for casting beds, curing and stacking area, batching plant with storage facilities for aggregates and cement, site testing laboratories, reinforcement steel yard and fabrication yard etc. An area of about 2.5 Ha to 3 Ha is required for each construction depot.

Pre-cast construction has following advantages: -

- Reduction in construction period due to concurrent working for substructure and superstructure.
- For segmental, pre-cast element (of generally 3.0m length), transportation from construction depot to site is easy and economical. For other type of construction i.e. I-Girder, U Girder etc. longer trailer and straighter roads are required but erection can be done by using road cranes in comparatively less time.
- As the pre-cast elements are cast on production line in a construction depot, better and uniform quality control can be exercised.
- This method reduces the interference to road users to minimum.

For casting of segments, both long line and short line method can be adopted. However, the long line method is more suitable for spans curved in plan while short line method is good for straight spans. A high degree of accuracy is required for setting out the curves on long line method for which pre-calculation of offsets is necessary. Match casting of segments is required in either method. The cast segments are cured on the bed as well as in stacking yard. Ends of the segments are to be made rough through sand blasting so that gluing of segments can be effective.

The segmental construction has following advantages.

- Segmental construction is an efficient and economical method for a large range of span lengths and types of structures. Structures with sharp curves and variable super elevation can be easily accommodated.
- It is easy to incorporate last minute changes in span configuration if the site situation so warrants.
- Segmental construction permits a reduction of construction time as segments are manufactured in a casting yard while substructure work is in progress, and erected rapidly thereafter.
- Better quality control is possible in the casting yard.
- It is easier to transport smaller segments by road trailers on city roads.
- Interference to the traffic during construction is significantly reduced.

5.9.2 Structural System of Viaduct

5.9.2.1 Sub-structure

Two broad categories of sub-structure i.e Pile Foundation and Open foundation are considered for Metro Systems. For heavy/medium loads and loose/soft/filled up upper strata, Pile foundation systems are proposed. This requires lesser space and time for excavation. Pile load bearing capacity is calculated as per IS 2911 Part 2 &

IRC- 78. At locations where, hard strata/rock is available close to ground level, open foundations may be adopted.

The viaduct superstructure will be supported on single cast-in-place RC pier. The shape of the pier follows the flow of forces. For the standard spans, the pier gradually widens at the top to support the bearing under the box webs. Circular pier of dia in the range of 1-5-1.7 m are commonly used as it occupies the minimum space at ground/road level where the alignment often follows the central verge of existing roads.

To prevent the direct collision of vehicle to pier, a Jersey Shaped crash barrier of 1.0m height above existing road level has been proposed all around the pier. A gap of 25mm has been also provided in between the crash barrier and outer face of pier. The shape of upper part of pier has been so dimensioned that the required minimum clearance of 5.5m is always available on road side beyond vertical plane drawn on outer face of crash barrier. In such a situation, the minimum height of rail above the existing road is 8.5m. The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.8m.

The space between the elastomeric bearings will be utilized for placing the lifting jack required for the replacement of elastomeric bearing. An outward slope of 1:200 will be provided at pier top for the drainage due to spilling of rainwater, if any. The transverse spacing between bearings would be about 3.0m. The orientation and dimensions of the piers for the continuous units or steel girder (simply supported span) have to be selected to ensure minimum footprint at ground/road level traffic. Since the vertical and horizontal loads will vary from pier to pier, this will be catered to by selecting the appropriate structural dimensions.

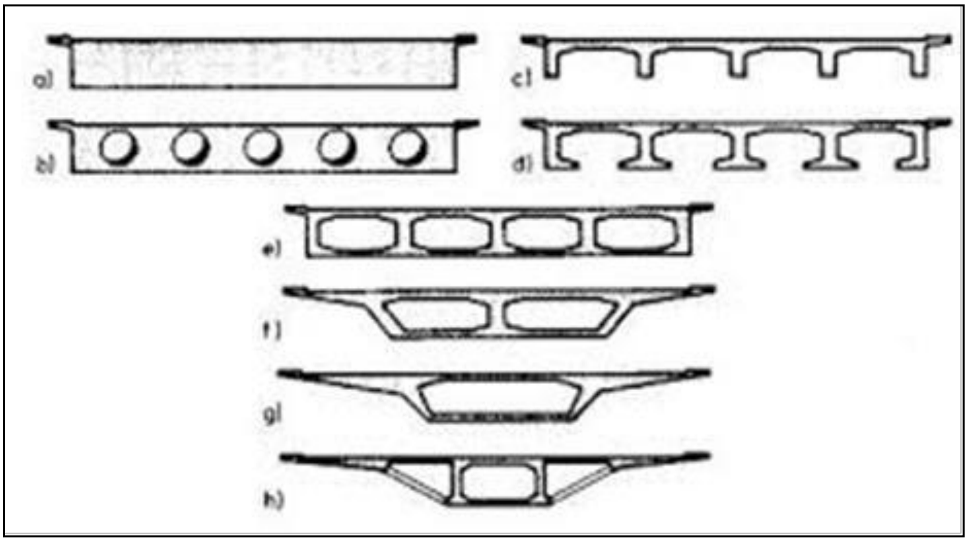
Pile caps are casted over the columns to support the superstructure. Soffit width of superstructure governs the width of pile cap. While box girder requires less width of pile, I-girder and U-girders require larger width of pile caps to support the full width of soffit of such superstructures. At locations where, elevated alignment moves from central verge of the road to side of the road and vice versa, Portal arrangement is made instead of column and pile cap. Also, at locations where elevated alignment takes a perpendicular left or right turn, portal type arrangement is provided to provide support to superstructure.

5.9.2.2 Superstructure

The choice of superstructure has to be made keeping in view the ease of constructability, maximum safety, least disturbance and inconvenience to road users and maximum standardization of the form-work for wide span ranges. Following types of superstructure may be considered.

i) Precast segmental box girder using external unbonded tendon.
ii) Precast U-Channel superstructure with internal pre-stressing.
iii) Precast U-Channel segmental superstructure using external unbonded tendon.
iv) I-Girder with internal pre-stressing.
v) Special spans

FIGURE 5.37: TYPES OF SUPERSTRUCTURE



Three types of superstructures are further deliberated as under: -

A) Precast Segmental Box Girder using External Unbonded Tendon

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

For Box girder segmental construction, normally span of 31m is kept by providing 9 segments of 3m length and two end segments of 2m length each. The other standard spans (c/c of pier) comprises of 25m, 28 m, 22m, 19m & 16m, which shall be made by removing/adding standard segments of 3.0m each from the center of the span.

The number of “breaks” in the stretch can be identified by number of continuous units. The suggested method of erection will be detailed in the construction drawings. The launching girder (or, more accurately, the “assembly truss”) is capable of supporting the entire dead load of one span and transferring it to the temporary brackets attached to the pier. The governing weight of the segments will be of the order of 55 M.T. The launching girder is slightly greater than two span lengths. It must be able to negotiate sharp curves in conjunction with temporary brackets.

FIGURE 5.38: LAUNCHING OF BOX GIRDER SEGMENTS

Transportation of segments from casting yard to the sites of erection will be affected by appropriately designed low-bedded trailers (tyre-mounted). The segments can be lifted and erected using erection portal gantry moving on launching girder.
In such construction, the pre-stressing is placed outside the structural concrete (inside the box section) and protected with high density polyethylene tubes which are grouted with special wax or cement. The match cast joints at the interface of two segments are provided with shear keys as in traditional segmental construction.

The main advantages of externally pre-stressed pre-cast segmental construction can be summarized as follows: -

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

However, higher depth and higher construction-transportation- erection cycle time are disadvantages of Box Girder.

B) Precast U-Channel Superstructure with Internal Pre-stressing

The single/Double U type of viaduct structure is also a pre-cast construction with internal pre-stressing. Double U-Girders are provided for 25-28m span. For shorter spans, Single U girders may be provided.

FIGURE 5.39: PRECAST U-CHANNEL SUPERSTRUCTURE

The main advantages for this type of structural configuration of superstructure are:

- Possibility to lower the longitudinal profile by approximately 1m compared to conventional design.
- Saving in construction and erection cycle time.
- Built in structural elements capable to maintain the coaches on the bridge in case of derailment (a standard barrier design allows this).

- Built in cable support and system function.
- Built in maintenance and evacuation path on either side of the track.
- Built in sound barrier.

However, Single U- girder has weight in the range of 300 MT per unit and it is difficult to transport girder of such length and weight. To reduce the weight per girder, double U- girder may be used, but it results into wider track center of 4.6 m to accommodate the two inside walls of the two girders.

FIGURE 5.40: LAUNCHING OF U-CHANNEL GIRDER

C) Precast U-Channel segmental Superstructure with Internal Pre-stressing

In this arrangement, superstructure consists of U-shape segments. These are to be launched in a similar way as box segments. This type of superstructure results in shallow depth of superstructure in comparison to box type segments.

D) Precast I-Girder Superstructure with Internal Pre-stressing

Pre cast I-Girders for various span ranges 20-34 m can be designed. At locations with restricted head room, I-Girder with span range of 20m may be used. Precast, pre-stressed I-Girders are casted in casting yard, transported to site and erected as 3/4 I-girders per span (depending upon Detailed design) by using road cranes, connected together at site by casting diaphragm wall and thereafter top slab is casted at site.

FIGURE 5.41: LAUNCHING OF I-GIRDER

The depth of I-girder is comparable to Box girder. Since unit length of I-Girder is for full span, their transportation is not possible for all locations. However, the unit weight of I-Girder is approximately in the range of 70 MT, which is almost half when compared to Double U-girder and hence can be launched with lower capacity road cranes. Deck Slab of I-Girder can easily be planned to accommodate curved alignment. I-Girders are most suitable for station locations, where Box and 'U' Girders are not continued.

E) Special span configuration

Regular spans upto 31m span are not suitable for crossing large openings like road over bridges, wide surface road crossings, railway tracks, wide canals etc. Cantilever construction Method using PSC spans are used in such situation. Some of common span arrangements are suggested as under: -

- 34m + 45m + 34m
- 34m + 60m + 34m
- 75m + 105m + 75m

Other span configurations may also be designed as per specific site requirement.

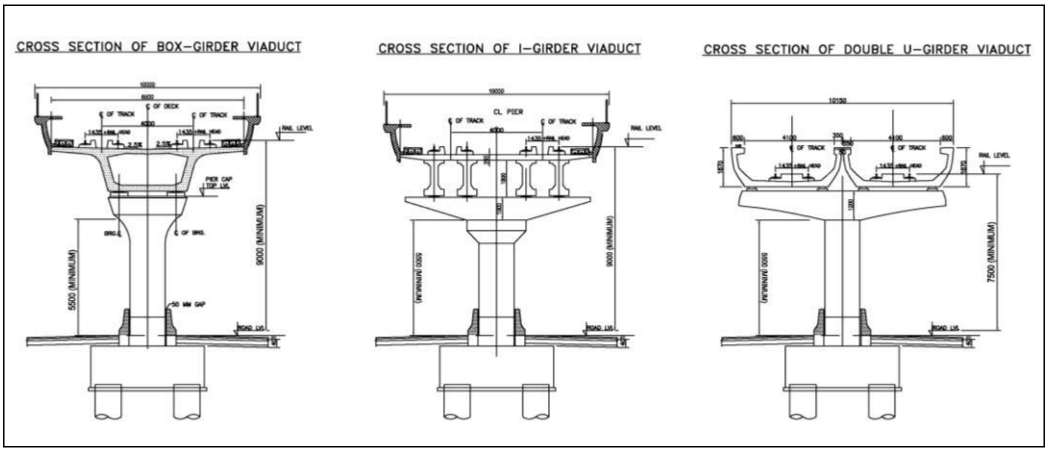
Other alternative is to use steel span. Steel span of upto 60m have been used in Metro systems in India.

FIGURE 5.42: CLC SPAN 75M + 105M + 75M AND STEEL SPAN 60M

Recommendation

The Design and Build Contractor may choose any type of super structure keeping in view site conditions, availability of construction time and other resources i.e. road cranes/launching girders/shuttering etc. Combination of above type of superstructure may also be chosen. Appropriate special spans may be provided for specific locations.

FIGURE 5.43: TYPICAL BOX GIRDER VIADUCT SECTION



5.9.3 Construction of Elevated Stations

Elevated stations with elevated concourse over the road are proposed for elevated stretch of alignment. To keep the rail level low, it is proposed not to take viaduct through the stations. Thus, a separate structural configuration is required, with shorter spans and lower depth of superstructure, although this may necessitate the 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 same manner. Two configurations as under are available for elevated station super-structure: -

a) Three-legged portal structure supporting concourse and platform level decks through series of Precast I girders resting on the Portal beam ledge.

b) Cantilever structure with single centre pier with the arms extending in transverse direction at concourse level and platform level. - Concourse and Platform decks are supported by I girders resting on extended pier arms.

Comparative analysis of above two types of structural arrangements is shown in **Table 5.32**.

TABLE 5.32: COMPARATIVE ANALYSIS OF TYPES OF STRUCTURAL ARRANGEMENTS

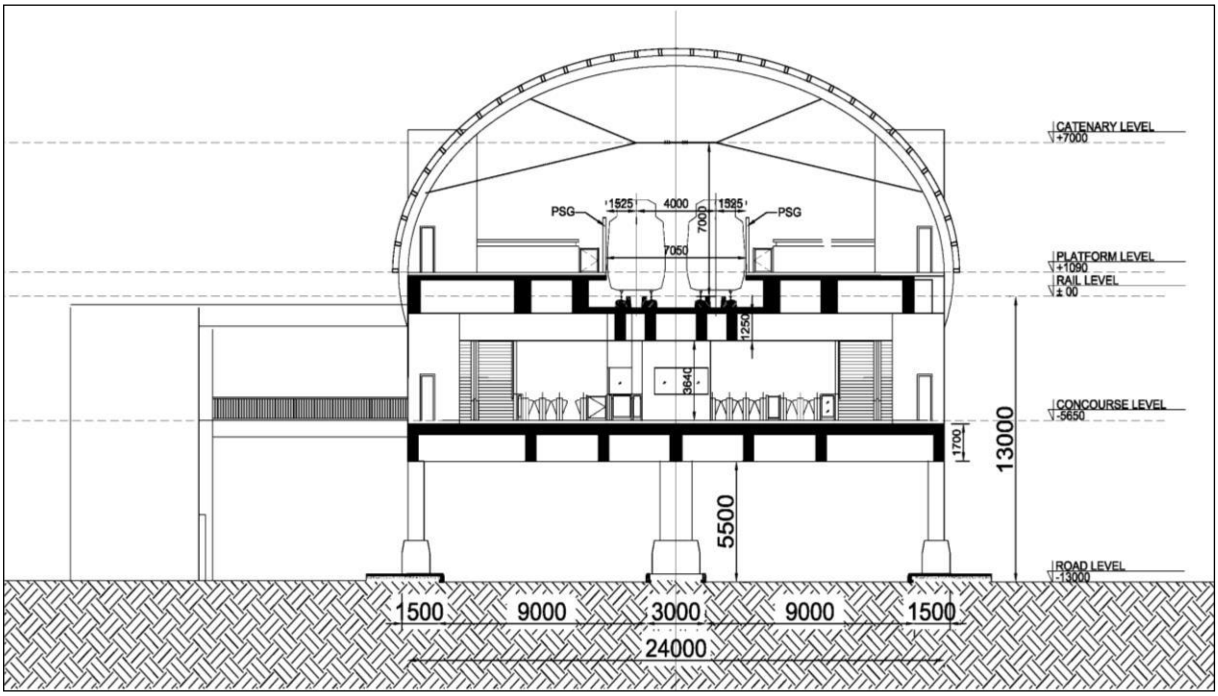
Item	Three-legged portal structure	Cantilever Structure
General	Three-legged portal structure is best suited for stations having high traffic load requiring more width. Central median of 3.0 m can be created to position the Central leg of the portal. This median can also divide the road traffic into two carriageways on either side of the median. Entry structures can be built beyond the carriageway on either side.	Cantilever station is more suitable for densely populated downtown areas having narrow ROW. The main elevated superstructure is already supported on cantilever pier caps. To accommodate the platform width (approx. 4m each), total 8m additional width of cantilever is required. The station rooms, entry/exit staircases etc. may be planned by providing more width at these locations only and such wider width can be supported on portal.
Merit	• Three-legged portal is a better structural arrangement with respect to vibration induced by the train loads, long term deflections of the concrete members etc., • The concentrated loads coming from escalators and stair cases connecting concourse level to platform level are effectively transferred to the ground through portal legs in the shortest path. • Need for Bus bays, drop/pick up points is avoided as the outmost lane can be used for this purpose.	• Station structure will be compact and economical. • No need to provide Service road to access adjoining properties. • The concentrated loads coming from escalators and stair cases connecting concourse level to platform level are to be transferred to the ground through portal arrangement.
Demerit	• Cost of the station structure will be more due to large built up area. Wherever there is scope of property development, same may be planned at Concourse level to use the available space. • Service lane need to be provided to ensure access to adjoining properties.	• There is need for Bus bays, drop/pick up points.

Typical Elevated Station

The elevated station is generally located on the road median 140 m long and 24 m wide and is a three-level structure. Passenger area on concourse is spread throughout the length of the station, with staircases leading from either side of the road. Passenger facilities 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. The public zone is further divided into paid and unpaid areas. Area left over in the unpaid zone, after accommodating the passenger movement and other station facilities is earmarked for commercial utilization.

Since the stations are planned generally in the middle of the road, minimum vertical clearance of 5.50 m has been provided under the concourse. Concourse floor level is about 7.0 m above the road. Consequently, platforms are at a level of about 13.0 m from the road. To reduce physical and visual impact of the elevated station, stations have been made transparent with minimum walls on the sides. **Figure 5.44** shows a typical cross section of elevated station.

FIGURE 5.44: TYPICAL ELEVATED STATION



5.9.4 Construction of Tunnels for Underground Alignment

For underground alignment, tunneling arrangements are decided based upon following objectives: -

- Minimization of the surface settlement to maintain all metropolitan activities without adverse effect.
- Expeditious tunnel execution to minimize duration and space of the surface effects due to tunnelling.
- Economy in tunnelling costs.

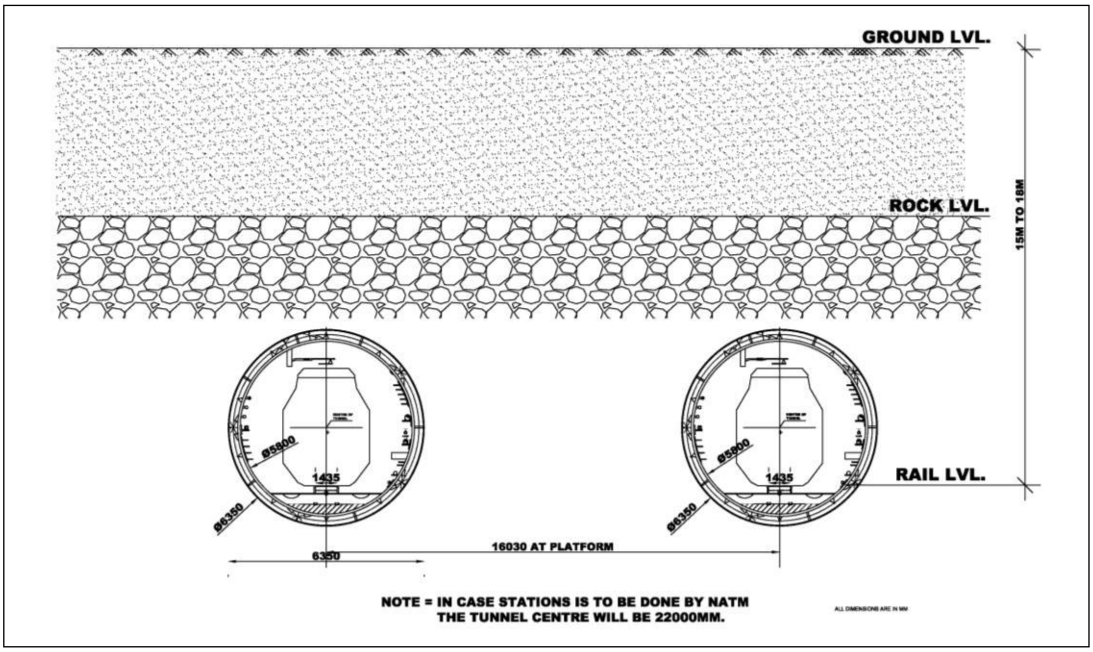
To achieve above objectives, use of Tunnel Boring Machine (TBM) is the prime method of tunneling. Locations where deployment of TBM is not possible (tunneling of short length, cross passages, underground stations which are not possible by cut and cover method etc.) are tackled by NATM method.

5.9.4.1 Selection of TBM

Choice of appropriate TMB depends upon the detailed geological studies and soil conditions. In the rocky strata, heavy disc cutters are required in the cutter head, whereas for excavating soft soils, scrappers are provided in the cutter head. In mixed soil conditions, the TBM should be capable of excavating soils and rocks both, hence combination of scrappers and disc cutters is used under such situations.

The most important issues to be addressed in selecting a Shield tunnelling method is face stability and minimum displacement/settlement of ground and structures confronting suitable TBM in this project will be the closed type. The Closed type TBM is further categorized as Earth- Pressure Balanced (EPB) TBM and Slurry type TBM. EPB is further categorized into Earth-pressure type TBM and Mud-pressure type TBM.

FIGURE 5.45: TYPICAL TWIN TUNNEL ARRANGEMENT



- **Earth-pressure type TBM**

  The Earth-pressure type TBM is suitable for certain types of soil that can be directly fluidized. Fluidized soil fills the cutter chamber and the screw conveyor is used for discharge of muck, thereby keeping the cut face stable. The shield machine is able to simultaneously excavate soil during shield advance, so not only is the face well stabilized, but also the effects on the surrounding ground are minimized.

FIGURE 5.46: EARTH PRESSURE BALANCE TBM

- **Mud-pressure type TBM**

  The Mud-pressure type TBM is that soil pressure at the face is transferred efficiently to ground that is high in sand content and low in fluidity through the addition of water, mud, and additives. It is applicable to a large range of soils, including soft ground with low solidity such as alluvial sand/gravel, sand, silt and clay, alluvial deposits, and alternating hard and soft soil layers. The only limitation is that the soil discharge screw conveyor is unable to operate when the ground has high hydrostatic pressure. For this reason, it is necessary to closely study the soil properties before implementation.

- **Slurry type TBM**

  Slurry type TBM (Air tunnel-boring machine) is used for tunnel-boring in highly permeable unstable terrain, or under civilian structures sensitive to ground disturbances.

  When digging in highly unstable or liquid terrain, the pressure exerted by the terrain is directly governed by the depth at which digging is performed. It is therefore necessary to balance the pressure exerted by the terrain: the front shield of the Slurry TBM is filled with excavated material, with the exception of one air-filled part. The pressure within this air bubble is subject to fine control. Bentonite injection waterproofs the working face and improves its resistance.

5.9.4.2 Proposed Dimensions

TABLE 5.33: DIMENSIONS OF TBM

Parameter	Proposed dimension
Tunnel internal diameter	5800 mm
Tunnel external diameter	6350 mm
Tunnel excavation diameter	6700 mm
TBM cutter head diameter	6770
Number of segments/rings	5 + 1 Key
Width of segments	1.2m/1.4m/1.5m
Thickness of segments	275 mm
Weight to segments	Normal segments Approx 3.0 T each Key segment 1 T
Grade of concrete	M - 45

5.9.4.3 Sequence of Tunnelling by TBM

Between two stations tunnel is constructed by TBM. It will be launched from launching shaft. It is dragged in station area and continues from other side of station. Ground settlement analysis and monitoring is required during tunneling by TBM. Two separate tunnels are constructed by two different TBM. Depending upon the soil/rock strata, suitable type of TBM shall be used for tunneling.

A) Pre-Assembly Activities

The following construction sequence is necessary before Assembly of TBM can be taken up:

1) Construction of Head Wall & Installation of rubber seal ring

This is a concrete structure designed to hold the main frame of the Entrance ring of TBM and prevent water and slurry flowing into the shaft during the assembly and operation of the TBM. Rubber Seal (25 mm thick) and seal retainers keep full contact with the shield TBM. Three air ventilation tubes are installed near the tunnel crown and one at the invert, to release the air, when the void is being filled with grout while launching the TBM. These can also be used for grouting.

2) Construction of Cradle

This is a Pre-fabricated steel structure over which the TBM is assembled in–situ. This also acts as guide to help TBM oriented in the required direction, while in operation. After the TBM becomes operational, the cradle will be carefully dismantled so that the same material can be used at different shaft.

3) **Construction of Reaction Frame**

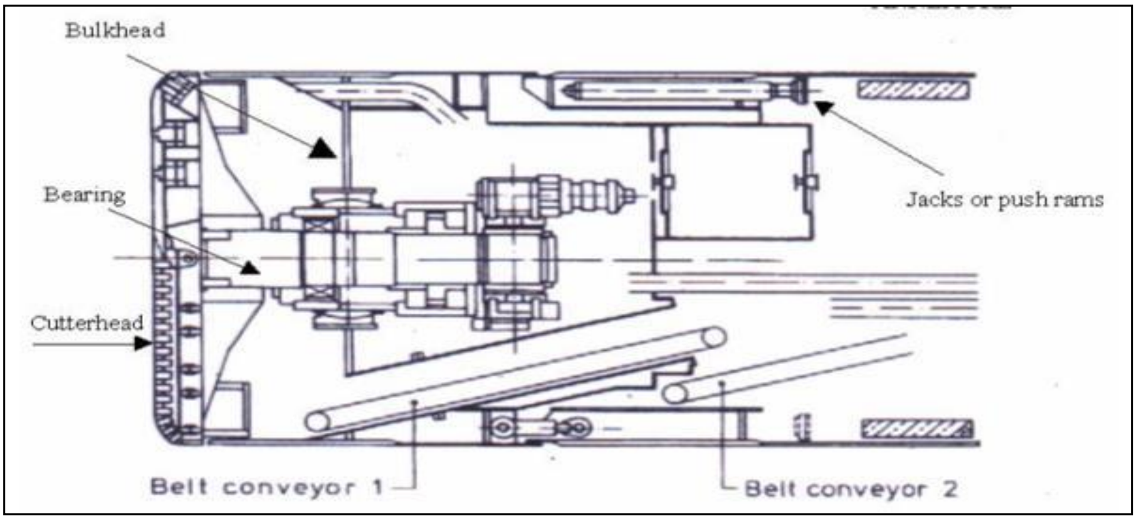
This is a steel Structure consisting of the Frame and supports which is fixed to the shaft floor and is designed to safely bear the thrust [a force of App. 1200 ton (30% of total thrust)] applied by the TBM during its working (force required by the cutting edge to cut the rock). The machine is to be assembled in- situ on a platform called Cradle and a Reaction frame is to be constructed in advance to bear the reaction of the force exerted by the main drive of the TBM for cutting the rock. Once the TBM becomes operational, the steel work in the Reaction Frame will be carefully dismantled as the same material is to be used repeatedly at subsequent assemblies at different sites.

B) Assembly of TBM

After the Head Wall, Entrance ring, Cradle, Reaction Frames are constructed and other preparatory works are completed, the TBM can be assembled in-situ in a launching chamber on the cradle and launched for tunneling. Metro underground station being constructed by cut and cover method can be used as launching shaft for TBM.

FIGURE 5.47: LAUNCHING CHAMBER

FIGURE 5.48: TYPICAL ASSEMBLY OF TUNNEL BORING MACHINE



Following steps are involved in the assembly of TBM:

1) Lowering of the shield,
2) Lowering of Cutter Head and fixing the same to the shield,
3) Fixing Segment erector and screw conveyor erection,
4) Lowering and Assembly of back up gantries.

FIGURE 5.49: ERECTOR, SCREW CONVEYOR & BACKUP SYSTEM

It takes about three-four weeks each for completing the preparatory work and actual assembly of TBM in position, before it could be launched.

FIGURE 5.50: MAIN SHIELD ERECTION

The cradle and the reaction Frames are specially designed for every situation depending upon the machine characteristics and the rock characteristics. A 35-ton crane with a traveling gantry (or a suitable road mobile crane) is required for assembling the TBM. A 50-ton mobile crane will be required at the receiving end for dismantling TBM before shifting the same to another location.

C) Excavation

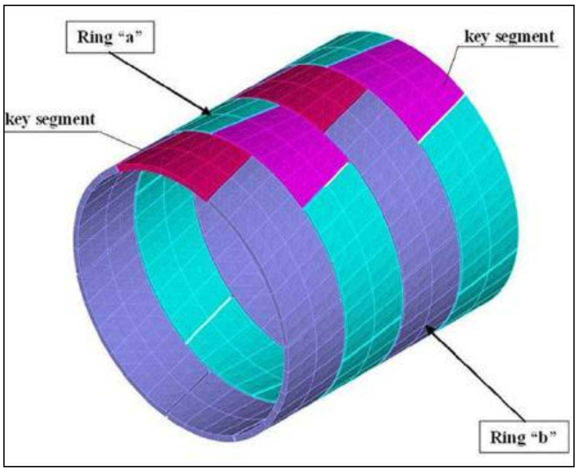
The TBM will operate at all times in enclosed mode. The pressure being maintained by balancing excavated material and foam introduced against material removed via the screw. A belt weighing device will be included on conveyor belt. This will measure the weight of the excavated material as it is transported on the conveyor belt.

FIGURE 5.51: EXCAVATION

D) Ring Erection

As the machine advances, the construction of the permanent lining takes place behind the excavation face of the machine and typically consists of 6 segments which make one ring.

FIGURE 5.52: RING SEGMENT



E) Settlement Control

Settlement is primary caused by over excavation by TBM and the failure to fill annular voids behind the segments. To prevent over excavation during the TBM drives the following actions will be carried out: -

- Surface monitoring scheme to be agreed and installed prior to TBM launch.
- Provision of belt weighing device to measure excavated material weight.
- Ground treatment of launch area & receiving area (if required)
- Display in TBM drivers cabin to show actual excavated volume vs. theoretical excavated volume in real time. Data to be recorded by TBM data logger.

To ensure settlement do not occur due to the annulus ring not being filled by grout the following actions will be carried out.

- Grouting system based on pressure control.
- Recording of grout volumes & pressure by TBM data logger.
- Tabulation of grout volumes to be done weekly showing running 10 ring averages. Grout pressure will be adjusted as necessary.

The above actions should ensure all annular voids are filled during the initial drive thereby controlling settlement caused by poor grouting practices.

F) Grouting and Waterproofing

After ring installation, theoretical void distance between the excavated radius and the external radius of the precast ring need to be filled up. Grouting fill the voids and it also controls the ground settlement. Grouting pressure is calculated on the basis of overburden pressure. Structures shall be watertight if the leakage does not exceed 5 ml/m2/hour. Inside surface above spring line of the tunnel shall be always kept dry condition.

Cavity grouting of segmental lining

Cavity grout shall be executed during the tunnelling in order to:

- Secure the waterproofing of the tunnel
- Maintain the tunnel ring shape
- Limit the surface settlement
- Distribute ground pressures evenly onto the lining

The grouting can be distinguished into two types. These are single compound type and the other is the two compounds type. The hardening time of the one compound type is relatively slow and its strength is also low. On the other hand it is relatively easy for the two compounds type to adjust the hardening time and strength. Hence it is recommended to use the two compounds type for the cavity grout.

The two compounds type is also distinguished into two types - liquid type and plastic type. The liquid type can be sometime diluted by the underground water and segregated. However, the plastic type is changed instantly into gel and kept very stable until it gets its own strength. Thus, plastic type grout is recommended. The major materials of the liquid-A for the plastic type are mainly cement, fly-ash and bentonite. And the major material of the liquid-B for the plastic type is sodium silicate.

Primary grouting is the initial cavity grouting which is applied simultaneously or immediately after a unit of lining has been built. Where primary grouting does not completely fill all cavities, secondary grouting shall be carried out. Primary grouting shall be undertaken at a pressure sufficient to place the grout properly but not greater than 1 bar above the prevailing hydrostatic pressure at the location of grouting. Primary grouting shall be timed so as to minimize ground movement and be injected through grout holes provided in the linings or via shield tail skin injection pipes.

Secondary grouting shall be undertaken in selected rings by means of removing grout plugs from the tunnel lining and drilling a hole to the back of the existing grout. Secondary grouting is the re-grouting of lining and shall be completed as soon as practicable but within 14 days of the primary grouting or when the face has advanced 50 m from the location of primary grouting whichever first occurs. Secondary grouting shall be at a pressure consistent with filling all voids. Automatic grouting system as TBM advances shall be equipped.

Segment Gasket

It is recommended to apply the three layers of gasket to the perimeter of the segment. The materials for the gasket are mainly distinguished into chloroprene rubber type and natural rubber type. It should be tested for durability and water swelling ratio before using. The natural rubber type is suitable for the tunnel under high water pressure and the chloroprene rubber type is suitable for the tunnel under low water pressure.

- Gaskets shall be fitted into the grooves provided in the edges of the segment to be sealed in the manner recommended by the gasket manufacturer. The gasket dimensions shall match the groove width, subject to the specified tolerance.
- Sealing strips of the hydrophilic or gasket type, or a combination of the two, shall be provided at all faces between segments to provide a seal against ingress of ground water. Gaskets must be capable of withstanding the anticipated water pressure when in use in the tunnel. Test certificates or other information shall be provided to demonstrate this capability.
- Elastomeric gasket materials shall comply with the requirements of BS 2494, including resistance to chemical attack and microbiological degradation.
- Immediately prior to the erection of a gasketed segment, the gasket shall be checked for cleanliness and position. The gasket shall be lubricated as recommended by the gasket manufacturer.

G) TBM in Station Area

Cradle will be installed to drag the TBM in station area and again drive to other end of station by cutting D-wall. One end of station is receiving chamber and other end is launching chamber.

FIGURE 5.53: TBM THROUGH THE DIAPHRAGM WALL

FIGURE 5.54: TBM PUSHED TO THE OTHER END OF THE STATION

5.9.5 New Austrian Tunnelling Method (NATM)

The term New Austrian Tunnelling Method Popularly Known as NATM, was first used by Mr. Rabcewicz in 1962. This method has been evolved as a result of experience gained in Austrian Alpine tunnelling condition. The first use of NATM in soft ground tunnelling is done in Frankfurt metro in 1969. The basic aim of NATM is for getting stable and economic tunnel support systems. Providing flexible primary lining in shape of shotcrete, wire mesh, rock bolts, lattice girder. In case of weaker rock mass the use of pipe forepole/pipe roofing is also resorted for crown support which in turn leads to less over-break as well as ensure safety during the execution. The main aspect of the approach is dynamic design based on rock mass classification as well as the in situ deformation observed. This method has been very useful in complex diversified geological condition where forecasting of the rock mass is difficult due to rapidly changing geology.

5.9.5.1 Cross Passage

It is recommended to follow NFPA 130 which is an international standard for the underground structures. Cross passageways shall not be further than 244m (800ft) apart according to the NFPA 130. At least one cross passage is required in each underground section between the stations. Construction method of cross passage is briefly explained below:

- The SGI segment is sometimes used at the location of the cross passage in order to strengthen the segment lining because some parts of the segment lining must be dismantled during the construction of the cross passage.
- Ground treatment is carried out from the ground surface. Usually the jet grout is applied. The jet grout is much more effective than other methods for the ground treatment because the original soil is totally replaced by the improved soil.
- Ground treatment is also carried out from the tunnel after the jet grouting above ground. The purpose of the grouting from the tunnel is supplementary grouting for the jet grouting above ground.
- Dismantling of the piece of the segments is commenced one piece by one piece together with carefully confirming of the soil condition. Additional grouting should be done if necessary.
- Excavation to the other tunnel with lagging or shotcreting.
- Structural work

5.9.6 Construction of Underground Stations

Construction of underground station is mostly done by **Cut and Cover Method** where adequate ROW is available to support the excavation width to cover the width of station including protection work. Margin for road traffic also need to be available beyond the excavation line. Where ROW is restricted, only half width of station will be tackled at a time. In cases where ROW is extremely restricted and cut & Cover method is not possible, excavation will be done by **New Austrian Tunneling Method (NATM).**

5.9.6.1 Cut and cover method

In this method, entire volume required to accommodate structure is first excavated, structures are casted followed by backfilling. The open cut excavation with slope but without support is not suited due to large depths of excavation involved. Hence support of excavated sides by way of diaphragm wall/sheet pile/soldier pile/secant pile is essentially done in cut and cover method. The support walls are often braced to effectively resist the huge earth pressure. The braced cut and cover method involves following steps: -

- Identification and diversion of utilities
- Construction of support walls
- Excavation between support walls along with bracing, ties or anchors
- Concrete construction
- Removal of temporary supports
- Backfilling and restoration of surface/utilities

There are two methods for cut and cover construction: -

i) **Bottom Up Construction**: This is the conventional construction method in which excavation is carried out through to the design depth and then construction starts from bottom most floor slab and proceeds upwards. In this method the restoration of top surface is possible only after all the structures are constructed upto top level and hence it involves longer restoration time.

ii) **Top Down Construction:** In this method, after excavation of first stage, floor slabs are constructed. These floor slabs are permanent structures which replace temporary steel struts in the braced excavation method to counteract the earth pressure from back of retaining wall. In this way, the underground structure construction is finished with the completion of excavation process. The floor slabs used in this method are heavier than steel struts used in conventional excavation method. In addition, superstructure being constructed simultaneously during excavation puts more weight on the column. Hence, bearing capacity of column is to be considered. Typical construction procedure of top down construction method is as under: -

1) Construct the retaining wall.
2) Construct piles. Place the steel columns where piles are constructed.
3) Proceed to the first stage excavation.
4) Cast the floor slab.
5) Begin to construct superstructure.
6) Proceed deeper to second stage of excavation. Cast the floor slab.
7) Repeat the same procedure till designed depth is achieved.
8) Cast bottom most slab.

The merit and de-merit of this method are as under:

TABLE 5.34: MERITS AND DEMERITS OF TOP-DOWN METHOD

Merit	De-merit
• Shortened construction period due to simultaneous construction of underground structure and superstructure. • Faster restoration of ground surface and utilities as topmost slab of underground construction is casted first. • Higher stiffness of floor slabs compared to steel struts improves the safety of excavation.	• Higher cost. • Possibility of lateral displacement of retaining wall or ground settlement is more due to longer construction period of bottommost slab. • Natural ventilation and illumination is affected due to construction of first slab.

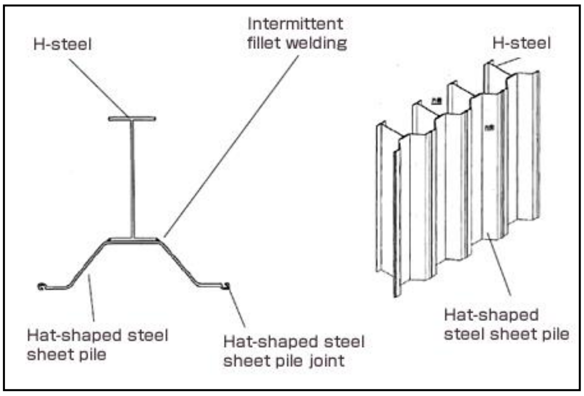
5.9.6.2 New Austrian Tunneling Method (NATM)

Where ROW is extremely restricted and it is not possible to adopt cut and cover method, stations are constructed by NATM. In this method, two separate tunnels consisting of one track and one platform are constructed by NATM method and are connected by means of cross passages. This method requires overburden of about 2-2.5 times dia of tunnel. In this method, progress is slow. This method is described in detail in tunnelling sub-section.

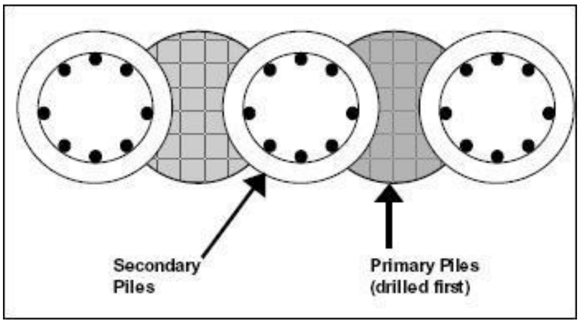
5.9.6.3 Earth retaining structures for underground stations

Following earth-retaining structures are used to support excavation for construction of underground stations: -

A) Soldier Piles: H/I section steel piles are driven in the ground at an interval of 1-1.5 m and the gap between the two piles is filled by using laggings of timber planks/steel sheets/GI sheets. These piles are reusable, can be easily pulled out and results into less ground disturbance while driving and pulling out. However, these piles are not watertight and dewatering measures are required. Void between soldier piles and surrounding soil need filling.



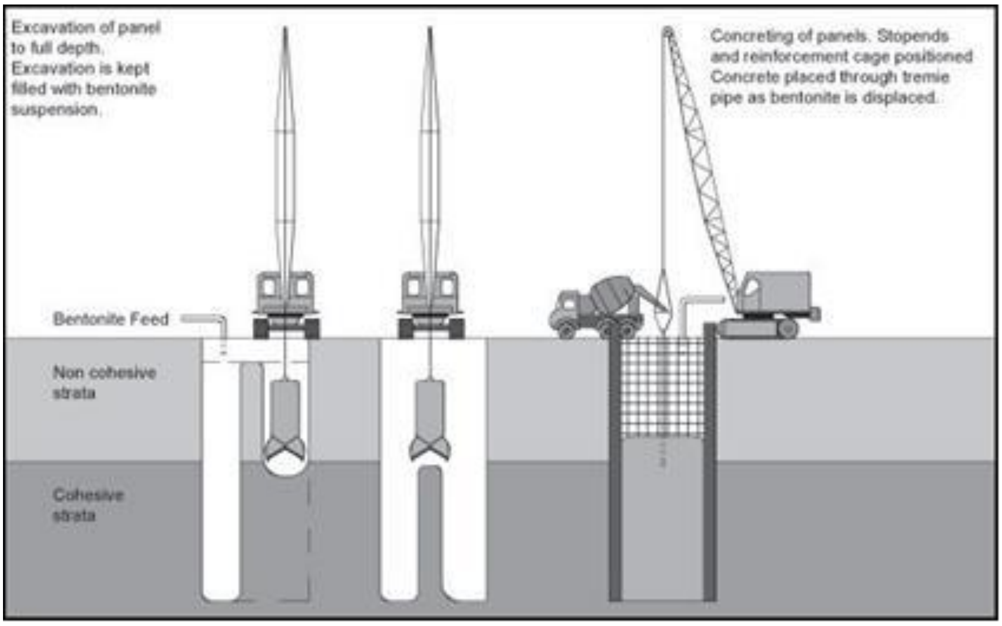
B) Sheet Piles: Sheet piles of 'Z' or 'U' shape are driven into soil by striking or static vibrating. The sheet pile is interconnected with adjoining piles to achieve interlocking and water sealing. Sheet piles can be used again and again and hence becomes economical. Driving of sheet piles require considerable efforts and cause vibrations to ground and adjoining structures. Sheet piles have higher stiffness than soldier piles.



C) Secant Piles: It is series of piles cutting into adjoining piles to achieve water tight retaining structure. In this method, alternate soft piles, called female piles, of dia (D) 800 to 1000 mm (without reinforcement) are cast at an inter-distance of less than D and when these piles are still green, hard piles (containing reinforcement) are bored by cutting female piles. Thus, a series of alternate and interconnected hard and soft pile is achieved which acts as rigid earth retaining structure. It has all the advantages of diaphragm wall, except that it cannot be used as part of permanent structure.

D) Diaphragm Wall: It is a rigid support system ensuring maximum safety against settlement/lateral displacement. Typically diaphragm wall of 1 m thickness is sufficient to retain the earth pressure in a cut cover construction. The diaphragm wall can be used as part of permanent structure. With diaphragm wall, it is possible to adopt top down construction method.

FIGURE 5.55: DIAPHRAGM WALL



5.9.6.4 Typical Underground Station

A typical underground station is three level station with entrances and ventilation shafts at the ground level, a concourse with ticketing and AFCs at the mezzanine level and finally platforms at the lowest level. 140 m long island platform is proposed on the stations. Platform is 12 m wide with 2 sets of staircase/ Escalator planned leading to either end of the station. A lift is planned in the centre. **Figure 5.56** shows a typical cross section of underground station.

Two end concourses have been proposed, one at each end. The concourse is divided into paid and unpaid area by the AFC gates. Paid area is limited to access to the stair / escalator and corridors connecting the two concourses, also lead to the lift which is centrally provided.

Since, very limited space is available on the ground at stations, all the over-ground structures are therefore, planned as and where space is available and are therefore, not necessarily grouped at ground level.

5.9.7 Flexible Joint at the Junction of the Tunnel and Station/Shaft

Following three models are considered for the connection.

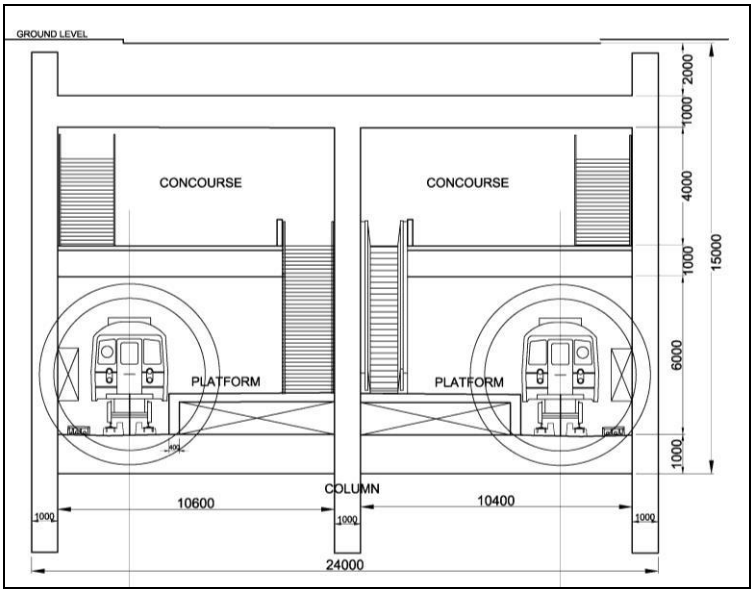
- Rigid connection
- Pin connection
- Free connection

The Rigid connection is recommended. There are some measures for such joint between the tunnel and station which are as follows.

- RC segment only
- RC segment with elastic washers for 7 meters (1D long)
- SGI segment for 7 meters (1D long)
- SGI segment with elastic washers for 7 meters (1D long)
- Flexible joint

Considering safety and cost for the construction it is recommended to apply the rigid joint at the connection between tunnel and station. Detailed analysis such as FEM analysis should be done for the earthquake to estimate the displacement of the joint**.**

FIGURE 5.56: TYPICAL UNDERGROUND STATION (2-LEVEL)



5.10 TRAFFIC MANAGEMENT PLAN DURING CONSTRUCTION

The aim of the traffic management measures is to relieve, wherever possible, or minimize the (short term) disruption to normal traffic likely to be caused by the construction of the metro works. The traffic management measures would need to cope, in safety, with all aspects of traffic, including those generated from

- Goods vehicles
- Public transport
- Essential services
- Pedestrian movement
- Local and through private traffic

The organization of traffic during construction activities is proposed to be phased into and coordinated with the long term strategic traffic plans under CMP.

5.10.1 Typical Traffic Diversion Plan

The typical traffic diversion plans have been prepared based on two scenarios as under:

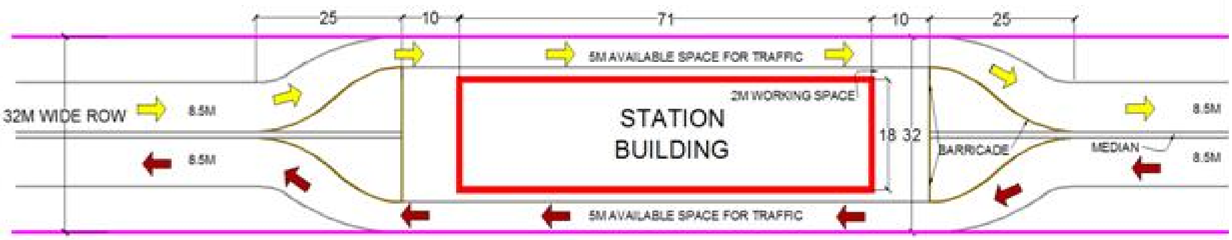
Scenario 1: - At stations where ROW> 32m

Scenario 2:- At stations where ROW< 32m

At stations where ROW> 32m

At stations where, existing ROW is more than 32m, traffic will be diverted on both sides of the proposed station built up area during construction. The typical traffic diversion plan for such stations is shown in **Figure 5.57**. To increase the available space width for traffic, the option of construction of station in two sequences (half by half method) can be adopted.

FIGURE 5.57: TYPICAL TRAFFIC DIVERSION PLAN (ROW> 32M)



At stations where ROW< 32m

At some of the stations existing ROW is between 22m to 32m, so the traffic will be diverted on such locations one side of the proposed station during construction and construction of station will be done half by half method in sequence. The typical traffic diversion plans for such stations are shown in **Figure 5.58** & **5.59**.

FIGURE 5.58: TYPICAL TRAFFIC DIVERSION PLAN (ROW< 32M)

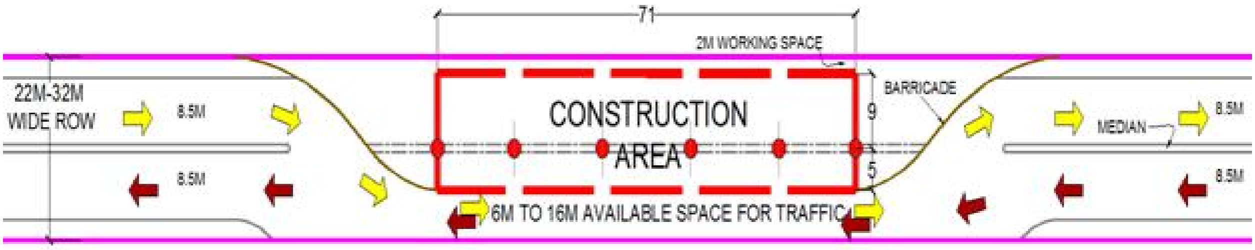
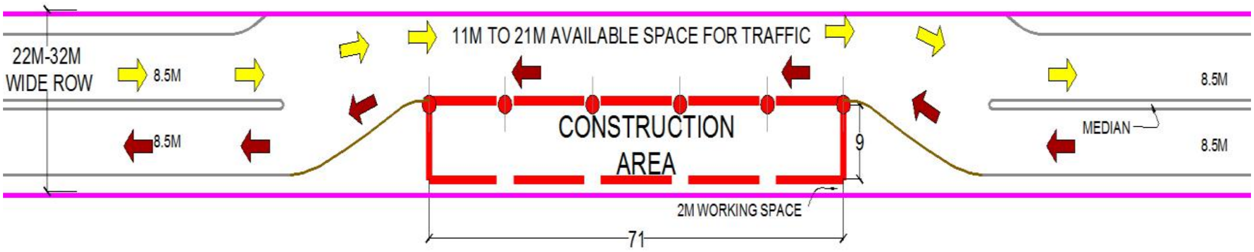


FIGURE 5.59: TYPICAL TRAFFIC DIVERSION PLAN (ROW< 32M)



5.11 MUCK DISPOSAL

Construction of underground tunnel for metro projects is a specialised and complex task. The proposed metro route is underground for 26.13 km including 29 stations in Corridor-3, 17.12 Km including 20 stations in Corridor-4 and 37.13 Km including 38 stations in Corridor-5. The construction activity involves tunnelling, cut and cover, foundation, fill and embankment. The Total quantity of muck for corridor 3, 4 & 5 is 84,21,975 cum.

TABLE 5.35: QUANTITY OF MUCK

S. No.	Corridor	Description	Length	Dia/ Width (m)	Depth	Vol. of Muck (cum)	Total Vol. of Muck (cum)
1	Corridor-3	Tunneling	20908	6.7	0	737143	2697343
		Station	4950	22	18	1960200	
2	Corridor-4	Tunneling	7484	6.7	0	263849	1071689
		Station	2040	22	18	807840	
3	Corridor-5	Tunneling	3864	6.7	0	136218	555978
		Station	1060	22	18	419760	

Protective measures shall be undertaken during construction phase for reduction of dust generation. Owing to paucity of space in the city, elaborate measures need to be adopted for collection, transfer, storage and disposal of excavated muck. Muck collection, transportation, disposal and its treatment need to be carried out in a systematic manner. Muck collection should be transported in containers from the Tunnel excavation sites. These containers should be such that muck should not spill during movement to disposal site. To avoid impact on land due to muck disposal, project proponent has identified options for disposal of muck by utilizing the muck for various purposes as described below.

- **Recycle and Reuse**: Muck generated can be reused as aggregate material for road beds, ballast for railways, construction material and graded material can be used in concrete. The re-use can be decided only after thorough geotechnical investigation, testing of the muck and choice of TBM. This alternative will require land for setting up a plant to convert the muck to a useful form.

5.12 UTILITY DIVERSION

5.12.1 Introduction

- Large number of sub-surfaces, surface and overhead utility services viz. sewers, water mains, storm water drains, gas pipe lines, telephone/ communication cables, Overhead power transmission lines, power cables, traffic signals, etc. exists all 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 and relocation or by supporting in position. Any interruption to these will have serious repercussions on the most sensitive suburban services and direct impact on the public besides set back in construction and project implementation schedule & costs. Therefore, meticulous detailed survey and planning will be required to protect/divert the utility services.
- Accordingly, overhead utilities were identified during physical survey of corridor. Moreover, liaison with concerned utility owners was made for identification and mapping of various underground utilities. No trenching / GPR survey etc. was conducted for underground utilities.

5.12.2 Agencies for Utility Services

For identification of likely utilities in the proposed metro Corridor -3, 4 & 5, liaison was made with Organizations/Departments shown in **Table 5.36**: -

TABLE 5.36: UTILITY RESPONSIBILITY DEPARTMENTS

S. No.	ORGANIZATION/ DEPARTMENT	UTILITY SERVICES
1	National Highway Authority of India	Road Construction and maintenance of National highways etc.
2	PWD	City Roads and Irrigation canals etc
3	Indian Railways	Railway crossings, subways, signals, bridges etc.
4	Chennai Metropolitan Water Supply & Sewerage Board	Water pipe lines and Sewerage pipe lines.
5	Tamil Nadu Electricity Board	HT/LT/other overhead Power lines.
6	Municipal Corporation of Chennai	Coordination with other private agencies
7	Gas Authority of India (GAIL)	Gas Pipelines
8	IOCL, BPCL	High pressure pipe lines

S. No.	ORGANIZATION/ DEPARTMENT	UTILITY SERVICES
9	Power Grid, BSNL	Telecom cables, junction boxes, telephone posts, O.H lines.
10	Tata Telecom Services, Airtel, Aircel, Vodafone, Idea, Reliance	Telecom cables, junction boxes, telephone posts, O.H. Lines.
11	Railtel	Tele cables, junction boxes, telephone posts, etc.

5.12.3 Guidelines for Diversion of Underground Utilities

While planning for diversion of underground utility services viz. sewer lines, water pipelines, cables, etc., during construction of MRTS, 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 concrete after completion of construction and retained as permanent lines.
- Where permanent diversion of the affected utility is not found feasible, 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.
- 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. The utility service can also be encased within the foundation piles.

5.12.4 Sewer Lines, Storm Water Drains and Water Lines

The storm water drains and water pipe lines generally exists either side of under main carriageway or at some places on the central verge, as a result of subsequent road widening. However, majority of sewer lines are running in the centre of the road.

The major sewer, storm water drains and water pipe lines 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 the column supports of viaduct by change in span or by suitably adjusting the layout of pile foundations. Where, this is not feasible, lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines.

5.12.5 Telecom Cables, OFC, Ducts and Trench

At several places, telecom cables, OFC, ducts and trenches of Vodafone, Idea, Aircel, Airtel and BSNL are also running along and across the proposed corridors and few of them are likely to be affected.

5.12.6 Above Ground Utilities

Above ground utilities namely Power transmission lines, transformers are running along and across the proposed corridors and few of them are likely to be affected.

5.13 LAND REQUIREMENT

5.13.1 Main Components

Land will be required for the following main components:

- MRTS Structure (including Route Alignment), Station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities, Depots, etc.
- Receiving/Traction Sub-stations
- Radio Towers
- Temporary Construction Depots and work sites.

5.13.2 Land for Underground stations

Stations sizes as mentioned in respective chapter are 190m / 150m long and 21.8m / 21.4m wide for Underground 2 level and 3 level cut & cover construction. Working space required during construction is about 3m around the periphery of the station box. Land requirement for underground stations has been evaluated for the area of 226m length x 28m width (excluding ancillary buildings and entry/exits of the stations) so as to keep buffer for variable station designs during construction. Additional land in station area shall be utilized for Traffic Integration & Property development.

5.13.3 Land for Switch-over Ramps

Switchover ramps are required for transition from the elevated to underground section and vice versa. The ramp covers a stretch at ground for the whole width of structure for two tracks. 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.

For Corridor-3 an area of 5028 sqm has been proposed along Old Mahabalipuram Road for locating ramp. For Corridor-4, an area of 5518 sqm has been proposed along Arcot Road for locating ramp. Similarily, for Corridor-5, an area of 4752 sqm and 4780 sqm has been proposed for ramp.

5.13.4 Land for Traffic integration

Govt. land has been proposed for integration with Rail system, Metro corridors and Bus system.

5.13.5 Land for Maintenance Depot

About 57.2 Hectares of Madhavaram Milk Colony land has been proposed to be acquired for major Depot for all three corridors out of which depot construction requires 27.8 Hectares land and remaining land shall be used for property development and parking facility, as suggested by CMRL. About 6.3 Hectares of private land in SIPCOT area has been proposed to be acquired for minor depot. This minor depot shall be constructed elevated in covered area of 4.5 Hectares. The total area underneath shall be used for property development and parking. About 17.4 Hectares land has been proposed to be acquired for major Depot for corridor-4 out of which depot construction requires 15.3 Hectares land and remaining land shall be reserved for staff quarters etc.

5.13.6 Land for TSS, RSS, ASS and DG Sets

Total of twelve RSS have been proposed along the corridors. An area of 3000 sqm has been proposed for each RSS. ASS and DG Sets are required at all stations.

5.13.7 Land Requirement (Permanent)

Permanent requirement of Land for Corridor – 3, 4 & 5 is tabulated in **Table 5.37**.

5.13.8 Temporary Construction Depot

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.

Also, large numbers of pre-cast tunnel segments are required for construction of tunnels for which a large Open area is required for setting up of casting yard. As far as possible, this area will be in temporary construction depot.

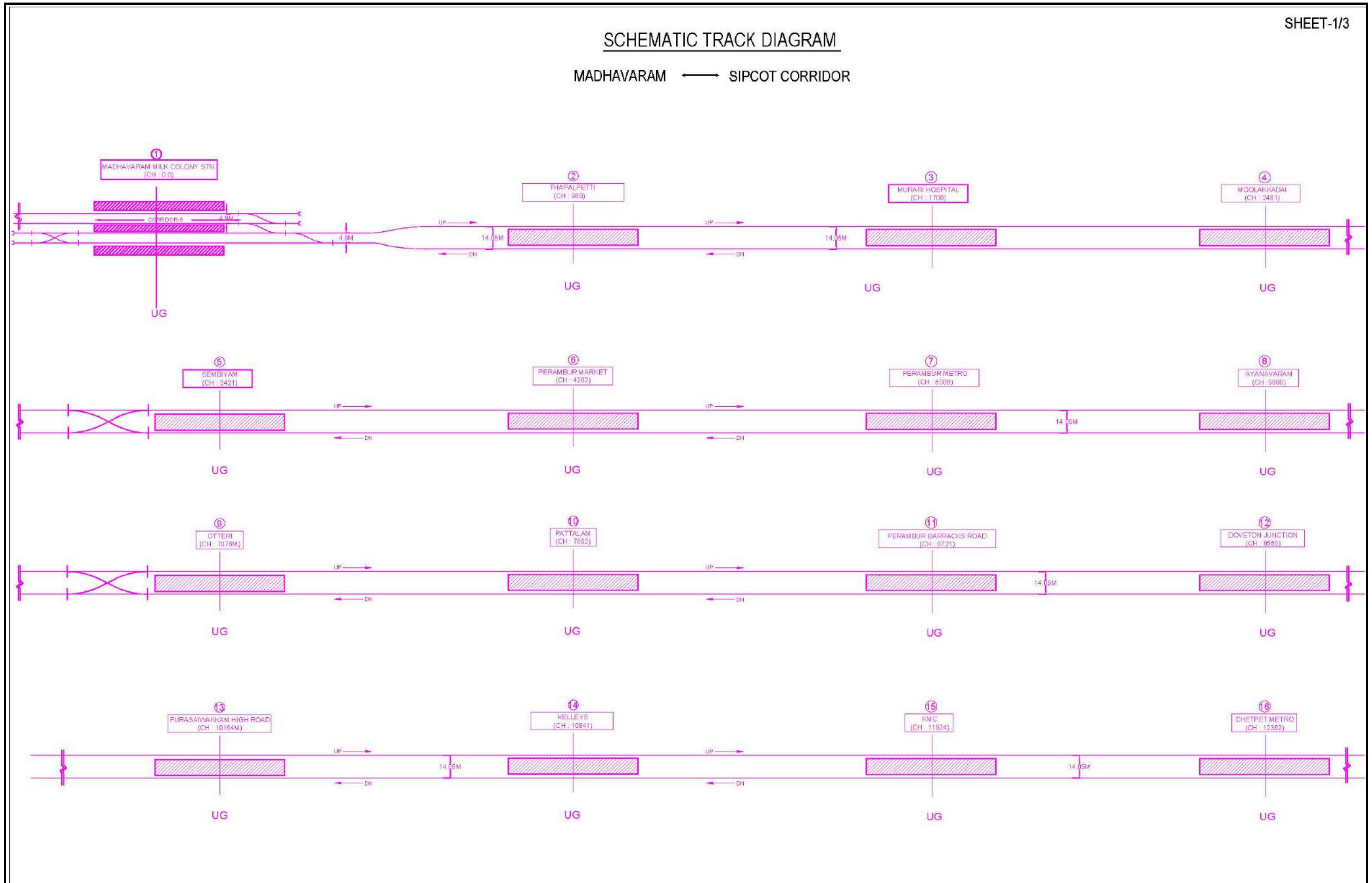
Since the area of land being acquired permanently at most of the stations is bare minimum, the land required for construction depots purpose is identified throughout the corridor, in the vicinity of the stations on temporary acquisition basis. These sites will be obtained on lease temporarily for the construction period. After completion of construction, these will be handed over back to the land-owning agency.

About **50 Hac** land each for Corridor-3 & 5 and **20 Hac** for Corridor-4 shall be required for construction depots along the corridors. This requirement shall be met with the construction's depots of Phase-I. Additional land, depending upon the need, area requirements, the location and size can be reassessed and temporary land acquisitions can be made accordingly.

TABLE 5.37: LAND & STRUCTURES REQUIREMENT (IN HA) FOR CORRIDORS 3, 4 & 5

Ownership	Purpose	Corridor 3			Corridor 4			Corridor 5		
		Permanent Land	Temporary Land	Structures (Floor area)	Permanent Land	Temporary Land	Structures (Floor area)	Permanent Land	Temporary Land	Structures (Floor area)
Central Govt	Alignment / Stations, ancillary buildings & Misc.	1.942	0	0	0	0	0	0.0957	0	0
	Total	**1.942**	**0**	**0**	**0**	**0**	**0**	**0.0957**	**0**	**0**
State Govt	Alignment / Stations, ancillary buildings & Misc. etc	1.327	0	0.371	4.066	0	0.5579	3.1796	0	0.4367
	Depot	32.3	0	0	17.4	0	0.4008	0	0	0
	Parking cum PD	31.2	0	0	0.9738	0	0	1.253	0	0
	Casting Yard (Approx.)	0	50	0	0	20	0	0	50	0
	Total	**64.827**	**50**	**0.371**	**22.4398**	**20**	**0.9587**	**4.4326**	**50**	**0.4367**
Private	Alignment / Stations, ancillary buildings & Misc., RSS, etc	10.905	0	7.425	5.7008	0	20.3885	10.5873	0	11.5621
	Total	**10.905**	**0**	**7.425**	**5.7008**	**0**	**20.3885**	**10.5873**	**0**	**11.5621**
Grand Total		**77.674**	**50**	**7.796**	**28.1406**	**20**	**21.3472**	**15.1156**	**50**	**11.9988**

ANNEXURE 5.1: SCHEMATIC DIAGRAM OF CORRIDOR-3

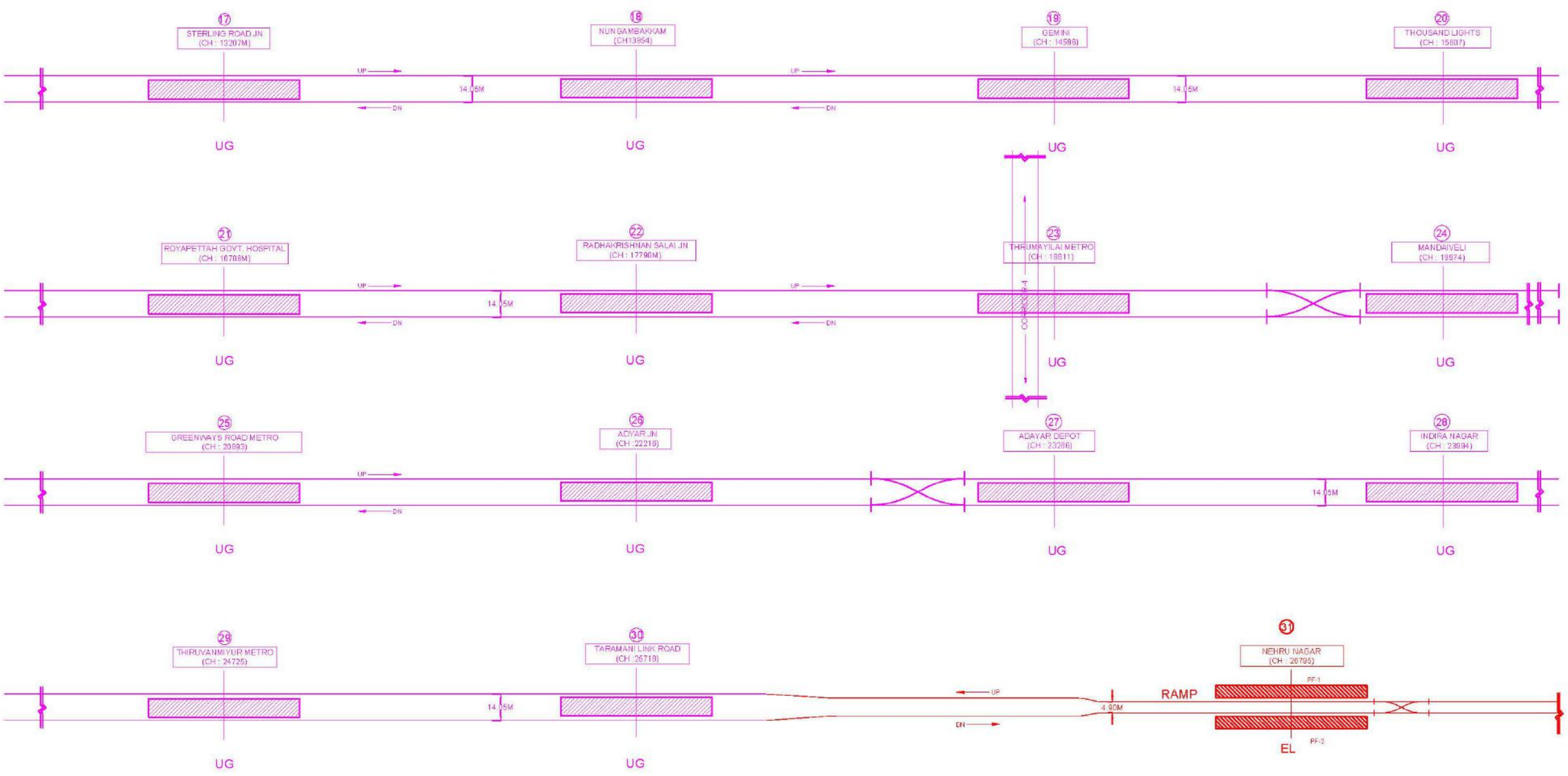


NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

SHEET-2/3

SCHEMATIC TRACK DIAGRAM

MADHAVARAM ⟷ SIPCOT CORRIDOR

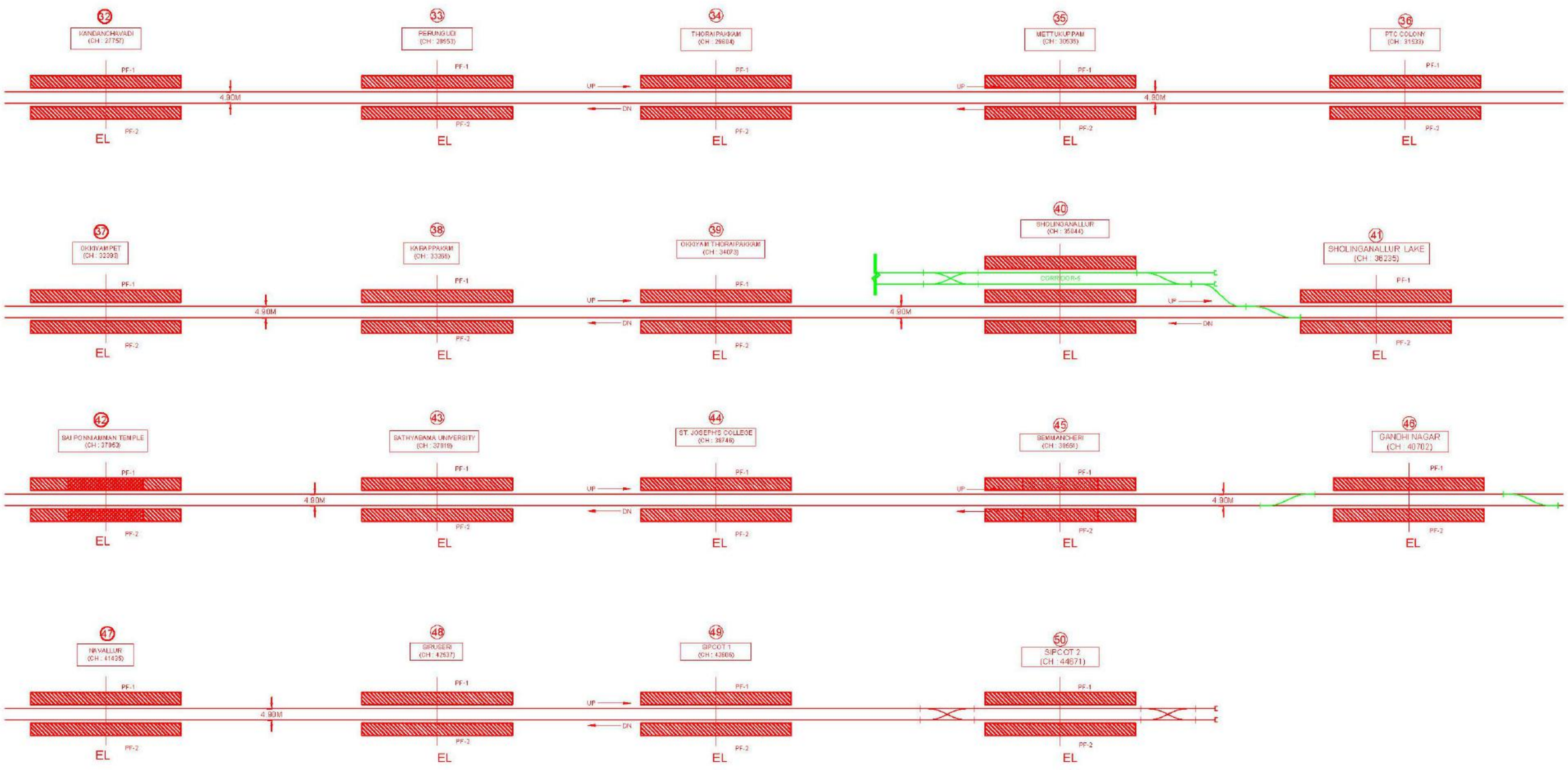


NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

SHEET-3/3

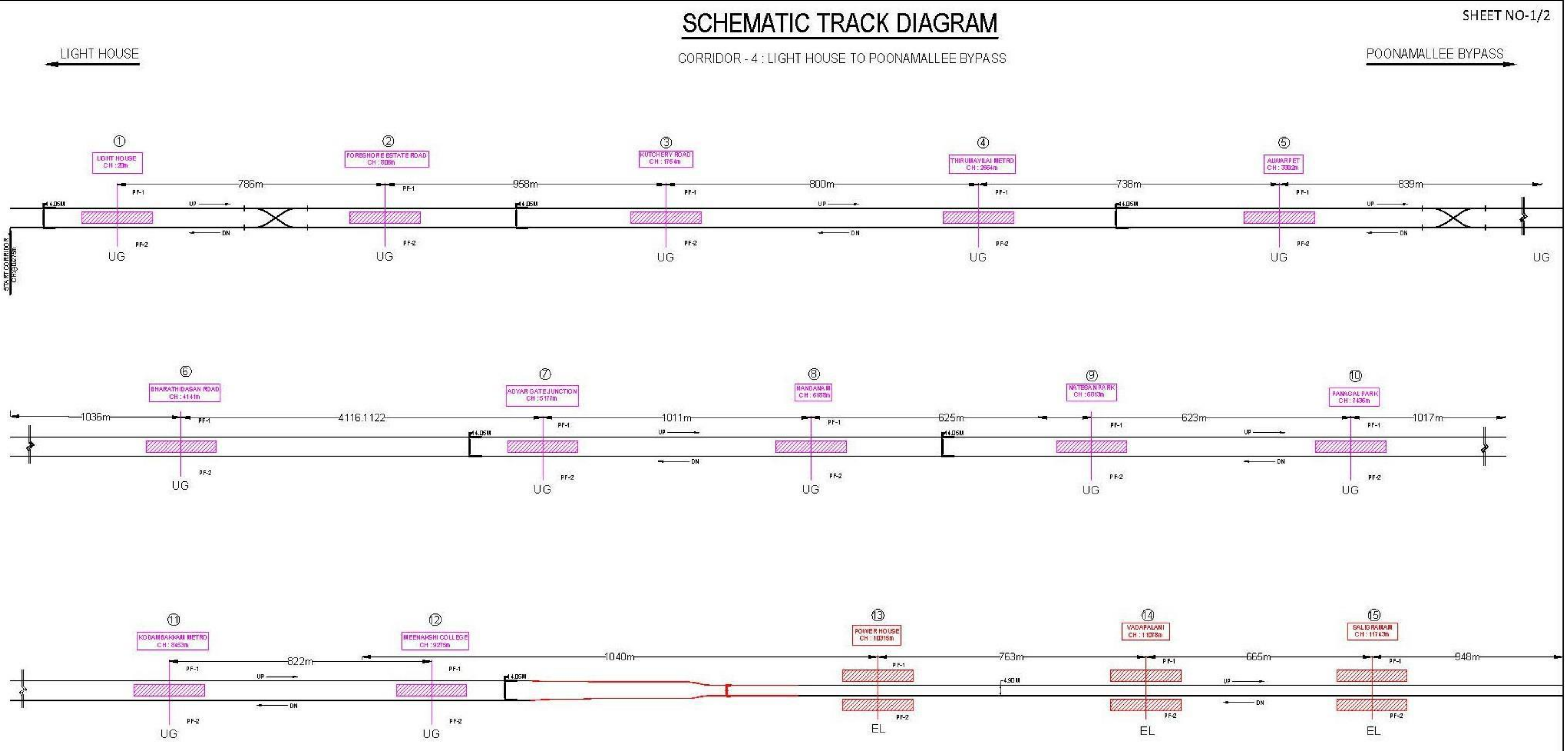
SCHEMATIC TRACK DIAGRAM

MADHAVARAM ⟷ SIPCOT CORRIDOR



NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

ANNEXURE 5.2: SCHEMATIC DIAGRAM OF CORRIDOR – 4



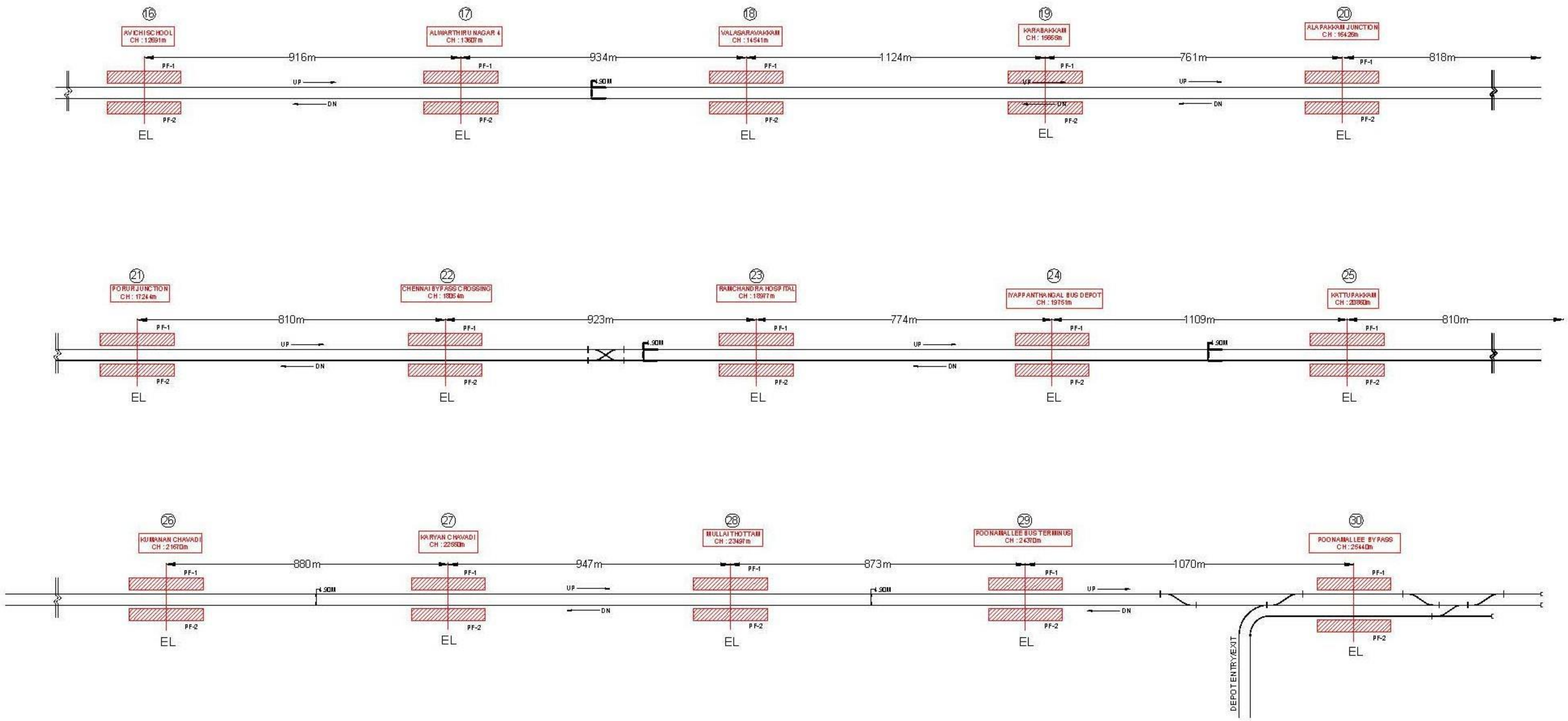
NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

SHEET NO-2/2

SCHEMATIC TRACK DIAGRAM

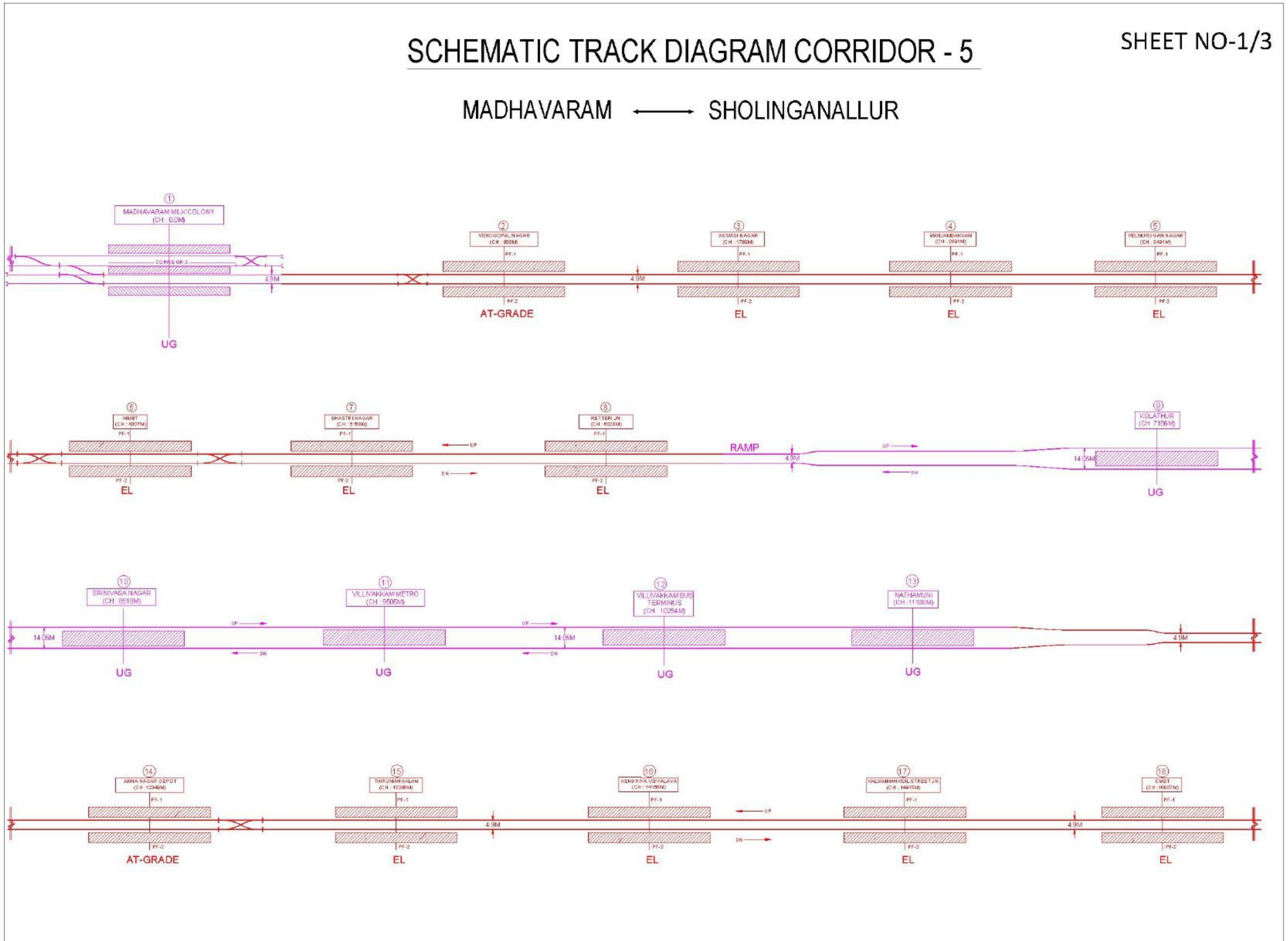
CORRIDOR - 4 : LIGHT HOUSE TO POONAMALLEE BYPASS

LIGHT HOUSE ← → POONAMALLEE BYPASS



NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

ANNEXURE 5.3: SCHEMATIC DIAGRAM OF CORRIDOR – 5

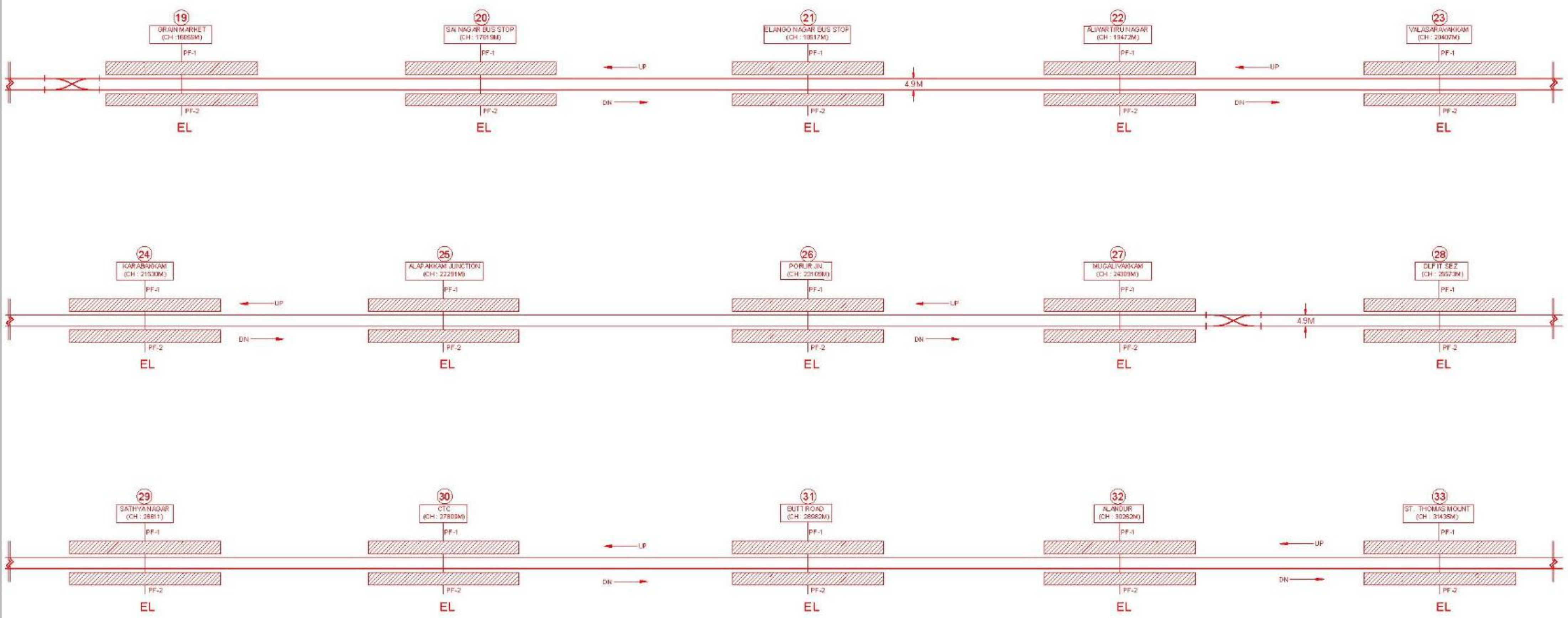


NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

SCHEMATIC TRACK DIAGRAM CORRIDOR - 5

SHEET NO-2/3

MADHAVARAM ⟷ SHOLINGANALLUR

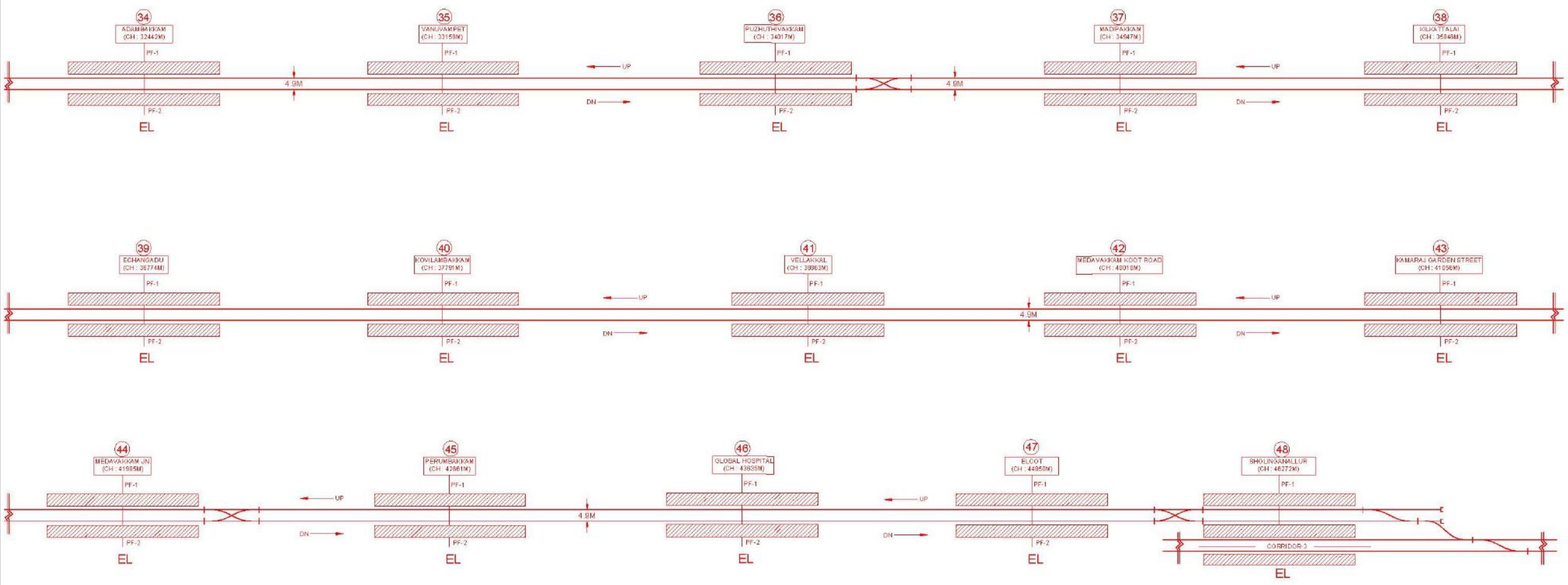


NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

SHEET NO-3/3

SCHEMATIC TRACK DIAGRAM CORRIDOR - 5

MADHAVARAM ⟷ SHOLINGANALLUR



NOTES:
1) IN UNDERGROUND SECTIONS, THE MAIN LINES WITH TRACK CENTRE 14.05M ARE PROVIDED WITH SCISSOR CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 190M.
2) IN ELEVATED SECTIONS, THE MAIN LINES WITH TRACK CENTRE 4.9M ARE PROVIDED WITH CROSSOVERS WITH 1 IN 9 TURNOUT & LEAD RADIUS 300M.
3) EL INDICATES ELEVATED AND UG INDICATES UNDERGROUND
4) NOT TO SCALE

6. STATION PLANNING

6.1 COVERAGE

The proposed metro rail system has been planned to serve major passenger catchment areas/ destinations and to enable convenient integration with other modes of transport. Stations vary in complexity along the route and have been located by an interactive process influenced by alignment, ridership forecasts, Inter-station Distance (ISD)/station spacing, land availability, interchange requirements with other modes of transport, utilities, road and pedestrian requirements, etc.

The locations of stations along the three metro corridors of Phase II have been finalized after joint site visits and extensive consultation with Chennai Metro Rail Limited (CMRL) officials.

The stations and their proposed attributes are presented in **Table 6.1** and **Figure 6.1**.

TABLE 6.1: INTER-STATION DISTANCE AND TYPE OF PROPOSED PHASE II STATIONS

SN	Station Name	Inter-station Distance (m)	Cumulative Distance (m)	Elevated/ Underground
	Corridor 3: Madhavaram to SIPCOT			
1	Madhavaram Milk Colony	-	0	UG (190x44.60) 2L
2	Thapalpetti	980	980	UG (150x21.40) 2L with ext. concourse
3	Murari Hospital	720	1700	UG (190x21.80) 2L
4	Moolakadai	761	2461	UG (190x21.80) 2L
5	Sembiyam	960	3421	UG (190x21.80) 2L
6	Perambur Market	861	4282	UG (190x21.80) 2L
7	Perambur Metro	727	5009	UG (150x21.40) ML
8	Ayanavaram	957	5966	UG (190x21.80) 2L
9	Otteri	1110	7076	UG (190x21.80) 2L
10	Pattalam	776	7852	UG (190x21.80) 2L
11	Perambur Barracks Road	869	8721	UG (190x21.80) 2L
12	Doveton Junction	829	9550	UG (190x21.80) 2L
13	Purasaiwakkam High Road	614	10164	UG (150x21.40) 2L with ext. concourse
14	Kelleys	677	10841	UG (150x21.40) 3L
15	KMC	683	11524	UG (150x21.40) ML
16	Chetpet Metro	838	12362	UG (150x21.40) ML
17	Sterling Road Junction	845	13207	UG (150x21.40) 2L With ext. concourse
18	Nungambakkam	747	13954	UG (150x21.40) ML

SN	Station Name	Inter-station Distance (m)	Cumulative Distance (m)	Elevated/ Underground
19	Gemini	642	14596	UG (150x21.40) ML
20	Thousand Lights	1071	15667	UG (150x21.40) ML
21	Royapettah Govt. Hospital	1041	16708	UG (150x21.40) ML
22	Radhakrishnan Salai Jn	1082	17790	UG (190x21.80) 2L
23	Thirumayilai Metro	1021	18811	UG (150x21.40) 2L With ext. concourse
24	Mandaiveli	1163	19974	UG (150x21.40) 2L With ext. concourse
25	Greenways Road Metro	919	20893	UG (190x21.80) 2L
26	Adyar Junction	1323	22216	UG (150x21.40) ML
27	Adyar Depot	1070	23286	UG (190x21.80) 2L
28	Indira Nagar	708	23994	UG (190x21.80) 2L
29	Thiruvanmiyur Metro	731	24725	UG (190x21.80) 2L
30	Tharamani Link Road	993	25718	UG (190x21.80) 2L
31	Nehru Nagar	1077	26795	Elevated (140x32.35)
32	Kandanchavadi	962	27757	Elevated (140x37.04)
33	Perungudi	796	28553	Elevated (140x32.35)
34	Thoraipakkam	1051	29604	Elevated (140x32.35)
35	Mettukuppam	931	30535	Elevated (140x32.35)
36	PTC Colony	998	31533	Elevated (140x32.35)
37	Okkiyampet	860	32393	Elevated (140x32.35)
38	Karapakkam	872	33265	Elevated (140x32.35)
39	OkkiyamThoraipakkam	808	34073	Elevated (140x32.35)
40	Sholinganallur	971	35044	Elevated (140x60.00)
41	Sholinganallur Lake	1191	36235	Elevated (140x32.35)
42	Sri Ponniamman Temple	818	37053	Elevated (140x32.35)
43	Sathyabama University	866	37919	Elevated (140x32.35)
44	St. Joseph's College	827	38746	Elevated (140x32.35)
45	Semmancheri	805	39551	Elevated (140x32.35)
46	Gandhi Nagar	1151	40702	Elevated (140x32.35)
47	Navallur	733	41435	Elevated (140x32.35)
48	Siruseri	1102	42537	Elevated (140x37.04)
49	SIPCOT 1	1069	43606	Elevated (140x21.95)
50	SIPCOT 2	1065	44671	Elevated (140x21.95)
	Corridor 4: Lighthouse to Poonamallee Bypass			
1	Lighthouse	20		UG (190x21.80) 2L
2	Foreshore Estate Road	806	786	UG (190x21.80) 2L
3	Kutchery Road	1764	958	UG (190x21.80) 2L
4	Thirumayilai Metro	2564	800	UG (190x21.80) 2L
5	Alwarpet	3302	738	UG (190x21.80) 2L
6	Bharathidasan Road	4141	839	UG (190x21.80) 2L

SN	Station Name	Inter-station Distance (m)	Cumulative Distance (m)	Elevated/ Underground
7	Adyar Gate Junction	5177	1036	UG (150x21.40) 3L
8	Nandanam	6188	1011	UG (150x21.40) ML
9	Natesan Park	6813	625	UG (150x21.40) 3L
10	Panagal Park	7436	623	UG (150x21.40) 2L With ext. concourse
11	Kodambakkam Metro	8453	1017	UG (150x21.40) ML
12	Meenakshi College	9275	822	UG (190x21.80) 2L
13	Power House	10315	1040	Elevated(140x21.95)
14	Vadapalani	11078	763	Elevated(140x21.95)
15	Saligramam	11743	665	Elevated(140x21.95)
16	Avichi School	12691	948	Elevated(140x21.95)
17	Alwarthiru Nagar	13607	916	Elevated(140x21.95)
18	Valasaravakkam	14541	934	Elevated(140x21.95)
19	Karabakkam	15665	1124	Elevated(140x21.95)
20	Alapakkam Junction	16426	761	Elevated(140x21.95)
21	Porur Junction	17244	818	Elevated(140x21.95)
22	Chennai Bypass Crossing	18054	810	Elevated(140x21.95)
23	Ramchandra Hospital	18977	923	Elevated(140x21.95)
24	Iyappanthangal Bus Depot	19751	774	Elevated(140x21.95)
25	Kattupakkam	20860	1109	Elevated(140x21.95)
26	KumananChavadi	21670	810	Elevated(140x21.95)
27	KaryanChavadi	22550	880	Elevated(140x21.95)
28	Mullaithottam	23497	947	Elevated(140x21.95)
29	Poonamallee Bus Terminus	24370	873	Elevated(140x21.95)
30	Poonamallee Bypass	25440	1070	Elevated(140x21.95)
	Corridor 5: Madhavaram to Sholinganallur			
1	Madhavaram Milk Colony	0		UG (190x44.60) 2L
2	Venugopal Nagar	868	868	At Grade(140x33.95)
3	Assissi Nagar	1789	921	Elevated(140x21.95)
4	Manjambakkam	2691	902	Elevated(140x21.95)
5	Velumurugan Nagar	3491	800	Elevated(140x21.95)
6	MMBT	4307	816	Elevated(140x21.95)
7	Shastri Nagar	5168	861	Elevated(140x21.95)
8	Retteri Junction	6028	860	Elevated(140x32.35)
9	Kolathur Junction	7186	1158	UG (190x21.80) 2L
10	Srinivasa Nagar	8518	1332	UG (190x21.80) 2L
11	Villivakkam Metro	9505	987	UG (150x21.40) ML
12	Villivakkam Bus Terminus	10254	749	UG (150x21.40) 2LWith extended concourse
13	Nathamuni	11106	852	UG (190x21.80) 2L
14	Anna Nagar Depot	12349	1243	Elevated(140x21.95)

SN	Station Name	Inter-station Distance (m)	Cumulative Distance (m)	Elevated/ Underground
15	Thirumangalam	13366	1017	Elevated(140x32.35)
16	Kendriya Vidyalaya	14158	792	Elevated(140x21.95)
17	Kaliammankoil Street Junction	14915	757	Elevated(140x21.95)
18	CMBT	16007	1849	Elevated(140x21.95)
19	Grain Market	16855	848	Elevated(140x21.95)
20	Sai Nagar Bus Stop	17619	764	Elevated(140x21.95)
21	Elango Nagar Bus Stop	18517	898	Elevated(140x21.95)
22	Alwartirunagar	19472	955	Elevated(140x21.95) Double ht., common with C4
23	Valasaravakkam	20407	935	Elevated(140x21.95) Double ht., common with C4
24	Karabakkam	21530	1123	Elevated(140x21.95) Double ht., common with C4
25	Alapakkam Junction	22291	761	Elevated(140x21.95) Double ht., common with C4
26	Porur Junction	23109	818	Elevated(140x21.95) Double ht., common with C4
27	Mugalivakkam	24309	1200	Elevated(140x21.95)
28	DLF IT SEZ	25573	1264	Elevated(140x21.95)
29	Sathya Nagar	26611	1038	Elevated(140x21.95)
30	CTC	27809	1198	Elevated(140x21.95)
31	Butt Road	28982	1173	Elevated(140x21.95)
32	Alandur	30262	1280	Elevated(140x21.95)
33	ST. Thomas Mount	31435	1173	Elevated(140x21.95)
34	Adambakkam	32442	1007	Elevated(140x21.95)
35	Vanuvampet	33159	717	Elevated(140x21.95)
36	Puzhuthivakkam	34017	858	Elevated(140x21.95)
37	Madipakkam	34947	930	Elevated(140x21.95)
38	Kilkattalai	35846	899	Elevated(140x21.95)
39	Echangadu	36774	928	Elevated(140x32.35)
40	Kovilambakkam	37791	1017	Elevated(140x21.95)
41	Vellakkal	38863	1072	Elevated(140x21.95)
42	MedavakkamKoot Road	40010	1147	Elevated(140x32.35)
43	Kamaraj Garden Street	41056	1046	Elevated(140x32.35)
44	Medavakkam Junction	41985	929	Elevated(140x21.95)
45	Perumbakkam	42661	676	Elevated(140x21.95)
46	Global Hospital	43635	974	Elevated(140x21.95)
47	ELCOT	44850	1215	Elevated(140x21.95)
48	Sholinganallur	46272	1422	Elevated(140x60.00)

FIGURE 6.1: CHENNAI METROPHASE - II CORRIDORS WITH STATION LOCATIONS

6.2 STATION PLANNING REQUIREMENTS

6.2.1 Station Planning – Coverage

The station planning will respond to and be determined by the following factors:

- Operational requirements in the use of center and side platforms: Generally, the underground stations are planned around island platforms, while elevated stations are proposed to have side platforms. In special circumstances, underground stations can also be planned with side platforms.
- Station boarding/alighting and the resulting entry/exit location requirements
- Ground constraints of rail levels due to the presence of existing/planned structures such as flyovers, ramps etc.
- Utilities such as firefighting systems, ventilation, water requirements
- Structural requirements
- Flexibility in design to allow stations to respond to site specific requirements
- Future expansion if required

The essential quality in a good station layout is the provision of adequate space for efficient movement of passengers between ground level entrances on to the trains and vice versa in the most direct, simple and logical way.

6.2.2 Salient Features of a Typical Station

a. Station entrances provide the link between station concourse and the surrounding streets and their location must reflect the separate constraints of both. Station entrances are located with particular reference to passenger catchment points and also cater for inter modal interchange which includes buses, IPTs, pick/drop by private mode etc.

b. Important criteria that has been applied in the development of station planning include:

- Sizing of Station Passenger Facilities
- Stipulated Design Standards
- Emergency Evacuation
- Passenger circulation, comfort, ease of use, safety and security
- Operational accommodation (Back of House Areas)
- Electrical and Mechanical Plant and Equipment space requirements

c. Concourse forms the interface between streets and the platform. This is where all the passenger amenities are provided.
d. Office accommodation, operational areas and plant room space are provided in the non-public areas of the station.
e. The platform level has been designed for adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario (emergency).
f. The location of DG set, Bore Well Pump House, Underground / overhead tank, chiller plant and Pump Houses are preferably proposed to be located in one area at ground level wherever possible.

6.2.3 Planning Norms & Standards

1. General

a. Station Planning is dependent on the peak hour traffic load for each station. The planning norms have been considered for the design year, when maximum PHPDT is achieved in each of the three Phase- II corridors. Accordingly maximum capacity required at any station for emergency evacuation has been adopted.

b. The platform length is planned for6 cars/train with a train length of 140m.

c. The station planning is also in compliance to the "Emergency Evacuation Guidelines" as per National Fire Protection Association (NFPA) 130, National Building Code 2016 & “Guidelines and Space Standards for Barrier Free Built Environment for Disabled and Elderly persons” published by the Ministry of Urban Affairs and Employment India in 1998.
d. Central Public Works Department’s (CPWD) “Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons-1998” and 2013 edition (under revision by Ministry of Home and Urban Affairs, MoHUA), and other international best practices / standards.
e. The egress requirement (Platform to Concourse), platform width calculations and evacuation time calculations for the design year 2055.

2. Entry/Exit

a. Entrances to stations have adequate capacity to satisfy predicted passenger flows and emergency evacuation requirement.

b. The position of entrances is determined by the juxtaposition of building location of roadway footpath width, space availability and flow directions of passenger traffic.

c. The numbers and width of staircases/ escalators are determined by checking the capacity/available width against peak passenger flows rates for both normal and emergency conditions such as delayed train service, fire etc.

d. All entrances extending to street level are proposed to be protected against flooding. This protection is done by the provision of a minimum of 3 steps up to a landing (+450 mm minimum)

3. Walkways/Ramps

a. Walkways / ramps are planned based on established principles of pedestrian flow and arranged to minimize unnecessary walking distances and cross-flows between incoming and outgoing passengers. Cross flow and changes in direction are minimized or eliminated.

b. Minimum Corridor width

- Unidirectional movement: 1.8m
- Bi-directional movement: 2.0m
- Where length of the corridor is more than 30m: 3.0m
- For staff: 1.2m

c. Ramps

- Preferred gradient: 1:20
- Maximum gradient: 1:12
- Minimum width:
  - Unidirectional movement: 1.2m
  - Bi-directional movement: 1.5m
- For ramp exceeding 10m,rest platform: 1.8m

d. The walkways, ramps, platform width etc have been planned for a minimum Level of Service (LOS) E. The pedestrian Flow Analogy with respect to Level of Service is detailed below in **Figure 6.2 and Table 6.2.**

FIGURE 6.2: PEDESTRIAN FLOW ANALOGY

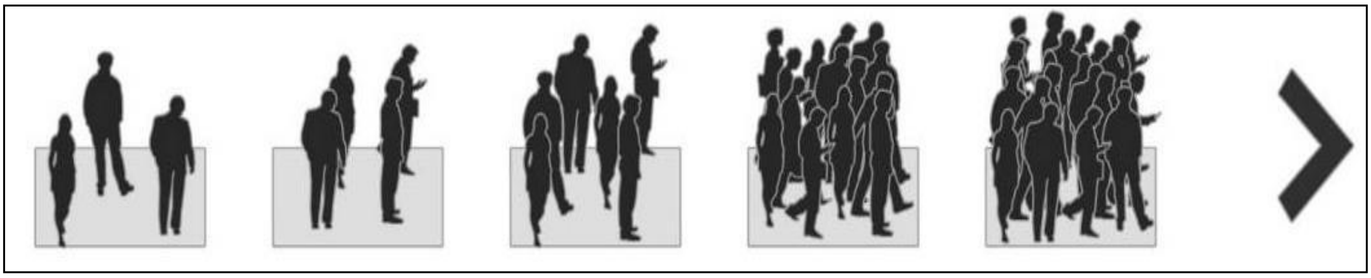


TABLE 6.2 LOS CRITERIA FOR PEDESTRIANS

LOS A	LOS B	LOS C	LOS D	LOS E	LOS F
1.2 m^2 /p	1.0 m^2 /p	0.6 m^2 /p	0.35 m^2 /p	0.2 m^2 /p	<0.15 m^2 /p
Space for standing and free circulation	Restricted circulation through queue without disturbing others	Restricted circulation through queue by disturbing others	Standing without personal conflict with others but circulation through queue is severely restricted	Space provided for standing with personal conflict. Circulation within queue is impossible.	Very close contact, physical and psychological discomfort.

4. Disabled Friendly Features

Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons-1998 and revised in 2013 by Ministry of Home and Urban Affairs and other international best practices have been considered.

Signage planning considering clear, concise, and consistent fonts to be adopted. All travellers need clear information about the purpose and layout of stations 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). The international symbol of accessibility is shown in **Figures 6.3** and **6.4.**

FIGURE 6.3: WAY FINDING SIGNAGE

FIGURE 6.4: INTERNATIONAL SYMBOL OF ACCESS

5. 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 etc. along the route traversed by the guidance paver. Also, there should be clear headroom of at least 2.1 m 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)

These pavers 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.

6. 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 metro stations or boarding areas.
- Guiding & warning tactile paving for metro systems are shown in the **Figures 6.5** & **6.6**.

7. Concourse Planning Standards

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

FIGURE 6.5: GUIDING PAVER

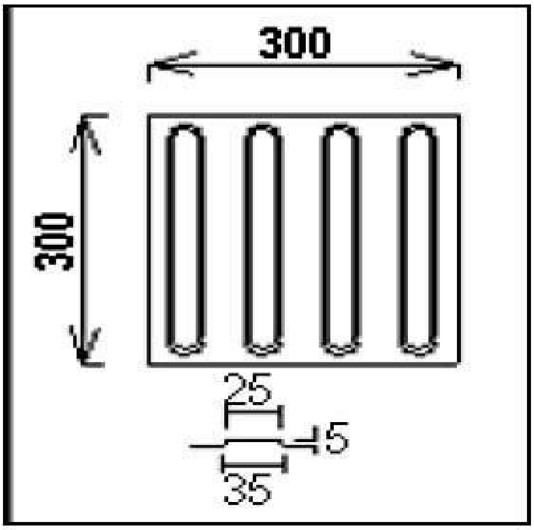
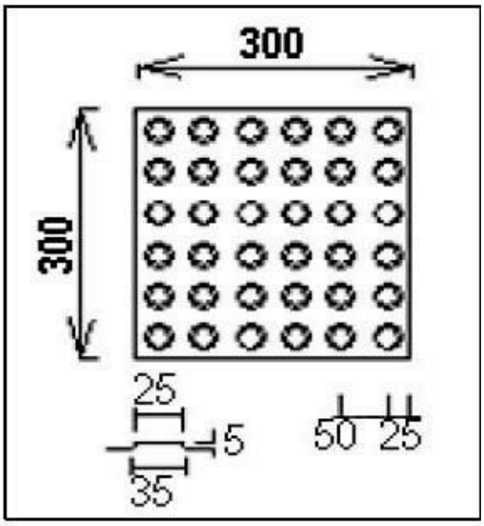


FIGURE 6.6: WARNING PAVER



The stations are divided into public and non-public areas (those areas where access is restricted). The public areas are further subdivided into paid and unpaid areas. The concourse contains Automatic Fare Collection system (AFC) in a manner that divides the concourse into two distinct areas called 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. **Figures 6.7** and **6.8** show typical arrangement of an elevated station and an underground station respectively.

FIGURE 6.7: ARRANGEMENT OF A TYPICAL ELEVATED STATION

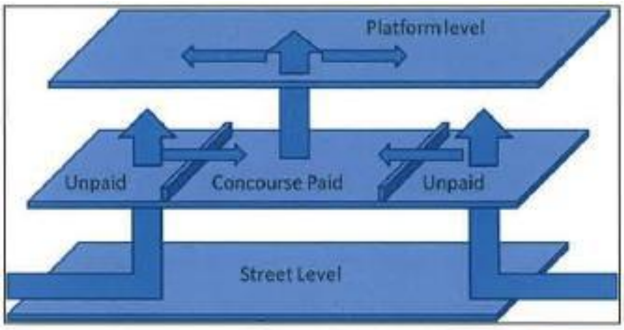
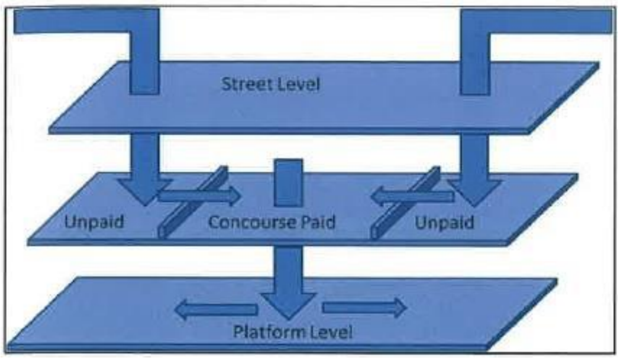


FIGURE 6.8: ARRANGEMENT OF A TYPICAL UNDERGROUND STATION



The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space.

Sufficient space for queuing and passenger flow has been proposed in front of the ticketing counters and AFCs gates.

The “Non Public Areas” comprise of the Back of House (BOH) areas. The BOH areas consists of PST, system rooms, operations, staff facilities, tunnel ventilation system, station ventilation system, water supply and drainage system and miscellaneous requirements. The description of such areas is also detailed in the subsequent paragraphs.

Passenger handling facilities comprise of stairs/escalators, lifts, ticketing counters/automatic ticket vending machines and ticket gates required to process the peak traffic from street to platform and vice-versa. These facilities are provided in the concourse and they also act as a medium to transfer between Paid and Unpaid areas (these facilities also enable evacuation of the station under emergency conditions, within a set safe time limit). Uniform number of these facilities has been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station based on the peak hour passenger load.

Figure 6.9 & Figure 6.10 shows a typical cross-section explaining the movement within an elevated station and an underground station respectively.

FIGURE 6.9: CROSS-SECTION OF A TYPICALELEVATED STATION

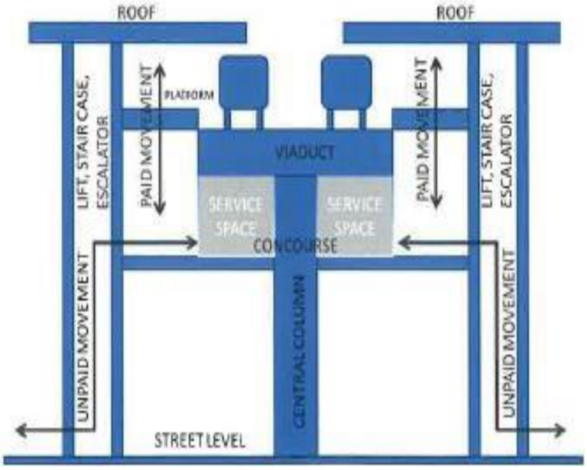
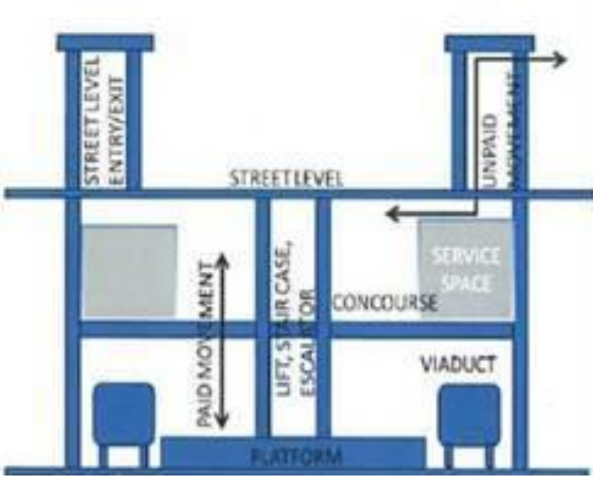


FIGURE 6.10: CROSS-SECTION OF A TYPICAL UNDERGROUND STATION



8. Operational Rooms for Public Use

Ticketing Gates

a. The ticketing system shall be simple, easy to use/operate, and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and requiring less man power.

b. The requirement of the number of gates is based on the peak hour passenger traffic at the station. Uniform space has been provided at all stations where gates can be installed in the unpaid area of the concourse. Ticketing gates provides a means of transfer between paid and unpaid area of the concourse.

c. Ticketing gates' requirement has been calculated taking the gate capacity as 28 persons per minute per gate (85% of the maximum practical capacity which is taken as 35 persons per minute per gate). In the design year output capacity of 35 passengers is assumed because of passenger's familiarity with system. At least two ticketing gates are provided at any elevated station and four ticketing gates for Underground stations even if requirement is satisfied with only one gate.

d. The gate design will depend upon;

- Check in and checkout (distance fare): implying bi-directional gates
- Fare media: smart card, magnetic or paper ticket.
- The most popular gates are with sliding glass panels ("pavel" design)

e. Special gates are designed for;

- Widened ticket gates for Disabled persons' access,
- Customers with luggage,
- Customers with strollers

f. The total number of gates also includes one service gate, one emergency exit door in case of breakdown, one separate gate for disabled in Elevated stations and two separate gates for disabled in Underground stations.

9. Ticket Counters and Ticket Vending Machines (TVMs)

a. It is proposed to deploy manual ticket issuing counters in the beginning of the operation of the line. At a later stage, automatic TVMs would be used, for which space provision will be made at the concourse. Capacity of manual ticket vending counters is assumed as 5 passengers per minute and it is assumed that only 10% of the commuters would purchase tickets at the stations while performing the journeyin design year. The rest are expected to buy prepaid tickets, prepaid cards, smart cards etc. About 10% of the smart card users will use the ticket window for renewal/recharging etc. Accordingly, the requirement of ticket counters has been calculated and the same provided for in the plans.

b. The number of TVMs required is governed by the peak hour passenger traffic, the fare policy and the ticketing. Depending on the composition of monthly pass/smart card users and single ticket users, the number of TVMs could change.

c. Adequate provision has been kept at the stations for the TVM and ticket counters in the unpaid area of the concourse and is suitably located for the ease of usability of the passengers. As a general thumb rule, it is proposed to provide 5 to 7 TVMs for stations with high traffic and 2 to 5 TVMs for other stations. Interchange stations may be provided with 7 to 10 TVMs. The ticket vending machines at stations is presented in **Figure 6.11.**

FIGURE 6.11: TICKET VENDING MACHINES AT STATIONS

MTR Wall mounted TVM with maintenance corridor in the back – Paris

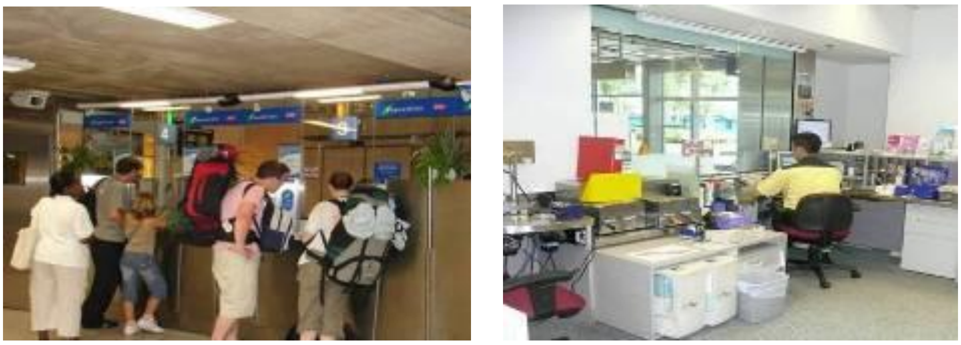
Shinjuku Station Tokyo

10. Ticket Office

a. The number of ticket offices is determined by the passenger traffic and the operation policy.

b. A minimum of 2 ticket office per station in the stations with high traffic, and 1 ticket office per station in the stations with low traffic have been planned **(Figure 6.12)**

FIGURE 6.12: TICKET OFFICE AT STATIONS



Passenger Amenities

Toilets for disabled are proposed to be provided at all stations in accordance with the technical provisions of the project.

11. Platform Planning Standards

a. The length of the Platform is 140 m. This allows for the length of 6 car train and a stopping tolerance for the rail corridor Platforms.

b. The nominal platform width measured from the platform edge to any continuous (longer than 2000mm) fixed structure shall be a minimum of 3000 mm. The minimum distance from the platform edge to any isolated obstruction e.g. columns, shall be 2500 mm (an isolated obstruction shall not be longer than 2000 mm). This clearance shall be maintained for safety reasons, irrespective of passenger flows. The platform width greater than the minimum may be required at stations with large passenger flows.

c. The platform edge shall have a safety margin of 600 mm wide with a non-slip surface and a yellow warning strip of 100 mm wide of contrasting texture. The platform ends shall be provided with a 1200 mm wide security gate and be installed with a pressure mat alarm system.

d. Platform widths shall be determined to cater to the following scenarios:

i. **Normal service:** The platform width shall be determined by multiplying the peak minute flow by 0.2 sqm/person and headway, then dividing by the platform length.

ii. **Delayed/Emergency service:** The platform width shall be determined by the peak minute flow, allowing for two missed headways. The crush load is taken as the sectional load between two stations. For an island platform, the area between the boundaries of the two platforms is included in the calculation.

e. The process to derive the platform width calculations are detailed below:

Disruption of time of service: Two missed headways

Peak Minute Peak Direction Boarding: Peak hour Peak direction boarding/50. The peak minute flow taken in the calculations is assumed to be 20% higher from the average minute flow as derived from the hourly passenger volume. This takes into account the peaking minute during the peak hour flow of the passengers.

Platform congregation during disrupted time of service: Peak minute peak direction boarding X disrupted time

Platform Width: {Platform congregation during disrupted time of service + Train Sectional Load} X 0.2/Platform length

(0.2 sq m/person has been taken as the platforms are planned for a minimum Level of Service E)

f. Platform shall be laid to a fall at 1:100 from the inner face of platform screen doors for a distance of 3000 mm towards the back of the platform.

g. Markings on the platform and ramps to assist and control the flow of passengers for boarding and alighting with a step free access from/to the trains shall be provided. Tactile Markings shall also be provided for guiding paths and warning strips for vision impaired persons to ease the travel for persons with disabilities. The built platforms shall also provide for bright colour contrast for low vision persons; large lettering and information displays and digital signage; lifts with lowered control panel with Braille and raised control buttons and auditory signals, wide doors and grip rails on the sidewalls of the elevator car; resting areas for senior citizens and disabled persons; well-lit platform corridors along with public announcement system. Inside the coaches, there will be designated spaces for wheelchair users, audio announcement with dynamic display and sensory door closing mechanisms.

h. Space occupied by stairs, escalators, structure, seating, platform supervisor's accommodation etc. is not be included as part of the platform area.

i. Platforms shall have a clear head room of at least 3000 mm to structures and platform signs to a width of at least 2000 mm from the platform edge over their entire length. Suspended signs, fittings, and fixtures shall have a minimum clearance of 2100mm above finished floor.

j. Platforms shall be provided with automatic screen walls/platform screen doors to ensure safety of passengers. The platform screen doors would open on arrival of train in sync with the train doors. The platform screen doors would be full height (till ceiling level) in Underground stations.

12. Emergency Evacuation Standards

a. The requirement is to evaluate people from a station platform to another location, initially the next level below or above and then on to street level without hindrance.

b. The principles to be followed are: -

i. The NFPA 130 states that the station also shall be designed to permit evacuation from the most remote point on the platform to a point of safety in 6 minutes or less. The maximum travel distance on the platform to a point at which a means of egress route leaves the platform shall not exceed 100 m (300 ft).

ii. For enclosed stations equipped with an emergency ventilation system, that concourse is permitted to be defined as a point of safety.

iii. As per NFPA, the maximum time to evacuate a platform should not be more than 4 minutes. Considering, that for the maximum occupant load, the last person takes 4 minute to reach the nearest staircase/escalator/ fire escape staircase, the evacuation time calculation for a 3 level underground station is stated below:

iv. The provision in the station layouts from the most remote point on the platform to an exit route has been kept within 50 m.

v. Check shall be made to ensure that sufficient capacity exists at the level to which passengers are evacuated as being a place of ultimate safety so that people can move freely away from stairs and escalators as they arrive.

vi. The emergency is assumed to be occurring in one direction of travel only at any given point of time.

c. To optimize the length of the platform, 3 level underground stations have been proposed. The Evacuation time calculation for a 3 level underground station is as follows:

Time taken by the last person to evacuate the platform	4min
Time for climbing stairs/escalator till lower concourse of vertical height 6m (considering travel speed of 14.63m/min as per NFPA 130)	0.41min
Time for walking 20m will stairs leading to upper concourse in Lower concourse level (considering travel speed of 37.8m/min as per NFPA 130)	0.53 min
Time for climbing stairs/escalator till upper concourse of vertical height 5.25m (considering travel speed of 14.63m/min as per NFPA 130)	0.36min
Time for walking max 20m in the Upper Concourse Level (considering travel speed of 61.0m/min as per NFPA 130)	0.33min
Total Time	**5.63min**

d. For ensuring adequacy of platform area, stair widths and requirement of additional emergency evacuation stairs, a maximum accumulation of passengers in the station has been considered to be comprising waiting passengers at the platform (including two missed headways) and section load (or full train load if the section load exceeds a full train load) expected to be evacuated from the peak direction at the station in case of an emergency. Also, waiting passengers congregated during this disrupted time of service (two missed headways) in the off-peak direction to be added in the evacuation from the platform to concourse in case of underground stations and concourse to ground in both underground as well as elevated stations.

13. Operational Rooms (BOH Areas)

Back of House (BOH) areas comprise of "Public" and “Non Public Areas”. The BOH areas consist of PST, system rooms, operations, staff facilities, water supply and drainage system and miscellaneous requirements. A list of BOH areas along with their preferred location and the minimum size requirements is given in **Table 6.3.**

TABLE 6.3: SPACE REQUIREMENT SYNTHESIS FOR OPERATIONAL ROOMS IN TERMINAL STATIONS

S No.	Room name	Location	Min Size Requirement (sq. m)	Remarks
1.	Station Control room	Concourse Level	46-65	The room must be located so as to have a good overview of concourse activities and be accessible from the non-paid area.

S No.	Room name	Location	Min Size Requirement (sq. m)	Remarks
2.	Ticket office [Ticket booth] [Supervisors room]	Concourse Level, Unpaid Area	1.7m x 2.4m per booth	Queuing areas associated with this facility should not obstruct normal passenger flows between entrances and ticket gates.
3.	Ticket office Store & Safe	Preferably at concourse level	5-10 sq. m at both ends	Preferably within the paid area for added security but could be elsewhere.
4.	Excess Fare Office (free standing unit)	Concourse level. Located adjacent to AFC gates	6.25 sq. m at both ends	
5.	Store Room	Concourse level	9	
6.	Cleaners Room	Platform level	10	
7.	Refuse Store	Concourse unpaid area	10	Adjacent to street access
8.	Staff Toilets - Male	Concourse level	5	
9.	Staff Toilets - Female	Concourse level	6	
10.	Locker Room - Male	Concourse level	7	
11.	Locker Room - Female	Concourse level	10	
12.	Lunch Room	Concourse level	10	
13.	Signaling Room	Platform level	28-30	End of platforms preferred, well separated from rooms containing transformers
	Intermediate Stations			for non- inter locking near communications room
	Terminal/ Mid- terminal stations			for Interlocking station closer to track cross over.
14.	Communication Room	Concourse level and Platform level	80	Adjacent to or as near as possible to the station control room but well separated from station sub- station. Must be adjacent to UPS & Battery room.
	[Terminal/ Interchange stations]			
	Intermediate Stations			
15.	UPS Room	Concourse level	63	Adjacent to signaling room telecommunication Room
16.	Auxiliary Sub- Station (ASS) room	Concourse level or Platform level	128 sqm in elevated stations at one end and at both ends	
17.	Water Tank and Pump (inclusive of Fire Pump & Sprinkler room)	Ancillary Building	250-500	Ancillary building
18.	DG Room	Ancillary Building	130	Ancillary building
19.	Tunnel Ventilation Fan Room (including plenum and TVS plenum)	On platform/ concourse level. One TVF Room at one end	200 sq. m at one ends	The room shall be connected through the tunnel ventilation plenum to the running tunnels

S No.	Room name	Location	Min Size Requirement (sq. m)	Remarks
		of the station. Not adjacent to public areas or offices unless architectural measures to reduce noise break- out to acceptable levels are taken.		by 2 nos 4.5 m X 4.5 m openings with motorizes dampers. The dampers connecting the tunnel ventilation plenum to the tunnels shall preferably be directly above track way. Distance to be confirmed with smoke extraction system designer. suitable openings for mechanical ventilation to be provided on track side.
20.	Tunnel Ventilation Shaft	One shaft to be provided at each end of the station vertically from ground to concourse or platform level.	5.5 m X 5.5 m = 30.25 sq. m	Connected to TVF Room Tunnel ventilation inlets/ outlets arranged with vent supply inlets and vent exhaust outlets to avoid short circuiting of air/ smoke back into the station and tunnels.
21.	Mechanical Equipment Room (includes TVF control rooms, TVFs & AHU rooms)	Concourse level	450 sq. m at both ends	Concourse level. Not adjacent to public areas or offices unless architectural measures to reduce noise breakout to acceptable levels are taken.
22.	Sewage & Drainage Water Pump Room	Platform level	12	Preferably near or below toilets
23.	Ventilation Exhaust Shaft	One shaft to be provided at each end of the station vertically from ground to Mechanical Equipment Room	4.0 m x 2.5 m = 10 sq. m at both ends	Mezzanine or Concourse, depending on the situation configuration
24.	Ventilation Supply Shaft	One shaft to be provided at each end of the station vertically from ground to Mechanical Equipment Room	4.0 m x 2.5 m = 10 sq. m at both ends	Mezzanine or Concourse, depending on the situation configuration
25.	Over Track exhaust shaft (OTE)	Platform Level (Opened in TVS)	4.1 m x 1.85 m = 7.5 sq. m at one end of each Platform	
26.	Under Platform Exhaust Shaft	Platform Level (Opened in TVS)	1.59 m x 1.59 m = 2.53 sq. m at one end of each Platform	

S No.	Room name	Location	Min Size Requirement (sq. m)	Remarks
27.	Chilling Cooling Plant Room	Ground Level	300	Ancillary building
		Ground floor or above	Varies	Ventilation termination louvers/ grilles, whether part of a free standing structure or incorporated in any building shall not be located closer than 5 m from any other opening. The distance shall be measured from the edge of the louver to the face (external edge) for openings opposite to it. If an intake louver is located on the same face of a building as an exhaust louver, it shall be located a minimum of 1 m below the latter. When intake and exhaust louvers are located at 90°.
28.	Draft Release Duct	From platform level to ground	5.8 X 5.5=31.9 on either side or one side	

Some of the areas and their functions are detailed below:

a. Station Control Room

The station control room is required to control and monitor the stations' equipments (fire-fighting systems, ventilation, etc.). It is generally located in the concourse of each station. It is recommended that the operator can easily access any part of the station from this office. This room is fitted with a dialog box for passenger information.

b. Ticket Office

The Ticket Office can also be used to inform passengers. If the main Ticket Office is located next to the Station master control room, it will be fitted with a self-closing door between these two rooms. The room will require special protection (as armored glass, metal doors, etc.).

c. Security/Police Room

This room is located in each station and is used by the security staff. It is preferable that this room is located at the concourse, in the public operation area allowing watching over the public. This room could be fitted with specific equipment in relation to the role of security staff.

d. Passenger Amenities

Toilets for public are not specific operation rooms but will be provided at all stations in accordance with the technical provisions of the project. The toilets would be located on both elevated and UG stations in the paid area.

e. Audit and Cash Storage Room

The audit and cash storage room will be located in the ticket office. A “protective wall” will be required in the ticket office, in order to obstruct the visibility of cash handling from the public. For security reasons, it is recommended to collect cash every day from the ticket office and at regular intervals from the ticket vending machines of the station.

f. Male and Female Locker and Rest Rooms

These rooms shall be close to the staff operation areas. Male & female staff members shall have separate access, in the non-public operation area. The area of these rooms will depend on the number of employees in each station.

g. Male and Female Staff Toilet

It is recommended to fit the stations with specific toilets for the employees. Separate male and female toilets shall be provided in each station.

h. Cleaner's Room

Cleaning and garbage rooms are not specific operation rooms but must be located in every station. These rooms shall be close to each other. Hot and cold water shall be available in the cleaning room.

Building Electrical and Mechanical Services (BEMS) Design Parameters

<u>Water Storage</u>

The planning of the water tank is based upon the assumption of 35 litre/person for raw and treated water. The capacity of the water tank is provided as 50 cu.m approximately for each elevated station and 200 cu.m for underground station.

<u>Electricity</u>

One DG set of 180 KVA is proposed to be provided at each elevated station (which does not include the power supply of the train) along with one auxiliary substation.

Two sets of 630 KVA and one auxiliary substation for underground stations are proposed.

Tunnel Ventilation System

The TVS is provided in a Subway system essentially to carry out the following functions:

a. Train Pressure Relief during Normal Operation

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.

b. Ventilation during Maintenance Periods, if required

c. Removal of Smoke during Emergency Conditions

The ventilation system should be capable of providing a smoke-free evacuation route for the passengers and for the intervention of the emergency crews in the event of fire in a running tunnel. Generally, the only practicable way to provide such conditions is to ventilate the incident tunnels longitudinally such that smoke moves only downstream of the fire. The strategy ensures that smoke free conditions are maintained upstream of the fire both for the passengers and for the emergency crews. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction.

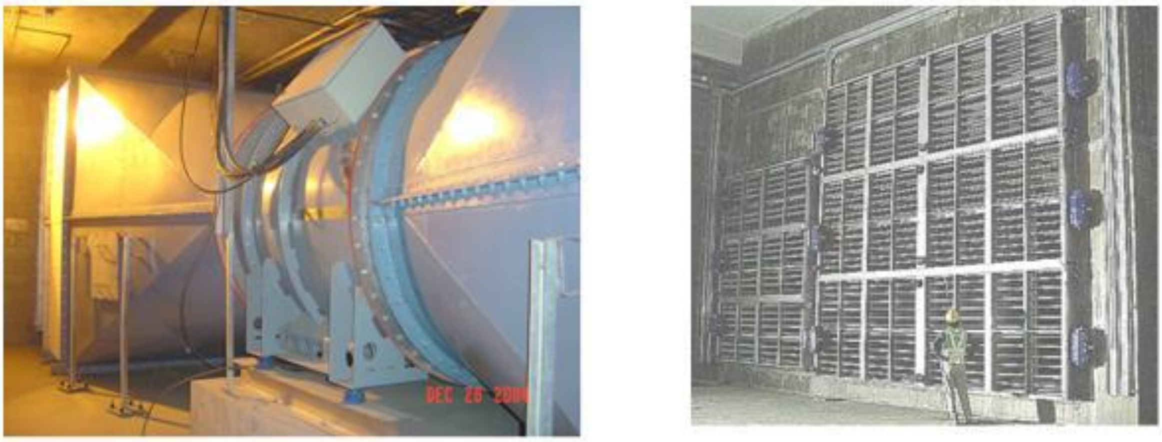
This arrangement incorporates shared fans where the ventilating air flow is directed to the incident running tunnel by means of the selective operation of control dampers. The ventilating air is delivered to the incident tunnel to control the movement of smoke within the tunnel. Similar plant at the downstream end of the tunnel is designed to capture the smoke and discharge it directly to atmosphere. The tunnel ventilation system is reversible and is able to ventilate an incident running tunnel in either direction. The selected direction of ventilation is determined by the location of the fire along the length of the incident train; to provide smoke-free conditions over the longer length of the train.

d. Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies

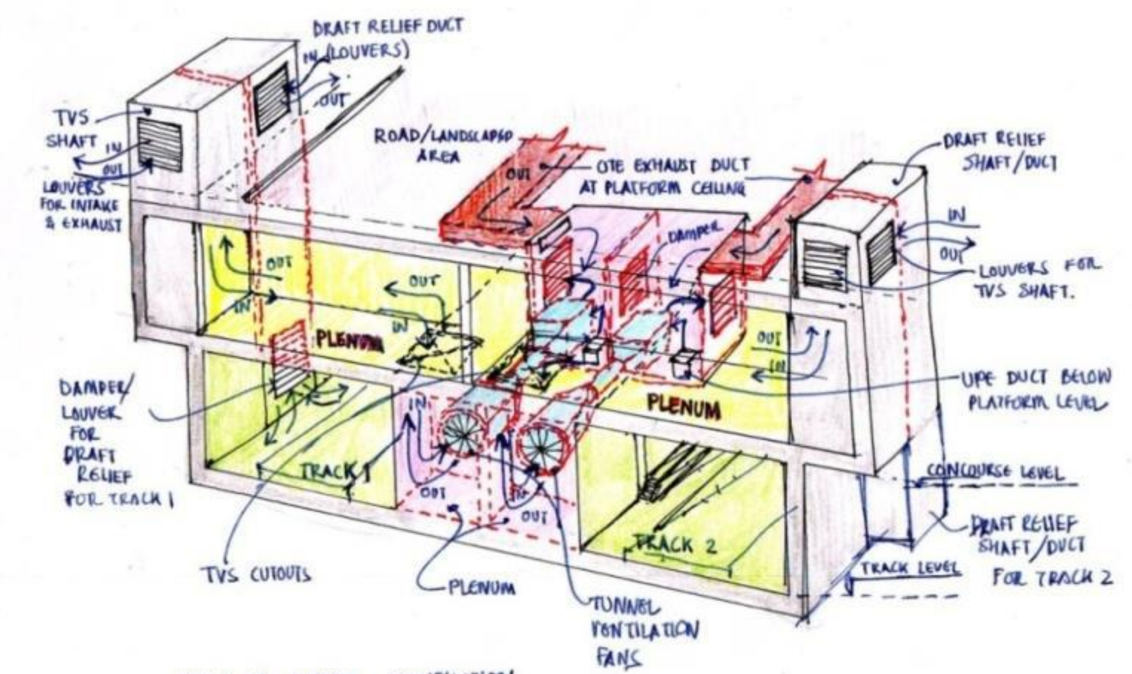
The design and sizing of the tunnel ventilation system of an underground metro rail project is defined principally by the following:

- Design of the rolling stock, including the design fire size
- Operating procedures, including the frequency and speed of the trains, and the procedures for the response to an incident
- Required maintenance practices
- Architecture of the stations
- Diameter and alignment of the running tunnels
- Accurate description of the climatic conditions, including the probability and extent of airborne sand and dust
- Target ridership and the corresponding levels of comfort
- Generally, each tunnel ventilation shaft has a fan room in which there are two fully reversible tunnel ventilation fans (TVF) are installed with isolation dampers. These dampers are closed when the fan is not in operation. The details for the shaft sizes, airflow exchange with the atmosphere, fan capacities can be estimated during the detailed design stage (**Figure 6.13**).

FIGURE 6.13: TUNNEL VENTILATION FAN & DAMPERS



The tunnel ventilation fans and TVS rooms exist at the platform level on both sides of the underground stations. In few cases, where ramp is proposed in alignment to rise to elevated tracks immediately after a station, then nozzles are not required at that end of the station. Due to space constraints, the tunnel ventilation system can be segregated at three levels. This system enables reduction in length of stations as the total space consumed by the assembly almost reduces by one-third compared to the conventional system.



VIEW OF TUNNEL VENTILATION SYSTEM & DRAFT RELIEF FOR TYPICAL UNDERGROUND STATION- TYPE 1 (2 LEVELS)

Dog-leg Shafts for Tunnel Ventilation and draft relief with horizontal grills on the ground level will be provided for better ventilation and to avoid rain water from directly coming inside the fans. Proper drainage will be provided to drain out any rainwater.

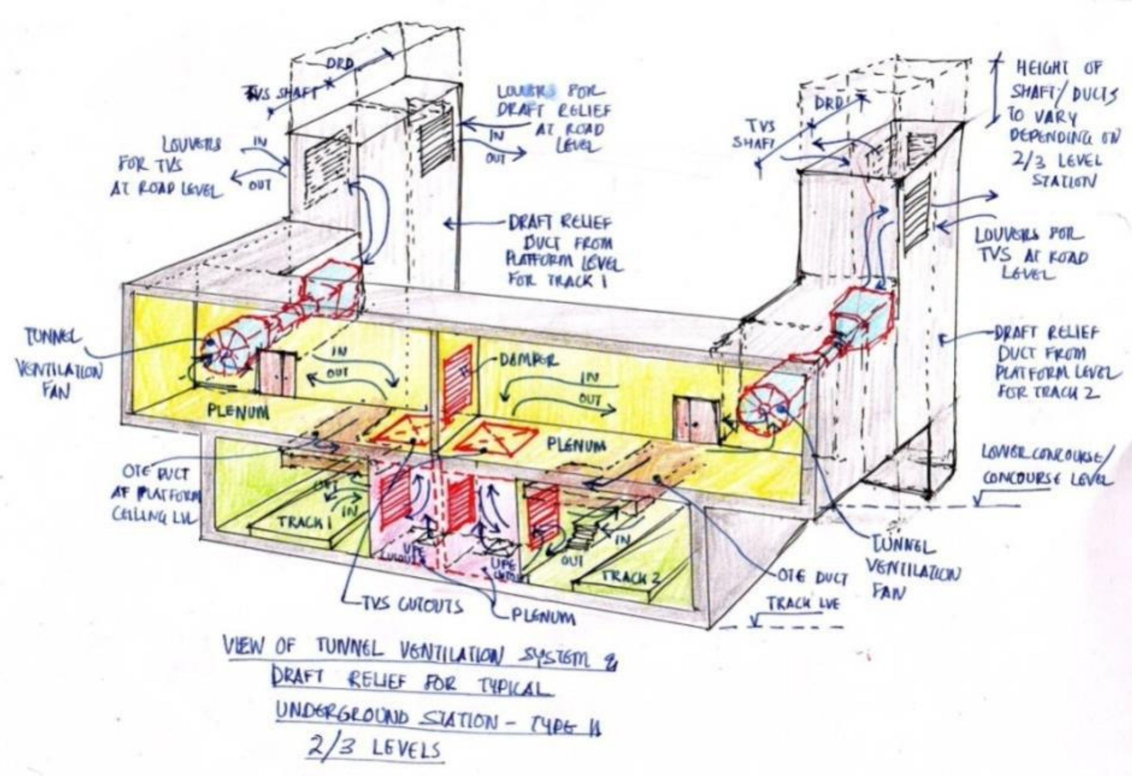
The three types of tunnel ventilation systems proposed are as follows:

i. Tunnel Ventilation Fans at Platform Level

In this type of arrangement, the two tunnel ventilation fans are arranged at platform level with knockout panels located on either sides in the fan room to bring out the fan for maintenance. The fan room is connected to the TVS Shaft on one side and the plenum for supply/exhaust or exhaust for Over Track Exhaust (OTE)&Under Platform Exhaust (UPE). The platforms are isolated from the tracks by full height platform security gates. Draft relief shafts are provided on each track on both ends of the station to balance the air pressure on arrival/departure of the train in the track. Under normal operations, fans on one side of the station are only operated regularly for Over Track Exhaust &Under Platform Exhaust. In emergency conditions either of the 2 fans push/pull air depending on the operation through the plenum/shaft located between the fans and the platform. The OTE & UPE is shut off under such conditions.

ii. Tunnel Ventilation Fans at Concourse Level

This type of TVS arrangement is done on the concourse level primarily in stations where required width for fan room (to accommodate 2 fans) is not available at platform due to station length of the station being shorter and lesser space being available. The work principle for this system is the same except that the 2 fans and 2 plenums and 2 cut-outs for TVS are located on the concourse level. The cut-outs are positioned such that they push/pull air to the tunnel through the supply/exhaust plenum located at the platform level. Separate cut-outs for draft relief shafts are located on the side of the track to balance the air pressure on arrival/departure of the train in the track.

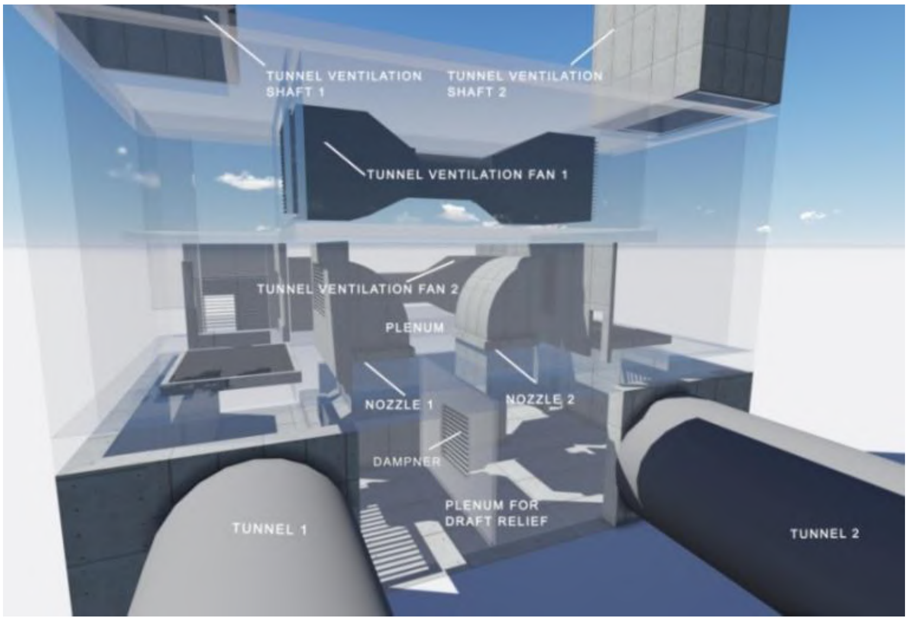


iii. Tunnel Ventilation Fans at Upper and Lower Concourse Level

This type of TVS system is applicable where stations are planned at 3 levels and the length of the station is restricted due to execution related issues.

In this arrangement, the draft relief plenum/shaft is located at platform level. One tunnel ventilation fan is located at lower concourse level which connects to TVS shaft at track level through a plenum. The other fan is located at the upper concourse level which also connects to the TVS shaft at track level through the same plenum and directs/pulls air downwards/upwards.

Depending upon the site conditions and length and width constraints, one of the TVS system is proposed in the stations.



Passenger Handling Facilities

Escalator Requirements

Standards, Codes and Regulations

The following regulations and standards shall form the basis for the design of escalator system.

- American National Standard Institute (ANSI)
- American Society of testing Materials (ASTM)
- International Electro technical Commissions (IEC)
- Indian Standard (IS)
- European Norm (EN)
- National Electrical manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Underwriter’s Laboratories, Inc. (UL)

6.2.4 Design Criteria

The escalators will be heavy duty “public” service escalators capable of operating safely, smoothly and continuously in either direction, for a period of not less than 20 hours per day, seven days per week, (except special holiday which may be operated 24 hours a day) within the environmental conditions prevailing within the well way and at the location where the escalators are installed. The maximum allowable passenger load of each step should not be less than load equivalent of three 65 kg person per step.

The escalators will be equipped with energy saving system. Speed of escalators will be in the range of 0.6-0.75 m/s for normal operation. The energy saving system will reduce speed of escalators to standby speed mode of 0.20 m/s during low traffic hour.

The number of flat steps at the upper landing should be in proportion to the vertical rise of the escalator. For 6.1 m to 18.3 m rise, minimum four flat steps should be provided and for a rise up to 6.1 m manufacturers' standards should be used (2-3 flat steps).

The design of the escalators which act as emergency stairways should meet all the criteria requirements in NFPA 130. The design of the escalators will be such that they can be used as fixed staircases under a condition of power failure, activation of stop button or activation by safety/protection devices.

When the escalators are stationed, no slipping, jerking, sliding and vibration should occur. Escalators will be equipped with protective barriers, where necessary.

Interfacing Requirements

The following escalators interface will be monitored by the Supervisory Control And Data Acquisition (SCADA) and abnormal conditions will be alarmed:

- Incoming power lines healthy.
- Direction status.
- Running
- Fault
- Emergency

Elevator Requirements

Standards, Codes and Regulations

The following regulations and standards will form the basis for the design of elevator system.

- American National Standard Institute (ANSI)
- American Society of testing Materials (ASTM)
- International Electro technical Commissions (IEC)
- Indian Standard (IS)
- European Norm (EN)
- National Electrical manufacturers Association (NEMA)

- National Fire Protection Association (NFPA)
- Underwriter's Laboratories, Inc. (UL)

Design Criteria

Lifts will be of the goods/passenger public service type and rated at minimum 180 starts per hour. Lifts will be of proven technology and designed to have low energy consumption, low operational costs and will provide environment friendly passenger service. Lifts will be rope traction type capable of operating safely and smoothly without jerking under all loading conditions, for a period of not less than 20 hours per day (except special holiday which may be operated 24 hours a day), seven days per week within the environmental conditions prevailing within the hoist-way and at the location where the elevators are installed.

Lift will be capable of carrying minimum loading of 750 kg, and may be sized for comfortably taking an injured person on a stretcher with room for the stretcher bearers to place the stretcher in the lift without difficulty.

The design of the lift will take into consideration fire prevention, elimination of dust and dirt traps, and easy access for cleaning and routine maintenance.

Lift will have a minimum internal size of 1,400 mm x 2,300 mm wide, the door width will be minimum 1,100 mm clear and 2,200 mm high. The drive machine, its associated machinery and all necessary control equipment of lifts at stations will be installed within the lift shaft without any lift machine room. Intercom will be provided inside the lift car to communicate with the Station Operation Room of the station where lifts are installed.

The leveling accuracy at the landing served, under no load and full load condition in either up and down direction, will be made within + 5 mm.
Speed of lift will be capable of reaching the uppermost discharge point in not more than one minute. The time will be calculated from the time the doors are fully closed at the lowest discharge point to the time that they begin to open at the uppermost discharge point. The minimum speed will be not less than 1.0 m/s irrespective of the travel distance. Lifts will be equipped with facilities for physically challenged people, in accordance with the relevant standards.

Interfacing Requirements

The following shall be monitored by the SCADA and abnormal conditions will be alarmed:

- Incoming power lines healthy.
- Direction status.
- Running
- Fault
- Emergency Status.

Stairs Requirements

- A central handrail is provided where stair width is 4.5m or more.
- Risers per flight: 3 minimum, 12 maximum
- All Steps in a flight of Stairs have the same dimensions
- Tread width of steps will be 300mm
- Riser will be 150mm
- Length of intermediate landing: lesser of 2m or width of stairs
- Handrail: 0.9m high, 50mm diameter, 45mm clearance to wall.
- Step noses will be rounded and color contrasted
- Minimum Stair width for public use: 2400mm
- Minimum Stair width for emergency evacuation: 1100mm

6.3.5 Commercial Programs

Advertising Areas

a. A high level of passenger traffic using the stations presents a great potential for high commercial value for advertising.

b. The conditions of success to attract announcers and advertising in transit systems include

   - A high level of passenger traffic:
   - Maximum of space and maximum of repetitions: minimum space for posters is around 96 positions to be efficient on the entire network (that means a minimum of 6 positions per station)
   - Importance of light and the treatment of light to see the posters
   - Advertising sales agency to manage the advertising space.

c. The different possibilities of advertising spaces include

   - On the platforms (20% of the spaces on the platform could be used for advertising).
   - On the walls beside the escalators
   - On the walls of the first level of the stations
   - Inside the Rolling Stock (specific dedicated areas)

- On the Rolling Stock: train wearing advertisement campaign (train is used as an advertising medium for one campaign).
- New technologies can be used especially on the platforms: LCS screens (about 8m²) with projection. It implies cables have to be set up in the stations and on the platforms. The screens include sensors to calculate the number of passengers who pass and see the poster. The screen can also communicate with mobile phones.

d. General Principles about the advertising space:

- Advertising spaces must be seen by the customers on the platforms.

<u>Commercial Areas for Retail Shops/Kiosks/ATMs</u>

a. Like advertising, retail shops in the stations could provide additional financial income. The expected level of passenger traffic in the stations provides great potential for a high commercial value for the retail shops. An agency will have to be preferably appointed for management of these retail shops at all stations on the proposed corridors.

b. The different area possibilities for location of retail shops;
   - Inside the stations (paid as well as unpaid areas)
   - Minimum space: 3.5 m of depth all the way across the station; 50m² (3.5 x 14 m) for the smallest stations

c. On the platforms
   - Space: 15 m² per platform for automatic vending machines (for drinks, eatables, etc.) or small convenience stores

d. Inside the stations (before the tool zone)
   - Space for automatic vending machines could be dedicated (for example: for cash, photos)
   - In the covered zone: space for a shopping mall could be created depending on the market potential.

e. Outside the stations (in front of the cars parks or the bus stops)
   - Small corners or kiosks; licenses could be created and negotiated for such shops.
   - Commercial areas and designs will be guided by the market characteristics and local habits.

6.3 PLANNING OF METRO STATIONS

The conceptual station planning are the adaptations of the typical stations finalized keeping in view the projected traffic, station requirements, site conditions, minimal land acquisition, method of construction and overall cost optimization.

Since land is at a premium throughout the corridor, the process of reconciling the land that is actually required for the station development has had a major influence upon the design process and important elements of the stations such as entry/exits, concourse, platforms, ancillary buildings etc have been designed and marked for each station to overcome land acquisition problems. But, wherever the vacant land parcels have not been found available, land acquisition has been proposed for placing the necessary utilities/facilities.

The most important design consideration is to provide a safe and comfortable environment to passengers during both normal and emergency operation. The space planning requirement for each of the stations with respect to the number of AFC gates, ticket windows, stair width, number of escalators, platform width etc. in normal and emergency conditions are based on peak hour passenger traffic.

Stations have been provided with an internal environment suitable for a world class metro railway system by incorporating the experience of international best practices. The stations have been planned in such a way that they are easily operated, maintained and can be upgraded in future. Accommodation for staff and plant rooms is provided at both platform and concourse levels within areas that are entirely separate from the public access. The main plant systems accommodated within the station are the auxiliary sub-stations at the concourse/platform level at each end, ECS plant rooms at concourse level at each end and adjacent to the station box and TVS plant rooms at platform level at each end, between the two tracks. S&T equipment rooms are provided between the subway and ECS plant room.

Internal arrangement for the stations is evolved in such a way that Back of House accommodation is organized, so that the rooms of a similar operational use are placed along a common corridor and plant accommodation is clearly distinct from habitable rooms.

A number of standardized station typologies, which can respond to the context at specific locations have been developed. The design of stations at Chennai is based on the 6 car rake composition with length of train to be 136.2 m. Therefore, the length of the platforms in both elevated stations and underground stations have been kept as 140m.

Based on the emergency traffic requirements**,** site constraints and stipulated standards, various sizes of the platform and staircases have been determined for all the stations.

The emergency traffic requirements and the site constraints has resulted into different sizes of the stations, hence the typology of stations have been determined. Emphasis has been laid on keeping minimum typologies that would broadly cover design of all 128 stations in the three corridors. Any minor variations from the one type have been included as a subtype and a separate typology has not been created for the same. Station typologies have been worked out as presented in **Table 6.4**.

TABLE 6.4: STATION TYPOLOGIES FOR CHENNAI METRO PHASE-II

Type	Station Type	Size (sq m)	Levels	Construction Type
A	Elevated	140 X 21.95	2	Cantilever
B	Underground	190 X 21.80	2	Cut and Cover
C	Underground with Ext. Concourse	150 X 21.40	2	Cut and Cover
D	Underground	150 X 21.40	3	Cut and Cover
E	Elevated(split concourse)	140 X 32.35	-	RCC framed structure
F	Elevated(split concourse)	140 X 37.04	-	RCC framed structure

The detailed descriptions for the various underground & elevated station typologies are detailed in subsequent sections.

6.3.1 Typical Elevated Station: Type A: 140m x 21.95m Cantilevered Structure

In **Type A** the size of the elevated station has been kept as **140m x 21.95m**. The stations are generally located on the road median. Total length of the station is 140m. All the stations are two-level stations. The passenger areas on concourse level is concentrated in a length of about 84m in the middle of the station, with 2 staircases, escalators & elevators leading from either side of the road. The total width of the station is restricted to 21.95m.

It is planned to be a cantilevered structure thereby keeping flexibility for provision of a wider carriageway in future below the concourse with 2.3m wide central median. 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, UPS &battery room, signaling equipment room, communication equipment room, TSS Room, auxiliary substations, security room, refuse store & cleaners Room, staff room, etc. The public zone is further divided into paid and unpaid areas. Public toilets, communication closets have been provided in the Platform Level.

Since the station is generally in the middle of the road, minimum vertical clearance of 5.5m has been provided under the concourse. Concourse floor level is about 8m above the road. Consequently, platforms are at a level of about 14.74m 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. The positive dimension of this impact has been accentuated to enhance the acceptability of an elevated station and the above ground section of tracks. Structures that afford maximum transparency and are light looking have been envisaged. A slim and ultra-modern concrete form is proposed, as they would look both compatible and modern high-rise environment as well as the lesser-built, low-rise developments along some parts of the corridor.

In **Type A** stations, 3.6m wide staircase is provided on either side of the platform along with two escalators on each side of the platform. Provision of 1 lift has been proposed.

Platform roofs that can invariably make a structure look heavy; have been proposed to be of steel frame with aluminium cladding to achieve light look. Platforms would be protected from the elements by providing an overhang of the roof and sidewalls would be avoided, thereby enhancing the transparent character of the station building. The rest of the station structure is supported on a single column, which lies unobtrusively on the central verge. The section and plans for Type A are presented in **Figures 6.14** & **6.15.** The room schedule for this typology is given in **Table 6.5**

FIGURE 6.14: CROSS SECTION OF TYPE A – ELEVATED STATION

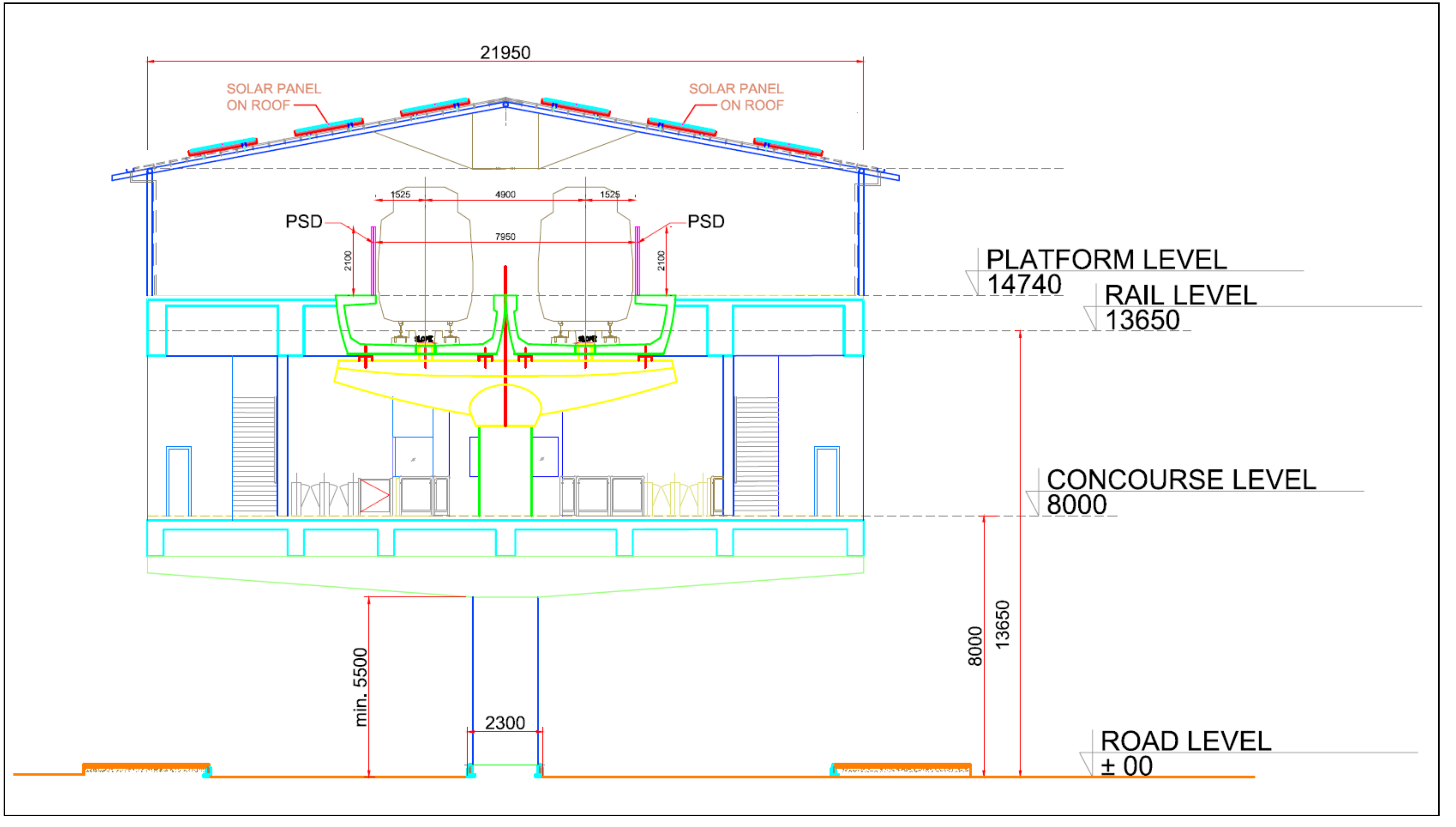
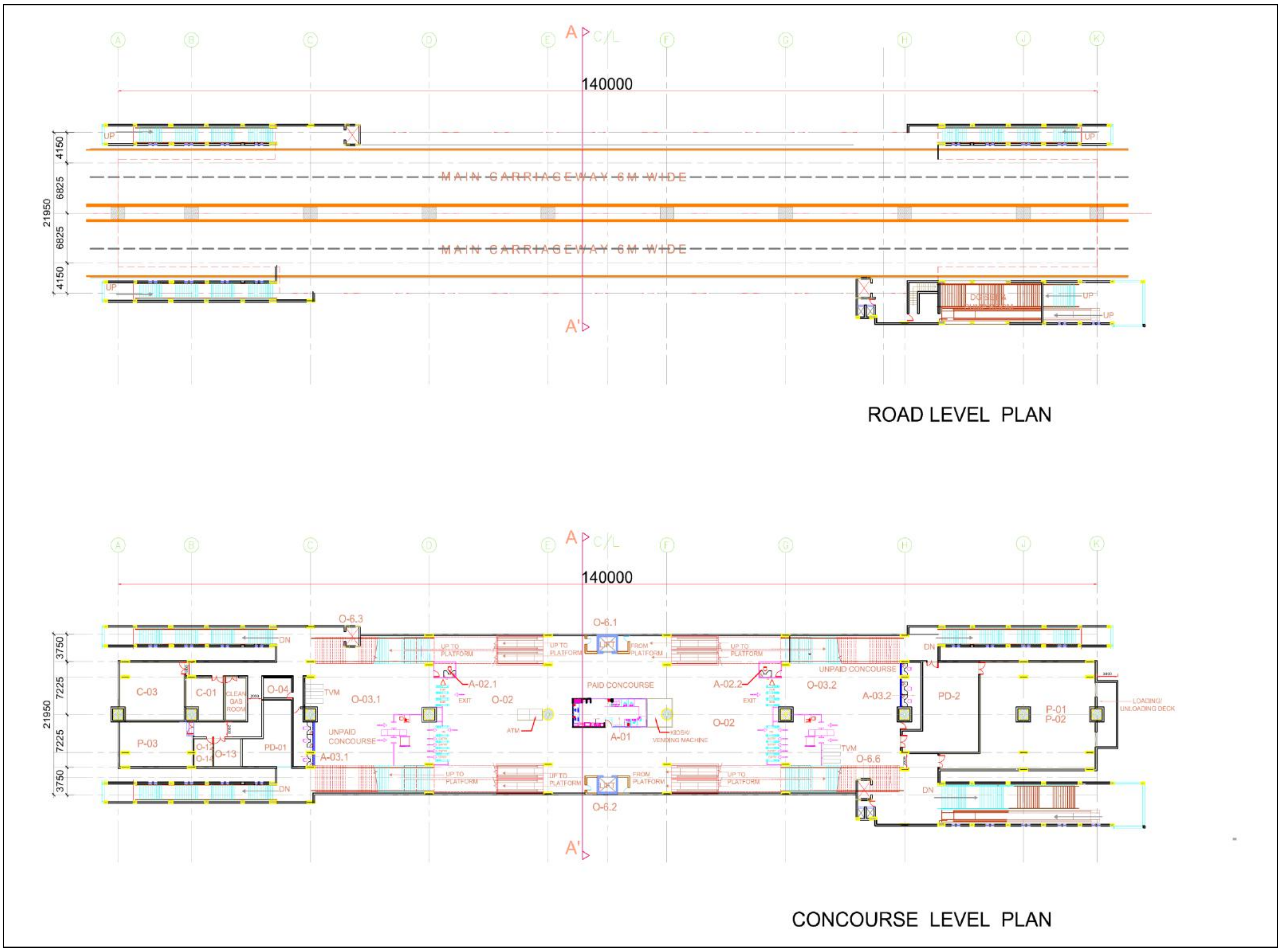


FIGURE 6.15: ELEVATED STATION TYPE A



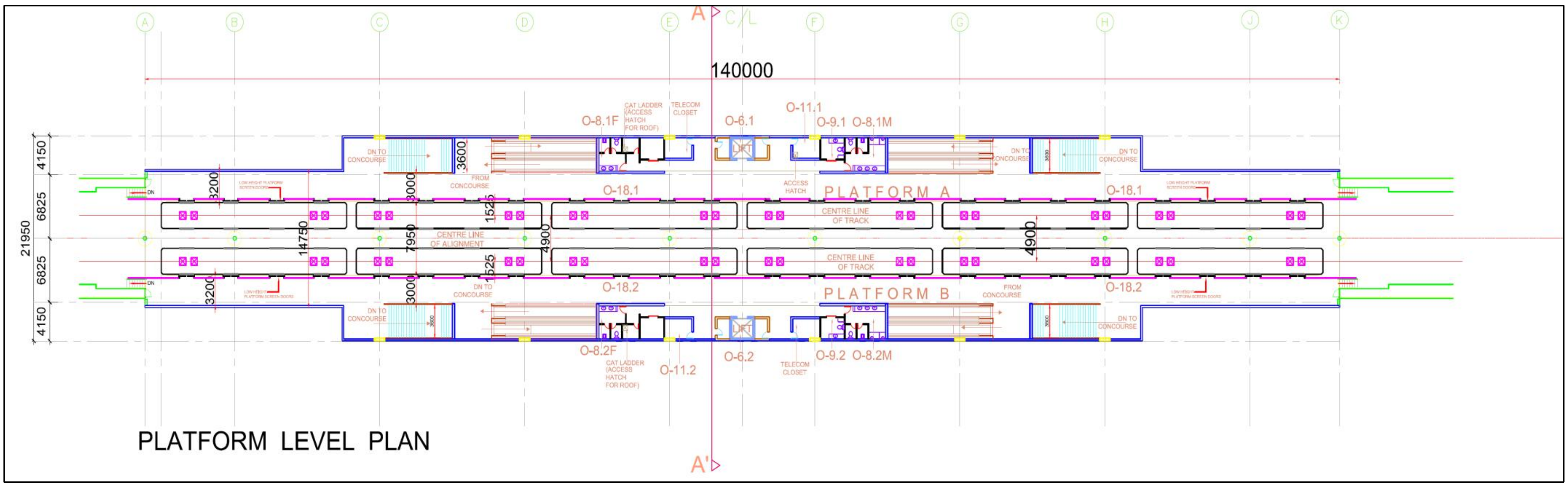


TABLE 6.5: ROOM SCHEDULE FOR

ELEVATED STATION TYPE A - 140M X 21.95M

R No.	Room Name	Room Size (m)		Area Provided (Sq.m)
A-0.1	Station Control Room	10.44	3.68	38.50
A02.1	Excess Fare Office	3.75	2.0	7.50
A02.2	Excess Fare Office	3.75	2.0	7.50
A03.1	Ticket Office	2.81	6.12	17.22
A03.2	Ticket Office	2.81	7.95	22.33
C-01	Signaling Equipment Room	5.38	5.84	28.01
C-03	Communication Equipment Room	9.23	7.95	73.37
P-01,02	Auxiliary Substation	VARIES	VARIES	250.95
P-03	UPS Battery S & T Room	7.97	5.45	43.53
-	Clean Gas Room	5.84	3.00	17.50
O-02	Paid Area	VARIES	VARIES	858.19
O-03.1	Unpaid			269.80
O-03.2	Unpaid			269.80
O-04	Security Room	4.0	2.725	10.92
O-08.1 F	Toilet Female	3.19	3.57	10.73
O-08.2 F	Toilet Female	2.75	3.57	10.43
O-08.1 M	Toilets Male	3.56	4.69	16.74
O-08.2 M	Toilets Male	3.56	4.69	16.74
O-09.1	Toilets (H)	2.76	2.28	6.30
O-09.2	Toilets (H)	2.76	2.28	6.30
O-11.1	Janitor's Room	3.19	2.17	6.90
O-12 & O-14	Cleaners Room & Refuse Store	2.70	3.87	10.44
O-13	Staff Room	3.90	3.87	15.093
O-18.1	Platform A			446
O-18.2	Platform B			446
PD-1		VARIES	VARIES	48.83
PD-2		VARIES	VARIES	106.70

6.3.2 Typical Underground Station: Type B - 190m x 21.80m x 2 levels

In **Type B** underground stations, there are two levels i.e. platform level and concourse level. In this typology, the size of station has been kept as **190m x 21.80m.** The typical underground station is a two-level station with platforms at the lower level and concourse on the upper level. The station box of 190m x 21.80 m consists of station operational, functional, public and non-public areas and an ancillary structure to accommodate Chiller room, UG Tanks, Pump room and DG Sets. The upper level has, in addition to the concourse, all the passenger amenities, station operation areas such as Station Control Room, Station Manager's Room, UPS & Battery Room, Communication Room, Mechanical Equipment Rooms, Security & Station Store Room, Staff Toilets, Staff Lockers, Refuge Room, TVS Panel Rooms etc. Lower level has platforms, tracks, Signalling Room, Telecommunication Closet, Room for Platform Screen door, DB rooms, seepage sump, pump room Tunnel ventilation room and similar ancillary spaces beyond the platforms on either side.

The section and plans for Type B are presented in **Figures 6.16** & **6.17.** The room schedule for this typology is given in **Table 6.6.** Two staircases of 2m width, 4 escalators and 2 fire escape stairs of 1.8 m have been proposed from concourse to platform to meet the high traffic demands. In addition, provision of lift has been done to bring passengers from concourse to platform level and vice versa.

Ventilation shafts, equipment hatch, transformer room, entrances and chiller plant rooms are above ground structures associated with the underground station and are being provided on the open spaces by the road side. Two entrances have been provided to the station, one at each end. Entrances could be increased to 4 nos. as requirements based on traffic projections and better connectivity. Structure of the underground station is essentially a concrete box about 21.80m wide, 14m high and 190m long with an intermediate slab. Sides of the box are made of 0.8- 1.2-m thick RCC walls.

6.3.3 Typical Underground Station with Extended Concourse: Type C–150m x 21.40m x 2 levels

In order to optimize the station block with respect to the length, the station boxes have been reduced to 150 m length with two levels and extended concourse. In **Type C** Underground stations, there are two levels i.e. Platform level, and concourse level. In this typology, the size of station is **150m x 21.40m**. The section and plans for Type B are presented in **Figures 6.18** & **6.19.** The room schedule for this typology is given in **Table 6.7.**

FIGURE 6.16: CROSS SECTION OF TYPE B – ELEVATED STATION

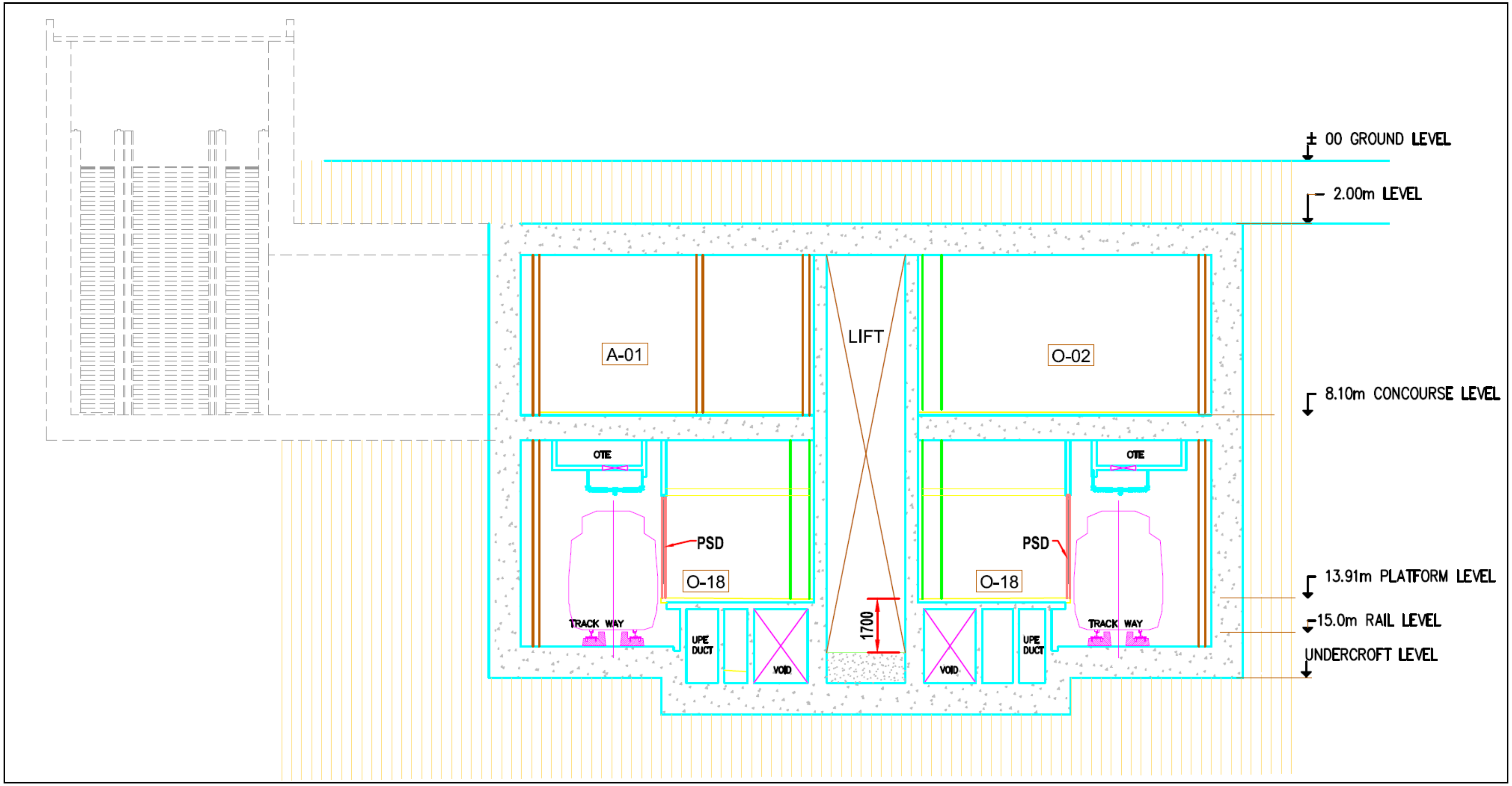


FIGURE 6.17: ELEVATED STATION TYPE B

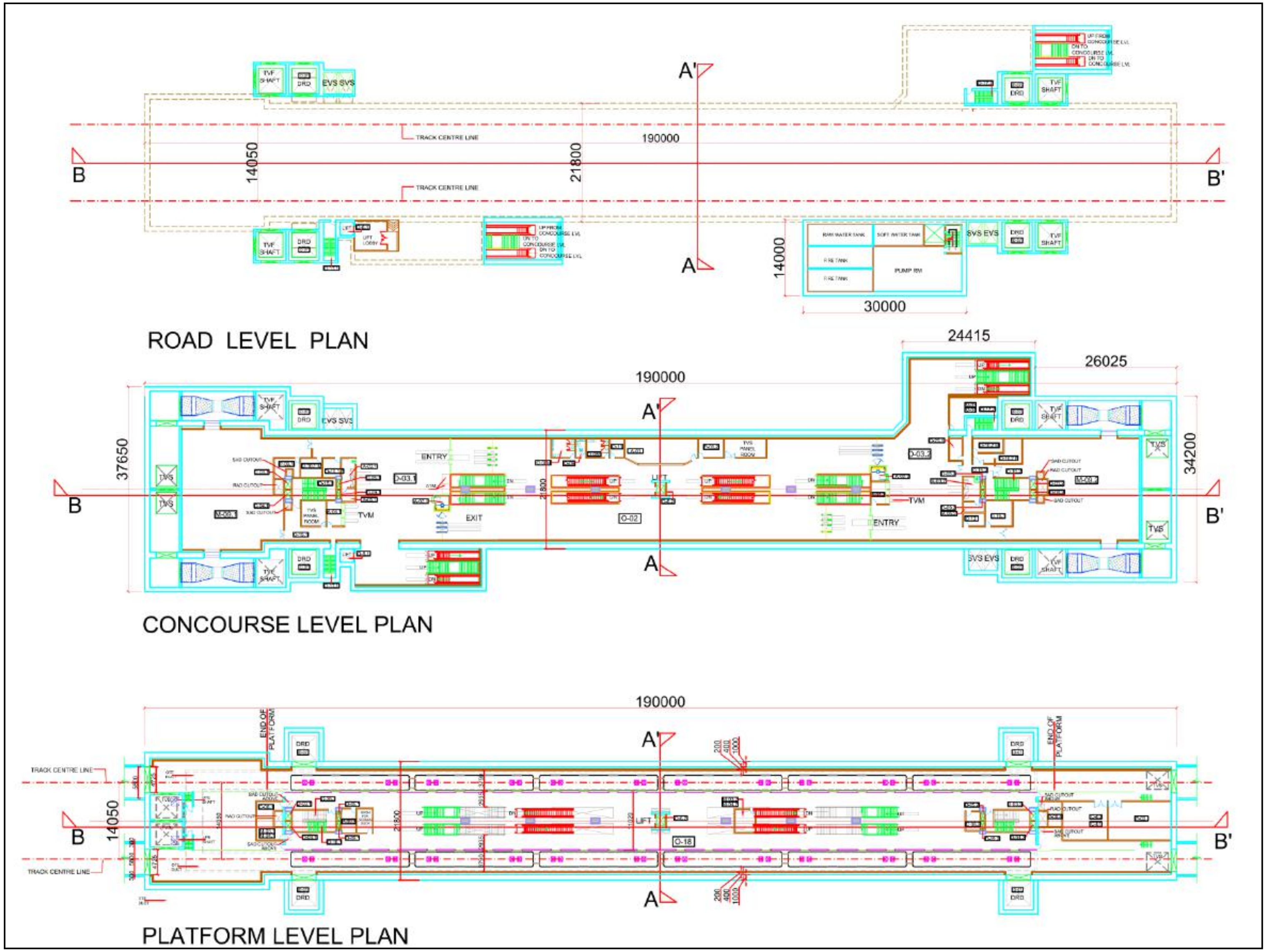


TABLE 6.6: ROOM SCHEDULE FOR UNDERGROUND STATION TYPE B

(190M X 21.80M X 2 LEVELS)

R NO.	Room Name	Room Size (m)		Area Provided
A-0.1	Station Control Room	13.30	4.60	58.64
A03.1	Ticket office	2.50	6.23	15.58
A03.2	Ticket office	3.04	4.32	13.17
A02.1	Excess Fare Office	2.5	2.5	6.25
A02.2	Excess Fare Office	2.5	2.5	6.25
A05.1	Ticket office Store & Safe	2.50	2.37	5.93
A05.2	Ticket office Store & Safe	3.84	1.75	7.05
C-01/ C-03	Signaling &Communication room	8.20	7.00	57.40
D-03.1	HT Cable Riser	1.1	1.7	1.86
D-03.2	HT Cable Riser	1.1	1.7	1.86
D-04.1	LT Cable Riser	1.1	1.7	1.86
D-04.2	LT Cable Riser	1.1	1.7	1.86
D-05.1	Cable duct	0.6	1.70	1.02
D-05.2	Cable duct	0.6	1.70	1.02
D09.1	Fire Shaft	0.6	1.70	1.02
D09.2	Fire Shaft	0.6	1.70	1.02
M-09.1	Mechanical Equipment Room	VARIES	VARIES	403.25
M-09.2	Mechanical Equipment Room	VARIES	VARIES	411.68
O-02	Paid Concourse Area	VARIES	VARIES	965.09
O-03.1	Unpaid Concourse Area	VARIES	VARIES	492.95
O-03.2	Unpaid Concourse Area	VARIES	VARIES	433.84
O-06.1	Lift	2.50	2.50	6.25
O-06.2	Lift	2.50	2.50	6.25
O-08 F	Toilets(Female)	4.11	3.42	14.08
O-08 M	Toilets(Male)	4.26	3.42	14.59
O-09	Toilet for differently abled	1.8	3.42	6.16
O-10.1F	Locker Room (Female)	3.32	3.51	11.20
O-10.1M	Locker Room (Male)	3.86	3.51	13.4
O-10.2F	Locker Room (Female)	3.26	4.62	18.13
O-10.2M	Locker Room (Male)	5.5	2.5	13.75
O-11	Janitor's Room	2.05	3.42	8.56
O-13	Lunch Room	3.84	2.34	9.03
O-16.1	Fire Escape Staircase	8.10	3.90	31.6
O-16.2	Fire Escape Staircase	8.10	3.90	31.6

R NO.	Room Name	Room Size (m)		Area Provided
O-17.1	Fireman Staircase	2.30	5.50	12.65
O-17.2	Fireman Staircase	1.5	11.360	17.04
O-19.1	Refuge Area	4.93	4.54	22.42
O-25.1	Fireman Store Room	2.31	3.95	9.15
P-03	UPS Room	11.55	7.00	80.85
P-09.1	DB Room	4.73	3.51	14.3
P-09.2	DB Room	4.6	3.42	15.75
C-08.1	Telecommunication Closet	4.80	2.90	11.39
C-08.2	Telecommunication Closet	2.56	3.40	8.57
M-03/M-04.1	Sewage &Drainage Pump Room	VARIES	VARIES	15.84
M-03/M-04.1	Sewage & Drainage Pump Room	3.71	4.16	15.45
O-16.1	Fire Escape Staircase	8.10	3.90	31.6
O-16.2	Fire Escape Staircase	8.10	3.90	31.6
O-26.1	Maintenance Access Staircase	8.10	1.8	14.58
O-26.2	Maintenance Access Staircase	8.10	1.8	14.58
P-09.3	DB Room	VARIES	VARIES	11.36
P-09.4	DB Room	VARIES	VARIES	13.9
M-01/M-02	Pump Room & Water Tanks	VARIES	VARIES	358.75
M-05	Chilling Cooling Plant Room	VARIES	VARIES	358.75
0-26.3	Maintenance Access Staircase (ancillary Building)	VARIES	VARIES	13.26 X 4
P-01/05	33 KV Ass Switchgear Room/ 33KV Transformer Room	21.87	13.54	296.14
P-02	Low Voltage Switch Gear Room	VARIES	VARIES	152.54
P-04	DG Room	7.850	16.70	131.095

The concourse level comprises of unpaid concourse, TOMs, AFC In and out Gates, public toilets (located in paid area) and EFO and few retail spaces. All the passenger amenities, mechanical equipment rooms, TVS panel rooms, UPS rooms, station operation areas such as station control room, communication room, UPS &battery room, janitors &refuge rooms etc are also provided in the concourse and the extended area. Platform level has platforms, tracks, Signalling Room, Telecommunication Closet, seepage room, sewage & drainage water pump rooms, Tunnel ventilation room and similar ancillary spaces beyond the platforms on either side. Two banks of 2m of staircases on each side, 4 escalators and 2 fire escape staircases have been designed from concourse to platform to meet the traffic demands. In addition, provision of lift has been done to bring passengers from concourse to platform level and vice versa.

FIGURE 6.18: CROSS SECTION OF TYPE C – UNDERGROUND STATION

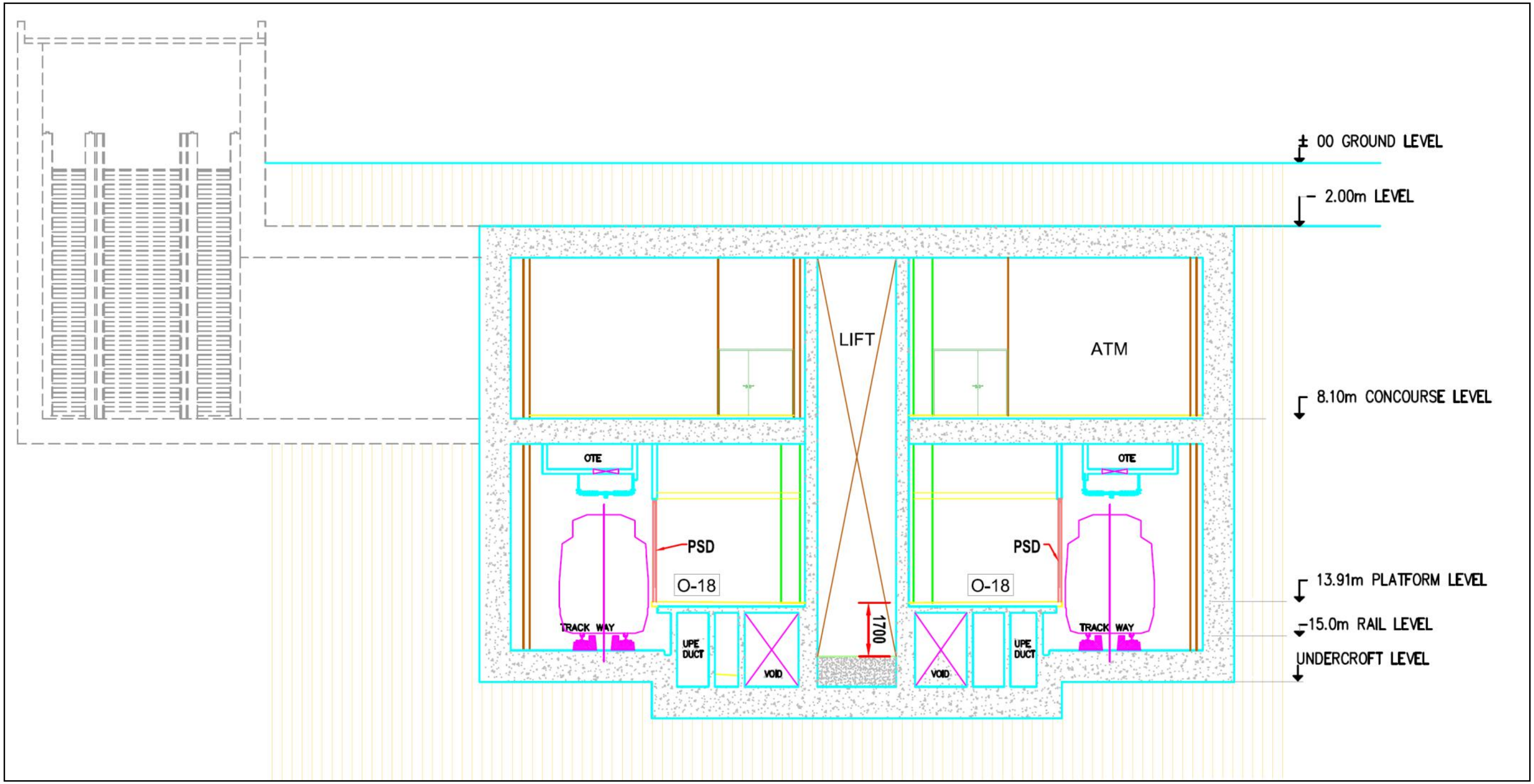
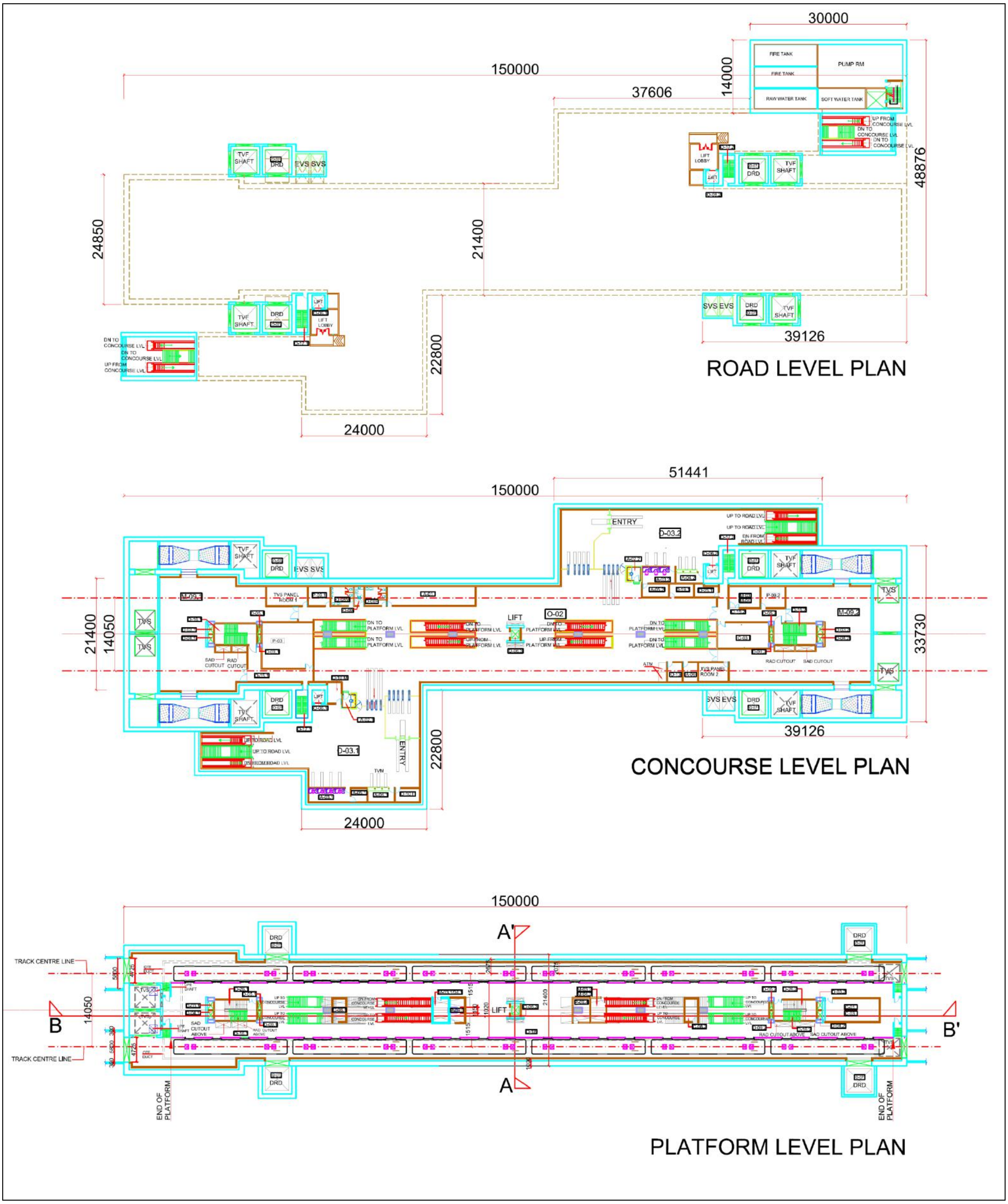


FIGURE 6.19: UNDERGROUND STATION TYPE C



Ventilation shafts, equipment hatch, entrances and chiller plants for ECS plant are above ground structures associated with the underground station and are being provided on the open spaces by the road side. Two entrances have been provided to the station, one at each end. Entrances could be increased to 4 nos. as requirements based on traffic projections and better connectivity. Structure of the underground station is essentially a concrete box about 23.55-m wide, 18.75m high and 150m long with two intermediate slabs. Sides of the box are made of 0.8-1.2-m thick RCC walls. The two entrances/exits at the road and upper concourse level and an ancillary building comprising of pump room & water tanks, Chiller Room, TSS (if required at that particular station location), DG and Cooling Towers have been placed on top of the box (at places, where the station is located under the road, then the ancillary building is located on either side of the road as per space availability).

TABLE 6.7: ROOM SCHEDULE FOR UNDERGROUND STATION WITH EXT CONCOURSE TYPE C(150M X 21.40M X 2 LEVELS)

R NO.	Room Name	Room Size (m)		Area Provided (sq.m)
A-0.1	Station Control Room	16.84	3.6	60.62
A03.1	Ticket office	7.94	2.5	19.9
A03.2	Ticket office	6.19	2.98	18.49
A02.1	Excess Fare Office	2.5	2.5	6.25
A02.2	Excess Fare Office	2.5	2.5	6.25
A05.1	Ticket office Store & Safe	3.02	2.5	7.53
A05.2	Ticket office Store & Safe	4.99	2.48	12.36
A06	Ticket office Store & Safe	3.02	3.64	11.03
C-03	Communication room	9.79	4.87	47.74
D-05.1	Cable duct	0.6	1.70	1.02
D-05.2	Cable duct	0.6	1.70	1.02
D09.1	Fire Shaft	0.6	1.70	1.02
D09.2	Fire Shaft	0.6	1.70	1.02
O-02	Paid Concourse Area	VARIES	VARIES	1082.79
O-03.1	Unpaid Concourse Area	VARIES	VARIES	421.17
O-03.2	Unpaid Concourse Area	VARIES	VARIES	396.68
O-06.1	Lift	2.50	2.50	6.25
O-06.2	Lift	2.50	2.50	6.25
O-08 F	Toilets(Female)	4.11	3.62	14.90
O-08 M	Toilets(Male)	4.25	3.62	15.44
O-09	Toilet for differently abled	1.8	3.62	6.52

R NO.	Room Name	Room Size (m)		Area Provided (sq.m)
O-10F	Locker Room	4.65	2.5	11.6
O-10M	Locker Room	5	2.5	10.00
O-11	Janitor's Room	2.5	3.63	9.075
O-13	Lunch Room	3.02	3.64	11.04
O-16.1	Fire Escape Staircase	8.10	3.90	31.59
O-16.2	Fire Escape Staircase	8.10	3.90	31.59
O-17.1	Fireman Staircase	2.3	5.40	12.42
O-17.2	Fireman Staircase	2.3	5.40	12.42
O-19.1	Refuge Area	4.57	2.48	11.3
O-25.1	Fireman Store Room	4.57	1.98	9.88
P-03	UPSRoom	4.18	3.61	15.16
P-09.1	DBRoom	4.18	3.61	15.16
P-09.2	DBRoom	4.59	4.02	18.48
C-01/ C-03	Signaling Room& Communication Room	10.41	4.39	47.67
C-08.1	Telecommunication Closet	2.40	4.35	10.44
C-08.2	Telecommunication Closet	2.40	4.35	10.44
M-03/M-04.1	Sewage &Drainage Water Pump Room	2.95	4.55	13.42
M-03/M-04.1	Sewage & Drainage Water Pump Room	2.95	4.55	13.42
M-09.1	Mechanical Equipment Room	VARIES	VARIES	378.65
M-09.2	Mechanical Equipment Room	VARIES	VARIES	346.60
O-16.1	Fire Escape Staircase	8.1	3.9	31.59
O-16.2	Fire Escape Staircase	8.1	3.9	31.59
O-18	Platform	VARIES	VARIES	1226.74
O-26.1	Maintenance Access Staircase	8.1	3.9	31.59
O-26.2	Maintenance Access Staircase	8.1	3.9	31.59
P-09.3	DB Room	2.8	4.56	11.37
P-09.4	DB Room	3.19	4.55	12.52
M-01/M-02	Pump Room & Water Tanks	VARIES	VARIES	358.75
M-05	Chilling Cooling Plant Room	VARIES	VARIES	358.75
0-26.3	Maintenance Access Staircase	VARIES	VARIES	13.26 X 4
P-01/05	33 KV Ass Switchgear Room/ 33KV transformer Room	21.87	13.54	296.14
P-02	Low Voltage Switch Gear Room	VARIES	VARIES	152.54
P-04	DG Room	15.00	13.54	203.10

6.3.4 Typical Underground Station: Type D – 150m x 21.40 m x 3 levels

In order to optimize the station block with respect to the length essentially to avoid land acquisition and enable flexibility in the alignment, the station boxes have been reduced to 150 m length and three levels stations have been evolved. In **Type D** Underground stations, there are three levels i.e. Platform level, lower concourse and upper concourse level. In this typology, the size of station is **150m x 21.40 m**.

The upper concourse level comprises of unpaid concourse, TOMs, AFC In and out Gates, public toilets (located in paid area) and EFO and few retail spaces. The lower concourse level has, in addition to the concourse, all the passenger amenities, mechanical equipment rooms, TVS panel rooms, UPS rooms, station operation areas such as station control room, communication room, UPS & battery room, janitors & refuge rooms etc. Platform level has platforms, tracks, Signalling Room, Telecommunication Closet, seepage room, sewage & drainage water pump rooms, Tunnel ventilation room and similar ancillary spaces beyond the platforms on either side. Two banks of 2m of staircases on each side 4 escalators and 2 fire-escapes of 1.8m have been designed from concourse to platform to meet the traffic demands. In addition, provision of lift has been done to bring passengers from concourse to platform level and vice versa.

Ventilation shafts, equipment hatch, entrances and chiller plants for ECS plant are above ground structures associated with the underground station and are being provided on the open spaces by the road side. Two entrances have been provided to the station, one at each end. Entrances could be increased to 4 nos. as requirements based on traffic projections and better connectivity. Structure of the underground station is essentially a concrete box about 23.55-m wide, 18.75m high and 150m long with two intermediate slabs. Sides of the box are made of 0.8-1.2-m thick RCC walls. The two entrances/exits at the road and upper concourse level and an ancillary building comprising of pump room & water tanks, Chiller Room, TSS (if required at that particular station location), DG and Cooling Towers have been placed on top of the box (at places, where the station is located under the road, then the ancillary building is located on either side of the road as per space availability).The section and plans for Type B are presented in **Figures 6.20 &6.21.**The room schedule for this typology is given in **Table 6.8.**

FIGURE 6.20: CROSS SECTION OF TYPE D – UNDERGROUND STATION

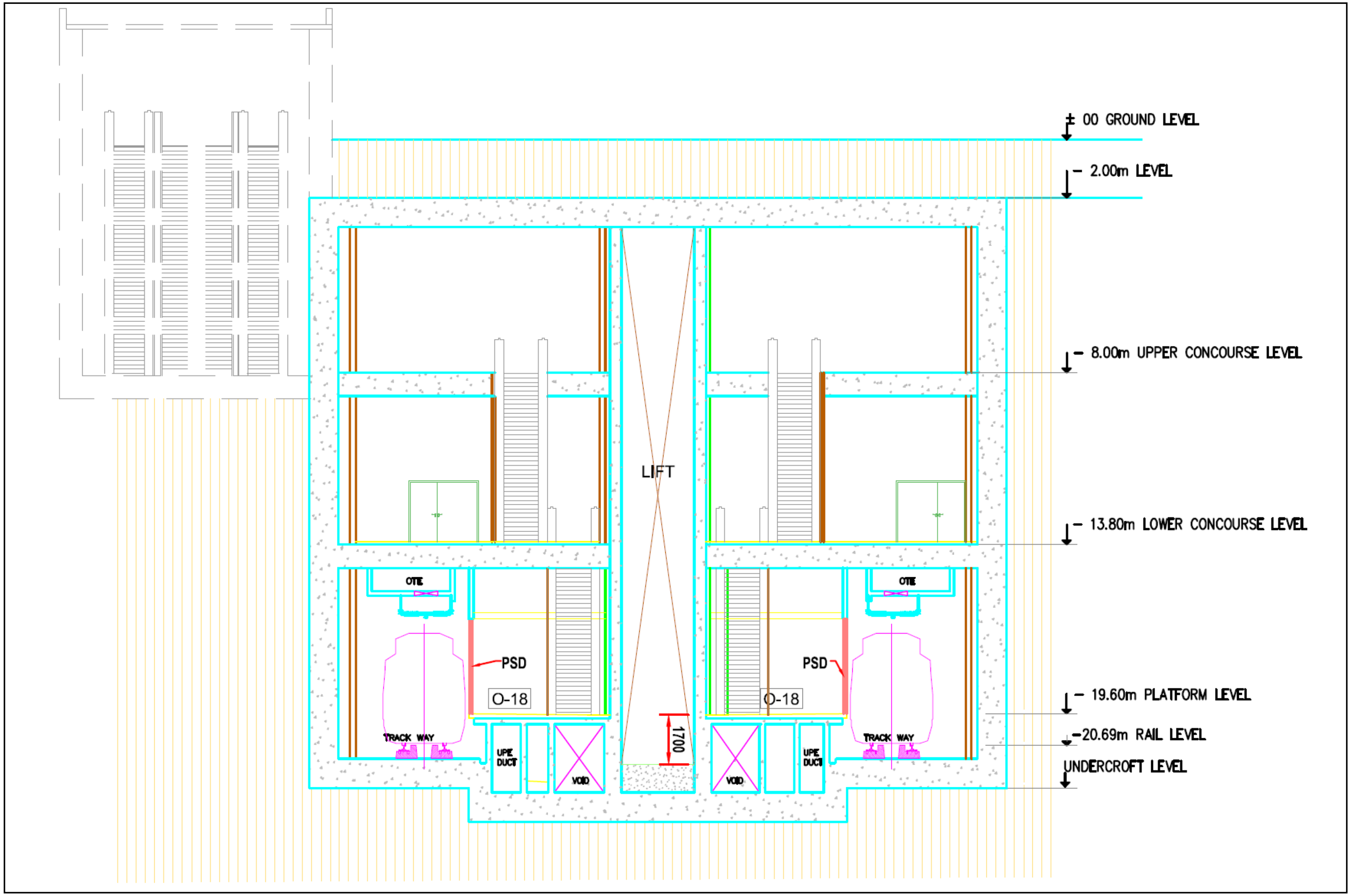
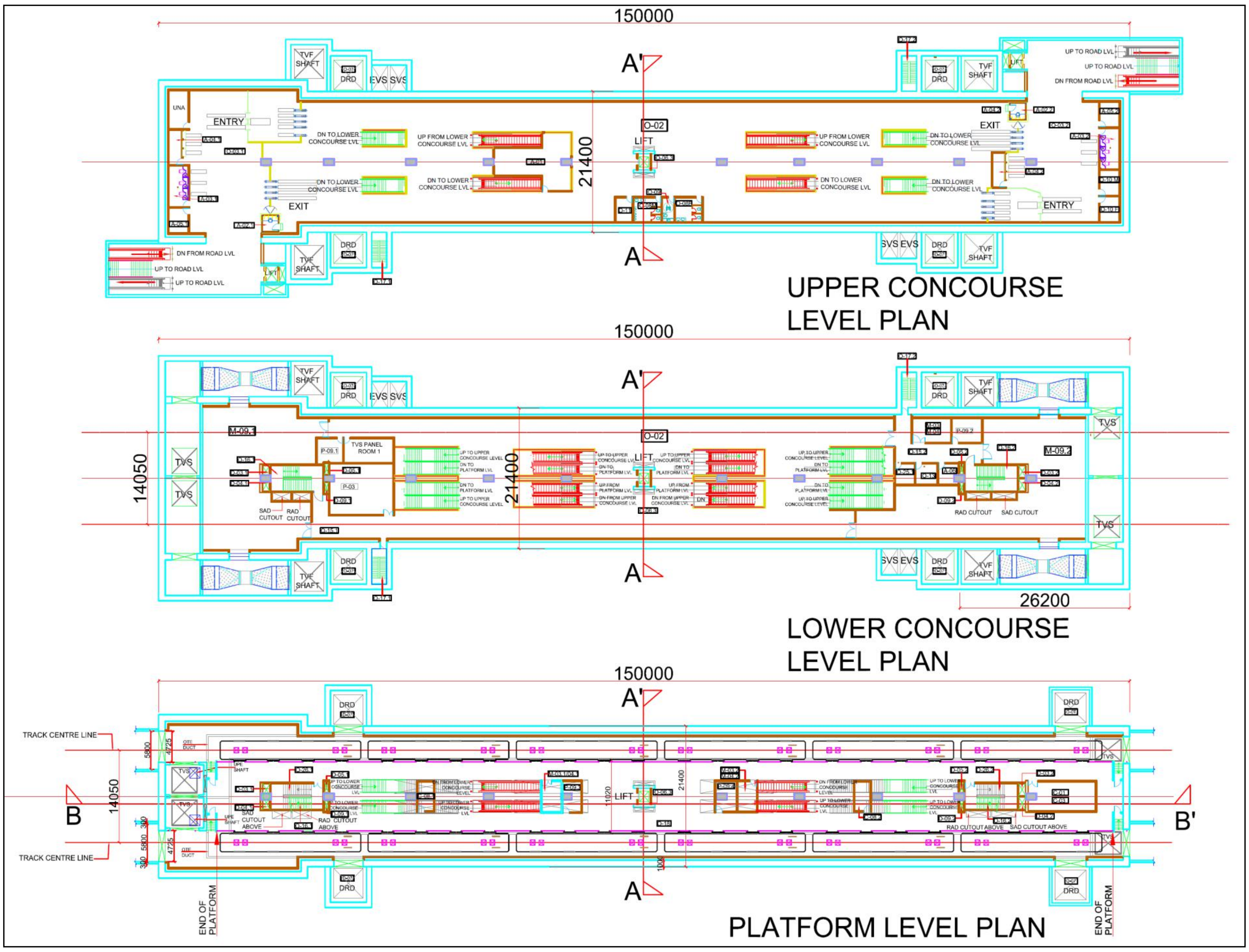


FIGURE 6.21: UNDERGROUND STATION TYPE D



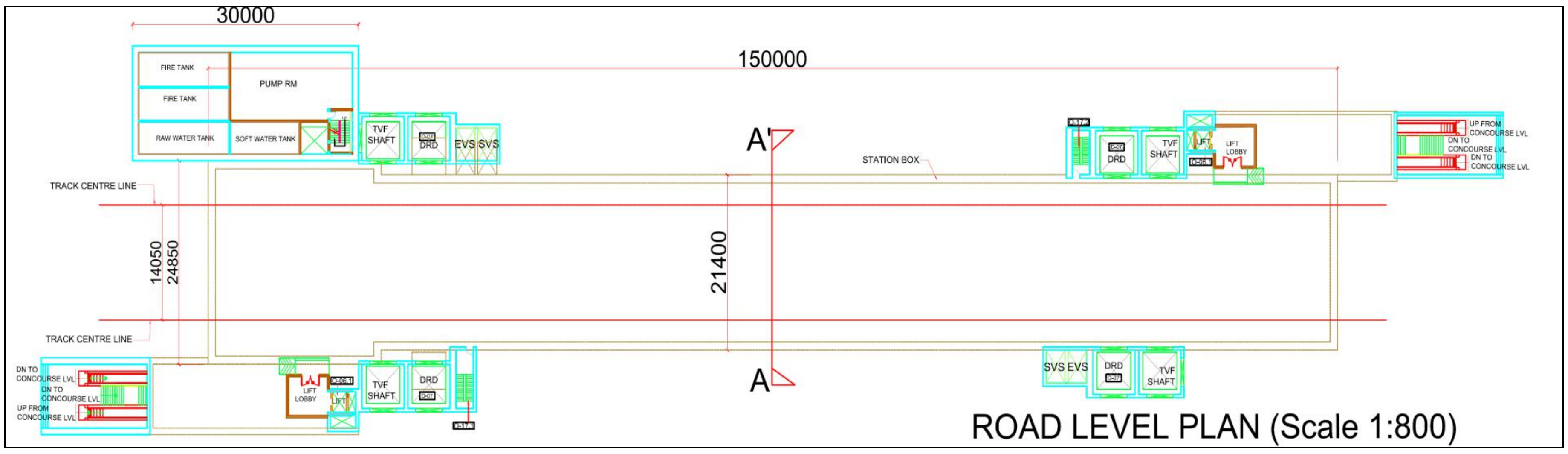


TABLE 6.8: ROOM SCHEDULE FOR UNDERGROUND STATION TYPE D

(150M X 21.40M X 3 LEVELS)

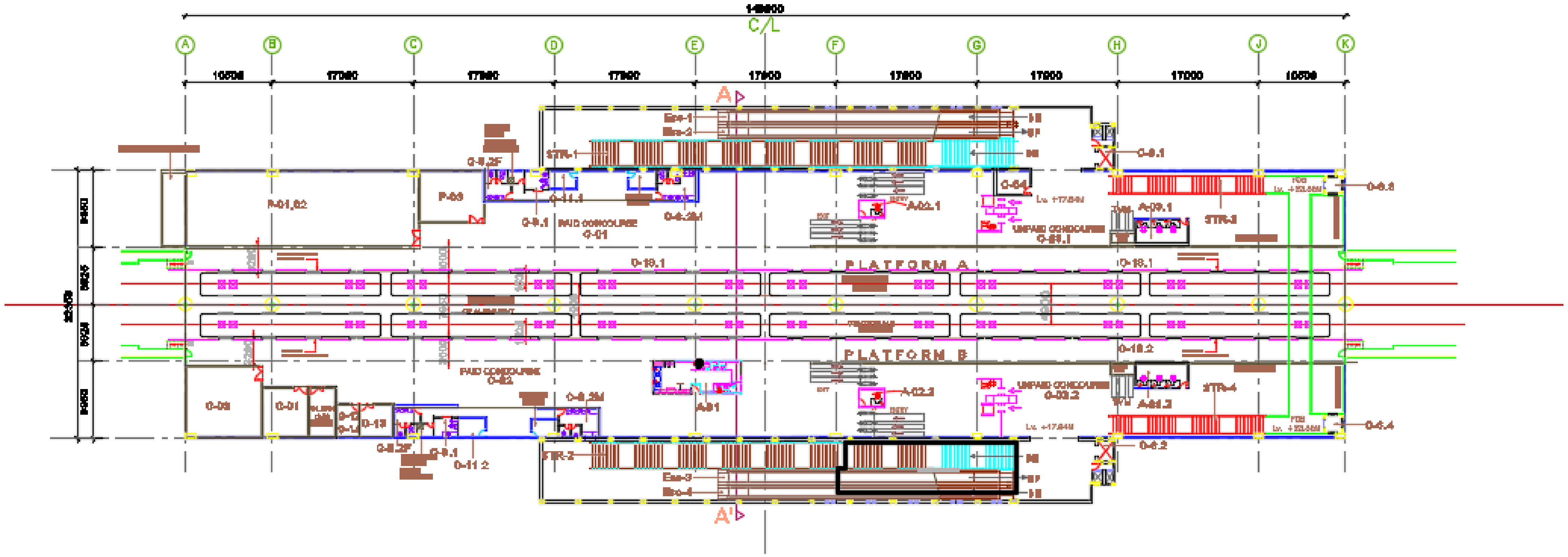
R NO.	Room Name	Room Size (m)		Area Provided (sq.m)
A-0.1	Station Control Room	VARIES	VARIES	66.85
A03.1	Ticket office	3.0	6.19	18.49
A03.2	Ticket office	VARIES	VARIES	18.49
A02.1	Excess Fare Office	2.5	2.5	6.25
A02.2	Excess Fare Office	2.5	2.5	6.25
A05.1	Ticket office Store & Safe	3.0	3.8	11.4
A05.2	Ticket office Store & Safe	2.98	3.8	11.35
C-03	Communication room	9.79	4.87	47.74
D-05.1	Cable duct	0.6	1.70	1.02
D-05.2	Cable duct	0.6	1.70	1.02
D09.1	Fire Shaft	0.6	1.70	1.02
D09.2	Fire Shaft	0.6	1.70	1.02
O-02	Paid Concourse Area	VARIES	VARIES	1810.08
O-03.1	Unpaid Concourse Area	VARIES	VARIES	385.55
O-03.2	Unpaid Concourse Area	VARIES	VARIES	348.03
O-06.3	Lift	1.9	2.50	4.75
O-08 F	Toilets(Female)	4.11	3.62	14.90
O-08 M	Toilets(Male)	4.25	3.62	15.44
O-09	Toilet for differently abled	1.8	3.62	6.52
O-10F	Locker Room	2.98	3.8	11.36
O-10M	Locker Room	2.98	3.8	11.36
O-11	Janitor Room	2.5	3.63	9.06
O-13	Lunch Room	3.29	3.1	10.22
O-16.1	Fire Escape Staircase	8.10	3.90	31.59
O-16.2	Fire Escape Staircase	8.10	3.90	31.59
O-17.1	Fireman Staircase	2.3	5.40	12.42
O-17.2	Fireman Staircase	2.3	5.40	12.42
O-25.1	Fireman Store Room	3.0	3.1	9.29
P-03	UPS Room	9.79	7.70	75.39
P-09.1	DB Room	4.0	3.62	14.49
P-09.2	DB Room	4.0	3.62	14.49
C-01/ C-03	Signaling Room & Communication Room	10.41	4.39	47.67

R NO.	Room Name	Room Size (m)		Area Provided (sq.m)
M-03/M-04.1	Sewage &Drainage Water Pump Room	2.95	4.55	13.42
M-03/M-04.1	Sewage & Drainage Water Pump Room	2.95	4.55	13.42
M-09.1	Mechanical Equipment Room	VARIES	VARIES	321.3
M-09.2	Mechanical Equipment Room	VARIES	VARIES	378.02
O-16.1	Fire Escape Staircase	8.1	3.9	31.59
O-16.2	Fire Escape Staircase	8.1	3.9	31.59
O-18	Platform	VARIES	VARIES	1226.74
O-26.1	Maintenance Access Staircase	8.1	3.9	31.59
O-26.2	Maintenance Access Staircase	8.1	3.9	31.59
P-09.3	DB Room	2.8	4.56	11.37
P-09.4	DB Room	3.19	4.55	12.52
M-01/M-02	Pump Room & Water Tanks	VARIES	VARIES	358.75
M-05	Chilling Cooling Plant Room	VARIES	VARIES	358.75
0-26.3	Maintenance Access Staircase	5.10	2.60	13.26 X 4
P-01/05	33 KV Ass Switchgear Room/ 33KV transformer Room	21.87	13.54	296.14
P-02	Low Voltage Switch Gear Room	VARIES	VARIES	152.54
P-04	DG Room	15.00	13.54	203.10
C-08.1	Telecommunication Closet	2.40	4.35	10.44
C-08.2	Telecommunication Closet	2.40	4.35	10.44

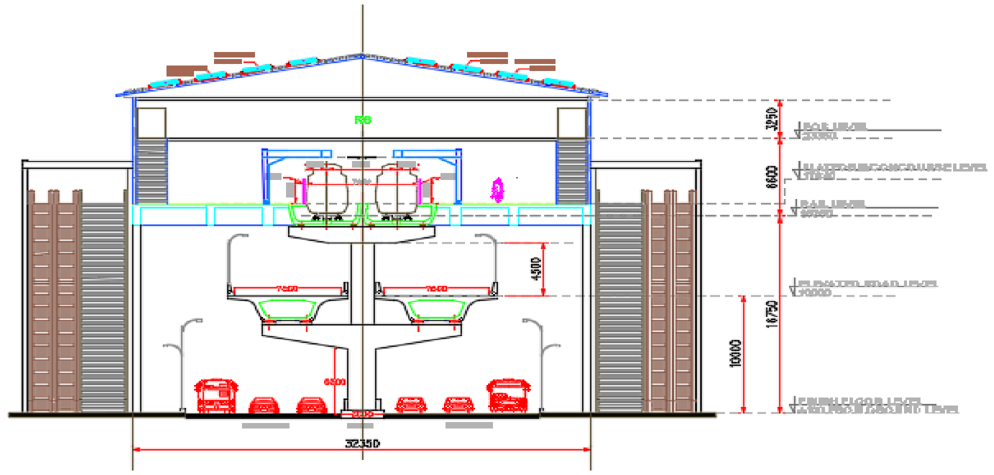
6.3.5 Elevated (Split Concourse) 140m X 32.35m

In this type of station, there are integrated concourse with platform both sides at double or more height as per the site requirements. There are two concourse attached with both platform separately i.e. one at each side.

FIGURE 6.22: ELEVATED (SPLIT CONCOURSE) STATION TYPE E



TYPICAL CONCOURSE/PLATFORM LEVEL PLAN OVER ELEVATED ROAD



TYPICAL CROSS SECTION OVER ELEVATED ROAD

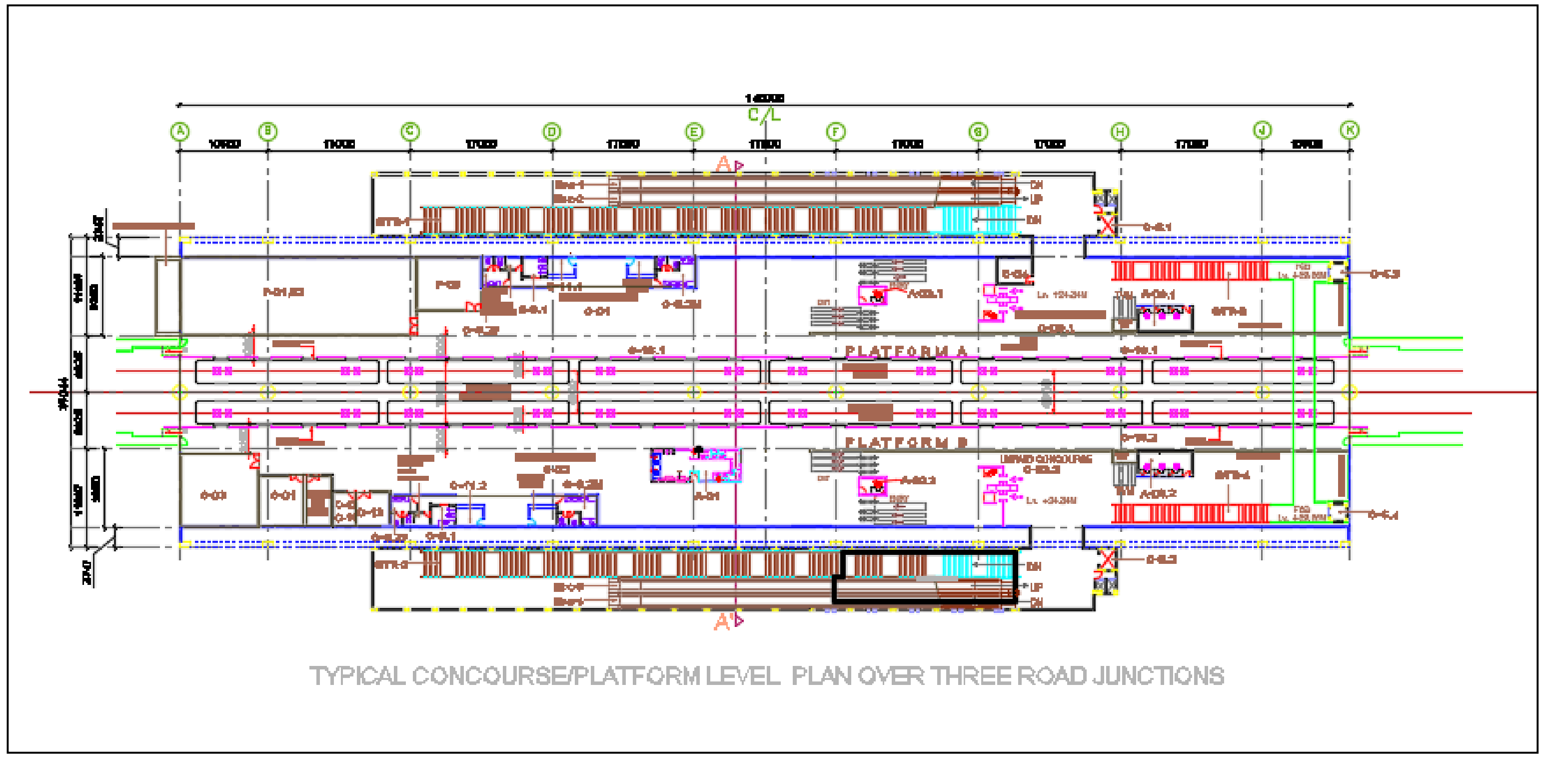
TABLE 6.9: ROOM SCHEDULE FOR ELEVATED(SPLIT CONCOURSE) STATION TYPE E (140M X 32.35M)

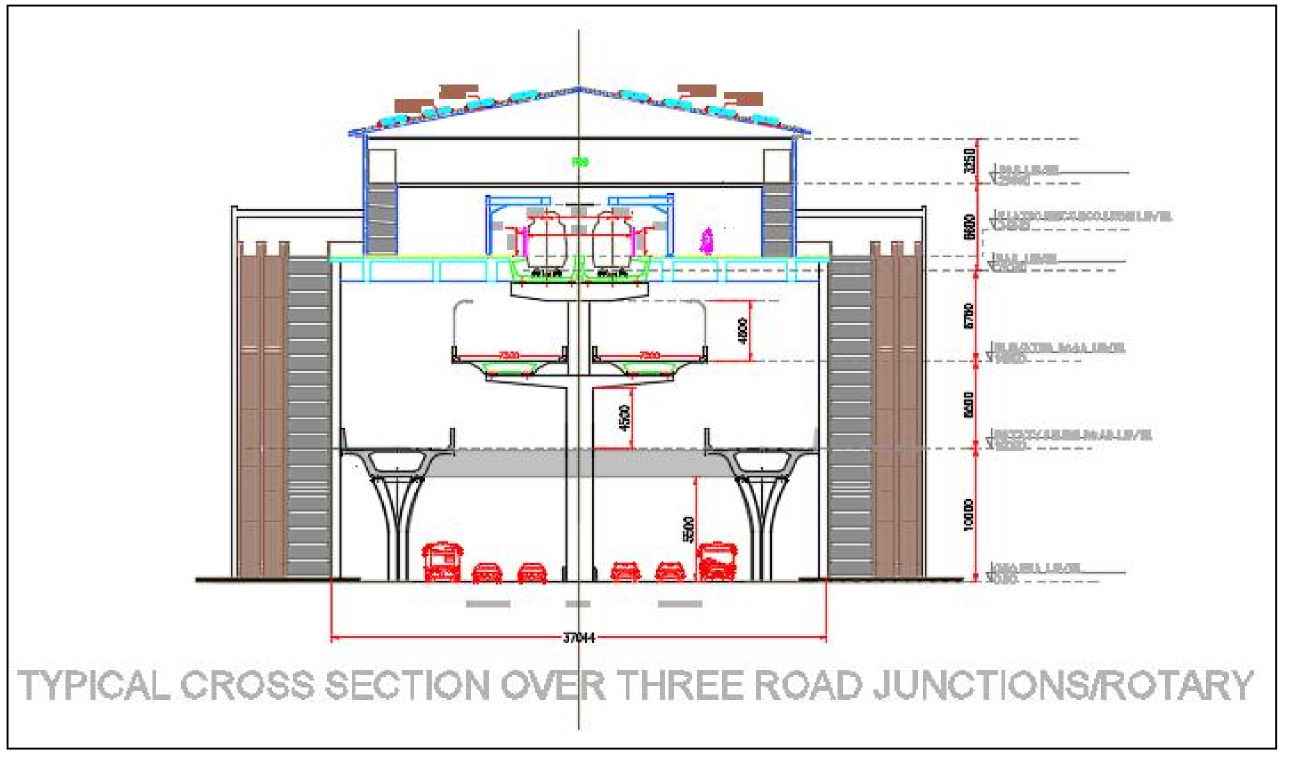
R NO.	Room Name	Room Size (m)		Area Provided (sq.m)
A-0.1	Station Control Room	10.44	3.68	38.50
A-02.1	Excess Fare Office	3.75	2.0	7.50
A-02.2	Excess Fare Office	3.75	2.0	7.50
A-03.1	Ticket Office Machine	2.95	6.2	18.29
A-03.2	Ticket Office Machine	2.95	6.2	18.29
C-01	Signalling Equipment Room	5.38	5.84	28.01
C-03	Communication Equipment Room	9.23	7.95	73.37
C-03	Communication room	9.79	4.87	47.74
P-01,02	Auxiliary Substation	VARIES	VARIES	250.95
P-03	UPS Battery S & T Room	7.97	5.45	43.53
O-01	Paid Area			728
O-02	Paid Area			728
O-03.1	Unpaid Concourse Area	VARIES	VARIES	504
O-03.2	Unpaid Concourse Area	VARIES	VARIES	504
O-04	Security Room	4	2.725	10.92
O-13	Staff Room	3.90	3.87	15.093
O-14 & O-12	Refuse Store & Cleaners Room	2.70	3.87	10.44
O-06.1	Lift	1.90	2.50	4.75
O-06.2	Lift	1.90	2.50	4.75
O-06.3	Lift	1.90	1.90	3.61
O-06.4	Lift	1.90	1.90	3.61
O-8.1 F	Toilet Female	3.19	3.57	10.73
O-8.2 F	Toilet Female	2.75	3.57	10.43
O-8.1 M	Toilet Male	3.56	4.69	16.74
O-8.2 M	Toilet Male	3.56	4.69	16.74
O-09.1	Toilet(H)	2.76	2.28	6.30
O-11.1	Janitor Room	3.19	2.17	6.90
O-11.2	Janitor Room	3.19	2.17	6.90
O-18.1	Platform A	-	-	420
O-18.2	Platform B	-	-	420

6.3.6 Elevated (Split Concourse) 140m X 37.044m

In this type of station, there are integrated concourse with platform both sides at double or more height as per the site requirements. There are two concourse attached with both platform separately i.e. one at each side.

FIGURE 6.23: ELEVATED (SPLIT CONCOURSE) STATION TYPE F





Note: Room Schedules is same as given in Table 6.9 above.

With respect to the safety features at stations, the security measures that have been considered in the design of the stations are detailed in **Table 6.10.**

TABLE 6.10: SECURITY MEASURES CONSIDERED FOR STATION DESIGN IN CHENNAI METRO PHASE - II

PERFORMANCE STANDARD AND FUNCTIONAL AREA CONSIDERATIONS	
1	**Site and Building Layout** - a. Main entrances/exits are located at the front of the site and in view of the street. b. There is a clear border definition of controlled space (public to private)
2	**Surface parking and parking structures** - Hidden recesses are avoided.
3	**Building Interior**- a. Natural surveillance for common/ open space areas is provided. b. Waiting areas and external entries to elevators/stairwells are located close to areas of active use to make them visible from the building entry.
4	**Entrances.** Entrances are designed to allow users to see into them before entering.
5	**Entrances** (To avoid confusion in locating building entrances) a. Entrances are easily recognizable through design features and directional signage. b. Entry access into facilities is limited. c. The number of entry points is minimized.
6	**Materials** (Usage of materials that reduce the opportunity for vandalism) a. Where large walls are unavoidable, vegetative screens are used.
7	**Stations and Terminals** a. Storage and baggage lockers are not incorporated in station design. b. Information centers, ticket vending machines and concessions are placed so as not to obstruct sight lines. c. Bathrooms are located near highly travelled part, not in a remote area. d. Where possible, stations/terminals have open shafts or skylights to bring in natural light. e. Stairways are left open to increase visibility. **Interior Layout** a. Operator booth is positioned for maximum presence and visibility within station
8	**Elevated Structures** a. Access to land below structure is restricted, where possible. b. Structure is set back from roads, parking areas and other buildings, if possible. c. Physical barriers such as fences, bollards and fenders enforce setbacks and prevent ramming. d. Adjacent roadways are designed to inhibit high-velocity ramming of columns e. Clear sight lines are provided under and around the structure.
9	**Strategies for Transit Stops (Interior layout):** a. Kiosks, ads and information are positioned so as to not disrupt sight lines.
10	**Administrative Buildings and OCCs** **Interior layout:** a. Building layout provides unobstructed sight lines, minimizing hidden areas and blind comers.

6.4 GREEN BUILDING FEATURES IN STATION PLANNING

Green building features to be incorporated in the station planning is as follows:

- Rainfall will be recharged to ground through rain water harvesting.
- Lifts and escalators consuming lesser energy than the conventional lifts and escalators should be installed.
- All elevated stations to be equipped with solar energy panels.
- Low flow water fixtures at the stations should be 30 percent more efficient than the baseline of IGBC's rating system.
- Energy efficient air-conditioning and lighting arrangements should be done.
- ETPs/STPs to be installed at various locations to treat the waste water.
- Fly ash to be used in concrete production and bricks to reduce cement consumption and CO2 emissions.
- Low VOC paints, adhesives and sealants to be used in the buildings to reduce the adverse health effect and improve quality of indoor air.
- Automatic controls for the outdoor lights to be installed.
- Adequate levels of daylight factor to be achieved through the design of the fenestrations for more than 50% of living areas in the concourse level in elevated stations.
- Efficient waste segregation and recycling of waste to be done.

6.5 POTENTIAL PARKING AND PROPERTY DEVELOPMENT SITES

Dedicated parking provision and property development for metro are key factors in determining success of a metro system. Parking provisions along pedestrian facilities like footpath and feeder systems would encourage more commuters to use the transit system who could safely park their vehicles at the nearest station, walk to the station or rely on feeder connectivity. The tentative sites for parking and property development have been identified station-wise along the corridors of Phase-II metro on the basis of preliminary reconnaissance and are presented in **Table 6.11.**

TABLE 6.11: DETAILS OF PARKING FOR ALL THREE CORRIDORS

S. No.	Station/Location	Parking Area in Sqm
Corridor-3 Around 29.4 Ha in Madhavaram Depot (State Govt. Land) and 6.3 Ha in Sipcot Depot (Private Land) has been reserved for Parking and Property Development. Out of this 35.7 Ha, if we take 50:50 ratio for Parking and PD, then 17.85 Ha can be taken for Parking and remaining 17.85 Ha in PD.		

S. No.	Station/Location	Parking Area in Sqm
Corridor-4		
1	Netasan Park	3000
2	Alwarthiru Nagar	3248
3	Poonamallee Bypass	3490
Corridor-5		
1	Madhavaram Milk Colony	2200
2	Thirumangalam	1030
3	Grain Market	3000
4	St. Thomas Mount	4000
5	Perumbakkam	2300

6.6 FEEDER SERVICES

The planning of seamless transport integration facilities at the influence zones of various metro stations is of utmost importance. The details of feeder services provided as part of Chennai Metro Phase-II is provided in **Chapter 7.**

6.7 DETAILS OF LIFT AND ESCALATORS CORRIDORWISE

Details of Lift and Escalator corridor wise are presented in **Table 6.12.**

TABLE 6.12: DETAILS OF LIFT AND ESCALATOR FOR ALL THREE CORRIDORS

SN	Station Name	Nos. of Lift	Nos. of Escalator
	Corridor 3: Madhavaram to SIPCOT 2		
1	Madhavaram Milk Colony	7	22
2	Thapalpetti	3	8
3	Murari Hospital	3	14
4	Moolakadai	3	14
5	Sembiyam	3	14
6	Perambur Market	3	14
7	Perambur Metro	3	24
8	Ayanavaram	3	14
9	Otteri	3	14
10	Pattalam	3	14
11	Perambur Barracks Road	3	15
12	Doveton Junction	3	15
13	Purasaiwakkam High Road	3	8
14	Kelleys	3	15
15	KMC	3	24
16	Chetpet Metro	3	24
17	Sterling Road Junction	3	8
18	Nungambakkam	3	24

SN	Station Name	Nos. of Lift	Nos. of Escalator
19	Gemini	3	24
20	Thousand Lights	3	24
21	Royapettah Govt. Hospital	3	24
22	Radhakrishnan Salai Jn	3	15
23	Thirumayilai Metro	3	8
24	Mandaiveli	3	8
25	Greenways Road Metro	3	15
26	Adyar Junction	3	24
27	Adyar Depot	3	15
28	Indira Nagar	3	15
29	Thiruvanmiyur Metro	2	15
30	Tharamani Link Road	2	15
31	Nehru Nagar	4	2
32	Kandanchavadi	4	2
33	Perungudi	4	2
34	Thoraipakkam	4	2
35	Mettukuppam	4	2
36	PTC Colony	4	2
37	Okkiyampet	4	2
38	Karapakkam	4	2
39	OkkiyamThoraipakkam	4	2
40	Sholinganallur	4	2
41	Sholinganallur Lake	4	2
42	Sri Ponniamman Temple	4	2
43	Sathyabama University	4	2
44	St. Joseph's College	4	2
45	Semmancheri	4	2
46	Gandhi Nagar	4	2
47	Navallur	4	2
48	Siruseri	4	2
49	Sipcot 1	4	9
50	Sipcot 2	4	9
	Total	**172**	**541**
	Corridor 4: Lighthouse to Poonamallee Bypass		
1	Lighthouse	2	8
2	Foreshore Estate Road	2	8
3	Kutchery Road	2	8
4	Thirumayilai Metro	2	8
5	Alwarpet	2	8
6	Bharathidasan Road	2	8

SN	Station Name	Nos. of Lift	Nos. of Escalator
7	Adyar Gate Junction	3	12
8	Nandanam	3	12
9	Natesan Park	3	12
10	Panagal Park	3	8
11	Kodambakkam Metro	3	12
12	Meenakshi College	2	8
13	Power House	4	9
14	Vadapalani	4	9
15	Saligramam	4	9
16	Avichi School	4	9
17	Alwarthiru Nagar	4	9
18	Valasaravakkam	4	9
19	Karabakkam	4	9
20	Alapakkam Junction	4	9
21	Porur Junction	4	9
22	Chennai Bypass Crossing	4	9
23	Ramchandra Hospital	4	9
24	Iyappanthangal Bus Depot	4	9
25	Kattupakkam	4	9
26	KumananChavadi	4	9
27	KaryanChavadi	4	9
28	Mullaithottam	4	9
29	Poonamallee Bus Terminus	4	10
30	Poonamallee Bypass	4	10
	Total	**101**	**276**
Corridor 5: Madhavaram to Sholinganallur			
1	Madhavaram Milk Colony	7	22
2	Venugopal Nagar	2	8
3	Assissi Nagar	4	9
4	Manjambakkam	4	9
5	Velumurugan Nagar	4	9
6	MMBT	4	9
7	Shastri Nagar	4	9
8	Retteri Junction	4	2
9	Kolathur Junction	3	9
10	Srinivasa Nagar	3	10
11	Villivakkam Metro	4	22
12	Villivakkam Bus Terminus	3	8
13	Nathamuni	3	10
14	Anna Nagar Depot	5	11

SN	Station Name	Nos. of Lift	Nos. of Escalator
15	Thirumangalam	4	2
16	Kendriya Vidyalaya	5	11
17	Kaliammankoil Street Junction	5	11
18	CMBT	7	26
19	Grain Market	7	22
20	Sai Nagar Bus Stop	4	9
21	Elango Nagar Bus Stop	4	9
22	Alwartirunagar	4	9
23	Valasaravakkam	4	9
24	Karabakkam	4	9
25	Alapakkam Junction	4	9
26	Porur Junction	4	9
27	Mugalivakkam	4	9
28	DLF IT SEZ	4	9
29	Sathya Nagar	4	9
30	CTC	4	9
31	Butt Road	4	9
32	Alandur	2	2
33	ST. Thomas Mount	4	9
34	Adambakkam	5	10
35	Vanuvampet	5	10
36	Puzhuthivakkam	5	10
37	Madipakkam	5	10
38	Kilkattalai	5	10
39	Echangadu	4	2
40	Kovilambakkam	5	10
41	Vellakkal	6	11
42	MedavakkamKoot Road	4	2
43	Kamaraj Garden Street	4	2
44	Medavakkam Junction	4	9
45	Perumbakkam	4	9
46	Global Hospital	4	9
47	Elcot	4	9
48	Sholinganallur	4	2
	Total	**204**	**329**

7. INTERMODAL INTEGRATION

7.1 COVERAGE

The metro network will have to be provided with enhanced convenience of interchanging facility with other transport modes for better mobility and reduction in travel time for commuters. Interchange facility with secondary/intermediate transport modes is important for seamless transfer of commuters. Multimodal integration is planned to provide first and last mile connectivity for commuters. Ministry of Housing and Urban Affairs (MoHUA) has laid down new metro policy guidelines 2017 to include the need and provision of all Public, Intermediate Public Transport (IPT) and private modes in DPRs for the metro systems.

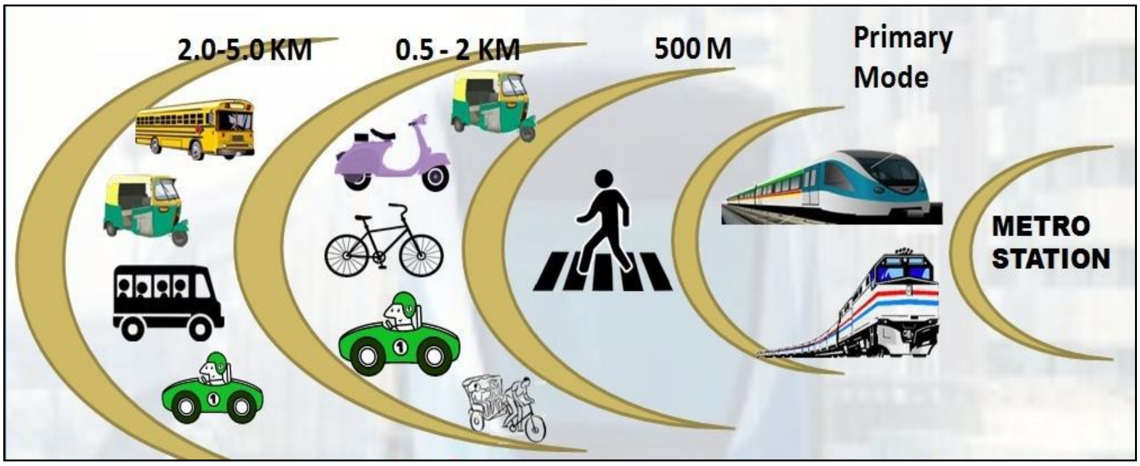
The share of various modes of secondary/ intermediary modes of travel is complex and debatable issue which is dependent on a large number of variables like available road width, penetration in the residential areas, road condition, distance from the existing metro stations, availability of parking and lay out and availability of circulating areas at the metro stations, business centre or markets & existing traffic densities. These factors relate with each other and evolve with development of new modal 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.

Multimodal integration depends on many factors such as nature of station terminal (terminal or en route), its catchment, availability of access/dispersal modes, and interchange with other mass transport, distance from station, trip length and destination. This includes planning for roads, footpaths/pedestrian facilities, bus stops, IPT stands, parking for different modes, pick and drop areas etc.

As some of the stations are proposed as interchanges between other mass transport systems, additional effort towards integration has been given on such stations.

Intermodal integration explores the coordinated use of two or more modes of transport for efficient, speedy, safe, pleasant and comfortable movement of passengers in urban areas (**Figure 7.1).** It provides convenient and economical connection of various modes to make complete journey from origin to destination.

FIGURE 7.1: METRO MULTIMODAL INTEGRATION IN THE CATCHMENT AREA



7.2 INTEGRATED MULTIMODAL URBAN TRANSPORT SYSTEM

Some of the essential features of an integrated multi-modal urban transport system are the physical integration of public transport services, fares, ticketing, infrastructure provision, management, pricing, and integration of transport authorities.

7.2.1 Physical Integration

Physical integration refers to the provision of jointly used transport facilities & equipment to provide seamless mobility. Integration of physical space, network planning and physical infrastructure have been planned to facilitate easy transfer of commuters between different modes of transport. Seamless mobility is proposed to remain connected between different transport modes i.e. mass rapid transit, city bus system, IPT, NMT and private modes i.e. cars, two wheelers etc.

Augmentation of carriageway and footpath in the station vicinity to cater to the traffic volumes has been proposed through strengthening of road shoulder areas and relocation of vendors/hawkers, on-street parking and all encroachments from the service/ access roads.

7.2.2 Operational Integration

This involves application of management techniques to optimize the allocation of transit resources and coordinate services. The techniques/principles of network integration include:

- Coordinated Routing and Scheduling- in which high-capacity, long-haul modes, such as rail rapid transit is considered as the trunk system and buses act as feeder to the rail system. Accordingly, the integrated route network is planned by generating feeder bus routes for each rail station.
- Rationalization of Redundant Services- The wasteful duplication of transit service by competing systems is eliminated and resources are redeployed to reduce headways on existing routes and extend services into new areas.
- Network coordination and access- in which access facilities need to be provided for non-motorized transport (pedestrians and cyclists) and private transport to support and enhance the public transport operations, to achieve overall network integration.

The service integration takes into account all modes services. That means all modes providing service should be complementary to each other.

7.2.3 Fare Integration

The basic principle behind fare integration is that one ticket provides access to all modes of transport even when managed by different companies. The financials of public transport provide important indicators to assess the sustainability of public transport. Choice of fare structure is a very important part of public transport planning. It directly influences operators' revenue. At its simplest, integration of fares, allows a person to make a journey that involves transfers (within or between different transport modes) with a single ticket that is valid for the complete journey, modes being buses, trains, subways, taxies, parking, etc. The major benefits of fare integration are as follows:

- It encourages people to use public transport by simplifying the transfer between transport modes and by increasing the efficiency of the services
- Provides a common ticket across the modes
- Improves the experience of seamless mobility

7.2.4 Information Integration

Creating the possibility to get information about the entire journey and not having to enquire at different sources. To take an informed decision during travel, real-time access to information is of strategic importance.

Information integration deals with the Information on routes, schedules, fares, and transfer points for all transit modes and services throughout the urban area, which is provided by a centralized source. Information services include route maps, timetables, fare schedules, and promotion materials, uniform street signs and vehicle identification, display at stops, transfer points and major stations, and telephone inquiry answering service. Providing integrated information during journey before and in between is important, to make them attractive.

7.2.5 Institutional Integration

City growth strategies are usually guided by documents like land use plans, development plans and master plans etc. and the urban transport models are determined by parameters like existing road network, public transport and its related infrastructure, personal vehicles, licensing mechanism and authorities, land ownership, fare structure of public transport, Intelligent Transport System (ITS) mechanism, traffic enforcement agencies and traffic law enforcing mechanisms, goods and freight movement and their operators, road safety and accident management system etc. All these agencies which prepare these policy documents and are in charge of governing these functions generally work independently and usually its observed that there is no synergy between them. There exists no umbrella agency that monitors and integrates these multiple bodies in order to ensure smoother functioning of all aspects related to urban transport in any city.

7.3 PRINCIPLES OF INTEGRATION

The planning principles taken into account for intermodal integration at the station locations are as follows:

- Seamless connectivity to and from catchment area of the station
- Integration with all possible modes including other mass transport systems
- Priority to be given to pedestrians followed by public transport
- Parking facilities for all modes including non-motorized transport (NMT)

- Minimal land acquisition
- Accommodate ground constraints

The multimodal integration proposals have been formulated for facilitating traffic dispersal and circulation facilities based on the following considerations:

- Minimizing pedestrian/vehicle conflicts and effective passenger interchange with feeder modes. Proper design of circulation area adjoining the station building to ensure rapid/ efficient dispersal of the passengers and avoiding conflicts between pedestrian and vehicular traffic.
- Pedestrians require a convenient and safe access to the proposed metro station. For smooth movement of pedestrians, all the footpaths in the metro station influence zone will be considered to be upgraded to desired level of comfort and also proposed new within the stations vicinity areas.
- High quality pedestrian access will be accomplished through design factors such as directness and connectivity, ease of movement, safety and security. The vendors if any on the footpaths shall be removed and desired accessibility to metro stations will be provided. The facilities (footpaths/ walkways) will be directly integrated with the metro system.
- Facilitating passenger interchange with other transit systems: Dedicated linkages proposed like subways, skywalks, covered walkways etc. which will reduce the passenger travel time and pedestrian load on the roads.
- Circulation area with adequate parking space, designated space for embarking and disembarking for vehicular traffic (pick-drop zones) and feeder modes like Buses, IPTs and NMT.
- Availability of total carriageway and footpath widths required to cater to the proposed traffic volumes to be augmented through strengthening of road shoulder areas and relocation of vendors/hawkers, on-street parking and all encroachments from the service/ access roads.

7.4 INTERCHANGE STATIONS

The metro corridors in Phase 1 and the proposed Corridors in Phase 2 will serve as a major mass transit system in Chennai. It will have major interchanges with other existing/proposed metro system/MRTS system/bus/rail terminals which will serve as complementary/ feeder for the passengers from their respective origins to destinations and vice versa. To integrate the interchange stations many factors such as nature of interchange station, its catchment, availability of access/dispersal modes, and interchange with other public transport modes, distance from station, trip length and destinations etc. are considered. Some of the passenger facilities as expected in the interchange stations are described below:

- **Pedestrian facilities:** Interchange stations will be expected to experience heavy pedestrian movements during peak hour. Therefore, pedestrian infrastructure facilities i.e. pedestrian pathways, skywalks, subways and foot over bridges are planned accordingly.

- **Traffic Dispersal Facilities:** Adequate traffic dispersal facilities in terms of continuous footpaths, city bus stops, IPT stands, pick-drop areas, traffic signages and parking within the proximity of the entries/exits, pedestrian crossing facilities, traffic calming measures along with signage, road markings, signals, speed table and NMT crossings has been planned near the interchange station influence area to facilitate the safe and smooth movement for both pedestrians & vehicles.

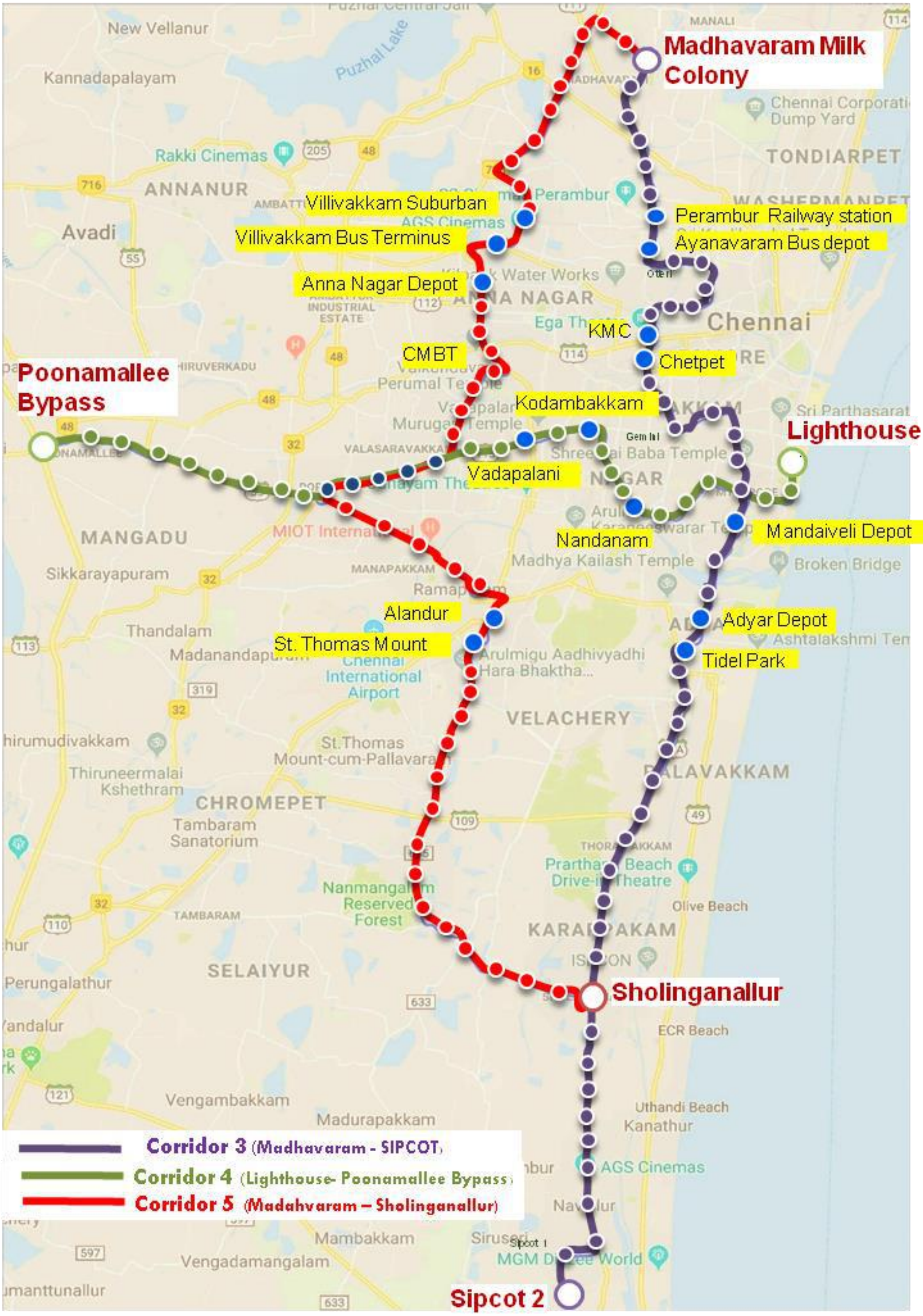
- **Embarking/Disembarking Zones/Parking Areas:** At interchange stations, long and short duration parking spaces, pick and drop facilities for different public & private modes are planned as per peak hour passenger station boarding/alighting. The parking areas will directly be connected to the proposed interchange stations through pedestrian pathways/ FOB/ subways.

Phase II corridors stations are interchange with Phase 1 Metro, Bus Terminus, MRTS and Suburban Rail. **Table 7.1** and **Figure 7.2** present the interchange stations on the proposed Phase II corridors with other modes of transport.

TABLE 7.1: INTERCHANGE STATIONS OF PHASE-II WITH OTHER MODES

Type	Corridor 3 (Madhavaram – SIPCOT)	Corridor 4 (Light house- Poonamallee Bypass)	Corridor 5 (Madhavaram – Sholingnallur)
Metro-Metro/MRTS	Madhavaram, KMC, Thirumayilai, Thiruvanmiyur Shollinganallur	Vadapalani, Nandanam, Thirumayilai	Madhavaram, CMBT, Alandur, St. Thomas Mount, Shollinganallur
Metro-Bus	Ayanavaram, Mandaiveli, Adyar	-	Annanagar, Villivakkam, CMBT
Metro-Suburban Rail	Perambur, Chetpet	Kodambakkam	Villivakkam, St. Thomas Mount

FIGURE 7.2: METRO PHASE-II INTERCHANGE STATIONS



Inter-modal integration facilities at the stations are proposed near catchment areas upto 1km. The city civic agencies like Chennai Municipal Corporation, State Highway Department etc. shall provide the passenger infrastructure beyond this catchment area in order to facilitate seamless connectivity to metro stations.

The following inter-modal integration and dispersal facilities have been planned at metro stations for efficient passenger movement and to meet the shortfall in capacity in terms of road capacity, traffic movement/ circulation, pedestrian facilities, bus stops, IPT stands/ Pick-Drop areas and parking.

i. Augmentation of Road Geometry &Footpaths:

- It is proposed to utilize the complete Right of Way to cater to the future traffic volume. The existing road shoulder areas and service lanes have been augmented/ strengthened in the design wherever possible.
- A continuous, encroachment free and well maintained footpath of 2m width is proposed on major roads near station locations. A continuous footpath of a minimum 1.8 m width is provided on the local roads connecting metro stations.
- The existing and proposed features of the road are shown in the multi-modal integration plan to essentially identify the degree of improvement proposed as part of the proposal.

ii. Seamless connectivity/Effective Passenger Interchange with Feeder Modes:

- The circulating area adjoining the station building is proposed to be properly designed to ensure rapid/efficient dispersal of passengers, avoiding conflict between pedestrians and vehicular traffic. Demarcated pick and drop zones and bays for feeder modes like buses, IPT are proposed near the station.
- The station entry/exit is planned keeping in view the major growth centers/activity areas. The entry/exit has been designed to integrate the station with existing/ proposed bus stops/bus bays, pick-drop zones and IPT services within walking distance.
- Off street parking is proposed wherein adequate land is available for encouraging park and ride. The existing on street parking can be moved to these parking lots for availability of total carriageway for vehicular movement.

iii. Uninterrupted Traffic Flow/Smooth Traffic Conditions:

- It is proposed to relocate the vendors/hawkers and parking for unobstructed movement of pedestrians and vehicles.

iv. Pedestrian & Disabled Friendly Design:

- To promote walking a minimum of 1.2m wide footpath has been proposed on the local roads whereas a continuous footpath of 2m width is proposed on the major roads to provide accessibility to people on wheel chairs. Wherever entry/exit is proposed on the footpath area, it has been ensured that minimum 3m width is left for walking.

- Junctions and intersections are proposed with proper pedestrian crossings. In the design, table top crossings has been proposed wherever possible, otherwise ramps with gentle slope ranging from 1:5-1:7 have been designed for pedestrians and wheelchair users.

- Proper road markings, Traffic Signages, Zebra crossings and pedestrian signals are proposed to provide safe and uninterrupted pedestrian movement

- Design considerations like ramps for wheelchair movement, lifts have been proposed in the station design for ease in movement of physically challenged.

Based on the above proposals, multimodal integration and dispersal plans for major selected stations are presented in **Annexure 7.1** to **Annexure 7.29.** (Refer at the end of this chapter).

7.5 FEEDER SERVICES

The planning of seamless transport integration facilities at the influence zones of various metro stations is of utmost importance. Feeder services to the proposed metro network will be essential to provide convenient and quick transfer of passengers from one mode of transport to another. As all commuters will not be living within walking distance of the proposed network, proper planning for feeder services will be necessary based on analysis of passenger demand on the system.

Various modes of transportation like feeder buses, auto rickshaw/taxi and bicycles can provide first mile as well as last mile connectivity other than walking to the metro station. For catchment area of about 0.5-1 km from the proposed network, commuter can easily access it by walk. People residing in the next 1 km can reach the station by cycles, 2-Wheeler and auto-rickshaws. Areas beyond the 2-km catchment will require regular feeder bus services to reach the metro station.

The feeder service facilities will be provided at the metro stations to connect the trip generation/ attraction areas in the influencing zone of metro corridors. The facilities of footpaths, feeder buses and bicycles (bike sharing) have been planned for peak hours of various horizon years.

7.5.1 Feeder Bus System

The feeder buses shall be of high quality, ultra-modern and customer oriented that can deliver fast, comfortable and cost-effective urban mobility. Easy-to-board (low floor), attractive and environmentally friendly buses with air conditioned Mini-buses are proposed for feeder system.

The facilities of feeder buses have been estimated for peak hours of various horizon years 2025, 2035, 2045 and 2055. The buses required along metro corridors are presented in **Table 7.2** and **Figure 7.3** to **Figure 7.5.**

7.5.2 Public Bicycle Sharing Service

This service will be provided for the passengers for 1 km to 2 km of the metro stations influence area. A bicycle sharing system is the service in which bicycles are made available for free and shared use to metro passengers on a short term basis. The main purpose is to allow passengers to depart or arrive at metro stations. The requirement of bicycles along the metro corridors is estimated and is presented in **Table 7.3.**

7.5.3 Pedestrianisation / Provision of Footpaths

Pedestrians require a convenient and safe access to the proposed metro station. For smooth movement of pedestrian, all the footpaths in the metro station influence zone will considered to be upgraded to desired level of comfort and also proposed new within the stations vicinity areas.

High quality pedestrian access will be accomplished through design factors such as directness and connectivity, ease of movement, safety and security. The vendors if any on the footpaths shall be removed and desired accessibility to metro stations will be provided. The facilities (footpaths/ walkways) will be directly integrated with the system.

TABLE 7.2: FEEDER BUS SYSTEM FOR PHASE-II METRO CORRIDORS

S N	Metro Station	Route No.	Feeder Bus Route Name	Reqd. No. of Buses in Peak Hour			
				2025	2035	2045	2055
Corridor-3: Madhavaram to SIPCOT							
1	Madhavaram Milk Colony	R1	Madhavaram Milk Colony to Madhaveli via Padmavati Nagar	2	3	4	4
		R2	Madhavaram Milk Colony To Meenakshi Theatre via Kamarajar Salai	3	4	5	6
2	Thapal Petti	R1	Thapalpetti Bus Stop to Balaji Nagarvia via Subraman iGraden Main Road	2	2	3	4
		R2	Thapalpetti Bus Stop to Kilburn Nagar via Madhavaram Red Hill Road	2	2	3	4
3	Moolakkadai	R1	Moolakkadai to Kannadasan Nagar	2	3	4	4
		R2	Moolakkadai to Tendral Nagar	2	3	4	5
4	Sembiyam	R1	Don Bosco to Kumaran Nagar	3	4	6	8
5	Perambur Market	R1	Perambur Market to Vysarpadi Bus Station	3	4	5	7
6	PeramburMetro	R1	Perambur Railway Station to CSI St. Johns Church	2	3	5	5
7	Aynavaram	R1	Aynavaram Bus Depot to Eswaran Koil Lake	2	4	5	7
8	Doveton Junction	R1	Doveton to Otteri	2	3	4	4
9	KMC	R1	KMC to Ewarts Women Christian College	2	3	3	5
		R2	KMC to Parmeshwaran	2	3	4	5
10	Mandaveli	R1	Mandaveli Bus Depot to Santhome Church	2	4	4	6
		R2	Mandaveli Bus Depot to Sriram Colony	3	3	4	6
11	Adyar Junction	R1	Adayar Aavin Bus Stop to Kotturpuram	2	4	4	5
		R2	Adayar Aavin Bus Stop to Algappa College	2	2	3	4
12	Kandhanchavadi	R1	Kandhanchavadi to Palvakkam	2	3	4	5
13	Mettukupakkam	R1	Mettukupakkam Bus Stop to Periya Nilangarai Kuppam	2	3	4	6
14	Sholinganallur	R1	Sholinganallur to Mayajaal Multiplex	5	7	10	12
15	Satyabama University	R1	Satyabama University to Medavakkam New Bus Stop	2	2	4	5

S N	Metro Station	Route No.	Feeder Bus Route Name	Reqd. No. of Buses in Peak Hour			
				2025	2035	2045	2055
16	SIPCOT 2	R1	SIPCOT 2 to Kelambakkam	1	1	3	3
			Total Buses Required for Corridor-3	**50**	**70**	**95**	**120**
Corridor-4: Lighthouse to Poonamallee Bypass							
1	Lighthouse	R1	Light House to NKT School Bus Stop	1	2	2	3
2	Thrumayilai MRTS	R1	Thrumayilai MRTS to Anna Sathya Nagar	1	1	2	2
		R2	Thrumayilai MRTS to Mandaveli Bus Depot	1	1	2	2
3	Adyar Gate Junction	R1	Adyar Gate Junction to CLRI	3	4	5	6
		R2	Adyar Gate Junction to Varada Puram	2	3	4	5
4	Panagal Park	R1	Panagal Park to Anna Salai	4	5	7	8
		R2	Panagal Park to Loyola College	3	4	5	6
5	Meenakshi College	R1	Meenakshi College to Govindan Road	1	1	2	3
		R2	Meenakshi College to Nelson Manickan Road	1	1	2	2
6	Vadapalani	R1	Vadapalani to Gandhi Nagar Via Vadapalani Bus Terminus	1	2	3	3
		R2	Vadapalani to Andavar Nagar Via Murugan Temple	2	2	3	3
		R3	Vadapalani to KK Nagar Via Azhagarperumalkoil Street	2	2	3	3
7	Avichi School	R1	Avichi School to Kaliammankoli Street.	1	2	3	3
		R2	Avichi School to Kamaraja Salai	1	1	2	2
8	Karambakkam	R1	Karambakkam to Mount Poonamalle High Road	1	2	2	3
		R2	Karambakkam to Alappakkam Road	1	2	2	2
9	Iyyapanthangal Bus Depot	R1	Iyyapanthangal Bus Depot to Mangadu Main Road	1	1	2	2
		R2	Iyyapanthangal Bus Depot to Poonamalle High Road	1	1	2	2
10	Kumananchavadi	R1	Kumananchavadi to Poonamalle High Road	2	3	4	5
		R2	Kumananchavadi to Mangadu Main Road	2	4	5	6

SN	Metro Station	Route No.	Feeder Bus Route Name	Reqd. No. of Buses in Peak Hour			
				2025	2035	2045	2055
11	Mullaithottam	R1	Mullaithottam to Thiruvalluvar City Road	2	2	4	4
		R2	Mullaithottam to St. Francis Church	2	2	3	3
12	Poonamallee Bypass	R1	Poonamallee Bypass	3	3	4	4
		R2	Poonamallee Bypass	3	3	4	4
			Total Buses Required for Corridor-4	**42**	**54**	**77**	**86**
Corridor-5: Madhavaram to Sholinganallur							
1	Manjambakkam	R1	Manjambakkam to Red Hills via Madhavaram Red Hill Road	3	4	4	4
2	MMBT	R1	MMBT to Puzhal via Guntur Chennai Highway	3	4	4	5
3	Retteri	R1	Retteri to Surapet via Perambur Red Hills High Road	2	3	4	4
		R2	Retteri to Ponnaiappan Medu via 80 Feet Road	2	3	4	4
4	Villivakkam Bus Terminus	R1	Villivakkam Bus Terminus to Velankanni Madha Church via Red Hills Road	1	3	4	5
5	Anna Nagar Depot	R1	Anna Nagar West to Kaplok Bus Stand via Udyam Nagar	3	4	5	9
		R2	Anna Nagar West to Golden Colony via Telephone Exchange Bus Stand	4	4	5	7
6	Alwartirunagar	R1	Alwartirunagar to Porur Junction via Valasaravakkam Bus Stop	2	1	3	4
7	Saint Thomas Mount	R1	St. Thomas Mount to Errikarai Velacheri Bus Stop via City Link Road	3	3	4	5
8	Echankadu	R1	Echankadu Bus Stop to Pallavaram Junction Bus Stop via Dharga Road	4	5	5	7
9	Velakkal	R1	Vellakallu Bus Stop to Chitlapakkam Lake via Dr.Rajendra Prasad Road	2	4	5	5
10	Perumbakkam	R1	Perumbakkam Bus Stop to Pallikaranai via Pilliyar Koil Street	1	2	3	4
			Total Buses Required for Corridor-5	**30**	**40**	**50**	**63**
			Grand Total Buses Required	**122**	**164**	**222**	**269**

FIGURE 7.3: PROPOSED FEEDER BUS ROUTES TO CORRIDOR-3 METRO STATIONS

FIGURE 7.4: PROPOSED FEEDER BUS ROUTES TO CORRIDOR-4 METRO STATIONS

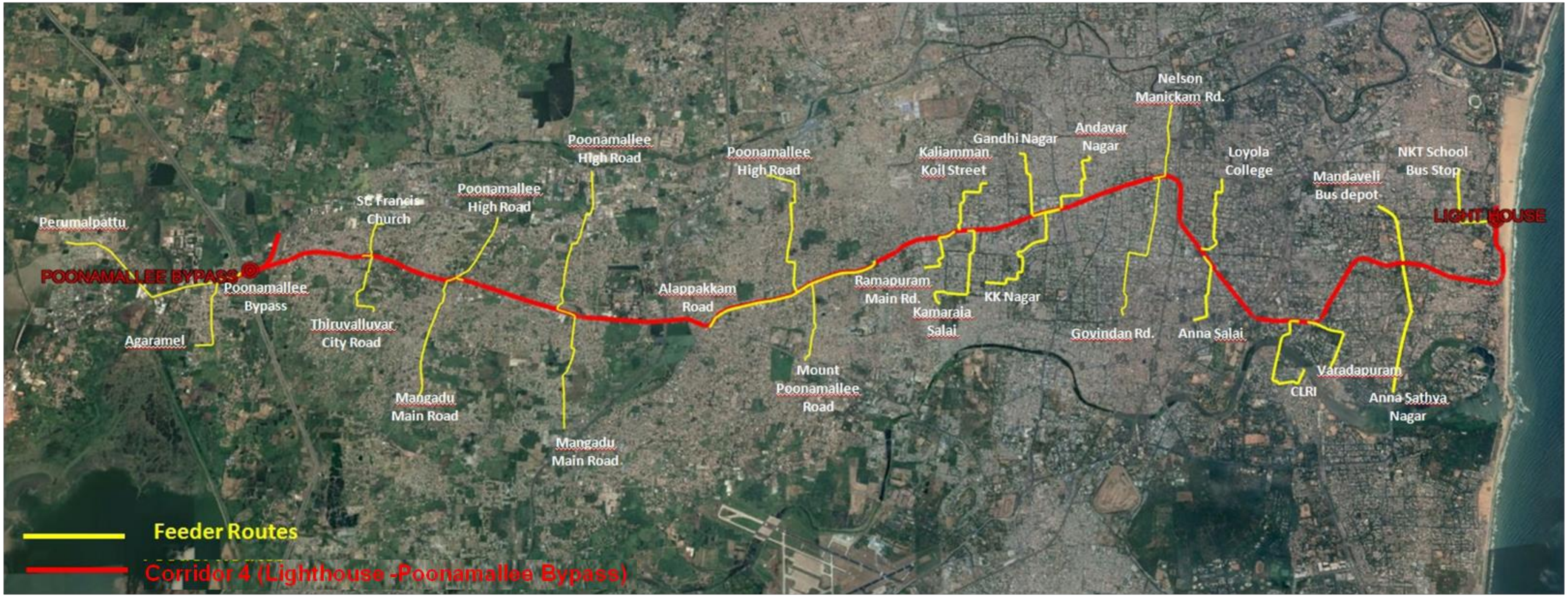


FIGURE 7.5: PROPOSED FEEDER BUS ROUTES TO CPRRIDOR-5 METRO STATIONS

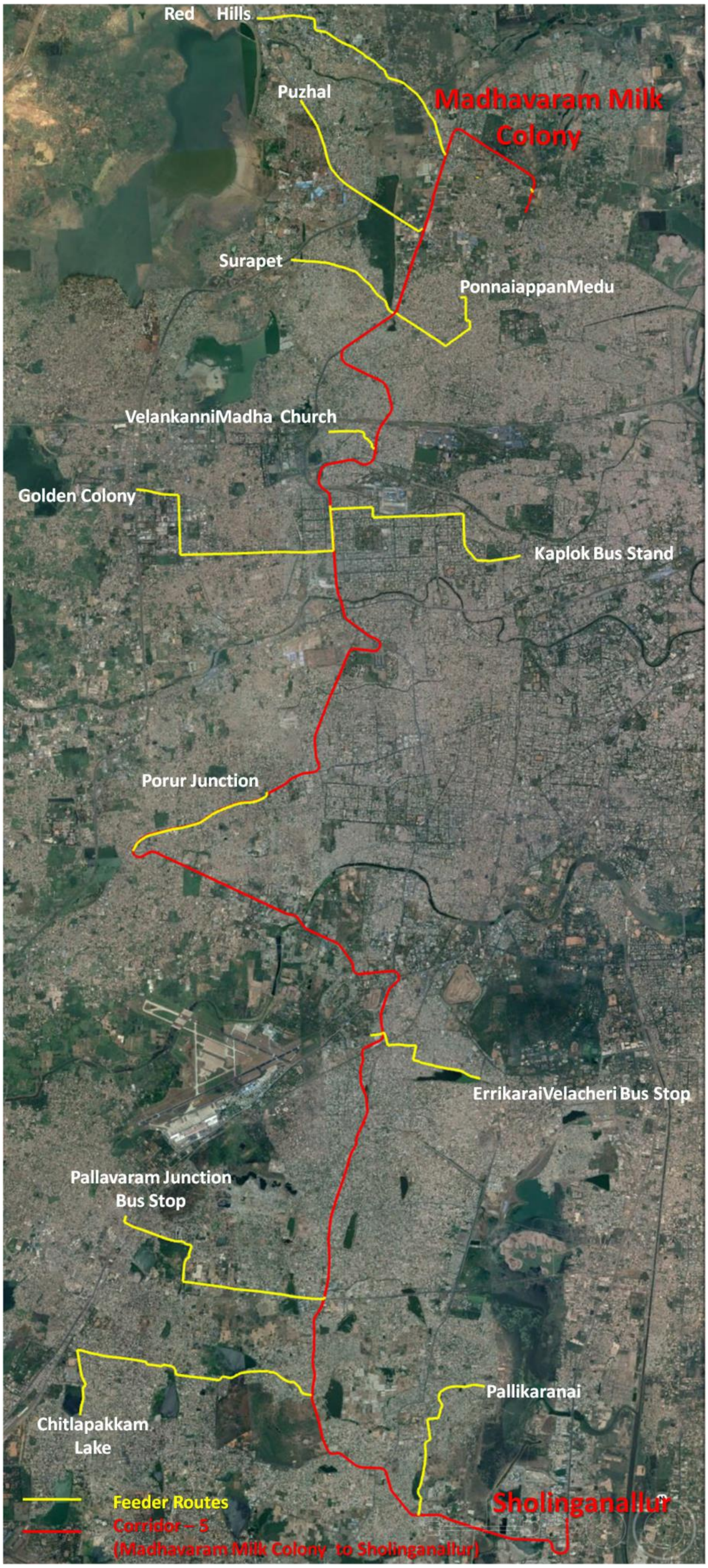
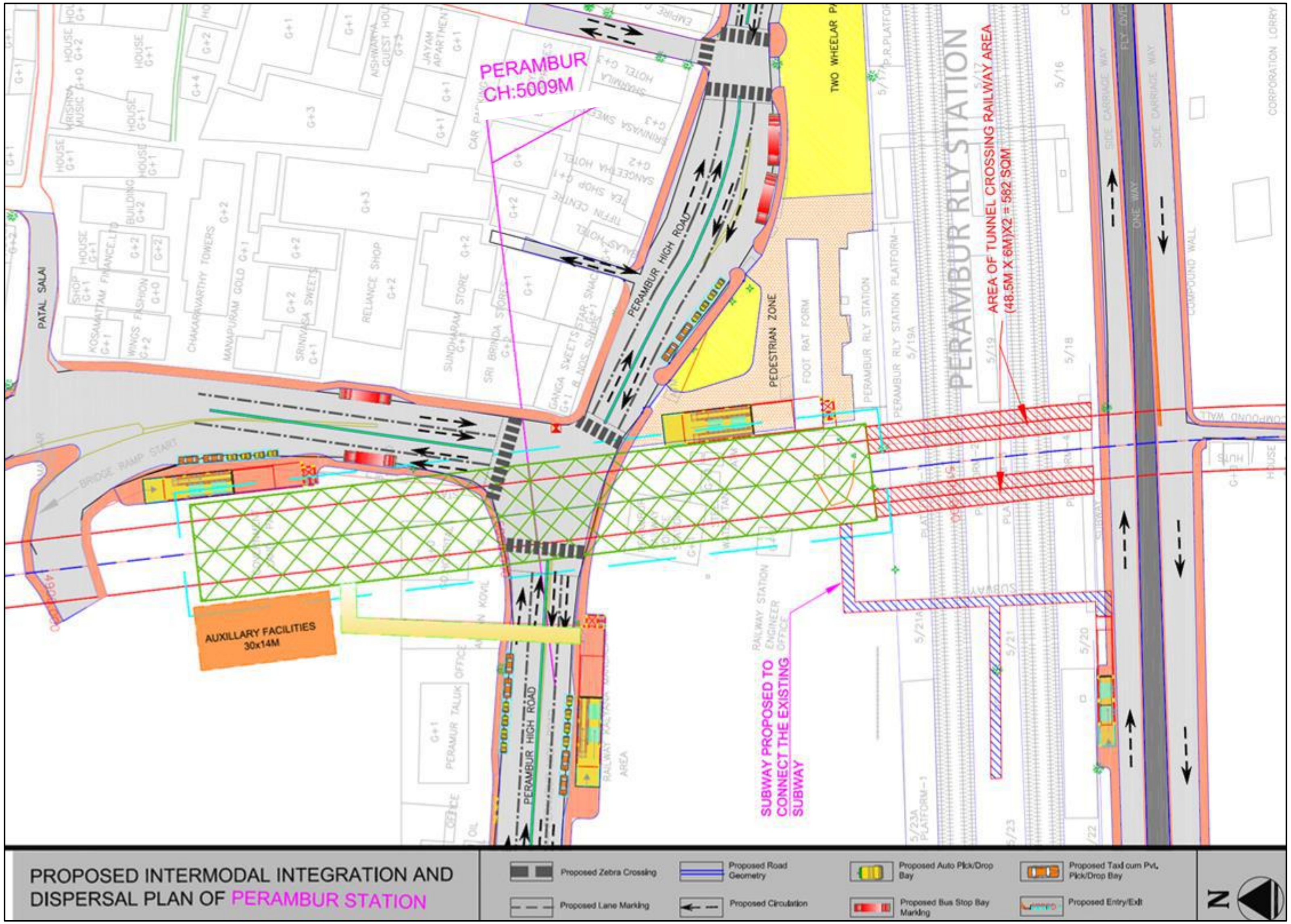


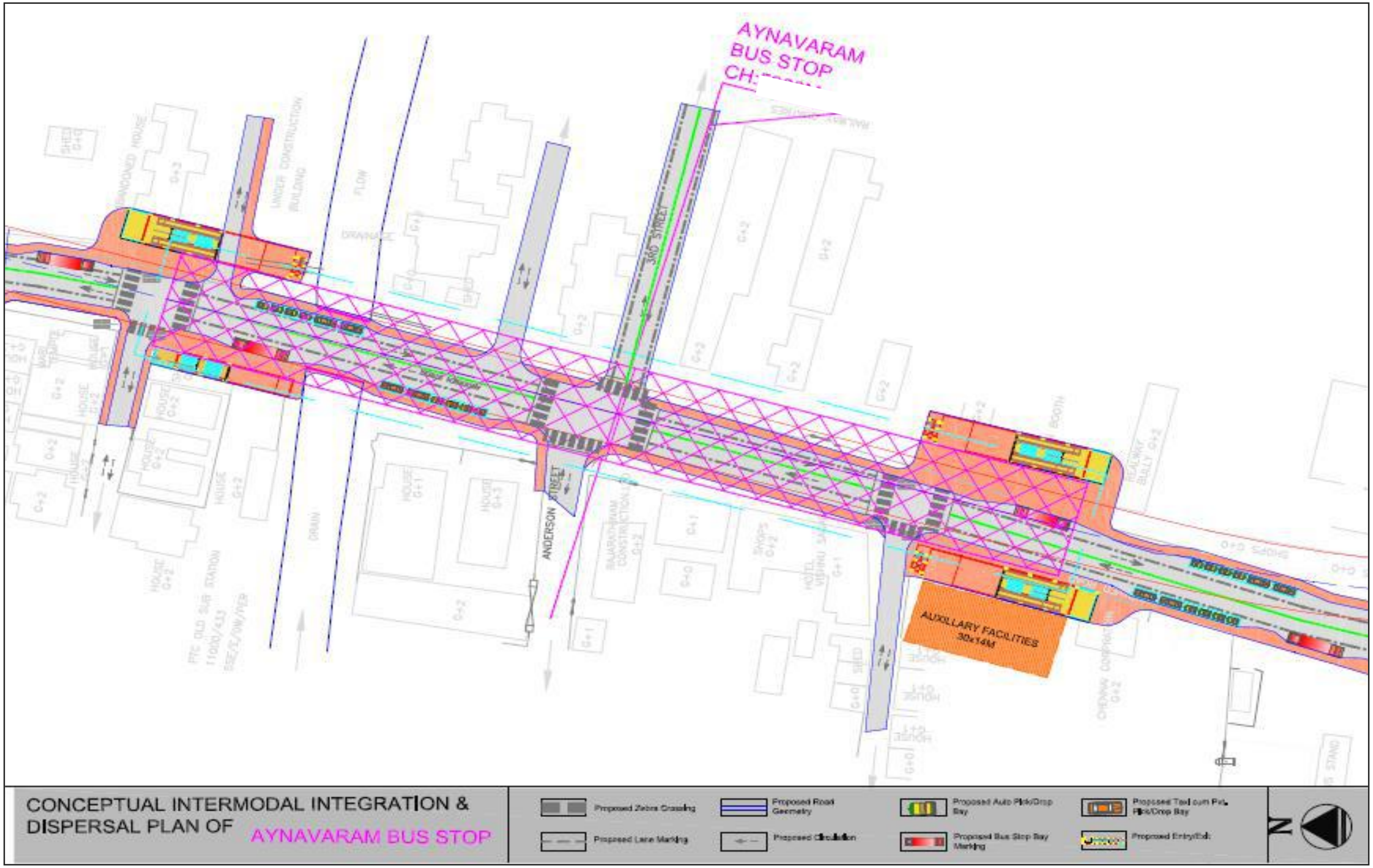
TABLE 7.3: BICYCLE SHARING SCHEME FOR PHASE-II METRO CORRIDORS

SN	Metro Station	No. of Bicycles Required in Peak Hour			
		2025	2035	2045	2055
Corridor-3: Madhavaram to SIPCOT					
1	Madhavaram Milk Colony	25	30	37	40
2	Thapal Petti	11	12	15	20
3	Moolakkadai	25	31	33	35
4	Sembiyam	40	46	65	70
5	Perambur Market	26	31	35	39
6	PeramburMetro	12	14	15	16
7	Aynavaram	32	35	38	40
8	Doveton Junction	15	20	21	24
9	KMC	48	60	65	70
10	Mandaveli	50	60	80	85
11	Adyar Junction	42	45	49	50
12	MGR Road Junction	12	14	18	20
13	Mettukupakkam	15	18	27	30
14	Sholinganallur	20	25	28	30
15	Satyabama University	8	10	10	14
16	SIPCOT 2	3	4	4	5
	Total Bicycles required for Corridor 3	**384**	**455**	**540**	**588**
Corridor-4: Light House to Poonamallee Bypass					
1	Light House	10	13	15	20
2	Thrumayilai MRTS	15	17	20	24
3	Adyar Gate Junction	30	38	43	49
4	Panagal Park	50	62	78	93
5	Meenakshi College	13	15	18	20
6	Vadapalani	20	35	42	50
7	Avichi School	12	20	29	40
8	Karambakkam	10	12	14	15
9	Iyyapanthangal Bus Depot	8	14	22	35
10	Kumananchavadi	20	35	48	65
11	Mullaithottam	20	25	41	67
12	Poonamallee Bypass	29	30	35	41
	Total Bicycles required for Corridor 4	**237**	**316**	**406**	**519**
Corridor-5: Madhavaram to Sholinganallur					
1	Manjambakkam	6	11	13	15
2	MMBT	13	15	18	20
3	Retteri	30	34	40	45
4	Villivakkam Bus Terminus	32	35	40	43
5	Anna Nagar Depot	36	47	50	52
6	Alwartirunagar	14	15	20	25
7	Saint Thomas Mount	20	21	22	23
8	Echankadu	26	31	38	42
9	Velakallu	8	10	12	15
10	Perumbakkam	3	4	6	10
	Total Bicycles required for Corridor 5	**188**	**223**	**259**	**290**
	Grand Total Bicycles Required	**809**	**994**	**1205**	**1397**

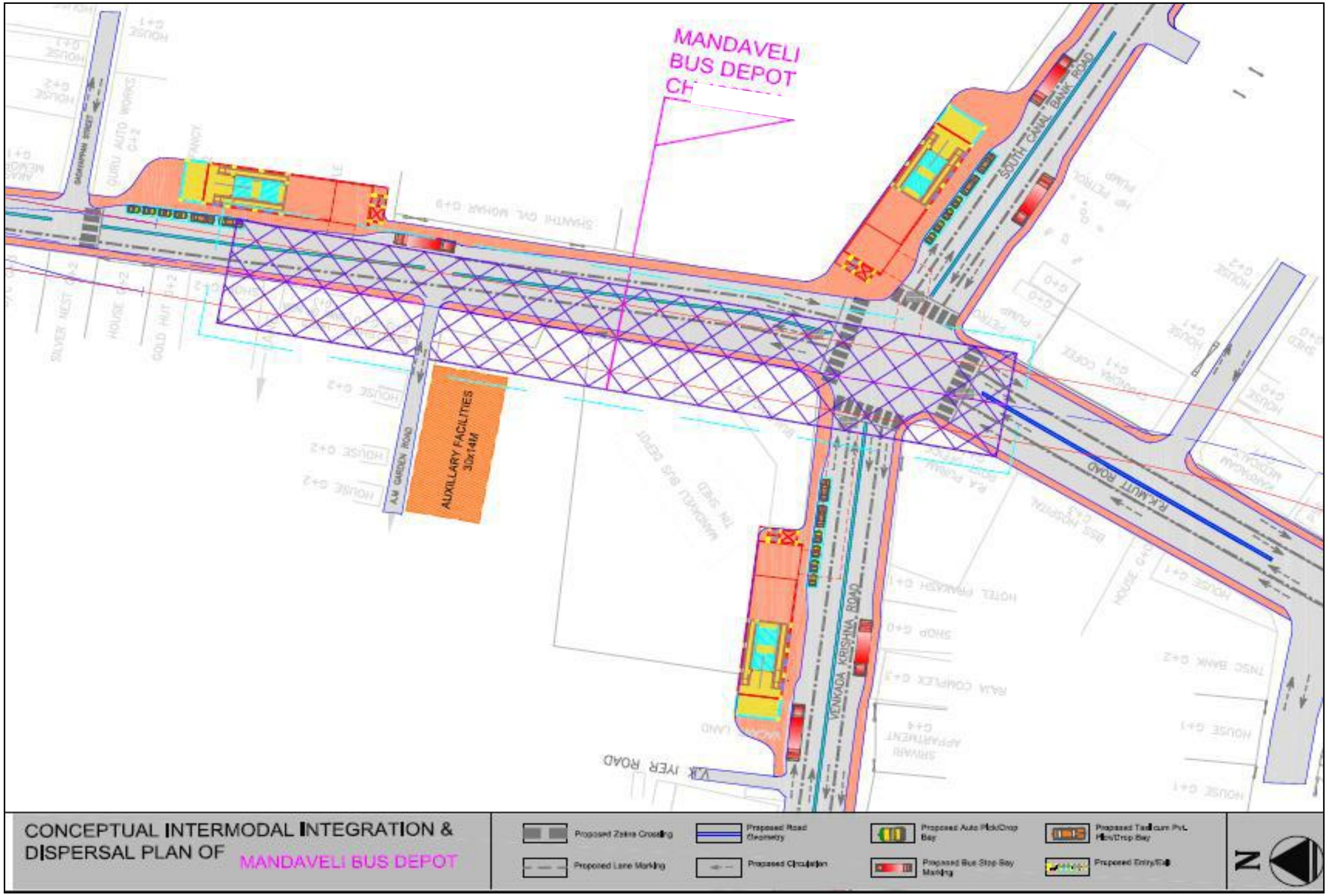
ANNEXURE 7.1. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF PERAMBUR STATION STATION



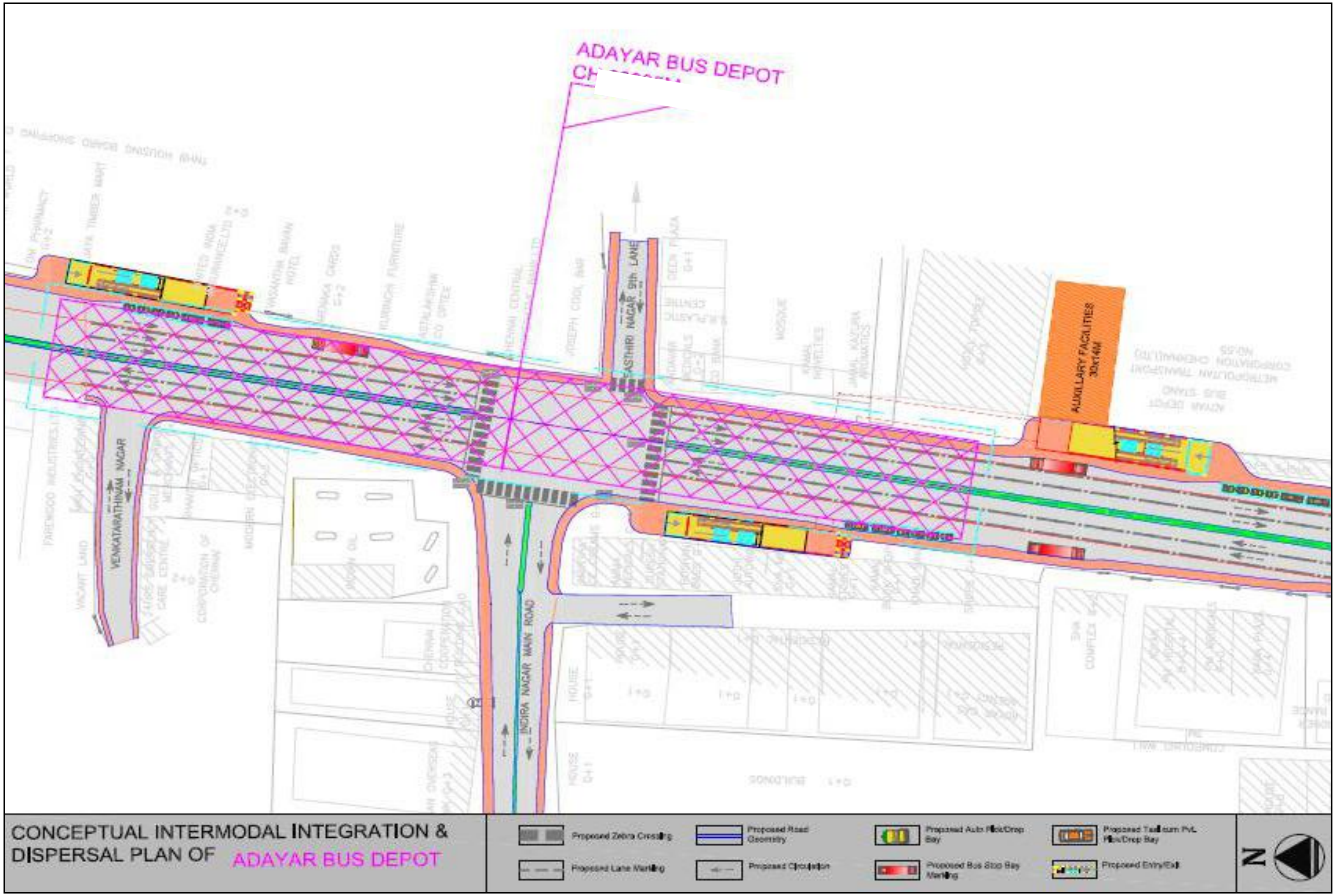
ANNEXURE 7.2. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF AYNAVARAM BUS STOP STATION



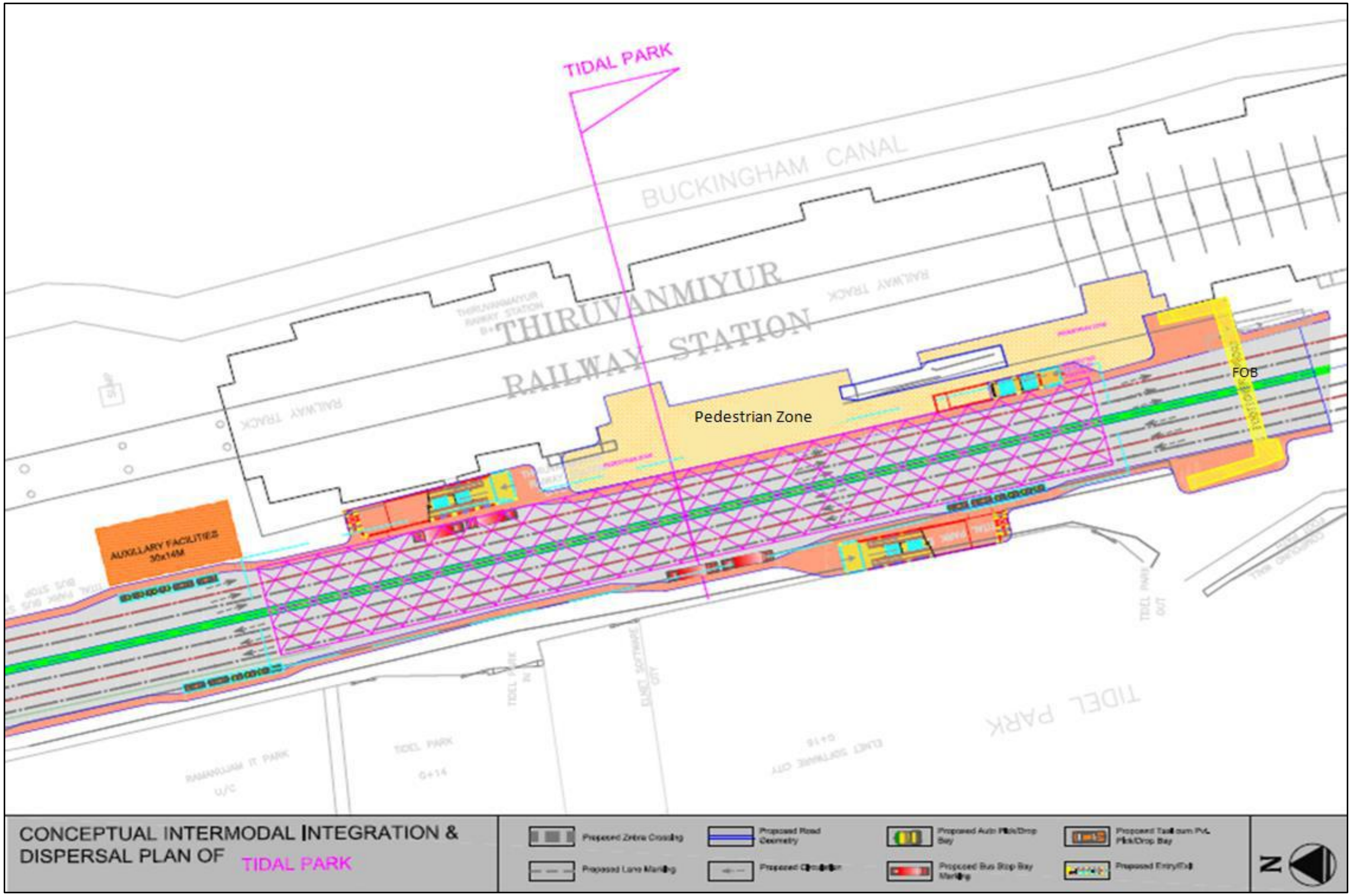
ANNEXURE 7.3. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF MANDAVELI BUS DEPOT STATION



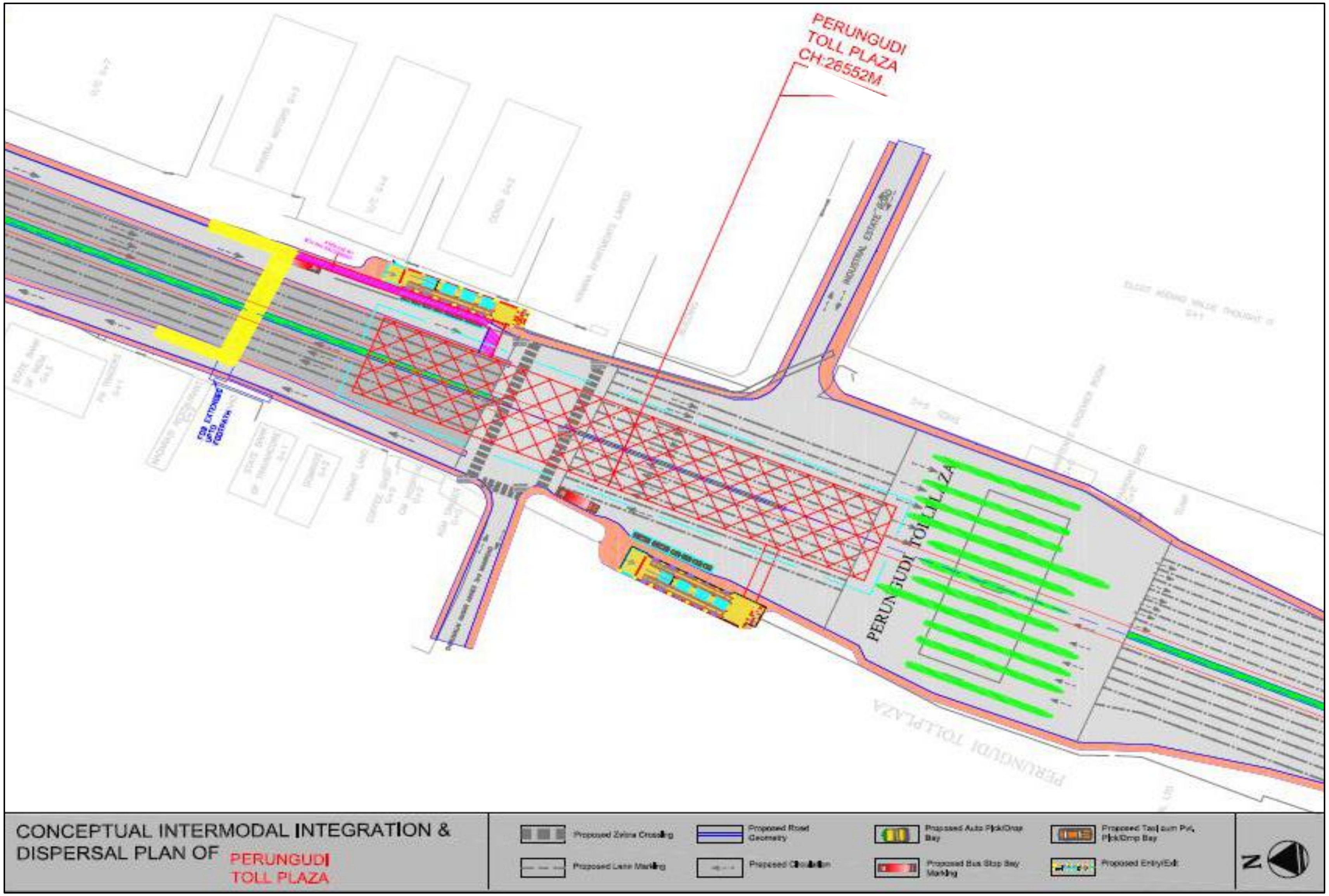
ANNEXURE 7.4. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF ADAYAR BUS DEPOT STATION



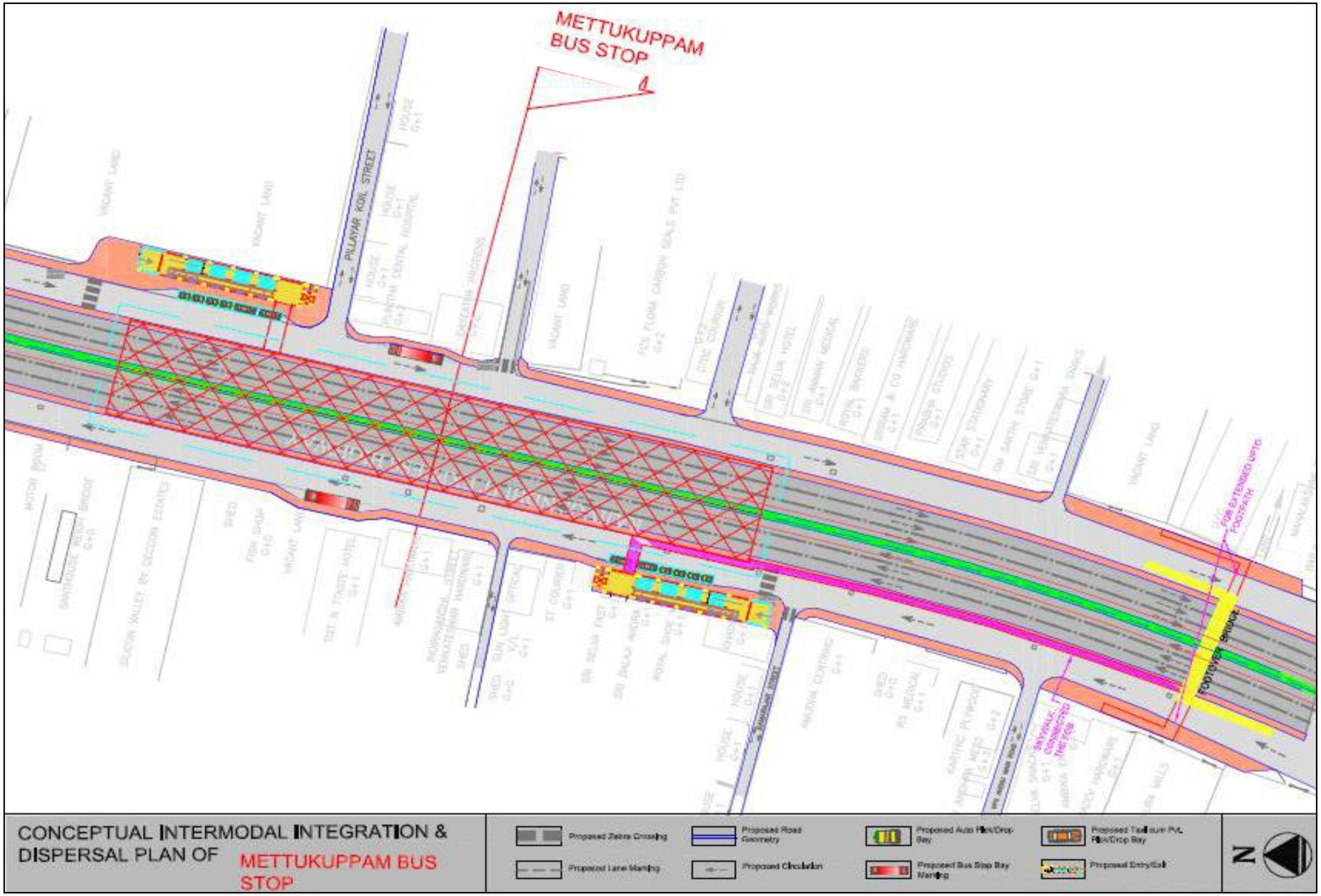
ANNEXURE 7.5. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF TIDAL PARK STATION



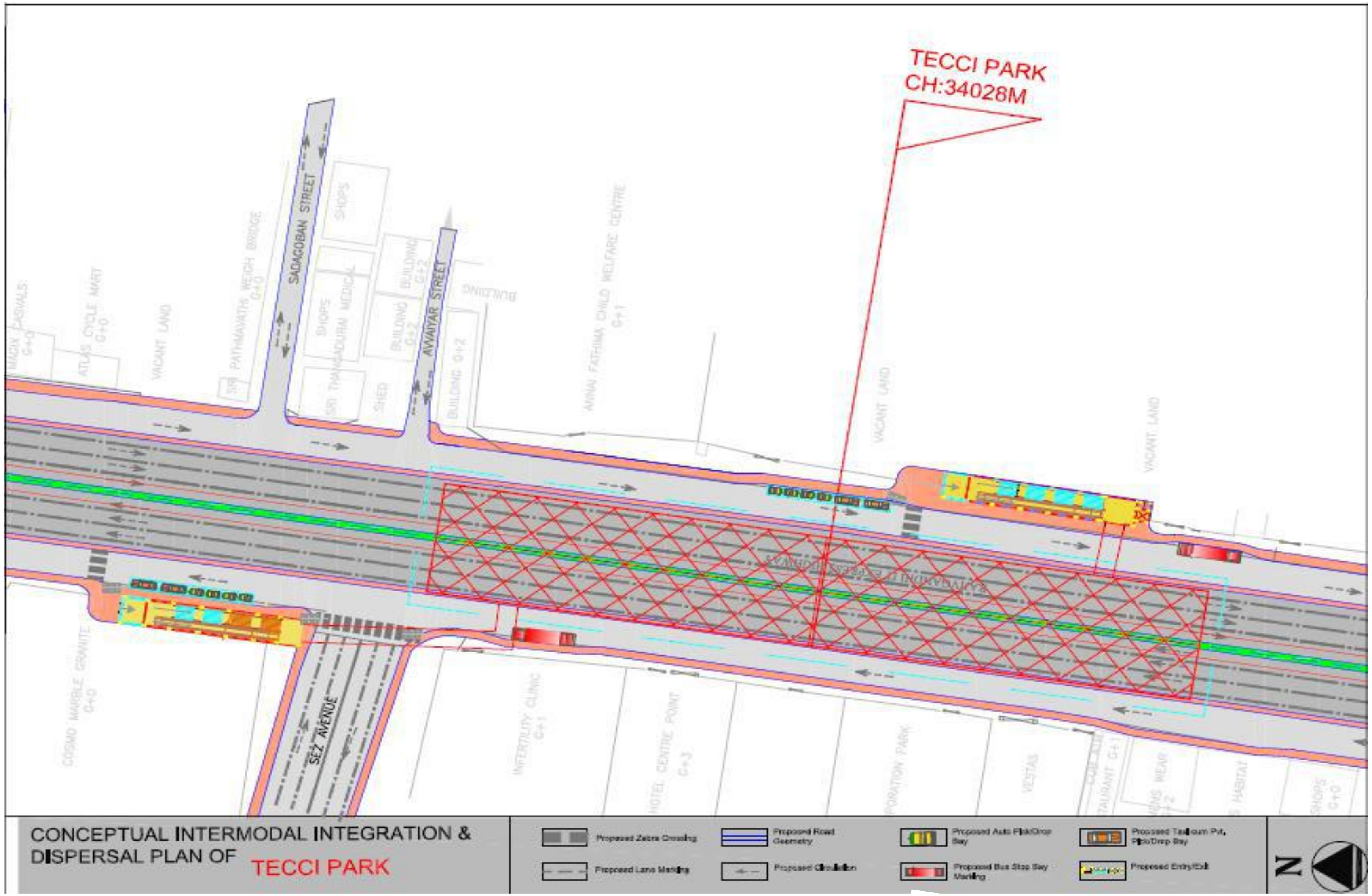
ANNEXURE 7.6. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF PERUNGUDI TOLL PLAZA STATION



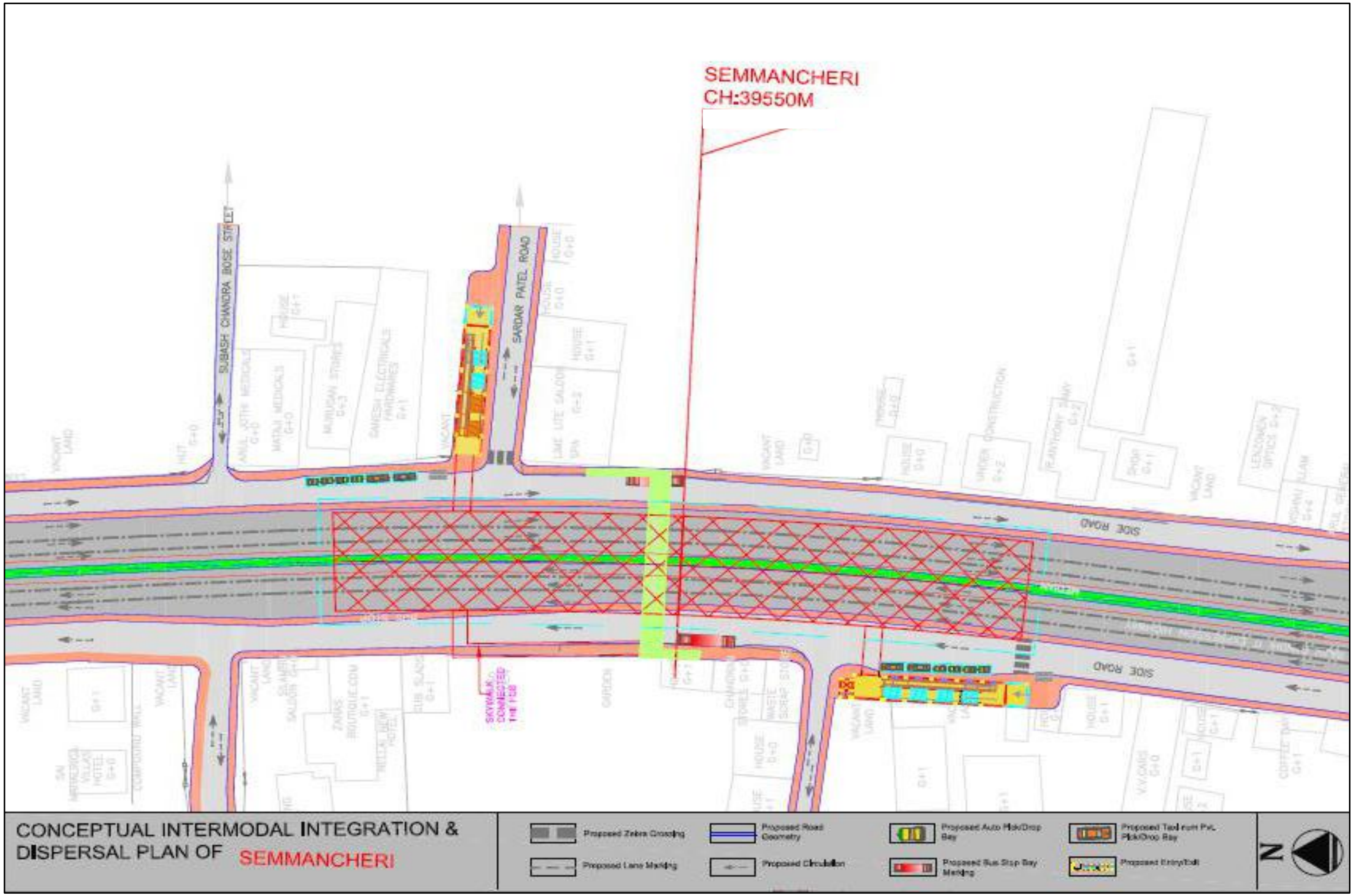
ANNEXURE 7.7. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF METTUKUPPAM BUS STOP STATION



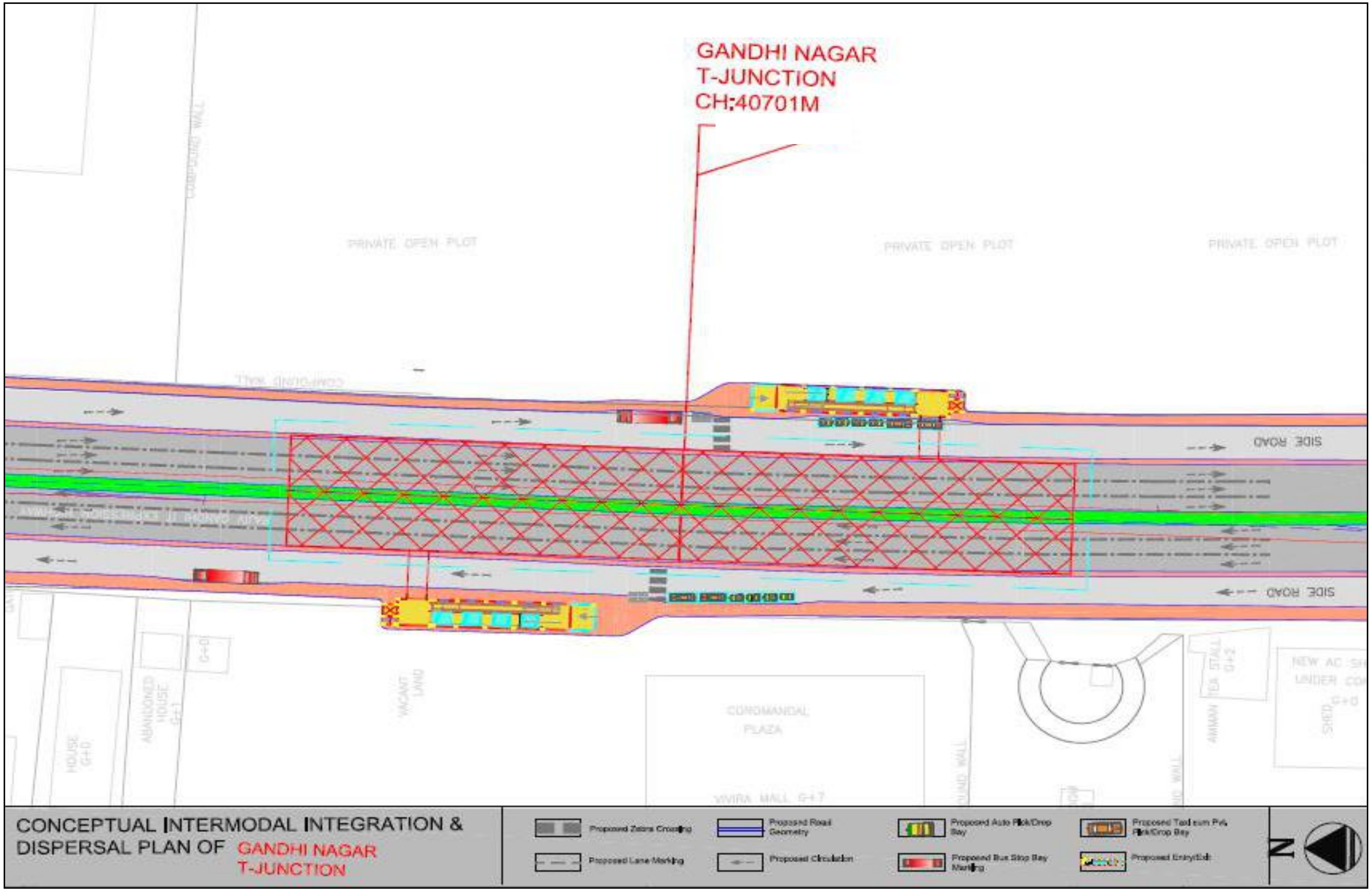
ANNEXURE 7.8. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF TECCI PARK STATION



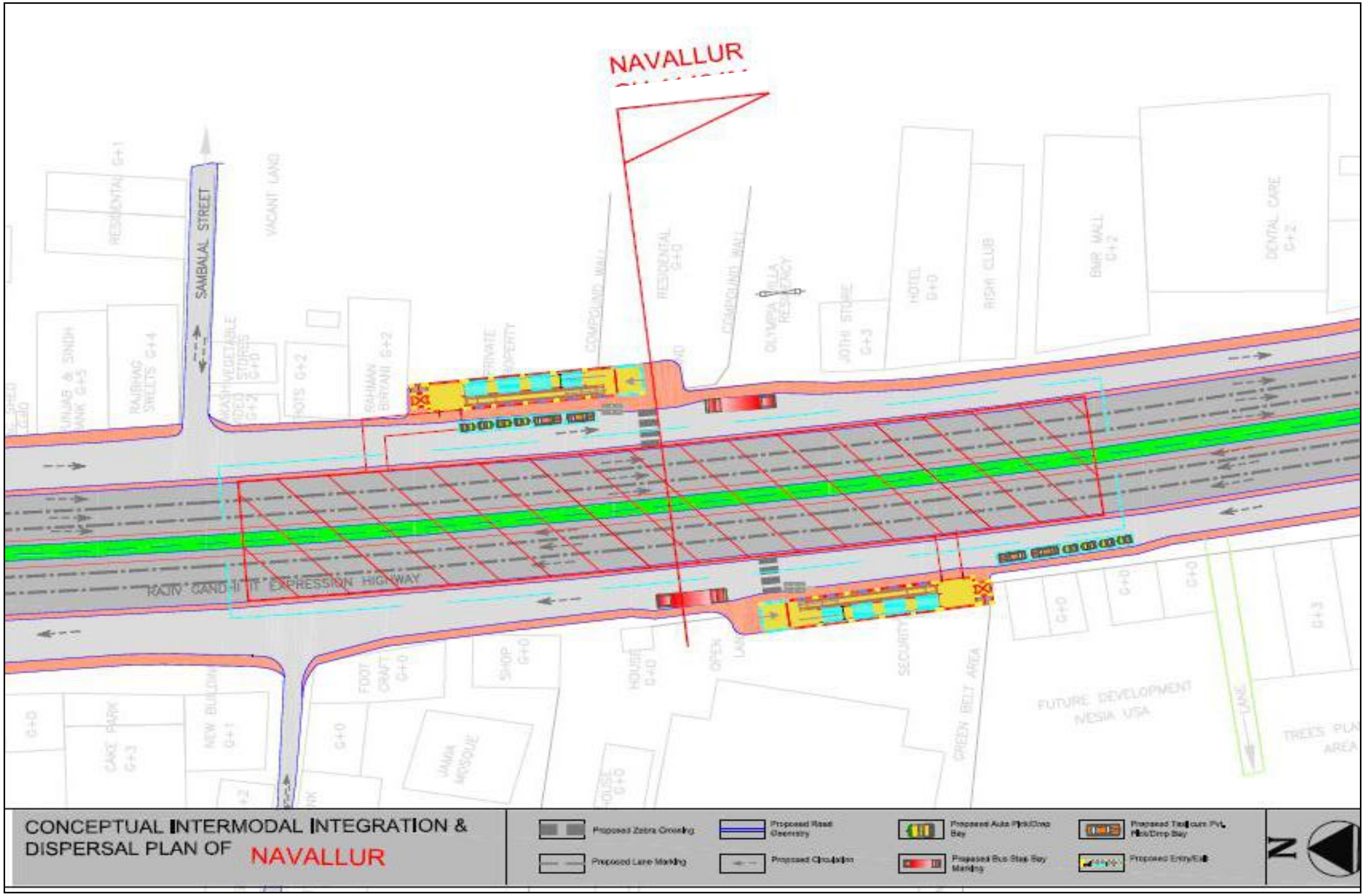
ANNEXURE 7.9. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF SEMMANCHERI STATION



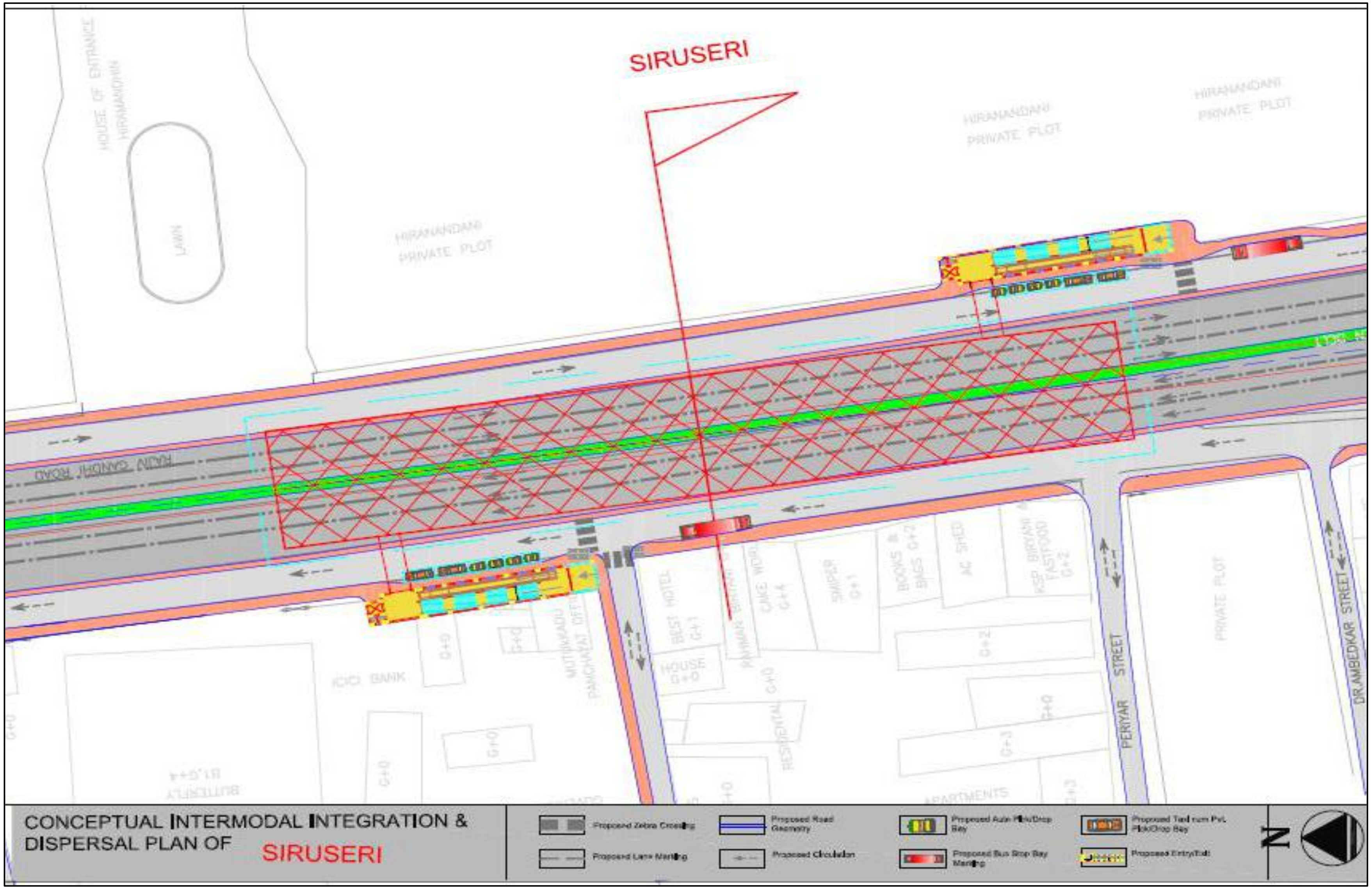
ANNEXURE 7.10. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF GANDHI NAGAR T- JUNCTION STATION



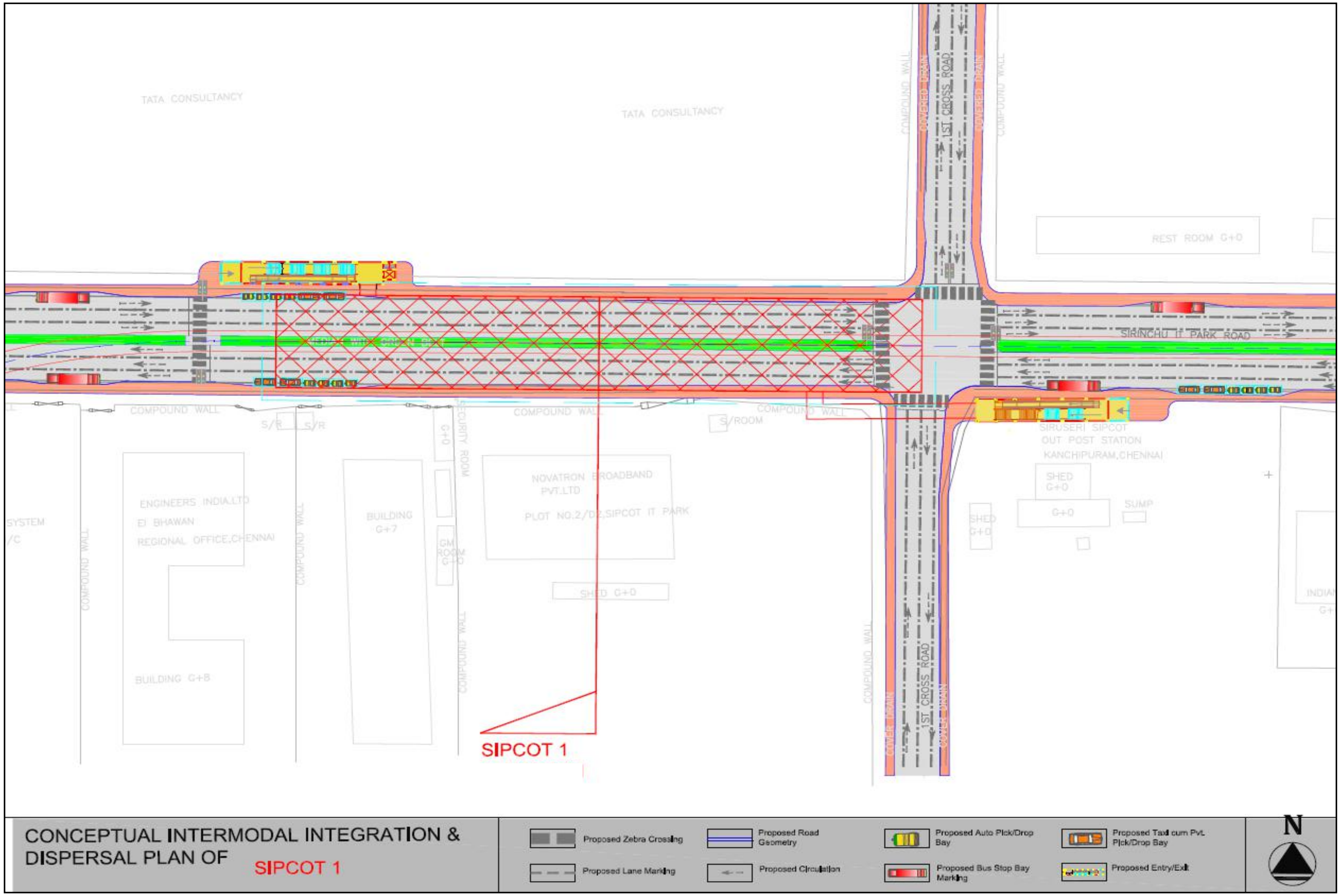
ANNEXURE 7.11. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF NAVALLUR STATION



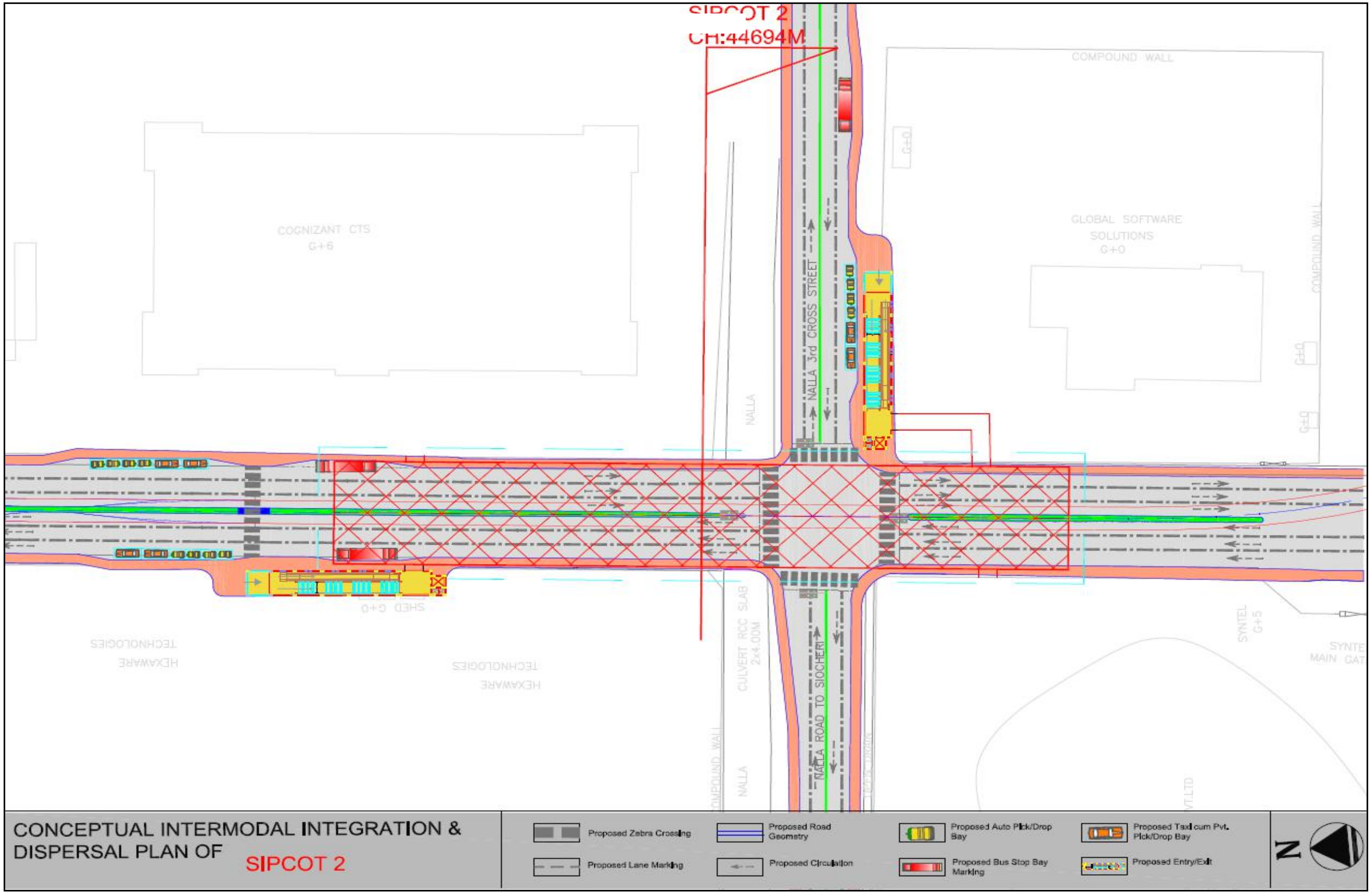
ANNEXURE 7.12. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF SIRUSERI STATION



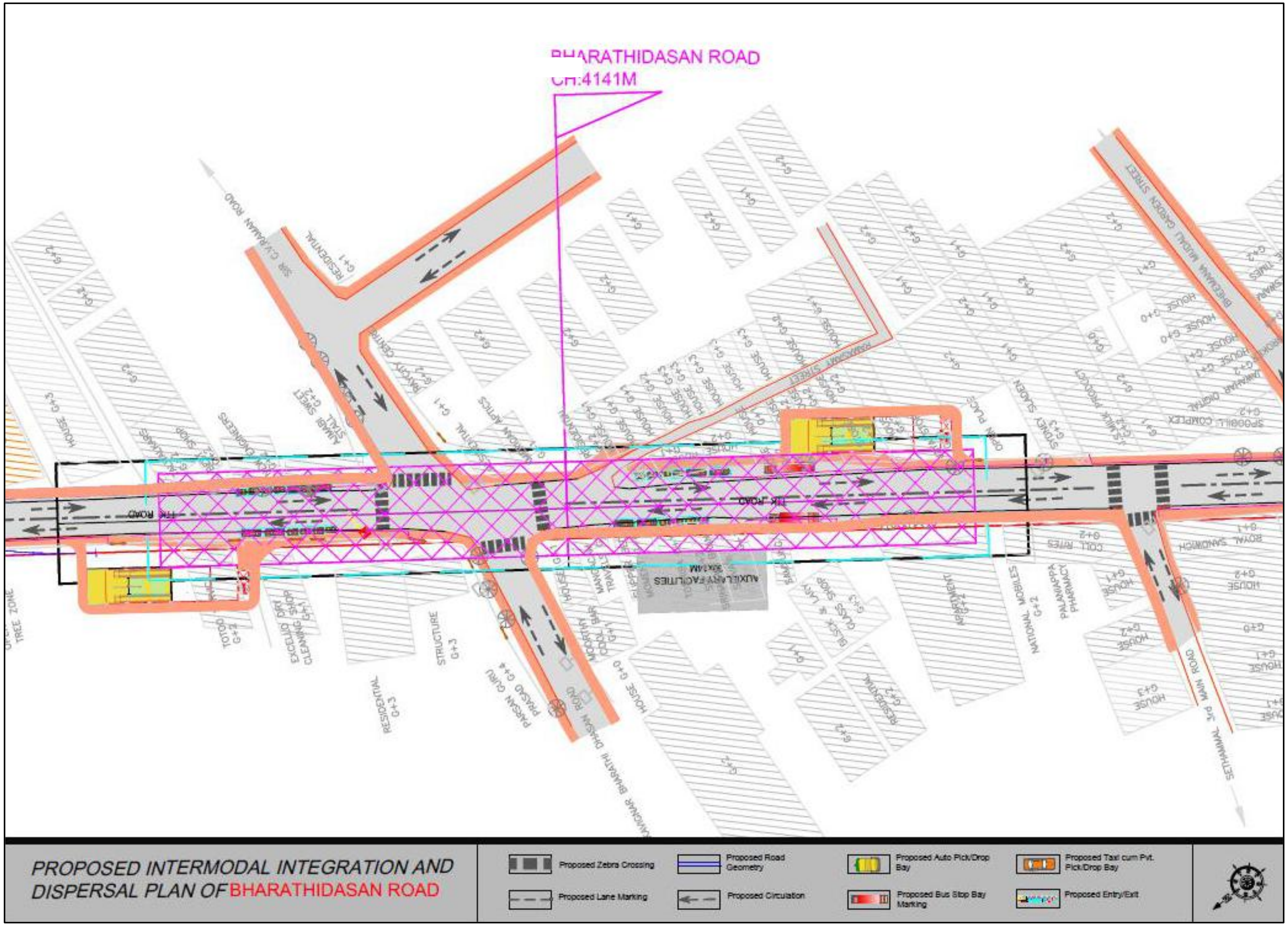
ANNEXURE 7.13. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF SIPCOT 1 STATION



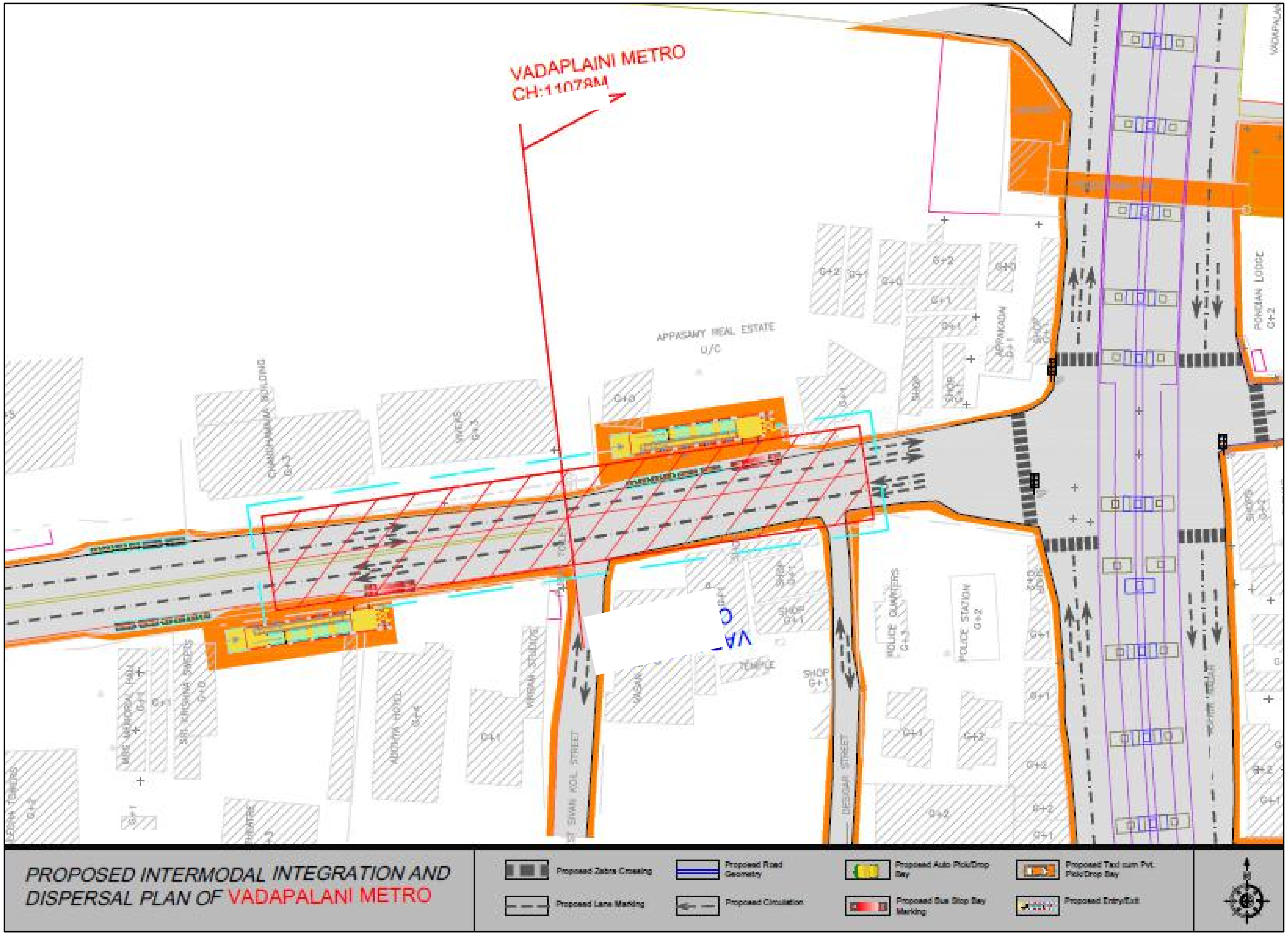
ANNEXURE 7.14. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF SIPCOT 2 STATION



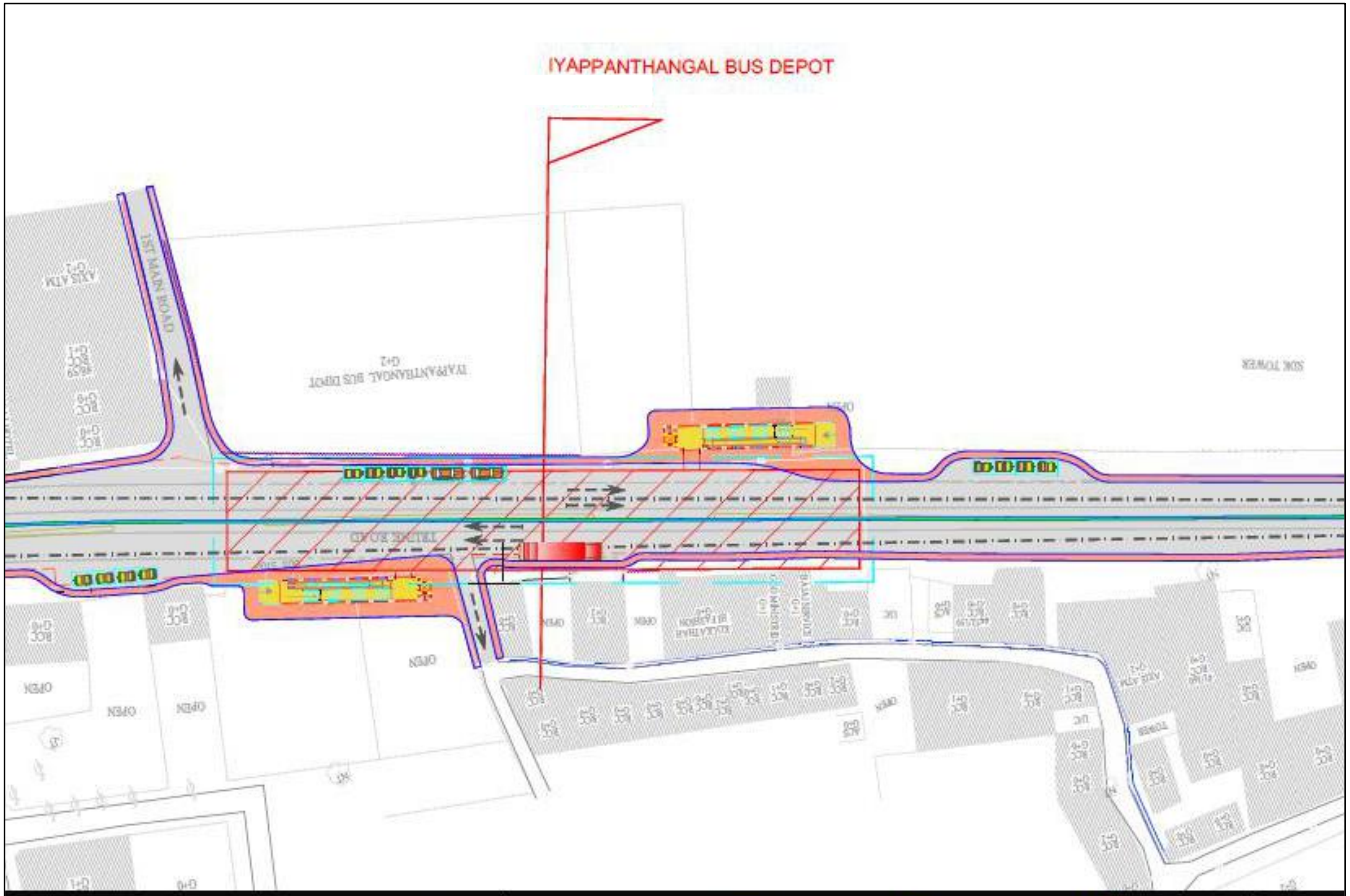
ANNEXURE 7.15. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF BHARATHIDASAN ROAD STATION



ANNEXURE 7.16. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF VADAPALANI METRO STATION

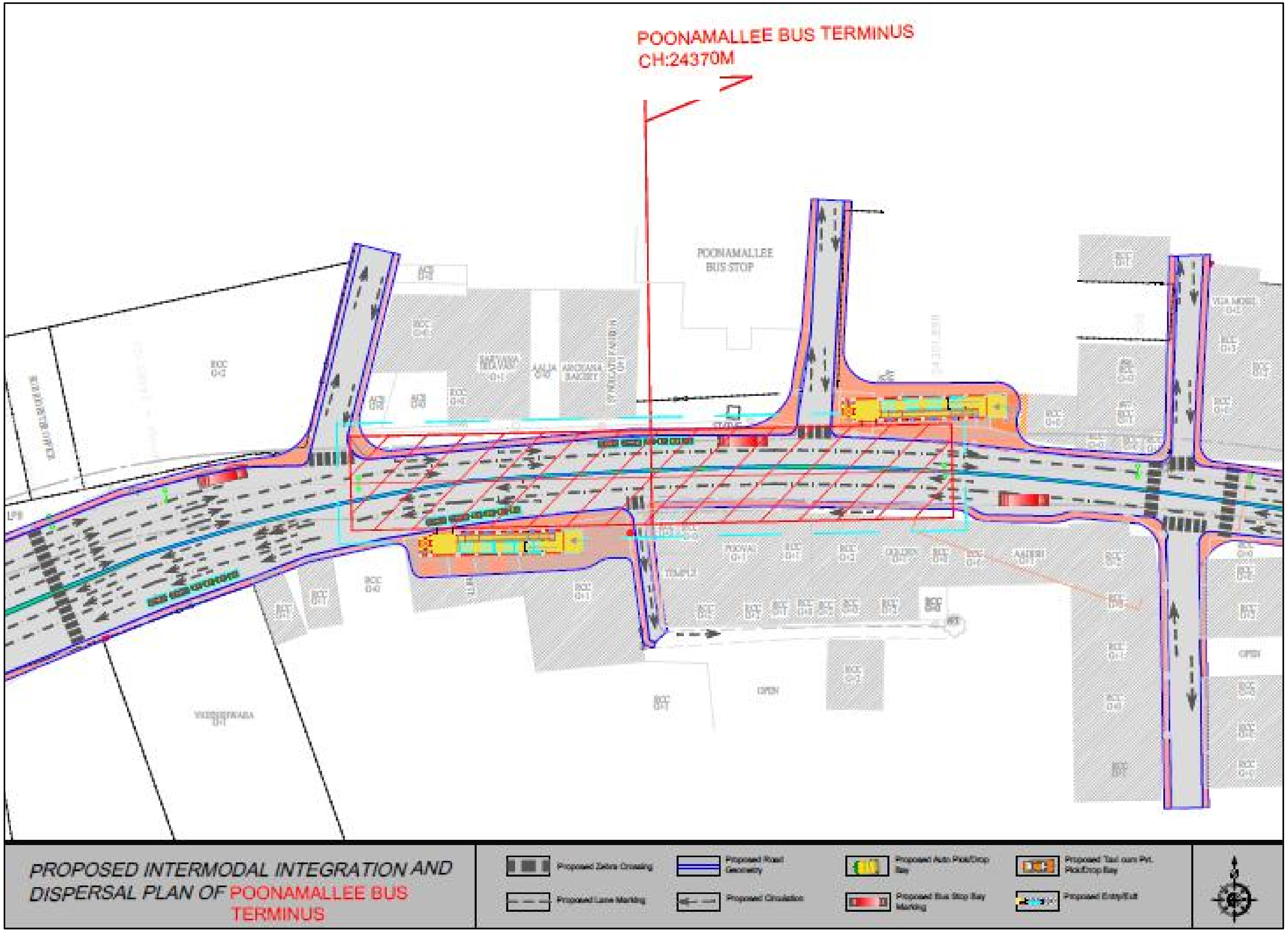


ANNEXURE 7.17. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF IYAPPANTHANGAL BUS DEPOT STATION

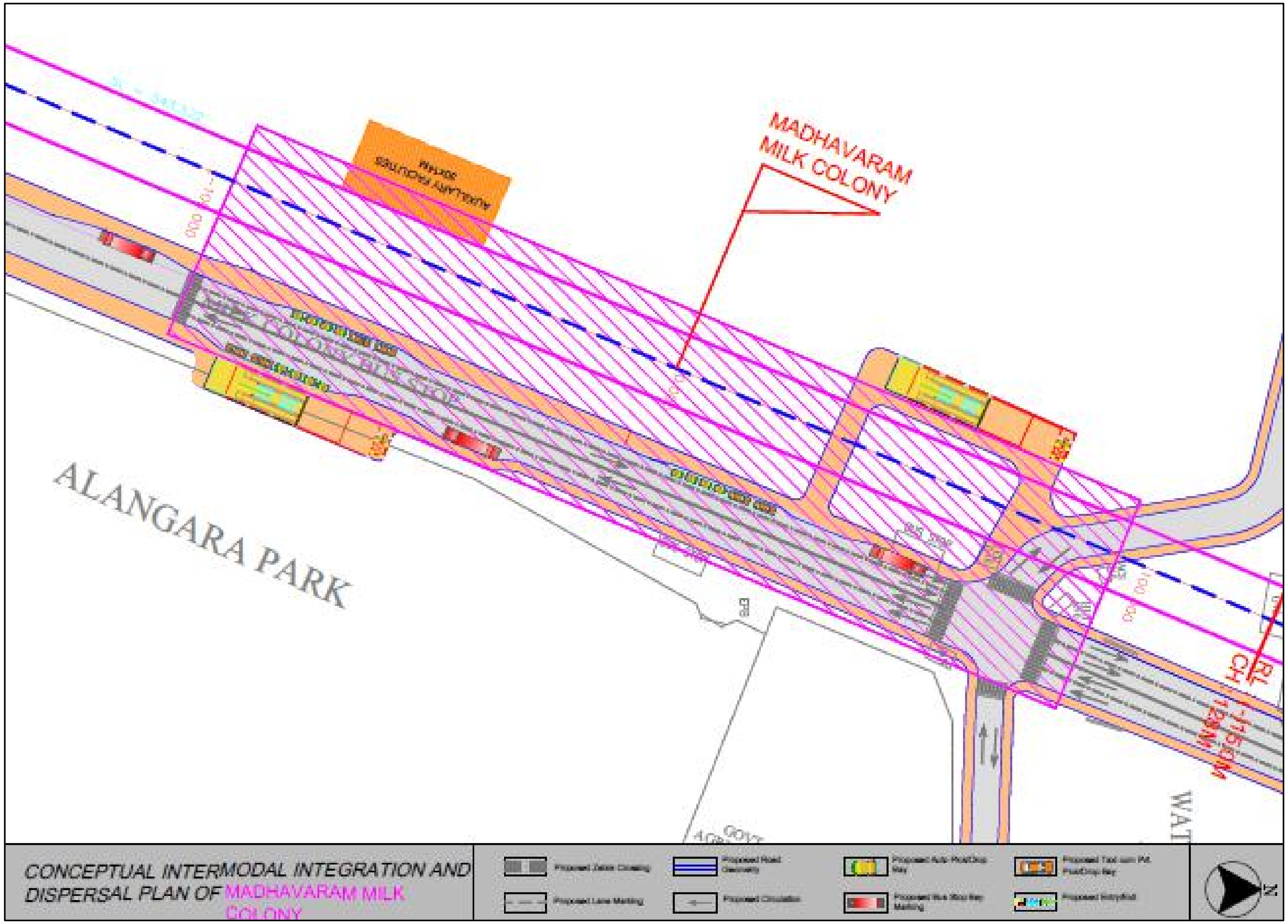


PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF IYAPPANTHANGAL BUS DEPOT

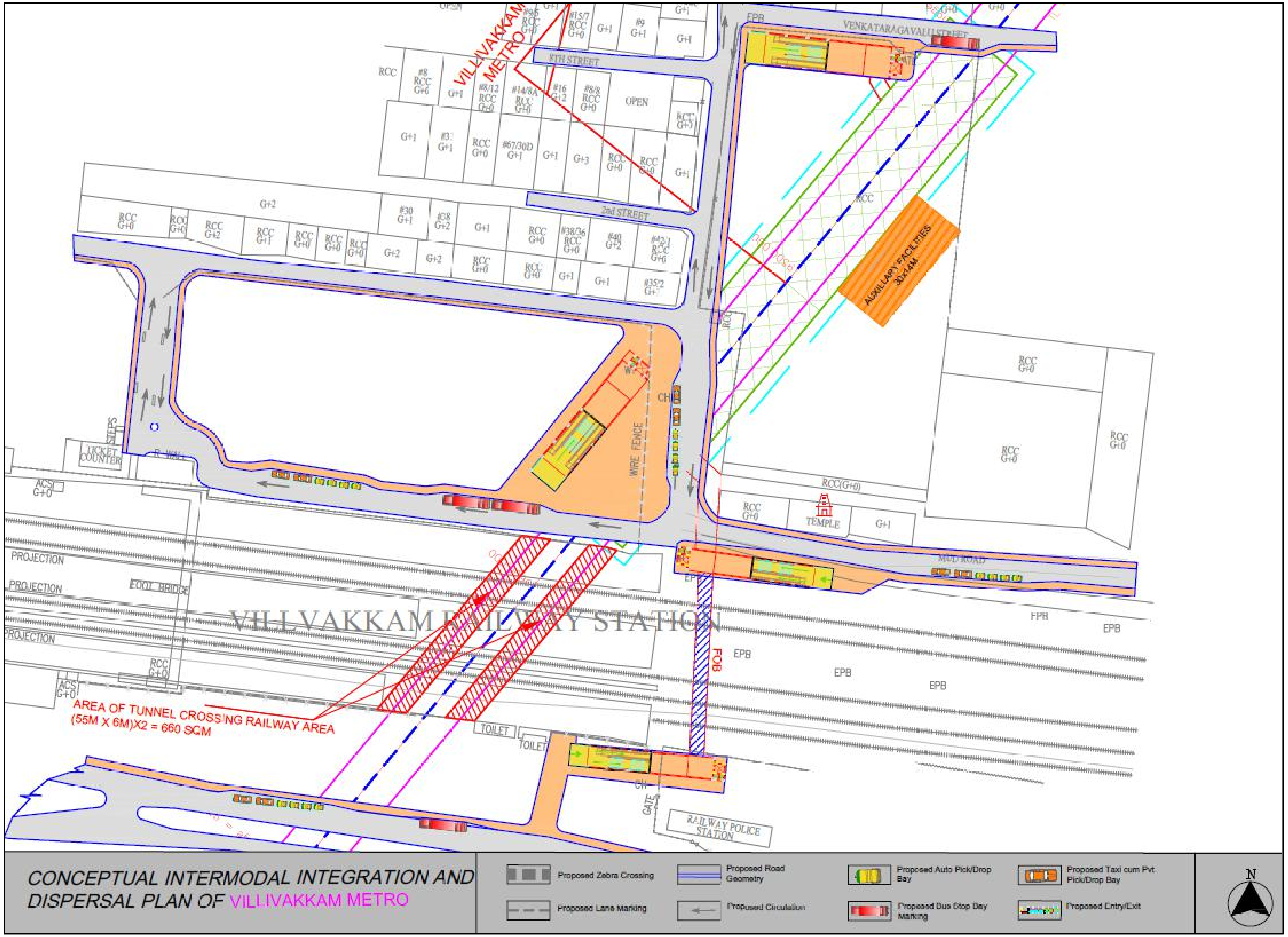
ANNEXURE 7.18. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF POONAMALLEE BUS TERMINUS STATION



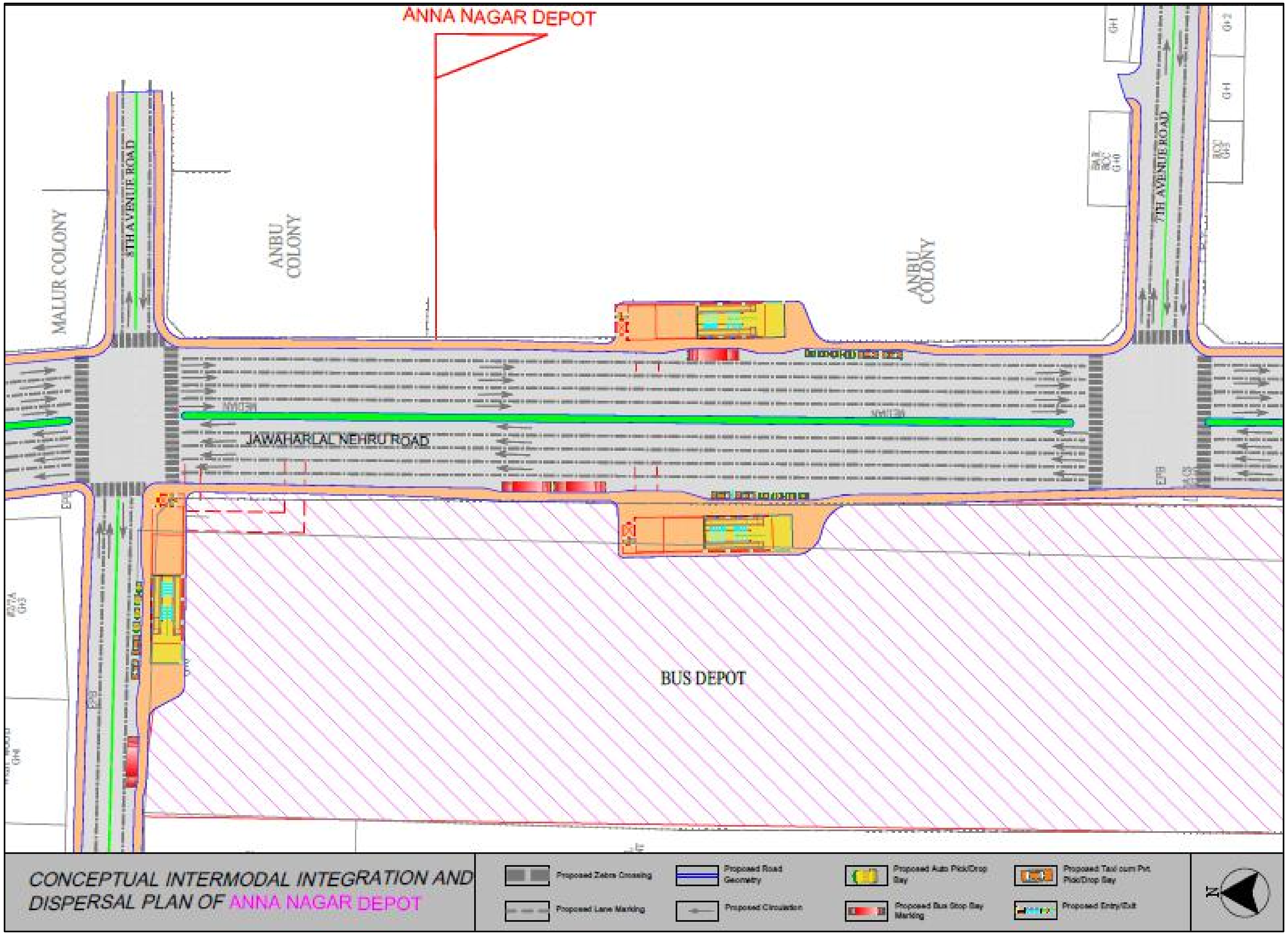
ANNEXURE 7.19. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF MADHAVARAM MILK COLONY STATION



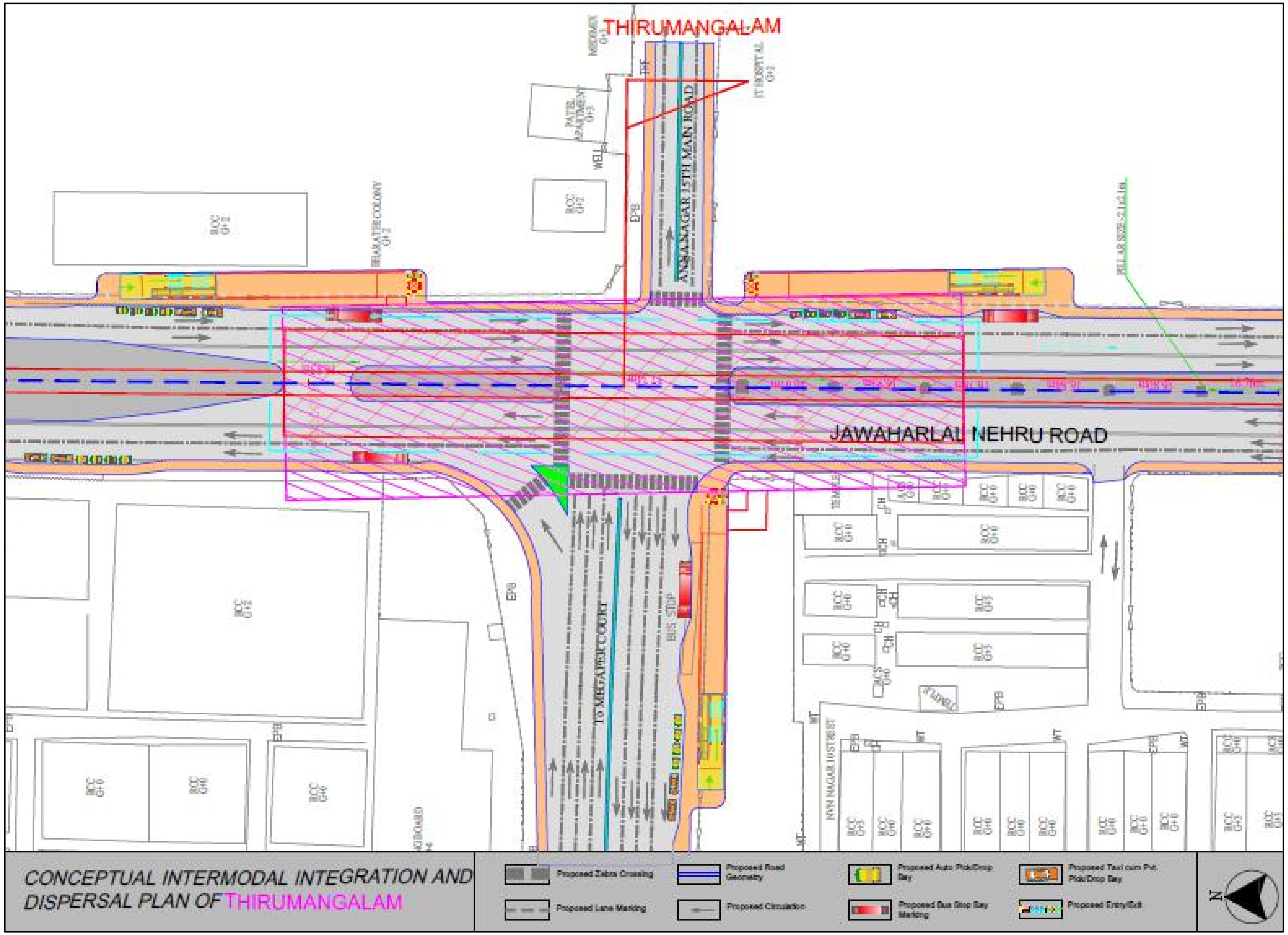
ANNEXURE 7.20. ROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF VILLIVAKKAM METRO STATION



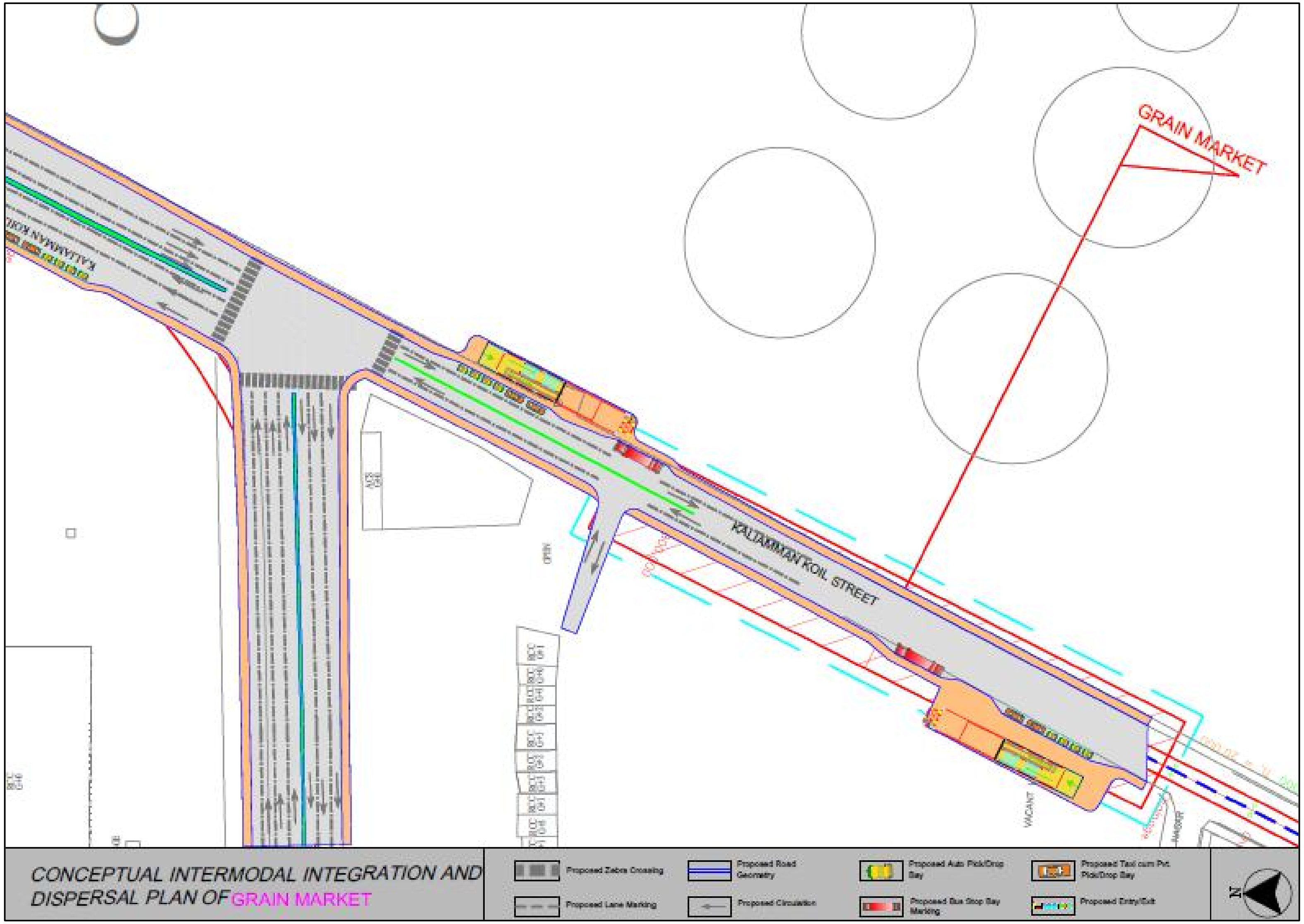
ANNEXURE 7.21. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF ANNA NAGAR DEPOT STATION



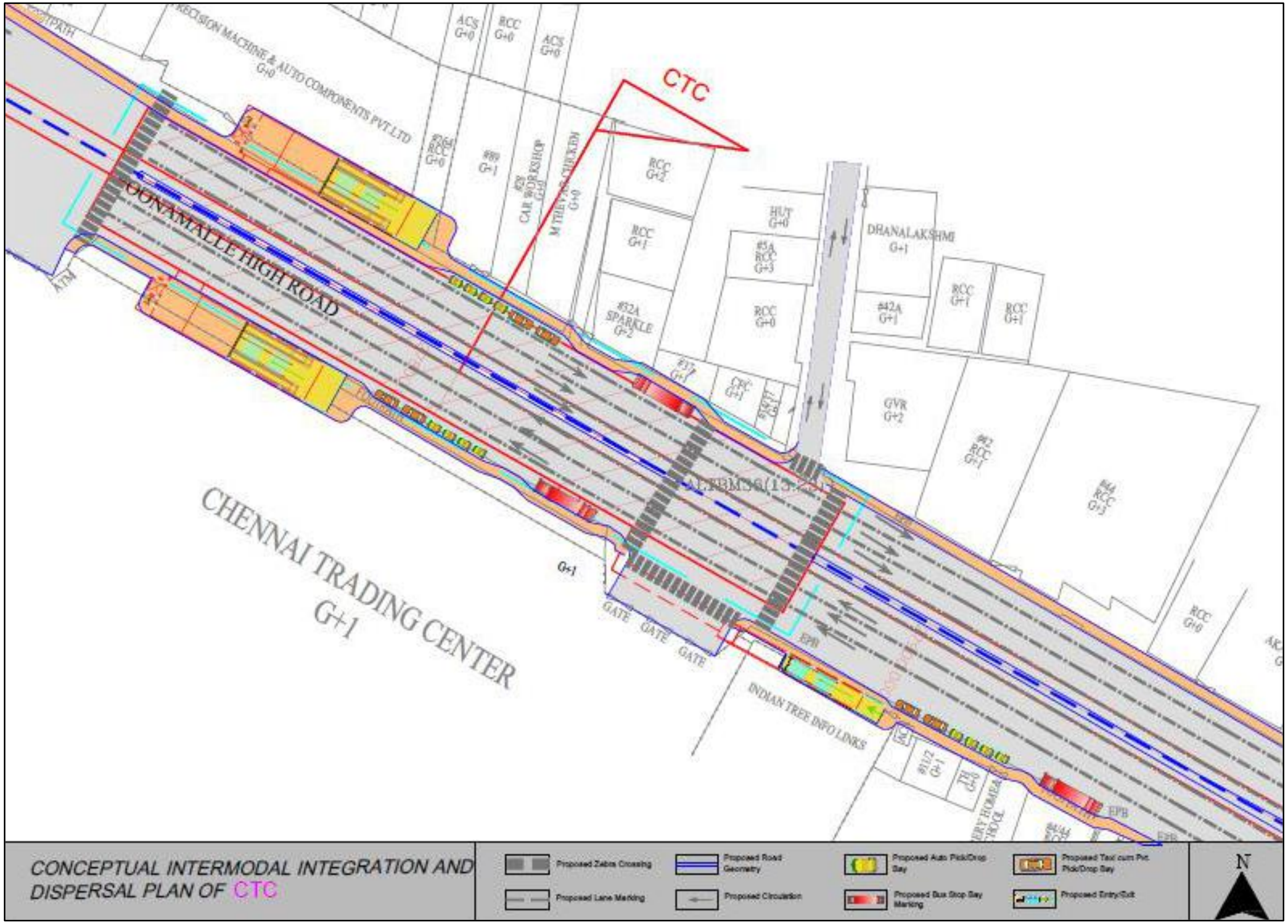
ANNEXURE 7.22. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF THIRUMANGALAM STATION



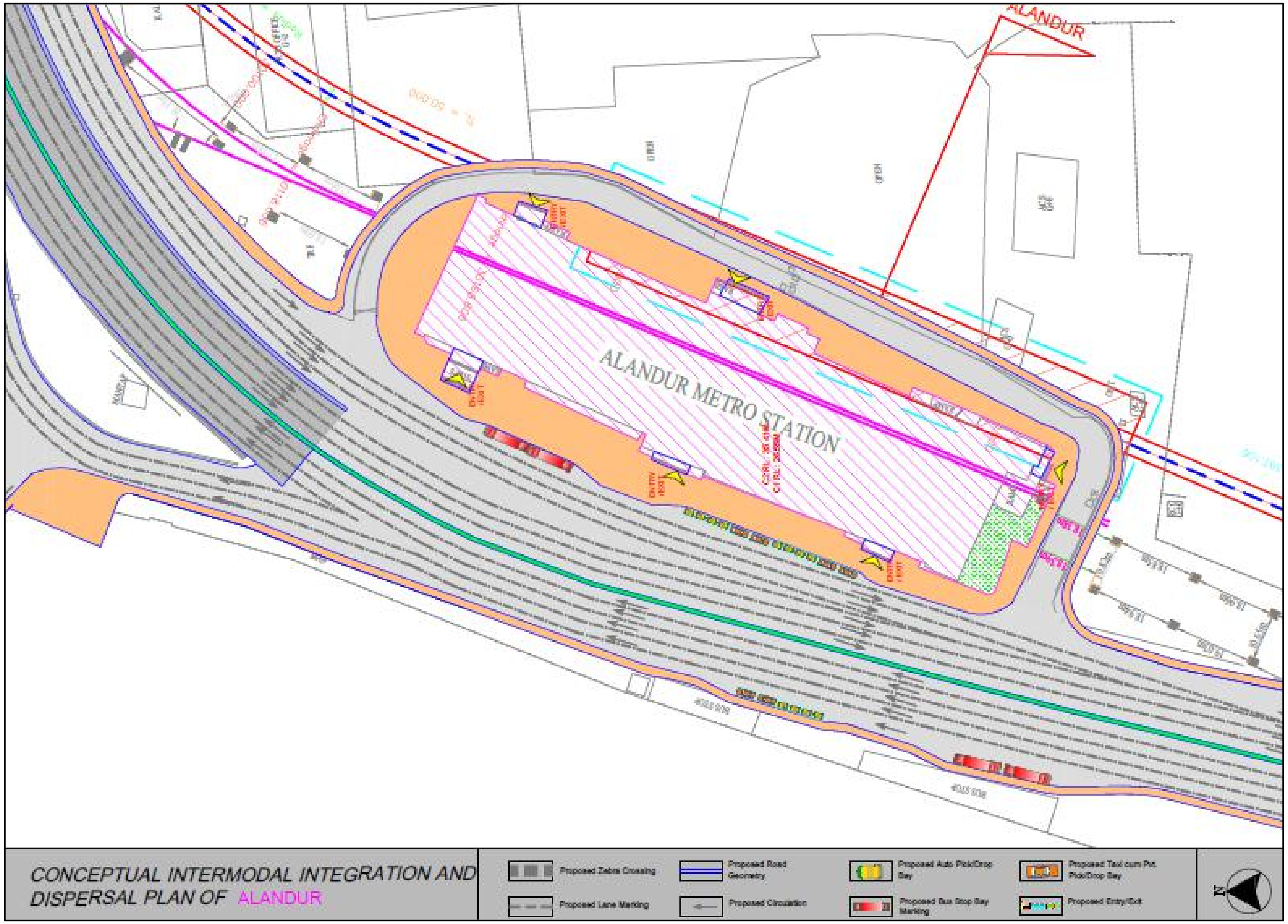
ANNEXURE 7.23. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF GRAIN MARKET STATION



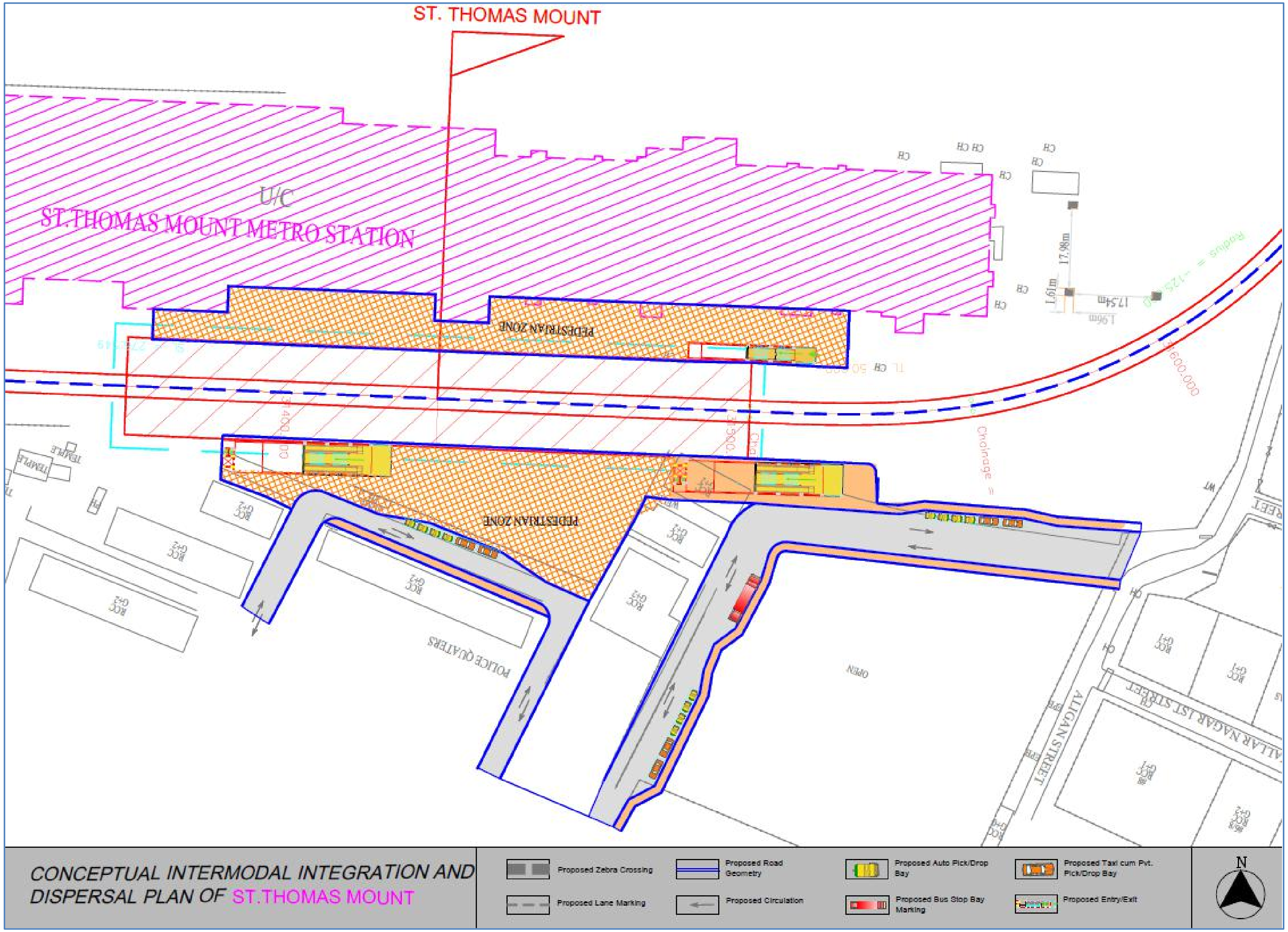
ANNEXURE 7.24. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF CTC STATION



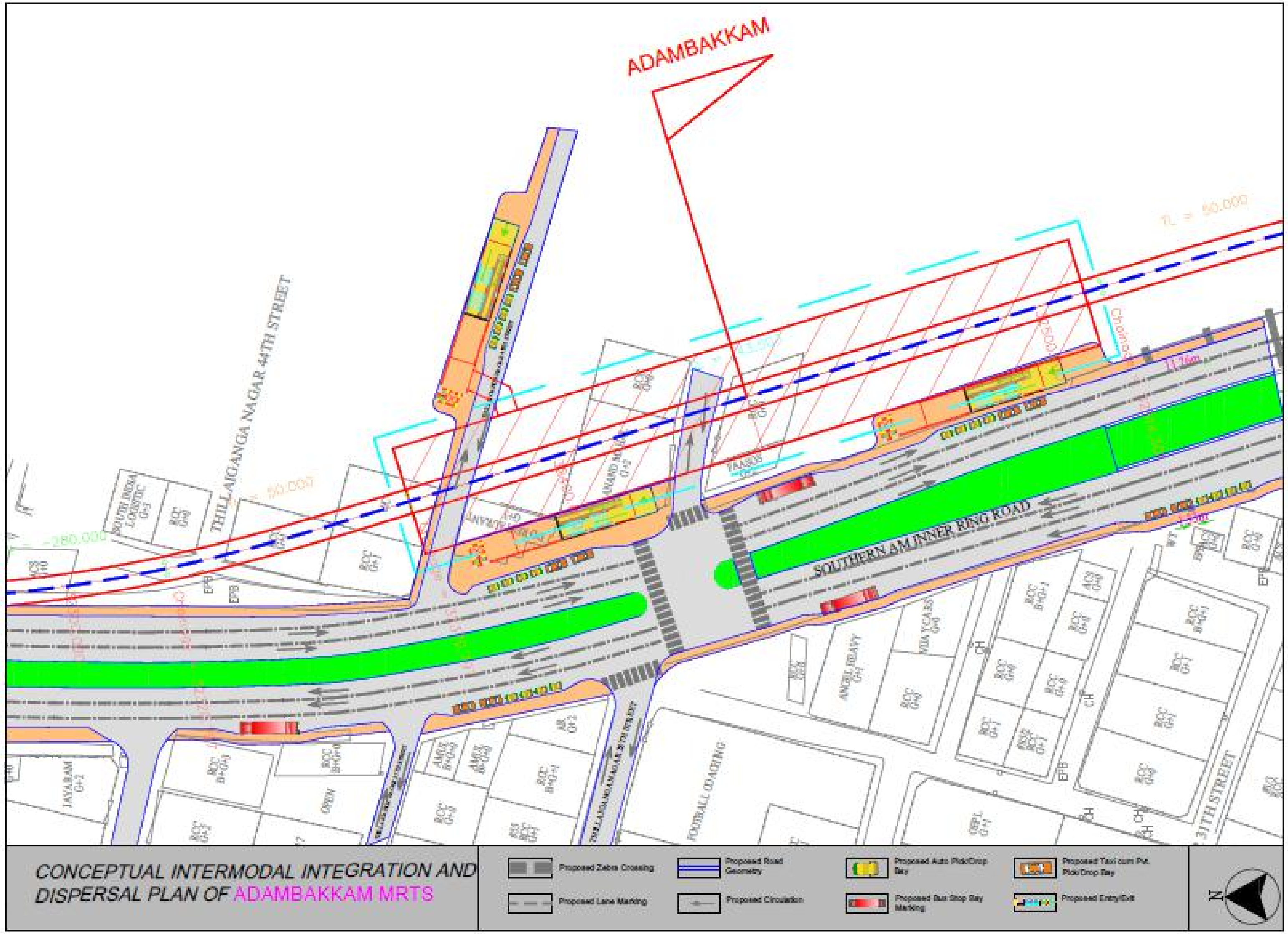
ANNEXURE 7.25. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF ALANDUR STATION



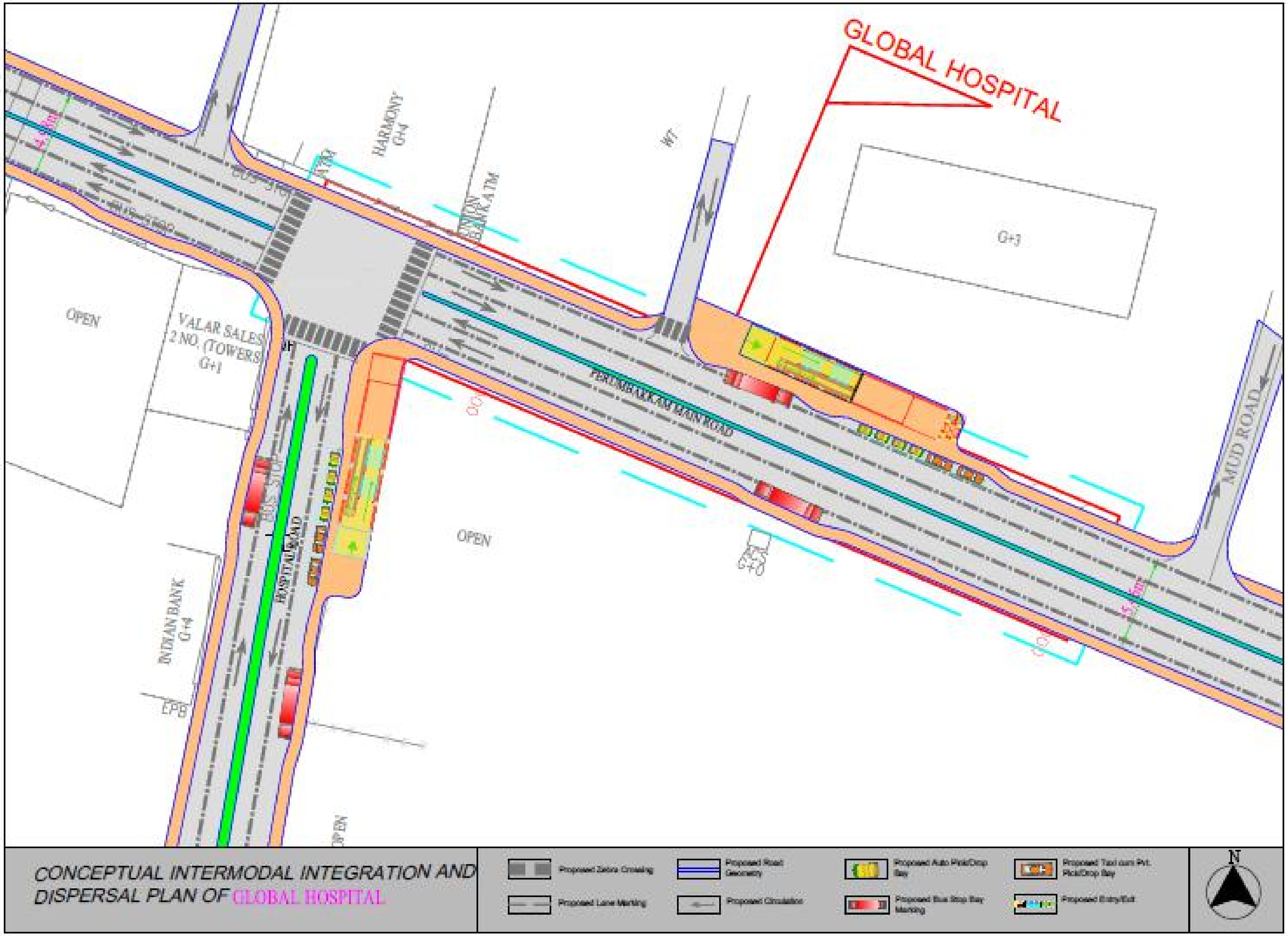
ANNEXURE 7.26. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF ST.THOMAS MOUNT STATION



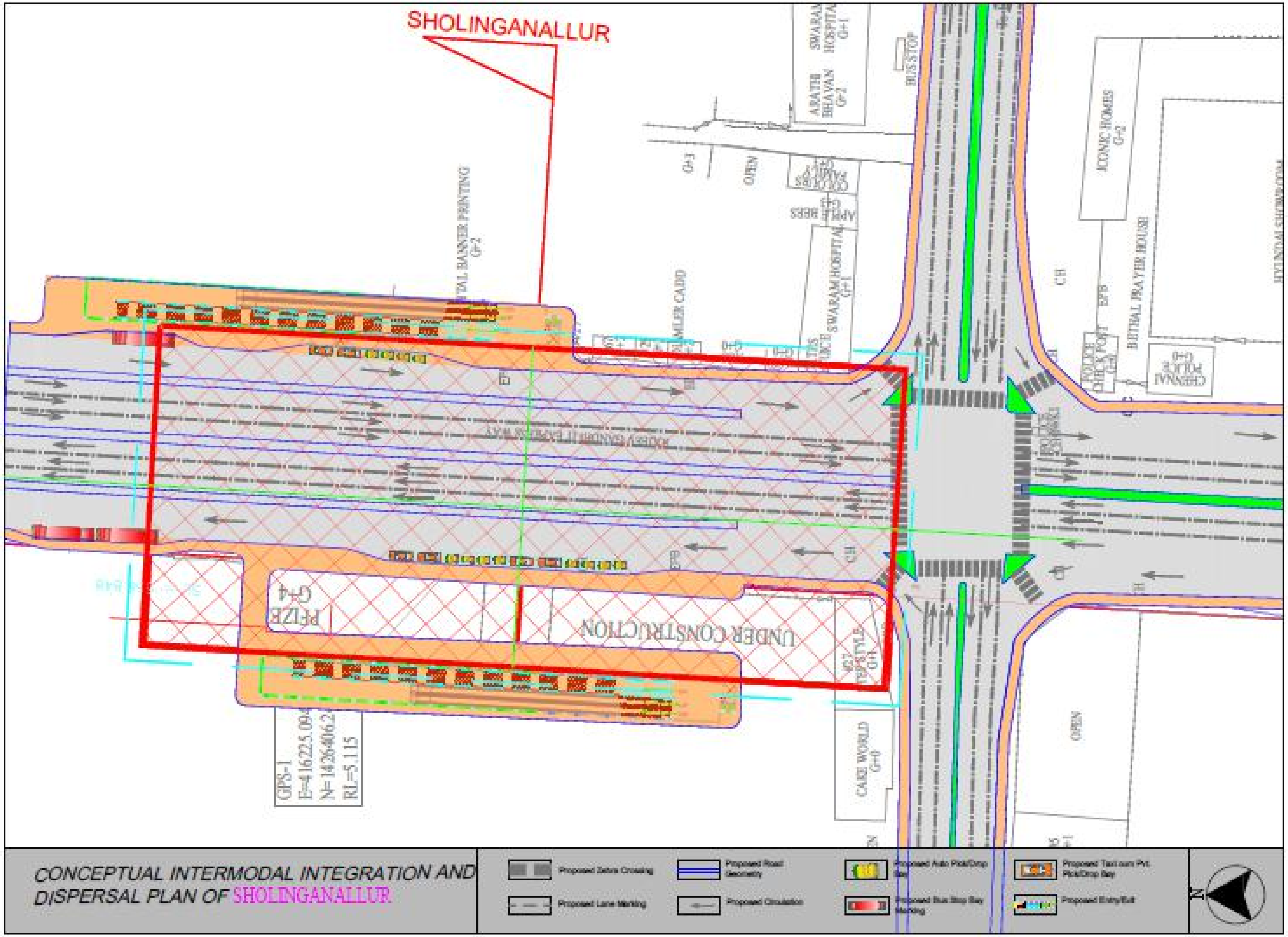
ANNEXURE 7.27. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF ADAMBAKKAM MRTS STATION



ANNEXURE 7.28. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF GLOBAL HOSPITAL STATION



ANNEXURE 7.29. PROPOSED INTERMODAL INTEGRATION AND DISPERSAL PLAN OF SHOLINGANALLUR STATION



8. TRAIN OPERATION PLAN

8.1 TRAIN OPERATION PHILOSOPHY

This chapter covers headway/ frequency, hourly train operation plan, rolling stock requirement etc.

The underlying operation philosophy is to provide mass rapid transit services at economical cost with fixed Infrastructure and rolling stock planning.

- Frequency of train services shall be optimized to provide sectional capacity commensurate with peak direction traffic demand during peak hours.
- Minimum train service frequency shall be provided during lean period so as to keep option of this service attractive even during lean period
- The frequency of services shall be regulated to meet the growing traffic demand in horizon years
- Basic unit selected is two motor car and one trailer car

Train operation plan for proposed corridors will be based on the following salient features:

- ➢ Running of normal services for 19 hours of the day (5 AM to 00:00AM i.e. midnight) with average station dwell time of 30 seconds,
- ➢ Make up time of 5-10% (on tangent track) with 8-12% coasting.
- ➢ Scheduled average speed for the corridors shall be 32 kmph.

8.2 TRAFFIC DEMAND

8.2.1 Peak Direction Traffic

Train operation plan for Phase II corridors has been formulated considering PHPDT for different sections of corridors. The PHPDT considered for the preparation of train operation plan is given in **Table 8.1**.

TABLE 8.1: PHPDT FOR DIFFERENT SECTIONS FOR DIFFERENT HORIZON YEARS

S.No.	Corridor/Section	2025	2035	2045	2055 (Design Year)
1.	Madhavaram-Sholinganallur	16289	22115	24301	27361
2.	Sholinganallur-SIPCOT	2213	3566	4050	4498
3.	Lighthouse - Poonamallee Bypass	11707	18944	23816	29940
4.	Madhavaram- CMBT - Sholinganallur	17539	24528	29441	35714

8.3 TRAIN FORMATION

To meet the above projected traffic demand, train operation plan has been formulated considering rolling stock of 2.9 m wide coaches. The physical and technical parameters of rolling stock have been discussed in detail in Chapter 11- Rolling Stock. The train operation plan has been formulated considering the following parameters:

8.3.1 Composition

The car composition to be adopted is given below-

DMC : Driving Motor Coach

TC : Non Driving Trailer Coach

MC : Non Driving Motor Coach

3-Car Rake Composition: ***DMC-TC-DMC***

6-Car Rake Composition: ***DMC-TC-MC-MC-TC-DMC***

Every coach shall be fully interchangeable with any other coach of same type.

3 coach trains can be converted to 6 coach trains by procuring additional trailer coaches and motor coaches compatible with the existing coaches in communication protocol, dimensions and other performance requirements.

8.3.2 Capacity

For the purpose of calculating rake requirement of rolling stock, passenger carrying capacity is considered as below in **Table 8.2**.

TABLE 8.2: CARRYING CAPACITY OF METRO RAIL

Description	Driving Motor Car (DMC)			Trailer Car (TC)/ Motor Car (MC)			3 Car Train			6 Car Train		
	Normal	Crush	Dense Crush	Normal	Crush	Dense Crush	Normal	Crush	Dense Crush	Normal	Crush	Dense Crush
Seated	43	43	43	50	50	50	136	136	136	286	286	286
Standing	103	205	273	110	220	293	316	630	839	646	1290	1718
Total	146	248	316	160	270	343	452	766	975	932	1576	2004

Normal - 3 per/sqm of standee area, **Crush**- 6 per/sqm of standee area **Dense Crush** – 8 per/sqm of standee area.

8.4 HEADWAY FOR DIFFERENT SECTIONS

To meet the projected traffic demand, the possibility of running trains with 3 car and 6 car rake composition at different headways has been examined. The traffic capacity and demand have been matched by suitable regulation of headways.

Train operation plan is envisaged with combination of 3 car and 6 car rake composition in the inception year 2025 and 6 car rake composition in design year. The infrastructure facilities are proposed to be designed for 6 car rake composition for the ultimate/design year considering following two different options:

- **Option 1:** Circular operation between corridors 3 & corridor 5 and independent train operation for corridor 4.
- **Option 2**: Independent train operation for all three corridors.

a) Option 1: Circular Operation Plan between Corridor 3 & Corridor 5 and independent train operation for Corridor 4

The trains are proposed to run between the following sections of the corridors:

- Madhavaram – Adyar – SIPCOT covering a total length (between first and last station) of 44.7 km
- Circular Train operation from Madhavaram – CMBT – Sholinganallur – Adyar – Madhavaram covering a total distance of 81.3 km
- MMBT- CMBT – Sholinganallur covering a total length of 42 km
- Independent train operation for Lighthouse - Poonamallee Bypass corridor covering a total length of 25.4 km

The details of the proposed train operation plan for different corridors are given in **Table 8.3**.

TABLE 8.3 : TRAIN OPERATION PLAN FOR PHASE II

Train Operation	Items	Year			
		2025	2035	2045	Design
(1) Madhavaram - CMBT-Sholinganallur – Adyar - Madhavaram	Cars/ Train	3,6	3,6	6	6
	Headway in Sec.	514	514	514	514
	Trains/hr (3 Car, 6 Car)	7(4,3)	7(2,5)	7(0,7)	7(0,7)
(2) Madhavaram -Adyar-SIPCOT	Cars/ Train	3	3	3	6
	Headway in Sec.	600	600	600	600
	Trains/hr (3 Car, 6 Car)	6 (6,0)	6 (6,0)	6 (6,0)	6 (0,6)

Train Operation	Items	Year			
		2025	2035	2045	Design
(3) MMBT-CMBT-Sholinganallur	Cars/ Train	3,6	3,6	6	6
	Headway in Sec.	450	450	450	360
	Trains/hr (3 Car, 6 Car)	8(7,1)	8(3,5)	8(0,8)	10(0,10)
(4) Light House - Poonamallee Bypasss	Cars/ Train	3	3,6	3,6	6
	Headway in Sec.	277	277	257	240
	Trains/hr (3 Car, 6 Car)	13(13,0)	13(6,7)	14(3,11)	15(0,15)

The train operation indicated above will result in different headways for different sections of the corridors as given below:

(i) <u>Madhavaram – SIPCOT Corridor</u>

➢ **Madhavaram to Sholinganallur section**

The headway for Madhavaram to Sholinganallur section will be a combination of **(1) MMC-CMBT-Sholinganallur-Adyar-MMC** and **(2) MMC-Adyar-SIPCOT** train operation indicated in above table.

➢ **Sholinganallur –SIPCOT Section**

The headway for Sholinganallur –SIPCOT section will be similar to the headway of **(2) MMC-Adyar-SIPCOT** as only the trains running from Madhavaram to SIPCOT will handle the traffic demand for the section.

(ii) <u>Madhavaram - Sholinganallur Corridor</u>

➢ **MMC to MMBT Section**

The circular train operation i.e. **(1) MMC- CMBT-Sholinganallur-Adyar-MMC** will cater to the traffic demand in the section from MMC to MMBT.

➢ **MMBT to Sholinganallur**

The train operation from **(3) MMBT- CMBT- Sholinganallur** and the circular train operation from **(1) MMC-CMBT-Sholinganallur-Adyar-MMC** will jointly handle the traffic demand for the section.

(iii) <u>Lighthouse - Poonamallee Bypass Corridor</u>

Independent train operation is proposed for Poonamallee Bypass to Light House corridor. Based on above, the headway and capacity provided for different sections of the corridor is given in **Table 8.4**.

TABLE 8.4: HEADWAY AND CAPACITY PROVIDED FOR OPTION 1

Corridor	Section	Items	2025	2035	2045	Design
Madhavaram (MMC) to SIPCOT	MMC- Adyar-Sholinganallur (1)+(2)	Cars/ Train	3,6	3,6	3,6	6
		Headway in Sec.,	277	277	277	277
		Trains/hr (3 Car, 6 Car)	13 (10,3)	13 (8,5)	13 (6,7)	13 (0,13)
		Capacity (@6p/m²)	12388	14008	15628	20488
		Capacity (@8p/m²)	15762	17820	19878	26052
		PHPDT	16289	22115	24301	27329
	Sholinganallur-SIPCOT (2)	Cars/ Train	3	3	3	6
		Headway in Sec.,	600	600	600	600
		Trains/hr (3 Car, 6 Car)	6(6,0)	6(6,0)	6(6,0)	6(0,6)
		Capacity (@6p/m²)	4596	4596	4596	9456
		Capacity (@8p/m²)	5850	5850	5850	12024
		PHPDT	2213	3566	4050	4500
Madhavaram (MMC) to Sholinganallur Corridor	MMC – MMBT (1)	Cars/ Train	3,6	3,6	6	6
		Headway in Sec.	514	514	514	514
		Trains/hr (3 Car, 6 Car)	7(4,3)	7(2,5)	7(0,7)	7(0,7)
		Capacity (@6p/m²)	7792	9412	11032	11032
		Capacity (@8p/m²)	9912	11970	14028	14028
		PHPDT	2838	4814	5081	7272
	MMBT-CMBT-Sholinganallur (1)+(3)	Cars/ Train	3,6	3,6	6	6
		Headway in Sec.	240	240	240	212
		Trains/hr (3 Car, 6 Car)	15 (11,4)	15 (5,10)	15 (0,15)	17 (0,17)
		Capacity (@6p/m²)	14730	19590	23640	26792
		Capacity (@8p/m²)	18741	24915	30060	34068
		PHPDT	17539	24528	29441	35714
Lighthouse to Poonamallee Bypass	Lighthouse to Poonamallee Bypass	Cars/ Train	3	3,6	3,6	6
		Headway in Sec.,	277	277	257	240
		Trains/hr (3 Car, 6 Car)	13 (13,0)	13 (6,7)	14 (3,11)	15 (0,15)
		Capacity (@6p/m²)	9958	15628	19634	23640
		Capacity (@8p/m²)	12675	19878	24969	30060
		PHPDT	11707	18944	23816	29940

Train operation plan is formulated such that the traffic demand for majority of sections is met with passenger loading @6 passengers/m^2. However, in the sections where planned capacity is less than section load, capacity can be met by carrying standees @8 passengers/ m^2 or higher which have been deliberatively planned for peak hour train operation for optimum utilization of rolling stock.

b) Option 2: Independent Train Operation for all three corridors

For independent train operation, trains shall operate between the following sections:

- Independent operation for Madhavaram to SIPCOT with mid terminal facility at Sholinganallur (44.7 km)
- Independent Operation between Lighthouse and Poonamallee Bypasss (25.4 km)
- Operation between Madhavaram and Sholinganallur via CMBT (46.3 km)

Based on the above mentioned train operation, the headway and capacity provided for different sections of the corridors of Chennai Metro Phase II is given in **Table 8.5.**

TABLE 8.5: HEADWAY AND CAPACITY PROVIDED FOR OPTION 2

Section	Items	2025	2035	2045	Design
Madhavaram (MMC) - Adyar-Sholinganallur	Cars/ Train	3,6	3,6	3,6	6
	Headway in seconds,	277	277	277	277
	Trains/hr (3 Car, 6 Car)	13(10,3)	13(8,5)	13 (6,7)	13
	Capacity (@6p/m^2)	12388	14008	15628	20488
	Capacity (@8p/m^2)	15762	17820	19878	26052
	PHPDT	16289	22115	24301	27329
Sholinganallur-SIPCOT	Cars/ Train	3	3	3	6
	Headway in seconds,	600	600	600	600
	Trains/hr (3 Car, 6 Car)	6 (6,0)	6 (6,0)	6 (6,0)	6 (0,6)
	Capacity (@6p/m^2)	4596	4596	4596	9456
	Capacity (@8p/m^2)	5850	5850	5850	12024
	PHPDT	2213	3566	4050	4500
Madhavaram (MMC) -CMBT-Sholinganallur	Cars/ Train	3,6	3,6	6	6
	Headway in seconds	240	240	240	212
	Trains/hr (3 Car, 6 Car)	15 (11,4)	15 (5,10)	15 (0,15)	17 (0,17)
	Capacity (@6p/m^2)	14730	19590	23640	26792
	Capacity (@8p/m^2)	18741	24915	30060	34068
	PHPDT	17539	24528	29441	35714
Lighthouse to Poonamallee Bypass	Cars/ Train	3	3,6	3,6	6
	Headway in seconds,	277	277	257	240
	Trains/hr (3 Car, 6 Car)	13(13,0)	13 (6,7)	14(3,11)	15(0,15)
	Capacity (@6p/m^2)	9958	15628	19634	23640
	Capacity (@8p/m^2)	12675	19878	24969	30060
	PHPDT	11707	18944	23816	29940

For Corridor 3, two loops of train operation have been planned. In one loop, the trains will run from Madhavaram to Sholinganallur and in other loop, the trains will continue from Madhavaram to SIPCOT. The combination of two operations will be capable of handling the projected traffic. Independent train operations have been planned for Corridor 4 and Corridor 5.

8.5 ROLLING STOCK REQUIREMENT

Rolling stock requirement for has been calculated for two scenarios of train operation plan discussed above. Requirements of coaches have been calculated as per following assumptions:

i) Coach requirement based on headway during peak hours.

ii) Turn round time as 6 min at terminal stations.

iii) Traffic/Operational spares have been considered @5% of bare requirement to cater to operational exigencies on the corridor.

iv) Repair and maintenance has been estimated as 10% of total coach requirement (Bare+Traffic Reserve) based on Intermediate overhaul and periodic overhaul interval.

v) Schedule speed has been taken as 32 kmph.

a) <u>Option 1: Circular Operation Plan between Corridor 3 & Corridor 5 and independent train operation for Corridor 4</u>

Based on the circular train operation as discussed above, the rake requirement for the corridors of Chennai Metro Phase II is worked out in **Table 8.6**.

TABLE 8.6 : RAKE REQUIREMENT FOR OPTION 1

Train Operation	Time horizon Year	Number of Train per hour		Section length km	Rake required		Total Coach Req.	Traffic spare @5%	Maint. Spare @10%	Total coach reqmt
		3 Car	6 Car		3 Car	6 Car				
MMC-CMBT-Sholinganallur-Adyar-MMC	2025	4	3	81.3	21.1	15.9	159	9	15	183
	2035	2	5	81.3	10.6	26.4	189	9	21	219
	2045	0	7	81.3	0.0	37.0	222	12	24	258
	Design	0	7	81.3	0.0	37.0	222	12	24	258
MMC-Adyar – SIPCOT	2025	6	0	44.7	18.0	0.0	54	3	6	63
	2035	6	0	44.7	18.0	0.0	54	3	6	63
	2045	6	0	44.7	18.0	0.0	54	3	6	63
	Design	0	6	44.7	0.0	18.0	108	6	12	126
MMBT- CMBT	2025	7	1	42.0	18.7	2.7	75	3	9	90

Train Operation	Time horizon Year	Number of Train per hour		Section length km	Rake required		Total Coach Req.	Traffic spare @5%	Maint. Spare @10%	Total coach reqmt
Sholinganallur	2035	3	5	42.0	19.8	2.8	78	6	12	126
	2045	0	8	42.0	8.5	14.1	108	6	12	156
	Design	0	10	42.0	0.0	22.6	138	6	18	192
Lighthouse to Poonamallee Bypass	2025	13	0	25.4	23.2	0.0	69	3	6	78
	2035	6	7	25.4	10.7	12.5	111	6	12	129
	2045	3	11	25.4	5.4	19.7	135	6	15	156
	Design	0	15	25.4	0.0	26.8	162	6	18	186

Total coach requirement for different horizon years for Chennai Metro Phase II corridors is given in **Table 8.7.**

TABLE 8.7: TOTAL COACH REQUIREMENT FOR OPTION 1

Year	2025	2035	2045	2055
Total Coach Requirement	414	537	633	762

b) <u>Option 2: Independent Train Operation for all three corridors</u>

For independent train operation on three corridors, the rolling stock requirement is worked out in **Table 8.8**. The scheduled speed considered for calculation of rake requirement is 30 kmph.

TABLE 8.8: RAKE REQUIREMENT FOR OPTION 2

Train Operation/ Corridor	Time horizon Year	Number of Train per hour		Section length km	Rake required		Total Coach Req.	Traffic spare@ 5%	Maint. Spare @10%	Total coach reqmt
		3 Car	6 Car		3 Car	6 Car				
MMC- Adyar- Sholinganalur	2025	4	3	35.0	10.1	7.6	78	3	9	90
	2035	2	5	35.0	5.1	12.7	93	6	12	111
	2045	0	7	35.0	0.0	17.7	108	6	12	126
	Design	0	7	35.0	0.0	17.7	108	6	12	126
MMC-Adyar-SIPCOT	2025	6	0	44.7	19.1	0.0	57	3	6	66
	2035	6	0	44.7	19.1	0.0	57	3	6	66
	2045	6	0	44.7	19.1	0.0	57	3	6	66
	Design	0	6	44.7	0.0	19.1	114	6	12	132
MMC- CMBT Sholinganalur	2025	11	4	46.3	36.2	13.1	180	9	18	207
	2035	5	10	46.3	16.4	32.9	246	12	24	282
	2045	0	15	46.3	0.0	49.3	294	12	30	336
	Design	0	17	46.3	0.0	55.9	336	18	36	390

Train Operation/ Corridor	Time horizon Year	Number of Train per hour		Section length km	Rake required		Total Coach Req.	Traffic spare@ 5%	Maint. Spare @10%	Total coach reqmt
		3 Car	6 Car		3 Car	6 Car				
Lighthouse to Poonamallee Bypass	2025	13	0	25.4	23.2	0.0	69	3	6	78
	2035	6	7	25.4	10.7	12.5	111	6	12	129
	2045	3	11	25.4	5.4	19.7	135	6	15	156
	Design	0	15	25.4	0.0	26.8	162	6	18	186

Total coach requirement for three corridors calculated for Option 2 is given in **Table 8.9.**

TABLE 8.9: TOTAL COACH REQUIREMENT FOR OPTION 2

2025	2035	2045	2055
441	588	684	834

From above rake requirement calculations, the number of rakes for option 2 of train operation is more as compared to the option 1. Hence, considering optimization of rolling stock, the circular train operation is recommended.

8.6 TRAIN OPERATION PLAN

The train operation plan for different horizon years is formulated such that there is optimum utilization of rolling stock and empty running of the trains is reduced. The operation of the trains with combination of 3 car and 6 car rake composition is proposed for the inception year which will be changed to 6 car rakes with increase in traffic during future years. The operation for design year is proposed with 6 car rake composition.

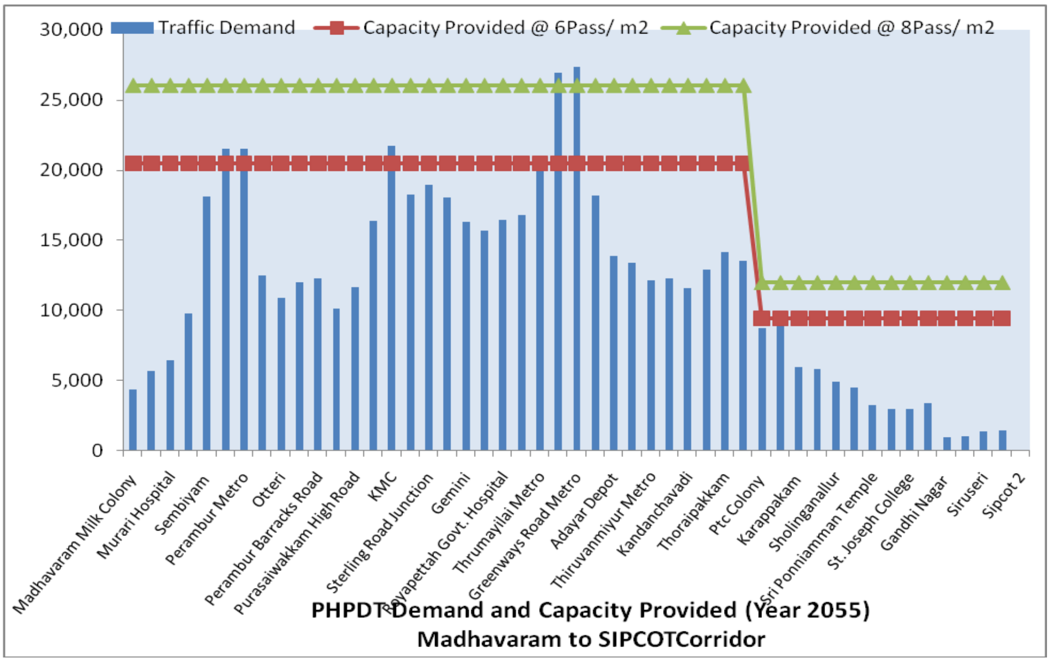
The train operation is planned with circular operation between Corridor 3 and Corridor 5 and independent train operation for Corridor 4. The capacity provided for the different sections of the corridors as a result of proposed train operation for the ultimate traffic demand in 2055 i.e. the design year is presented graphically below:

- **Madhavaram – SIPCOT (Corridor 3)**

Train operation plan for Madhavaram - Sholinganallur section of the corridor in year 2055 is planned with 6 car rake composition and 277 seconds headway during peak period. The planned PHPDT capacity is 20488 @ 6 passengers/m^2 of standee area (Capacity of 26052 @ 8 passengers/m^2 of standee area under dense loading conditions). The planned capacity is less than the PHPDT demand of 27361 passengers in few sections. However, capacity in this section can be met by carrying standees @ 8 passengers/ m^2 or higher which have been deliberatively planned for peak hour train operation for optimum utilization of rolling stock.

Between Sholinganallur and SIPCOT, PHPDT is very less i.e. 4498 passengers for year 2055. However, to make metro services attractive for passengers, trains are run at 600 seconds headway i.e. 6 trains per hour during the peak hours. These trains will have the capability to carry 9456 passengers @6p/m^2 (12024 passengers @8p/m^2) during the peak hours of operation.

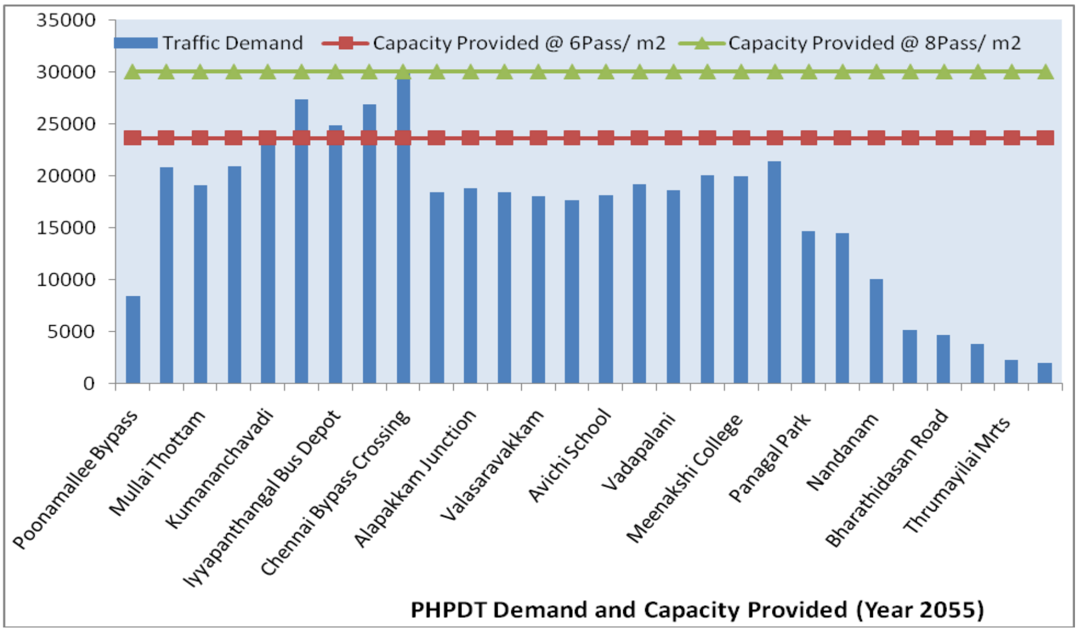
FIGURE 8.1: PHPDT DEMAND AND CAPACITY PROVIDED (2055) FOR MADHAVARAM - SIPCOT CORRIDOR



➢ **Lighthouse - Poonamallee Bypass Corridor (Corridor 4)**

Train operation for Lighthouse - Poonamallee Bypass corridor in the design year is planned with 6 car rake composition at 240 seconds headway during peak period. The carrying capacity of the trains during peak hours will be 23640 @ 6 passengers/m^2 of standee area (Capacity of 30060 @ 8 passengers/m^2 of standee area). The planned PHPDT capacity is less than PHPDT demand of 29940 passengers in section between Kumananchavadi and Porur Junction station. However, capacity in this section can be met by carrying standees @8 passengers/m^2 which has been deliberatively planned for peak hour train operation for optimum utilization of rolling stock.

FIGURE 8.2: PHPDT DEMAND AND CAPACITY PROVIDED (2055) FOR LIGHTHOUSE - POONAMALLEE BYPASS CORRIDOR



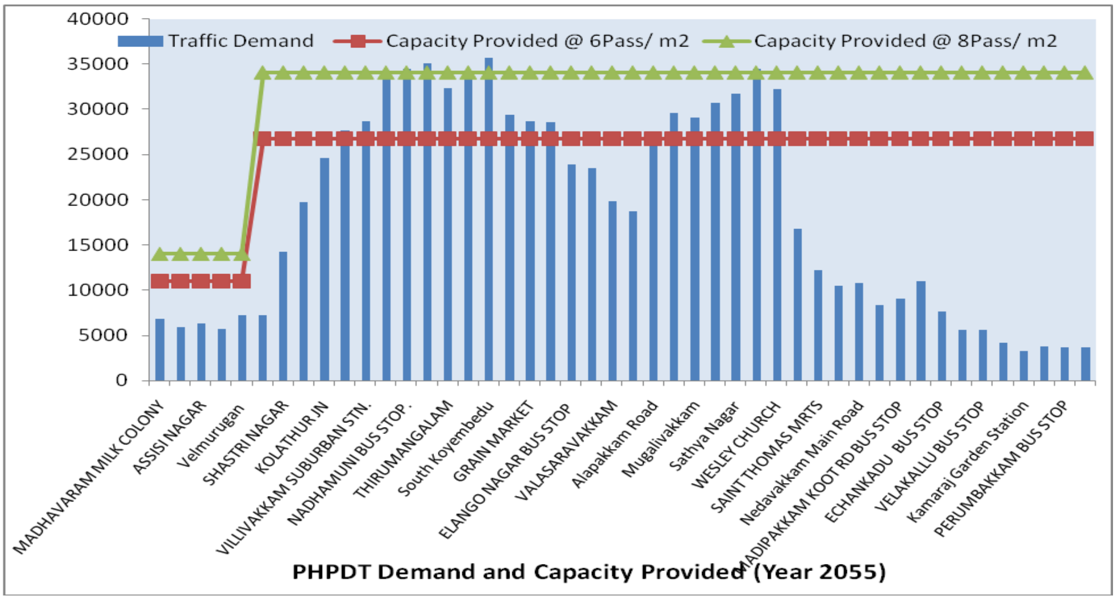
- **Madhavaram – Sholinganallur Corridor (Corridor 5)**

For Madhavaram (MMC) – Sholinganallur Corridor, the traffic is handled by circular train operation from Madhavaram – CMBT – Sholinganallur – Adyar – Madhvaram and by the train operation between MMBT and Sholinganallur.

For Madhavaram to MMBT of Corridor 5, traffic demand of 5171 passengers can be met by circular movement of the trains. Thus the headway for Madhavaram to MMBT section is 514 seconds i.e. 7 trains per hour. The capacity provided for the section is 11032 passengers (@6p/m^2) and 14028 passengers (@8p/m^2).

For MMBT and Sholinganallur, traffic demand of 35714 will be handled by operating trains at a headway of 212 seconds in design year. The passenger carrying capacity of trains for year 2055 will be 26792 passengers @6p/m^2 (34068 passengers @8p/m^2). With the proposed headway, planned capacity is slightly less than PHPDT demand in few sections of the corridor. However, capacity in this section can be met by carrying standees @8 passengers/ m^2 which have been deliberatively planned for peak hour train operation for optimum utilization of rolling stock.

FIGURE 8.3: PHPDT DEMAND AND CAPACITY PROVIDED (2055) FOR MADHAVARAM - SHOLINGANALLUR



Rolling stock is designed for carrying higher density loading @8 standee passengers per square meter and in sections where PHPDT demand exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of rolling stock and the optimum utilization of rolling stock will be achieved.

8.7 HOURLY TRAIN OPERATION PLAN

The services for Chennai Metro Phase-II shall be operational for 19 hours of a day (5:00 hrs to 00:00 hrs). No services are proposed between 00:00 hrs to 5:00 hrs which are reserved for maintenance of infrastructure and rolling stock. Hourly distribution of daily train operation various horizon years is enclosed in **Table 8.10.**

TABLE 8.10: HOURLY DISTRIBUTION OF TRAIN OPERATION

HOURLY TRAIN OPERATION PLAN FOR MMC-CMBT-SHOLINGANALLUR-ADYAR-MMC										
Time of Day	Year 2025 (3 and 6 Car)			Year 2035 (3 and 6 Car)			Year 2045 (6 Car)		Design (6 car)	
	Headway (min)	Trains/hr		Headway (min)	Trains/hr		Headway (min)	Trains/hr	Headway (min)	Trains/hr
		3 car	6 car		3 car	6 car		6 car		6 car
5 to 6	15.0	4	0	15.0	0	4	15.0	4	15.0	4
6 to 7	12.0	4	1	12.0	0	5	12.0	5	12.0	5
7 to 8	10.0	4	2	10.0	1	5	10.0	6	10.0	6
8 to 9	**8.6**	**4**	**3**	**8.6**	**2**	**5**	**8.6**	**7**	**8.6**	**7**
9 to 10	**8.6**	**4**	**3**	**8.6**	**2**	**5**	**8.6**	**7**	**8.6**	**7**

HOURLY TRAIN OPERATION PLAN FOR MMC-CMBT-SHOLINGANALLUR-ADYAR-MMC										
Time of Day	Year 2025 (3 and 6 Car)			Year 2035 (3 and 6 Car)			Year 2045 (6 Car)		Design (6 car)	
	Headway (min)	Trains/hr		Headway (min)	Trains/hr		Headway (min)	Trains/hr	Headway (min)	Trains/hr
		3 car	6 car		3 car	6 car		6 car		6 car
10 to 11	10.0	4	2	10.0	1	5	10.0	6	10.0	6
11 to12	10.0	4	2	10.0	1	5	10.0	6	10.0	6
12 to 13	12.0	4	1	12.0	0	5	12.0	5	12.0	5
13 to 14	15.0	3	1	15.0	0	4	15.0	4	15.0	4
14 to 15	12.0	4	1	12.0	0	5	12.0	5	12.0	5
15 to 16	10.0	4	2	10.0	1	5	10.0	6	10.0	6
16 to 17	10.0	4	2	10.0	1	5	10.0	6	10.0	6
17 to 18	**8.6**	**4**	**3**	**8.6**	**2**	**5**	**8.6**	**7**	**8.6**	**7**
18 to 19	**8.6**	**4**	**3**	**8.6**	**2**	**5**	**8.6**	**7**	**8.6**	**7**
19 to 20	10.0	4	2	10.0	1	5	10.0	6	10.0	6
20 to 21	10.0	4	2	10.0	1	5	10.0	6	10.0	6
21 to 22	12.0	4	1	12.0	0	5	12.0	5	12.0	5
22 to 23	12.0	4	1	12.0	0	5	12.0	5	12.0	5
23 to 24	15.0	4	0	15.0	0	4	15.0	4	15.0	4
Total No. of trains per direction per day		**75**	**32**		**15**	**92**		**107**		**107**

HOURLY TRAIN OPERATION PLAN FOR MMC- ADYAR – SIPCOT								
Time of Day	Year 2025 (3 Car)		Year 2035 (3Car)		Year 2045 (3 Car)		Design (6car)	
	Headway (min)	Trains/hr	Headway (min)	Trains/hr	Headway (min)	Trains/hr	Headway (min)	Trains/hr
5 to 6	15	4	15	4	15	4	15	4
6 to 7	12	5	12	5	12	5	12	5
7 to 8	12	5	12	5	12	5	12	5
8 to 9	**10**	**6**	**10**	**6**	**10**	**6**	**10**	**6**
9 to 10	**10**	**6**	**10**	**6**	**10**	**6**	**10**	**6**
10 to 11	12	5	12	5	12	5	12	5
11 to12	12	5	12	5	12	5	12	5
12 to 13	15	4	15	4	15	4	15	4
13 to 14	15	4	15	4	15	4	15	4
14 to 15	12	5	12	5	12	5	12	5
15 to 16	12	5	12	5	12	5	12	5
16 to 17	12	5	12	5	12	5	12	5
17 to 18	**10**	**6**	**10**	**6**	**10**	**6**	**10**	**6**
18 to 19	**10**	**6**	**10**	**6**	**10**	**6**	**10**	**6**
19 to 20	12	5	12	5	12	5	12	5
20 to 21	12	5	12	5	12	5	12	5
21 to 22	12	5	12	5	12	5	12	5
22 to 23	15	4	15	4	15	4	15	4
23 to 24	15	4	15	4	15	4	15	4
		94		**94**		**94**		**94**

HOURLY TRAIN OPERATION PLAN FOR MMBT-CMBT-SHOLINGANALLUR										
Time of Day	Year 2025 (3 and 6 Car)			Year 2035 (3 and 6 Car)			Year 2045 (6 Car)		Design (6 car)	
	Headway (min)	Trains/hr		Headway (min)	Trains/hr		Headway (min)	Trains/hr	Headway (min)	Trains/hr
		3 car	6 car		3 car	6 car		6 car		6 car
5 to 6	12.0	5	0	12.0	0	5	12.0	5	10.0	6
6 to 7	10.0	5	1	10.0	1	5	10.0	6	8.6	7
7 to 8	8.6	6	1	8.6	2	5	8.6	7	7.5	8
8 to 9	**7.5**	**7**	**1**	**7.5**	**3**	**5**	**7.5**	**8**	**6.0**	**10**
9 to 10	**7.5**	**7**	**1**	**7.5**	**3**	**5**	**7.5**	**8**	**6.0**	**10**
10 to 11	8.6	6	1	8.6	2	5	8.6	7	7.5	8
11 to12	8.6	6	1	8.6	2	5	8.6	7	7.5	8
12 to 13	10.0	5	1	10.0	1	5	10.0	6	8.6	7
13 to 14	12.0	5	0	12.0	0	5	12.0	5	10.0	6
14 to 15	10.0	5	1	10.0	1	5	10.0	6	8.6	7
15 to 16	8.6	6	1	8.6	2	5	8.6	7	7.5	8
16 to 17	8.6	6	1	8.6	2	5	8.6	7	7.5	8
17 to 18	**7.5**	**7**	**1**	**7.5**	**3**	**5**	**7.5**	**8**	**6.0**	**10**
18 to 19	**7.5**	**7**	**1**	**7.5**	**3**	**5**	**7.5**	**8**	**6.0**	**10**
19 to 20	8.6	6	1	8.6	2	5	8.6	7	7.5	8
20 to 21	8.6	6	1	8.6	2	5	8.6	7	7.5	8
21 to 22	10.0	5	1	10.0	1	5	10.0	6	8.6	7
22 to 23	10.0	5	1	10.0	1	5	10.0	6	10.0	6
23 to 24	12.0	5	0	12.0	0	5	12.0	5	12.0	5
		110	**16**		**31**	**95**		**126**		**147**

HOURLY TRAIN OPERATION PLAN FOR LIGHTHOUSE - POONAMALLEE BYPASS										
Time of Day	Year 2025 (3 Car)		Year 2035 (3 and 6 Car)			Year 2045 (3 and 6 Car)			Design (6 car)	
	Headway (min)	Trains/hr	Headway (min)	Trains/hr		Headway (min)	Trains/hr		Headway (min)	Trains /hr
		3 car		3 car	6 car		3 car	6 car		6 car
5 to 6	15.0	4	15.0	2	2	15.0	1	3	12.0	5
6 to 7	8.6	7	8.6	3	4	7.5	2	6	7.5	8
7 to 8	6.7	9	6.7	4	5	6.0	2	8	5.5	11
8 to 9	**4.6**	**13**	**4.6**	**6**	**7**	**4.3**	**3**	**11**	**4.0**	**15**
9 to 10	**4.6**	**13**	**4.6**	**6**	**7**	**4.3**	**3**	**11**	**4.0**	**15**
10 to 11	6.0	10	5.5	5	6	5.5	2	9	5.0	12
11 to12	7.5	8	7.5	4	4	6.7	2	7	6.7	9
12 to 13	8.6	7	8.6	3	4	7.5	2	6	7.5	8
13 to 14	15.0	4	15.0	2	2	15.0	1	3	12.0	5
14 to 15	8.6	7	8.6	3	4	7.5	2	6	7.5	8
15 to 16	7.5	8	7.5	4	4	6.7	2	7	6.7	9
16 to 17	6.0	10	5.5	5	6	5.5	2	9	5.0	12
17 to 18	**4.6**	**13**	**4.6**	**6**	**7**	**4.3**	**3**	**11**	**4.0**	**15**
18 to 19	**4.6**	**13**	**4.6**	**6**	**7**	**4.3**	**3**	**11**	**4.0**	**15**

HOURLY TRAIN OPERATION PLAN FOR LIGHTHOUSE - POONAMALLEE BYPASS										
Time of Day	**Year 2025 (3 Car)**		**Year 2035 (3 and 6 Car)**			**Year 2045 (3 and 6 Car)**			**Design (6 car)**	
	Headway (min)	**Trains/hr**	**Headway (min)**	**Trains/hr**		**Headway (min)**	**Trains/hr**		**Headway (min)**	**Trains /hr**
		3 car		**3 car**	**6 car**		**3 car**	**6 car**		**6 car**
19 to 20	6.0	10	5.5	5	6	5.5	2	9	5.0	12
20 to 21	7.5	8	7.5	4	4	6.7	2	7	6.7	9
21 to 22	8.6	7	8.6	3	4	7.5	2	6	7.5	8
22 to 23	12.0	5	12.0	2	3	12.0	1	4	10.0	6
23 to 24	15.0	4	15.0	2	2	15.0	1	3	12.0	5
Total No. of trains per direction/ day		**160**		**75**	**88**		**38**	**137**		**187**

8.8 VEHICLE KILOMETER

Based on above planning, vehicle kilometers have been estimated. Vehicle kilometers for proposed train operation for years 2025, 2035, 2045 and 2055 is given below in **Tables 8.11, 8.12, 8.13 & 8.14**.

TABLE 8.11: VEHICLE KILOMETER: MADHAVARAM-CMBT-SHOLINGANALLUR-ADYAR-MADHAVARAM

Year	2025		2035		2045	2055
Section Length	81.3		81.3		81.3	81.3
No of Cars/ Train	3&6		3&6		6	6
No of working Days/year	365		365		365	365
Number of Trains per day each way	75	32	15	92	107	107
Daily Train – Km	12201	5205.8	2440.2	14966.6	17406.8	17406.8
Annual Train - Km (10^5)	44.53	19.00	8.91	54.63	63.53	63.53
Annual Vehicle- KM (10^5)	133.60	114.01	26.72	327.77	381.21	381.21

TABLE 8.12: VEHICLE KILOMETER: MADHAVARAM-ADYAR-SIPCOT

Year	2025	2035	2045	2055
Section Length	44.7	44.7	44.7	44.7
No of Cars per Train	3	3	3	6
No of working Days/year	365	365	365	365
Number of Trains per day each way	94	94	94	94
Daily Train – km	8403.6	8403.6	8403.6	8403.6
Annual Train - km (10^5)	30.7	30.7	30.7	30.7
Annual Vehicle - km (10^5)	92.0	92.0	92.0	184.0

TABLE 8.13: VEHICLE KILOMETER: MMBT-SHOLINGANALLUR

Year	2025		2035		2045	2055
Section Length	42.0		42.0		42.0	42.0
No of Cars per Train	3&6		3&6		6	6
No of working Days/year	365		365		365	365
Number of Trains per day each way	110	16	31	95	126	147
Daily Train – km	9240.0	1344.0	2604.0	7980.0	10584.0	12348.0
Annual Train - km (10^5)	33.7	4.9	9.5	29.1	38.6	45.1
Annual Vehicle - km (10^5)	101.2	29.4	28.5	174.8	231.8	270.4

TABLE 8.14: VEHICLE KILOMETER: LIGHTHOUSE- POONAMALLEE BYPASS

Year	2025	2035		2045		2055
Section Length	25.4	25.4		25.4		25.4
No of Cars per Train	3&6	3&6		3&6		6
No of working Days/year	340	340		340		340
Number of Trains per day each way	160	75	88	38	137	187
Daily Train – km	8128	3810	4470.4	1930.4	6959.6	9499.6
Annual Train - km (10^5)	27.6	13.0	15.2	6.6	23.7	32.3
Annual Vehicle - km (10^5)	82.9	38.9	91.2	19.7	142.0	193.8

9. SIGNALING AND TELECOMMUNICATION

9.1 SIGNALING SYSTEM

The signaling system shall provide means of an efficient train control ensuring safety in train movements. It assists in optimization of metro infrastructure investment and running of efficient train services on metro network. System will have the following design parameters:

- Ridership (Design Year 2055): 27361 PHPDT (Corridor-3), 29940 PHPDT (Corridor-4) & 35714 PHPDT (Corridor-5)
- Standard Gauge: 1435 mm
- Average Speed: 32 kmph
- Total Stations: 50 (Corridor -3), 30 (Corridor -4) & 48 (Corridor – 5)
- Train Configuration: 3 & 6 Car Rake
- Required Headway: 277seconds (Corridor-3), 240 seconds (Corridor -4) & 212 seconds (Corridor-5)

9.1.1 Options for Signaling Systems

Depending on type of the railway network, main line or metro rail, Signaling & Train Control can be achieved by adopting any of the following Signaling System / Technologies available:

- Automatic Signaling
- ETCS Level – 1
- ETCS Level – 2
- Distance to Go (DTG)
- Communication Based Train Control (CBTC)

While systems at S.No. (i) – (iii) have been developed / used for Main Line Railway networks, systems at S.No. (iv) – (v) are for metro railway Networks. Therefore, to have a fair idea of the Signaling & Train Control systems for metro railway, the relative merits & limitations of Distance to Go (DTG) and Communication based train control system (CBTC) are discussed as below:

a) Distance to Go (DTG) Signaling System:

Distance to Go (DTG) signaling system is mainly used for MRTS and adopted by most of the recently commissioned MRT systems in India viz. Chennai Metro Phase 1, DMRC (Delhi Metro) Phase-I, Phase-II, Delhi Airport Metro Express Line, BMRCL Phase-I (Bengaluru Metro) & JMRCL (Jaipur Metro).

It has advanced features of Continuous Automatic Train Control (CATC) consisting of sub-systems like Automatic Train Supervision (ATS), Automatic Train Protection (ATP) and Automatic Train Operation (ATO).

These sub-systems are briefly described below:

- **Automatic Train Supervision (ATS)**

Automatic Train Supervision (ATS) is used to provide overall control of trains operation and remote control of station. The main function of ATS is automatic management of train's movement by interfacing with ATP / CBI systems for route setting, train supervision and regulation. The system supervises train movements continuously and optimizes train movements in case of abnormalities. ATS system also logs each train movement and displays it on traffic controller work stations and over view display panel at OCC and also on workstations placed in the Station Control Room (SCR) for Station Controller.

- **Automatic Train Protection (ATP)**

Automatic Train Protection (ATP) system (both on-board and way-side) in conjunction with Electronic interlocking , track profile and brake characteristics of rolling stock is provided to ensure safe as also optimal train services. ATP system includes continuous transmission of various safety parameters (authorized speed, movement authority etc.) from track to train through coded audio frequency track circuit. This information received from way-side ATP systems by on-board ATC system provides Cab signaling i.e. display of maximum safe speed, current speed and target speed / distance. Facilities for automatic enforcement of temporary / permanent speed restrictions are also built in to enhance safety during maintenance work.

- **Automatic Train Operation (ATO)**

Automatic Train Operation (ATO) operates the trains automatically from station to station within the safety envelope / parameters of ATP & also controls (opens / closes) the train doors. Train Operator (TO) is only required to close the train doors and press a Start button when train is ready to depart. ATO in conjunction with ATP & ATS, can control / regulate running & dwell time at stations in accordance with headway / timetable regulation and also regulates automatic reversal/turn back of trains at terminal stations.

- **Pros and Cons of DTG (Distance to Go) Signaling System:**

Distance to Go (DTG) Signaling system provides safety level of CENELEC SIL-4 (Safety Integrity Level) and permits an operational headway of 150 seconds with Continuous Automatic Train Control. DTG works on fixed block principle and needs Audio Frequency Track Circuits (AFTC) for train detection and track to train communication. The reliability of system depends on reliability of AFTC.

With the advent of Communication Based Train Control (CBTC) at almost same costs, metro transport authorities / organizations are now favoring adoption of CBTC over DTG based Signaling System for all new projects. World over, for new MRTS projects, while adoption of DTG based systems is on a decline, adoption of CBTC based systems, because of their advanced features and low life cycle costs, are increasing steadily. In conclusion, while DTG based System can be considered technology of the past, CBTC based system can be considered technology for the present & future.

Considering the high cost of Distance to Go (DTG) Signaling system and advent of new technology viz. Communication Based Train Control (CBTC*),* which supports advance features such as Unattended Train Operation, moving block *etc.* and is available at almost same cost, Distance to Go (DTG) Signaling system is **NOT recommended** for Chennai Metro corridors.

b) Communication based Train Control (CBTC) Signaling System:

Communication based Train Control (CBTC) Signaling System is mainly used for MRTS networks. It is the latest Signaling and Train Control Technology available and is being adopted by modern metros around the world. It is also being adopted by all upcoming MRTS Networks in India viz, DMRC Phase-III, Kochi Phase-I, BMRCL Phase-II etc.

Communication based Train Control (CBTC) Signaling System also has ATP,ATS, ATO/UTO functionality and works on the Moving or Virtual Block principle to reduce headways and increase transport capacity. CBTC relies on continuous two-way digital communication between each controlled train and a wayside control centre. On a moving block equipped railway, the line is usually divided into areas or regions, each area under the control of a computer and each with its own radio transmission system. Each train transmits its identity, location, direction and speed to the area computer which makes the necessary calculations for safe train separation (moving authority) and transmits this to the following train.

The radio link between each train and the area computer is continuous so the computer knows location of all the trains in its area all the time. It transmits to each train the location of the train in front and gives it a braking curve to enable it to stop before it reaches that train. In effect, it can be termed as a dynamic Distance-to-Go system.

As the CBTC based system has very few way side equipment and supports UTO, total life cycle cost of the system shall be substantially lower than other Signaling Systems due to low Maintenance & Operation (man power) costs.

- **Pros and Cons of CBTC Signaling System**

CBTC Signaling system provides adequate safety level of CENELEC SIL-4 (Safety Integrity Level) and permits an operational headway of **90 seconds** with continuous automatic train control. CBTC Technology is proven now in many metros around the world and is also suitable for UTO (Unattended Train Operation) / DTO (Driverless Train Operation).

If UTO system is considered for adoption, then provision of PSD (Platform Screen Doors) shall also have to be considered as it is a safety requirement for UTO operations.

After reviewing all available Signaling & Train Control Signaling Technologies, **Communication Based Train Control (CBTC)** system, which is the latest technology available, is recommended for Chennai Metro corridors.

9.1.2 Standards

Table 9.1 shows the standards that will be adopted.

TABLE 9.1: STANDARDS TO BE ADOPTED FOR SIGNALLING SYSTEM

Description	Standards
CBTC System	IEEE 1474.1
Operation of Points	With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.
Fail Safe Principles	SIL4 safety levels as per CENELEC standard for signal application.
Immunity to External Interference	All data transmission on telecom cables/OFC/Radio. All Signaling and telecom cables will be separated from power cables. CENELEC standards to be implemented for EMC.
Other Items	Suitable International Standards like CENELEC etc. shall be followed as per good industry practices.

9.2 TELECOMMUNICATION SYSTEM

Telecommunication system acts as communication backbone for Signaling and other systems and provides telecommunication services to meet operational and administrative requirements of metro network.

9.2.1 The telecommunications system used in different metros are as given **Table 9.2**.

TABLE 9.2: TELECOMMUNICATION SYSTEM USED IN DIFFERENT METROS

Metro Operator		System Used	
CMRL	Ph-1	A	Digital Transmission System (DTS) Optical Fiber Cable Main Telecommunications Bearer: SDH - STM 16
		B	Telephone System: Hybrid PBX
		C	Mobile Radio Communications: Digital Trunk Radio System (TETRA)
		D	Public Address/Voice Alarm (PA/VA) System
		E	Centralized Clock System: Digital & Analog Clocks and Time Synchronization System
		F	Passenger Information Display System: LCD based
		G	Network Management & Station Management System
		H	CCTV
		I	SCADA
DMRC	Line 1	A	Digital Transmission System (DTS) Optical Fiber Cable Main Telecommunications Bearer: SDH - STM 4 155Mbps network
		B	Telephone System: EPABX
		C	Mobile Radio Communications: Digital Trunk Radio System (TETRA)
		D	Public Address (PA) System
		E	Centralized Clock System: Digital & Analog Clocks and Time Synchronization System
		F	Passenger Information Display System: LED based
		G	Network Management & Station Management System
		H	CCTV Cameras were provided later on for Security purposes
DMRC	Line 2 Line 3 Phase II		Same as above with Closed Circuit Television: fixed and PTZ Camera and PIDS LED and LCD based.
BMRCL	Phase I	A	Digital Transmission System (DTS) - Optical Fiber Cable - Main Telecommunications Bearer: SDH - STM 4 155Mbps network
		B	Telephone System : EPABX
		C	Mobile Radio Communications: Digital Trunk Radio (TETRA)
		D	Public Address System
		E	Centralized Clock System: Digital and Analog Clock System

Metro Operator		System Used	
		F G H	Passenger Information Display System: LED & LCD based. Network Management & Station Closed Circuit Television System : Fixed and PTZ Camera with monitors
Hyderabad Metro	Phase I	A B C D E F G H	Digital Transmission System (DTS) - Optical Fiber Cable - IP based system with Layer 2, Layer 3 and Access switches with OF interfaces Telephone System: EPABX Mobile Radio Communications: Digital Trunk Radio (TETRA) Public Address System Centralized Clock System: Digital and Analog Clock System Passenger Information Display System: LED & LCD based. Central Fault Reporting system (CFRS) Closed Circuit Television: fixed and PTZ Camera
JMRC	Phase I	A B C D E F G H	Digital Transmission System (DTS) - Optical Fiber Cable - Main Telecommunications Bearer: SDH - STM 4 155Mbps network Telephone System : EPABX Mobile Radio Communications: Digital Trunk Radio (TETRA) Public Address System Centralized Clock System: Digital and Analog Clock System Passenger Information Display System: LED & LCD based. Network Management System Closed Circuit Television: fixed and PTZ Camera

9.2.2 Proposed Telecommunication System and Transmission Media

The state of the art latest technology being used in different metros worldwide, is proposed to be used for the Chennai Metro.

9.2.3 Digital Transmission System (DTS)

Optical Fiber Cable - Main Telecommunication Bearer

IP, GE (Giga Ethernet) based system is proposed for entire telecom network. OFC backbone network shall be formed by laying two outdoor single mode optical fiber cables (to be laid on either side of tracks). The normal and protected routes shall be in two different cables for path diversity. Considering channel requirement and keeping in view the future expansion requirements a minimum 96 Fiber, optical fiber cable is proposed in ring configuration with path diversity. Additional OFC can be considered to be provided if there is a demand for leasing Fiber from Telcos / Industries, providing a source of revenue generation.

IP network shall consist of highly reliable and fault tolerant Layer-2, Layer-3 and Access switches configured with due redundancy both at Back bone and Access levels for the MAN/LAN. The switches shall have IP interface cards of 10 GBPS for backbone, 1 GBPS for interface with all telecommunication and non-telecommunication sub-systems and 2 MBPS and higher levels for access level. All interfaces with other sub systems shall be IP based with minimum 2 MBPS capacity.

- **Telephone Exchange**

A cost effective solution of an IP PBX having at least 50 IP extensions will be provided at each station and 500 IP extensions PBX will be provided at the central, intermediate location on corridor and depot. The Exchanges will serve the subscribers at all stations, OCC and depot. Capacity of Exchanges can be suitably augmented, if required, depending on available subscribers. The exchanges will be interconnected at multiple IP interfaces (2 MBPS) through redundant optical fiber cable paths.

- **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 stations and 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 as shown in **Figure 9.1.**

FIGURE 9.1: TRAIN CAB RADIO AND COMM. FACILITY FOR MAINTENANCE

The frequency band for operation of the system i.e 410-430 or 380-400 MHz may be taken as per availability. The system shall provide mobile radio communication between the motorman of moving cars from any place and Central Control. The motorman can also contact any station in the network through 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. In addition to TETRA Radio Coverage for internal use of metro, the city is also having Mobile Coverage from Private Operators.

- **Public Address System**

The public Address System shall be capable of digitized voice announcements and long range PA functionality suitable for evacuation situations in emergency. The public address is to for stations will generally operate in automatic mode providing information for time and destination of next schedule train, special upcoming event, safety and security announcement at pre-determined intervals and general information to enhance the travel experience for all users but more specially the visually impaired.

- **Centralized Clock System**

Clock System shall provide synchronized time for the whole rail system. The time source shall be obtained from the Cesium Master Clock and Global Positioning System (GPS). The synchronized time information shall be displayed on slave clock units and provided to all other sub systems including Rolling Stock & signaling via the Digital Transmission System and Track-Train Communication system as shown in **Figure 9.2.**

FIGURE 9.2: MASTER CLOCK

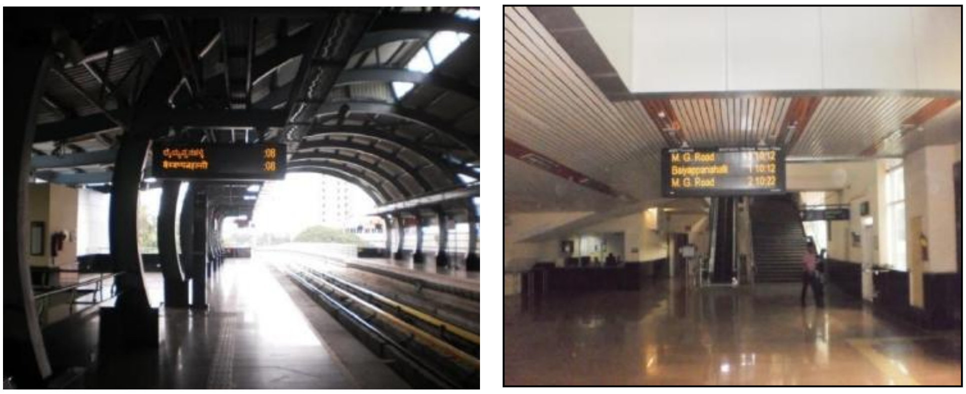
- **Passenger Information Display System**

At all stations, suitable Electronic Passenger Information Display Boards preferably LCD/LED (Flat Panel) will be provided as shown in **Figure 9.3**. The PIDS shall be train actuated (controlled by signaling system) along with facility for manual inputs from the local station as well as the central location (OCC).

FIGURE 9.3: PASSENGER INFORMATION DISPLAY SYSTEM

Passenger Information display boards will be provided at convenient locations at all stations to provide trilingual i.e. Tamil, English & Hindi visual indication of the status of the running trains and will typically indicate information such as destination, platform numbers, arrival/departure time, and also special messages in emergencies. The boards will be provided at all platforms and concourses of terminal & junction stations as shown in **Figure 9.4.**

FIGURE 9.4: PIDS AT PLATFORM AND CONCOURSE



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

- **Close Circuit Television (CCTV)**

CCTV system should ensure real time full coverage, high quality surveillance of all public and selected areas such as tunnel cross passages, ancillary buildings, on board conditions for secure passenger management, crowed control and other emergency situations. Event reloading shall be possible for post video analysis. CCTV cameras shall also be provided in Operational rooms like OCC, SCR etc. A proper IP based recording and storing facility to record and store events for minimum of one month shall be ensured.

- **Central Voice Recording System (CVRS)**

A centralized digital voice recording system will be provided at OCC to record all Two-way Telephone conversation, PA calls from station and OCC, Two Way Radio Conversation of all controllers, TOs, SCRs and other users in OCC and Depot. In addition, all conversation of the Radio System including private calls of all subscribers including Controllers, TOs shall also be recorded. Arrangement of free space audio recording in OCC, SCRs and Driver Cab shall also be made available.

- **Central Fault Reporting System (CFRS)**

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide a CFRS / SCADA system which will help in reporting and diagnosing the 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.

- **Uninterrupted Power Supply**

The uninterrupted power supply (UPS) of 60 KVA, 415 V ± 1%, 3 phase with Battery bank of 800AH capacity at each interlock station and 30 KVA with Battery bank of 300AH capacity at each non interlock station will be provided for 2 hour back up. The standards that will be adopted with regard to the Telecommunication system is shown in **Table 9.3**. These will conform to appropriate IRS/International standards.

TABLE 9.3: STANDARDS TO BE ADOPTED FOR TELECOMMUNICATIONS SYSTEMS

Description	Standards
Transmission System	**IP, GE (Giga Ethernet)** based system for the entire telecom network. OFC backbone network shall be formed by laying two outdoor single mode optical fiber cables (to be laid on either side of tracks). The normal and protected routes shall be arranged in

Description	Standards
	two different cables for path diversity.
Optical Fiber cable	OFC for underground environment shall be steel armoured and manufactured from Fire Retardant/resistance, Low Smoke and zero halogen materials. For elevated portion of corridor, it shall be steel armored and conforming to IRS specifications.
Public Address System	Passenger Announcement System shall be interfaced with signaling system for online update of train information. IEC 60268 as applicable or any equivalent international/National standard. The methods of measurement for variation in parameters for the equipment shall be in accordance with IEC268 Part 1to17– Sound System Equipment. Fire resistant Low Smoke Zero Halogen cables shall be used to maintain the circuit integrity in case of fire.
Telephone Exchange	IP based Electronic Exchange (IP PBX)
Passenger Display Information System	It shall be interfaced with signaling system for online update of train information. IEC as applicable or any equivalent international/National standard.
Synchronized Clock system	GPS based, master – slave system IEC 61588 or equivalent standard
CCTV/ Camera	CCTV network shall be as per IEEE standards. External storage device with RAID 5 protection.
Network connection for CCTV	Ethernet/10/100Base T PoE with IEEE802.3 compliant.
Redundancy (Major System)	Redundancy on Radio base station equipment including server level for all communication sub-systems.
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 coordination. Card/module level replacement will be done in the field and repairs undertaken in the central laboratory/manufacture's premises.

9.3 PLATFORM SCREEN DOORS

Platform Screen Doors (PSD) are mainly provided at metro stations to ensure safety and comfort of passengers. The principle advantages of PSD are:

i) It prevents accidental falls off the platform onto the lower track area, suicide attempts and homicides by pushing.

ii) It prevents or reduces wind felt by the passengers caused by the piston effect which could in some circumstances make people fall over.
iii) It reduces the risk of accidents, especially from service trains passing through the station at high speeds.
iv) It improves climate control within the station especially underground stations (heating, ventilation, and air conditioning are more effective when the station is physically isolated from the tunnel).
v) It improves security - access to the tracks and tunnels is restricted.
vi) It lowers operating costs- eliminate the need for motormen or conductors when used in conjunction with Unattended Train Operation (UTO).
vii) It prevents litter build up on the track, which can be a fire risk.
viii) It improves the sound quality of platform announcements, as background noise from the tunnels and trains that are entering or exiting is reduced.

There are some disadvantages of Platform Screen Doors, which are indicated:

i) Primary disadvantage is their cost; installing a system typically costs approx. Rs. 3 Crore per platform.
ii) When used to retrofit older systems, they limit the kind of rolling stock that may be used on a line, as train doors must have exactly the same spacing as the platform doors;
iii) Maintenance facilities in the depot are required to be augmented for maintenance of platform screen doors also.
iv) They impede natural ventilation, increasing climate control costs.

Since, advantages far outweigh the disadvantages, Platform Screen Doors (PSD) are proposed to be provided at all stations to ensure safety & comfort of commuters. The broad outline/details of Platform Screen Doors (PSD) is described hereunder:

9.3.1 System Configuration

The PSDs comprise Platform Screen Doors (PSD), Manual Secondary Doors (MSD), Emergency Escape Doors (EED) and Fixed Screens (FS) to form a glazed barrier along the edge of the platform for the passenger area. The configuration and location of the EEDs and FS will be such that the PSDs will correspond to location of train doors when the train has berthed in Correct Stopping Position (CSP) at platform.

(i) Platform Screen Door (PSD)

These powered glass doors are located along the platform at the platform edge throughout the passenger area and door locations are corresponding to the train car passenger door locations. Opening/closing of the PSD will be after receipt of the doors open/doors close command signals from the Signaling Link. Signaling link enables automatic operation of PSD only when the train stops within ±300 mm limits. The platform screen door is shown in **Figure 9.5.**

FIGURE 9.5: PLATFORM SCREEN DOOR

(ii) Manual Secondary Door (MSD)

These are manual glass doors located at one end of platform providing access from the platform onto the trackside. In case of emergency evacuation from tunnel/trackside the MSD can be opened from the trackside by using a push bar. The door will be designed to swing open and be held at an open position of 90^o. The door will be self-closing to the closed and locked position safely upon the opening position less than 90^o, without need for staff intervention. Operation of the MSD is the same as for the EED. The manual screen door is shown in **Figure 9.6.**

FIGURE 9.6: MANUAL SCREEN DOOR

(iii) Emergency Escape Door (EED)

EEDs are located around PSDs of leading and trailing passenger cars. If the train does not stop at correct position and opened train doors are not in front of PSD doors, the train passengers can go to the platform after opening the EED by pressing the emergency push bar located on the track side of the EED. Operation of the EED is same as for the MSD. The arrangement is shown in **Figure 9.7.**

FIGURE 9.7: EMERGENCY ESCAPE DOORS & FIXED SCREENS/PANELS

(iv) Fixed Screens/Panels (FP)

Platform length sections not provided with any of PSD/EED/MSD i.e. fixed panels are provided with fixed glass screens called "Fixed Panel" (FP). Apart from acting as a safety feature for the passengers from falling off on the tracks, PSDs also help in reducing the power consumption for the station HVAC and reduce the track-side noise on the platform.

Options & Recommendations

There are mainly two options for providing Platform Screen Doors viz. Full height PSD or Half height PSD. The advantages & limitations of PSD have been brought out above. The half-height and full height PSD are shown in **Figure 9.8** and **Figure 9.9** respectively. To ensure the safety of the passengers, Half Height Platform Screen Doors is proposed to be provided at all the elevated stations and Full Height Platform Screen Doors at all the U/G stations to reduce the energy consumption at underground stations.

FIGURE 9.8: HALF HEIGHT PSD

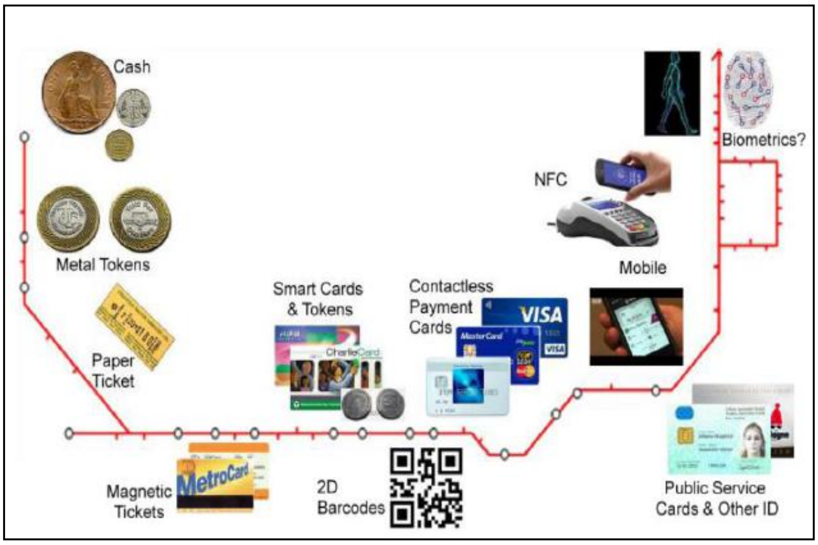
FIGURE 9.9: FULL HEIGHT PSD

10. FARE COLLECTION SYSTEM

10.1 INTRODUCTION

Mass Rapid Transit Systems handle large number of passengers. Ticket issual and fare collection play a vital role in efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. Automatic fare collection system meets these requirements. Fare collection technology development is as shown in **Figure 10.1.**

FIGURE 10.1: FARE COLLECTION TECHNOLOGY DEVELOPMENT



Keeping in view metro rail Automatic Fare Collection System and the fact that Contactless card/ token technology proves to be cheaper than other technologies in life cycle cost due to reduced maintenance as it has less wear and tear and is less prone to dusty environment, it is proposed to provide computer based automatic fare collection system with Contactless smart token/card type ticketing for Chennai Metro.

The equipments for the same may be provided at each station viz. Automatic Fare Gates, Ticket Office Machines, Ticket Readers, Portable Ticket Decoders, Central and Station Computers, Passenger Operated Machines/Ticket Vending Machines (POMs/TVMs) and UPS. The typical AFC System Operation Process and Architecture is shown in **Figures 10.2** & **Figure 10.3** respectively.

AFC system shall be interoperable with existing AFC systems functioning and to be planned in future. Existing AFC System Central Computer (CC) has a capacity to cater for upto 256 stations. AFC system shall also have functionality of interface to existing CCHS (Central Clearing House System) capable of handling upto 32 operators and 10 million transactions with provision of integration with other transit (metro, bus etc) and non-transit (parking, toll etc) which may be planned in future in line with the state / national policy.

FIGURE 10.2: AFC OPERATION PROCESS

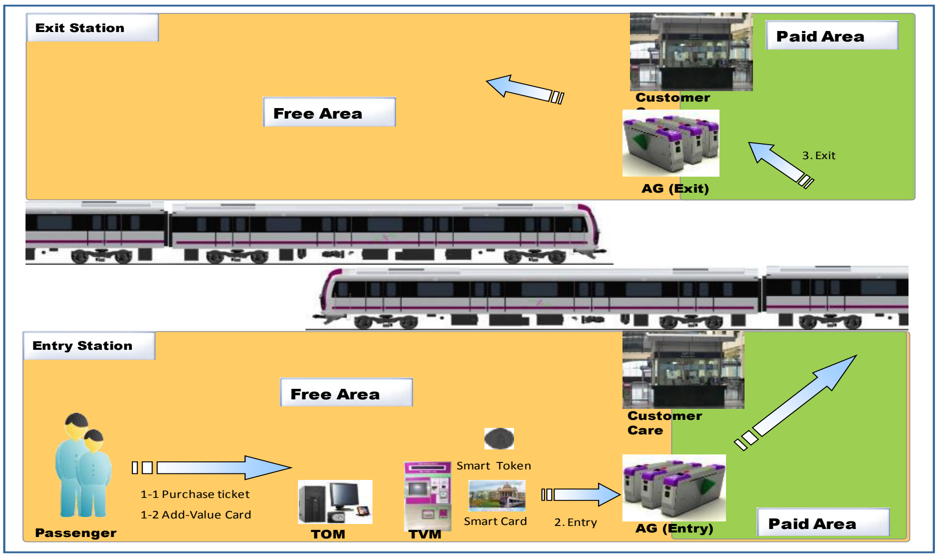
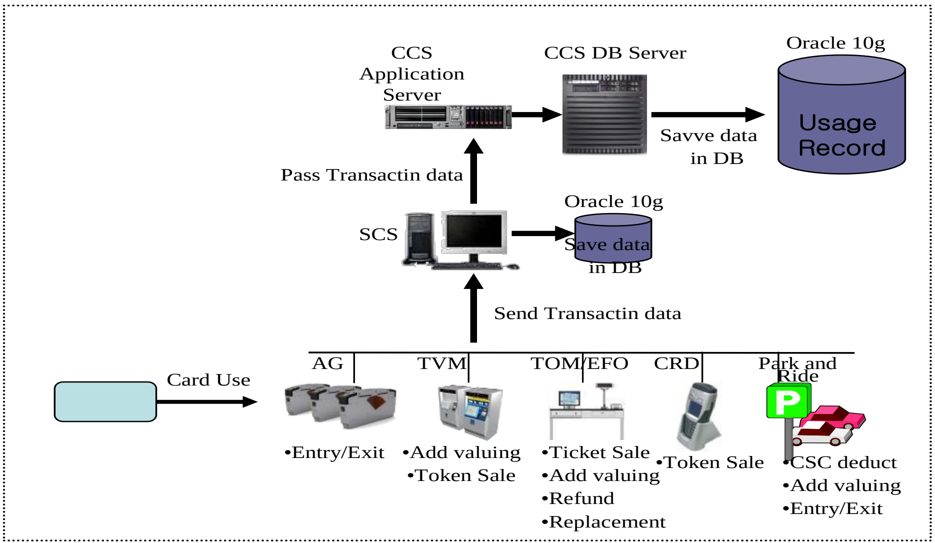


FIGURE 10.3: AFC SYSTEM ARCHITECTURE



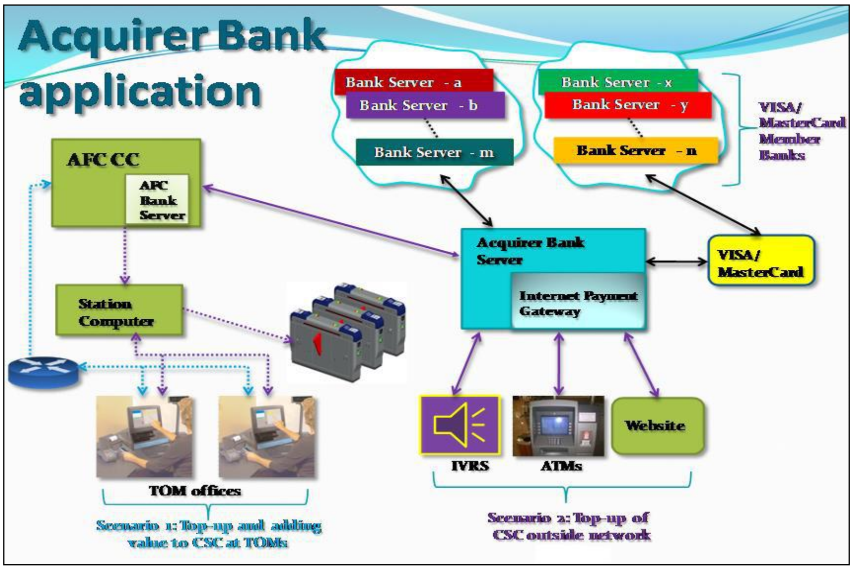
In addition, the proposed AFC system shall also be NFC (Near Field Communication) enabled so that customers can use their NFC enabled Mobile phones. Facility of recharging of Travel Cards using Cash, Debit/Credit Cards and Netbanking/web portal shall also be available. AFC system shall also support offsite sales terminals also, wherein cards and tokens can be dispensed at locations outside metro premises.

10.2 RECENT TECHNOLOGY DEVELOPMENT IN INDIA

A) Bank operator: AFC Ticketing system

Recent developments in mass transit and financial payments industries have created opportunities for convergence and collaboration. Banks are thus too keen to enter into the transit market. In present dispensation, the banks are only acting as a partner to distribute combo cards. The ownership of card lies with bank, but the transit product on the card is owned by transit operator. Probably preferential treatment to passengers having links with acquirer Bank may be given e.g. separate queue so as to reduce rush at counters. Banks will see this as value addition and probably will pay higher royalty. The Banking interface is shown in **Figure 10.4**.

FIGURE 10.4: BANKING INTERFACE



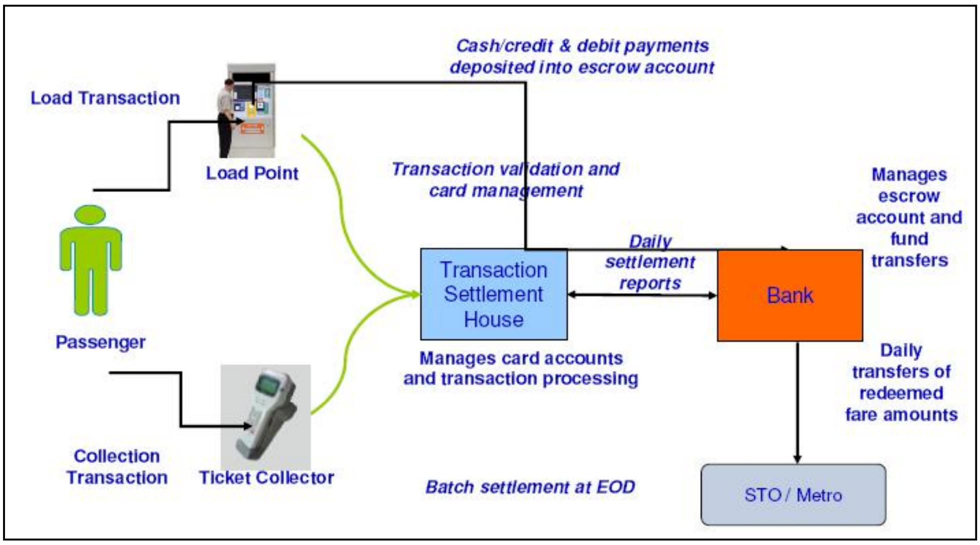
The scope of banks is to provide the following services:

- Providing POS terminals at ticket counters and Automatic Ticket Vending machines
- Topping-up of smart cards at ATMs
- Topping-up of smart cards through Net banking and Mobile banking
- Topping-up of smart cards through Payment gateway at website
- Topping-up of smart cards through Auto-top up using Standing Instructions from Bank customers / commuter.

B) Common Mobility Card

Common Mobility Card (CMC) Smart Card will provide Common Fare Collection System across different operators (both Government and Private) and different modes of public transport. Tipped as a nationwide interoperable transport card, the card aims to be a single point of transaction, applicable in state buses, metro and even parking. The whole system overview is presented in **Figure 10.5.**

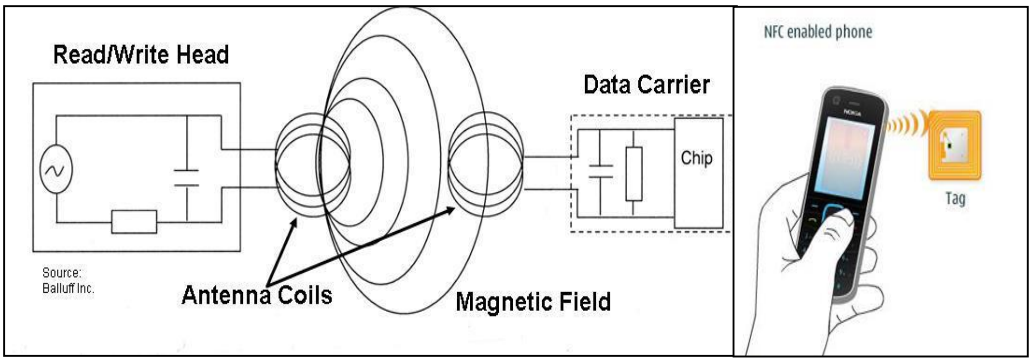
FIGURE 10.5: COMMON MOBILITY CARD OVERVIEW



C) Near Field Communication (NFC)

It is a Wireless communication technology based on inductive-coupling, enables data transfer between machines and uses the concept of Radio Frequency Identification (RFID). RFID is a technology that does communication through radio waves, that exchanges data between an electronic tag put on an object and a reader. NFC works using magnetic induction between two loop antennas located within each other's 'near field' and its operating frequency is 13.56 MHz. data rate 106 kbit/s to 424 kbit/s. NFC use an initiator and a target; initiator actively generates an RF field that can power a passive target. The near field communication is shown in **Figure 10.6.**

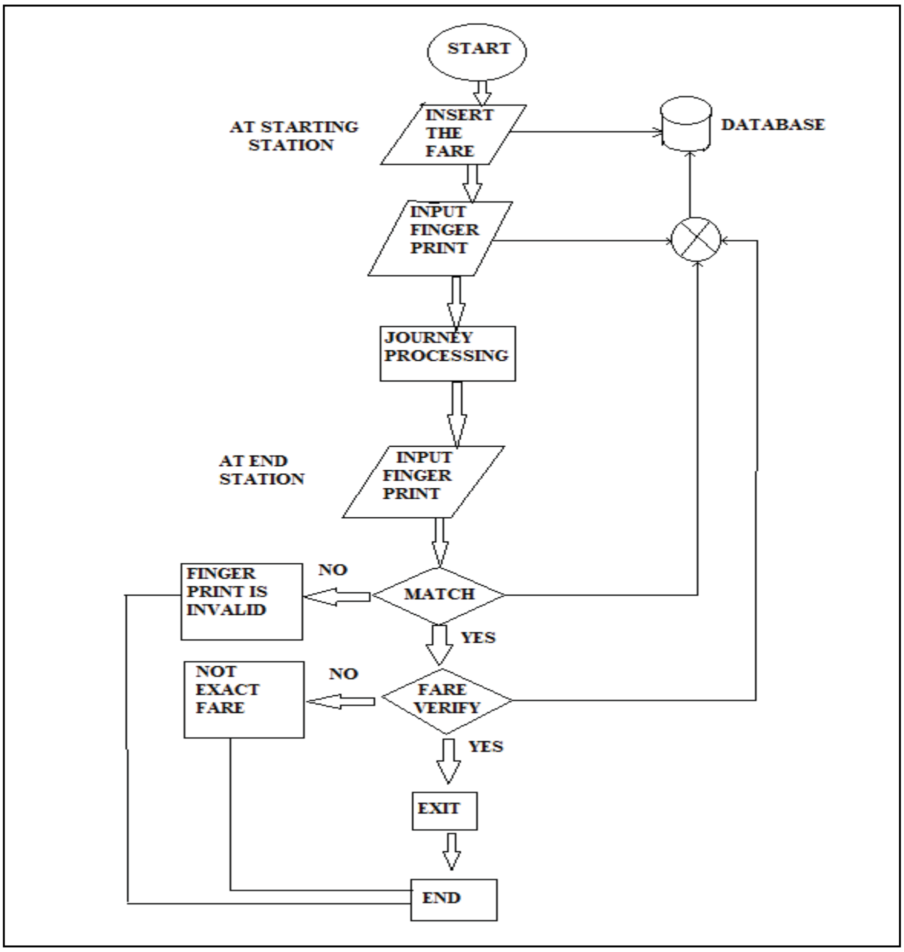
FIGURE 10.6: NEAR FIELD COMMUNICATION



D) Biometric System

The biometric system may easily be applicable to Railway Ticketing System Management in three ways: First, it takes an image of fingers by the finger print scanner machine. Second, it keeps the image as record in an easily manageable database. Lastly, when a passenger comes in front of the biometric gate and touches finger print, it tries to idetify and recognise the finger print from the previous database. The biometric system flowchart is shown in **Figure 10.7.**

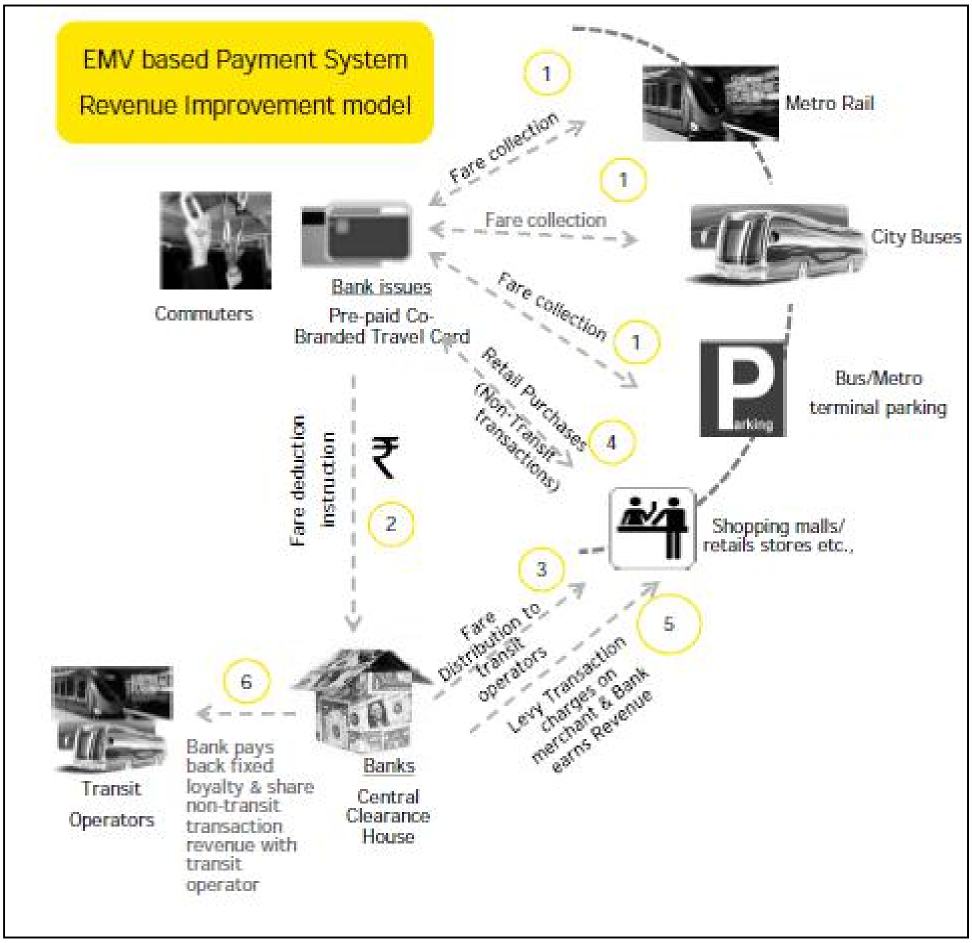
FIGURE 10.7: BIOMETRIC SYSTEM FLOW CHART



E) EMV Open Loop System

An EMV (Europay, Maser and Visa) a global standard is a credit or debit card with an embedded microchip designed to enable secure payment at compatible point of sale (POS) terminals. EMV cards can also support contactless payment through near-field communication (NFC) wireless connectivity. Transit Operator hires one or multiple financial institutions to issue a prepaid EMV enabled travel card to its commuters. The EMV based smart cards can be accepted within network of transit operator's terminals. The transit operators fare acceptance terminals would need EMV enabled card readers. The same card can be used on network of other payment methods at any merchant outlet. Model is convenient for a commuter as Transit Card and acts as an eWallet that can be used for all payment needs as single media. The EMV model also aids commuters to gain loyalty points for usage of cards on transit or non-transit network. The EMV based system is showm in **Figure 10.8.**

FIGURE 10.8: EMV based Payment System



10.3 AUTOMATIC FARE COLLECTION SYSTEM EQUIPMENT STANDARDS

The standard equipment proposed for AFC systems are given in the **Table 10.1**.

TABLE 10.1: STANDARDS PROPOSED FOR AFC SYSTEMS

Equipment	Description
Fare media	**Contactless smart token** – For single journey. It will have stored value amount for a particular journey. Tokens will be captured at the exit gate. **Contactless smart card** – For multiple journeys. **Virtual Fare Card** – To tap and pay the transit fare using securely stored virtual card on the mobile phone **Open loop Compliant Media** – For fare payment on point of entry/exit **Hands free ticketing** – Valid ticketing medium without presenting media to a touch-point.

Equipment	Description
Gates	Computer controlled automatic gates at entry and exit. There will be following types of gates: Entry Exit Reversible – can be set to entry or exit **Disabled –** Wide reversible gate for disabled people.
Station computer, Central computer and AFC Net work	All the **fare collection equipments** will be connected in a **local area network** with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control centre through the optic 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 **Ticket office machine** may be installed in the stations for selling cards/ tokens to the passengers.
Ticket reader and portable ticket decoder.	**Ticket reader will** be installed near EFO for passengers to check information stored in the token / cards.
Ticket Vending Machine (TVM)	**Ticket Vending Machines (TVMs)** having facility of issue of single journey tokens & recharge of travel cards using cash, debit/credit cards shall be installed in non-paid areas.
UPS (uninterrupted power at stations as well as for OCC).	Common UPS of S&T system will be utilized.
Maintenance philosophy	Being fully Contactless system, manpower requirement for maintenance is much less compared to other systems. However, adequate facilities to be provided similar to that of S&T systems.

10.4 STATION WISE REQUIREMENT OF AFC GATES

Based on the peak boarding and alighting at the stations, the station wise tentative requirement of AFC gates for year 2025 and 2055 is calculated. However, the minimum requirement of 2 entry and 2 exit and 1 differently abled gate per access may be considered during design stage as per the requirement of station access. Tentative station wise estimation for C3, C4 & C5 are shown below in **Table 10.2, 10.3 & 10.4:**

TABLE 10.2: STATION WISE NUMBER OF AFC GATES FOR C3

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
1	Madhavram Milk Colony	2184	1023	44	20	2	2	1	4363	2022	87	40	3	2	1
2	Thapapetti	593	508	12	10	2	2	1	2327	1804	47	36	2	2	1
3	Murari Hospital	530	245	11	5	2	2	1	997	446	20	9	2	2	1
4	Moolakadai	2257	1285	45	26	2	2	1	3895	1715	78	34	3	2	1
5	Sembiyam	2881	1234	58	25	2	2	1	9178	2258	184	45	6	2	1
6	Perambur Market	2404	1155	48	23	2	2	1	4052	2354	81	47	3	2	1
7	Perambur Metro	1197	637	24	13	2	2	1	1664	1707	33	34	2	2	1
8	Ayanavaram	2899	4330	58	87	2	3	1	3936	10801	79	216	3	7	1
9	Otteri	477	1119	10	22	2	2	1	984	2984	20	60	2	2	1
10	Pattalam	1394	1047	28	21	2	2	1	3471	2915	69	58	2	2	1
11	Perambur Barracks Road	883	863	18	17	2	2	1	1632	2663	33	53	2	2	1
12	Doveton Junction	973	1357	19	27	2	2	1	2585	2843	52	57	2	2	1
13	Purasaiwakkam High Road	1842	1809	37	36	2	2	1	3436	3704	69	74	2	2	1
14	Kelleys	2260	2275	45	46	2	2	1	5049	2646	101	53	3	2	1
15	KMC	3823	3338	76	67	3	2	1	7666	3789	153	76	5	3	1
16	Chetpet Metro	1439	1870	29	37	2	2	1	3564	4574	71	91	2	3	1
17	Sterling Road Junction	1180	1347	24	27	2	2	1	2335	1607	47	32	2	2	1
18	Nungambakkam	582	591	12	12	2	2	1	1260	1705	25	34	2	2	1
19	Gemini	732	755	15	15	2	2	1	1014	2101	20	42	2	2	1
20	Thousand Lights	511	452	10	9	2	2	1	1207	1380	24	28	2	2	1
21	Royapettah Govt. Hospital	1108	643	22	13	2	2	1	2252	1563	45	31	2	2	1
22	Radhakrishnan Salai Jn.	422	417	8	8	2	2	1	1242	1107	25	22	2	2	1

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
23	Thirumayilai Metro	2670	2178	53	44	2	2	1	6813	3674	136	73	5	2	1
24	Mandaiveli	5401	3650	108	73	4	2	1	9894	7144	198	143	7	5	1
25	Greenways Road Metro	2901	2578	58	52	2	2	1	6380	6118	128	122	4	4	1
26	Adyar Junction	4446	5257	89	105	3	4	1	4716	10385	94	208	3	7	1
27	Adyar Depot	2178	3211	44	64	2	2	1	2621	5323	52	106	2	4	1
28	Indira Nagar	514	570	10	11	2	2	1	871	1301	17	26	2	2	1
29	Thiruvanmiyur Metro	1637	2566	33	51	2	2	1	3770	3057	75	61	3	2	1
30	Taramani Link Road	637	1082	13	22	2	2	1	1640	1589	33	32	2	2	1
31	Nehru Nagar	720	822	14	16	2	2	1	1386	1981	28	40	2	2	1
32	Kandanchavadi	426	622	9	12	2	2	1	2697	1023	54	20	2	2	1
33	Perungudi	1869	1634	37	33	2	2	1	3507	3721	70	74	2	2	1
34	Thoraipakkam	2206	2291	44	46	2	2	1	4716	4969	94	99	3	3	1
35	Mettukuppam	864	2796	17	56	2	2	1	3557	8946	71	179	2	6	1
36	PTC Colony	2087	1229	42	25	2	2	1	5142	2901	103	58	3	2	1
37	Okkiyampet	1627	2751	33	55	2	2	1	4639	6794	93	136	3	5	1
38	Karapakkam	1248	886	25	18	2	2	1	3228	2062	65	41	2	2	1
39	Okkiyam Thoraipakkam	906	1228	18	25	2	2	1	2098	3724	42	74	2	2	1
40	Sholinganallur	877	1681	18	34	2	2	1	1849	3271	37	65	2	2	1
41	Sholinganallur Lake	1431	1591	29	32	2	2	1	3228	3775	65	76	2	3	1
42	Sri Ponniamman Temple	540	1351	11	27	2	2	1	2360	2744	47	55	2	2	1
43	Sathyabama University	335	221	7	4	2	2	1	437	529	9	11	2	2	1
44	St. Joseph's College	260	577	5	12	2	2	1	412	809	8	16	2	2	1
45	Semmancheri	1865	1071	37	21	2	2	1	3501	2842	70	57	2	2	1
46	Gandhi Nagar	422	342	8	7	2	2	1	693	747	14	15	2	2	1
47	Navallur	501	473	10	9	2	2	1	753	819	15	16	2	2	1

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
48	Siruseri	305	363	6	7	2	2	1	716	836	14	17	2	2	1
49	Sipcot 1	907	1039	18	21	2	2	1	1849	1805	37	36	2	2	1
50	Sipcot 2	141	132	3	3	2	2	1	217	220	4	4	2	2	1

TABLE 10.3: STATION WISE NUMBER OF AFC GATES FOR C4

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
1	Poonamallee Bypass	3823	4371	76	87	3	3	1	3926	8480	79	170	3	6	1
2	Poonamallee Bus Terminus	2023	1844	40	37	2	2	1	20332	7808	407	156	14	5	1
3	Mullai Thottam	2255	2174	45	43	2	2	1	5811	8429	116	169	4	6	1
4	Karayanchavadi	5108	3595	102	72	3	2	1	11482	5524	230	110	8	4	1
5	Kumananchavadi	1233	1494	25	30	2	2	1	5746	3627	115	73	4	2	1
6	Kattupakkam	1948	2000	39	40	2	2	1	4978	3356	100	67	3	2	1
7	Iyyapanthangal Bus Depot	1144	891	23	18	2	2	1	3158	3224	63	64	2	2	1
8	Ramachanrda Hospital	649	609	13	12	2	2	1	3659	1116	73	22	2	2	1
9	Chennai Bypass Crossing	4138	2199	83	44	3	2	1	5199	2994	104	60	3	2	1
10	Porur Junction	2897	5834	58	117	2	4	1	5271	13129	105	263	4	9	1
11	Alapakkam Junction	676	641	14	13	2	2	1	1771	881	35	18	2	2	1
12	Karambakkam	1232	1164	25	23	2	2	1	3558	3612	71	72	2	2	1
13	Valasaravakkam	110	298	2	6	2	2	1	611	814	12	16	2	2	1
14	Alwarthirunagar	1475	1452	30	29	2	2	1	3054	3003	61	60	2	2	1
15	Avichi School	1160	1104	23	22	2	2	1	2779	2442	56	49	2	2	1

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
16	Saligramam	2470	1899	49	38	2	2	1	5283	3971	106	79	4	3	1
17	Vadapalani	2303	1948	46	39	2	2	1	5055	4097	101	82	3	3	1
18	Powerhouse At Damro	1044	1044	21	21	2	2	1	1953	1984	39	40	2	2	1
19	Meenakshi College	1138	1493	23	30	2	2	1	2299	3470	46	69	2	2	1
20	Kodambakkam Suburban	3180	3162	64	63	2	2	1	4676	7076	94	142	3	5	1
21	Panagal Park	4820	7177	96	144	3	5	1	7563	13863	151	277	5	9	1
22	Natesan Park	1092	951	22	19	2	2	1	2870	2095	57	42	2	2	1
23	Nandanam	4279	4051	86	81	3	3	1	5535	8257	111	165	4	6	1
24	Adyar Gate Junction	3134	2642	63	53	2	2	1	5443	5456	109	109	4	4	1
25	Bharathidasan Road	816	638	16	13	2	2	1	1753	1260	35	25	2	2	1
26	Alwarpet	1043	682	21	14	2	2	1	1886	1088	38	22	2	2	1
27	Thrumayilai Mrts	1643	1320	33	26	2	2	1	2286	2940	46	59	2	2	1
28	Kutchery Road	414	334	8	7	2	2	1	669	631	13	13	2	2	1
29	Foreshore Road	278	388	6	8	2	2	1	843	1117	17	22	2	2	1
30	Light House	852	908	17	18	2	2	1	2000	2595	40	52	2	2	1

TABLE 10.4: STATION WISE NUMBER OF AFC GATES FOR C5

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
1	Madhavaram Milk Colony	2536	1380	51	28	2	2	1	5363	6820	107	136	4	5	1
2	Venugopal Nagar	307	266	6	5	2	2	1	1341	573	27	11	2	2	1

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
3	Assissi Nagar	572	510	11	10	2	2	1	1326	2963	27	59	2	2	1
4	Manjambakkam	401	573	8	11	2	2	1	1057	1244	21	25	2	2	1
5	Velumurugan Nagar	912	747	18	15	2	2	1	2384	2119	48	42	2	2	1
6	MMBT	1201	840	24	17	2	2	1	4367	1382	87	28	3	2	1
7	Shastri Nagar	2823	1838	56	37	2	2	1	7531	3943	151	79	5	3	1
8	Retteri Jn.	3482	1649	70	33	2	2	1	7080	3270	142	65	5	2	1
9	Kolathur Jn.	1750	872	35	17	2	2	1	5696	1668	114	33	4	2	1
10	Srinivasa Nagar	2074	1229	41	25	2	2	1	4177	2130	84	43	3	2	1
11	Villivakkam Metro	2832	3532	57	71	2	2	1	9904	9752	198	195	7	7	1
12	Villivakkam Bus Terminus	3070	2779	61	56	2	2	1	7131	5886	143	118	5	4	1
13	Nathamuni	2762	2374	55	47	2	2	1	4138	4416	83	88	3	3	1
14	Anna Nagar Depot	3240	4493	65	90	2	3	1	10172	9946	203	199	7	7	1
15	Thirumangalam	1847	3033	37	61	2	2	1	5081	13020	102	200	3	7	1
16	Kendriya Vidyalaya	1559	1206	31	24	2	2	1	5436	2822	109	56	4	2	1
17	Kaliammankoil Street Jn.	2194	2592	44	52	2	2	1	6710	5299	134	106	4	4	1
18	CMBT	5940	6252	119	125	4	4	1	15249	14734	305	295	10	10	1
19	Grain Market	1014	1015	20	20	2	2	1	3227	3153	65	63	2	2	1
20	Sai Nagar Bus Stop	698	903	14	18	2	2	1	2141	1161	43	23	2	2	1
21	Elango nagar Bus Stop	3357	2904	67	58	2	2	1	4910	7997	98	160	3	5	1
22	Alwartirunagar	594	957	12	19	2	2	1	1499	2104	30	42	2	2	1
23	Valasaravakkam	3136	3170	63	63	2	2	1	6907	6839	138	137	5	5	1
24	Karabakkam	672	878	13	18	2	2	1	2321	2001	46	40	2	2	1
25	Alapakkam Junction	1944	2107	39	42	2	2	1	10681	3608	214	72	7	2	1
26	Porur Jn.	3860	4041	77	81	3	3	1	8452	7312	169	146	6	5	1
27	Mugalivakkam	447	282	9	6	2	2	1	1355	1116	27	22	2	2	1

SN	Station	2025							2055						
		Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate			Total Board	Total Alight	Peak Min Board	Peak Min Alight	Gate		
						Entry	Exit	Disabled					Entry	Exit	Disabled
28	DLF IT SEZ	1350	1067	27	21	2	2	1	4886	2904	98	58	3	2	1
29	Sathya Nagar	794	1142	16	23	2	2	1	2059	2669	41	53	2	2	1
30	CTC	1306	1459	26	29	2	2	1	5403	3423	108	68	4	2	1
31	Butt Road	2059	1169	41	23	2	2	1	2400	3727	48	75	2	3	1
32	Alandur	1085	3742	22	75	2	3	1	1832	17425	37	349	2	12	1
33	St. Thomas Mount	2485	3213	50	64	2	2	1	3513	6313	70	126	2	4	1
34	Adambakkam	1172	946	23	19	2	2	1	2580	2496	52	50	2	2	1
35	Vanuvampet	553	340	11	7	2	2	1	1184	678	24	14	2	2	1
36	Puzhuthivakkam	1471	942	29	19	2	2	1	2216	3530	44	71	2	2	1
37	Madipakkam	1054	508	21	10	2	2	1	2949	1424	59	28	2	2	1
38	Kilkattalai	365	3257	7	65	2	2	1	894	7996	18	160	2	5	1
39	Echangadu	2401	1176	48	24	2	2	1	7543	3365	151	67	5	2	1
40	Kovilambakkam	1533	975	31	20	2	2	1	5223	3456	104	69	3	2	1
41	Vellakkal	760	438	15	9	2	2	1	2119	1313	42	26	2	2	1
42	Medavakkam Koot Road	1220	1115	24	22	2	2	1	2995	2970	60	59	2	2	1
43	Kamaraj garden Street	536	591	11	12	2	2	1	839	1509	17	30	2	2	1
44	Medavakkam Jn.	1152	812	23	16	2	2	1	2396	2035	48	41	2	2	1
45	Perumbakkam	300	290	6	6	2	2	1	2323	2385	46	48	2	2	1
46	Global Hospital	975	1054	20	21	2	2	1	2218	3327	44	67	2	2	1
47	ELCOT	766	384	15	8	2	2	1	3684	1889	74	38	2	2	1
48	Sholinganallur	574	2093	11	42	2	2	1	987	3761	20	75	2	3	1

11. ROLLING STOCK

11.1 COVERAGE

Required transport demand forecast is the governing factor for choice of Rolling Stock. The chapter broadly covers the proposed physical parameters viz. capacity, dimensions, weight etc. and typical technical aspects of proposed rolling stock.

11.2 COACH DIMENSIONS

In India, mainly two types of rolling stock sizes are being used. These are 2.9m wide coaches and 3.2m wide coaches. Coaches with 3.2m width have capability to handle more number of passengers in comparison to the 2.9 m wide coaches. However, use of 3.2m wide coaches will have significant cost implication in terms of tunneling or viaduct construction. The land requirement for track alignment and depot will increase considerably.

The minimum required headway as per the traffic projection upto 2055 i.e. the design year is 3.5 minutes. Practically achievable headway is 2.5 minutes as practiced in Delhi Metro. Therefore, in case of increase in traffic beyond the projection, headway can be reduced and the train frequency can be increased. Hence, there may be no need for 3.2 m wide coaches. Also, because of higher weight of coaches, the specific energy consumption will increase in case of 3.2 m coaches which will affect traction energy consumption.

2.9 m wide coaches are standard products of a large number of manufacturers. On the other hand, 3.2m wide coaches are not the standard products and hence the procurement of the coaches will be costly and time consuming.

Considering the above factors, **2.9m wide coaches** which are similar to those being used in CMRL Phase I are recommended for use in CMRL phase II.

The following dimensions of coach are proposed for Chennai Metro Phase II **(Table 11.1).**

TABLE 11.1:COACH DIMENSIONS

Type of coach	Length*	Width	Height
Driving Motor Car (DMC)	21.64 m	2.9 m	3.9 m
Trailer car (TC)/Motor Car (MC)	21.34 m	2.9 m	3.9 m

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

11.3 PASSENGER CARRYING CAPACITY

In order to maximize passenger carrying capacity, longitudinal seating arrangement shall be adopted. The whole train shall be vestibuled to distribute passengers evenly in all coaches. Criteria for calculation of standing passengers are 3 persons per square meter of standing floor area in normal state, 6 persons in crush state of peak hour and 8 persons in dense crush state of peak hour.

The train composition is proposed as 3 - Car Train and 6- Car Train. The carrying capacity is indicated in **Table 11.2**.

TABLE 11.2: CARRYING CAPACITY OF METRO RAIL

Description	Driving Motor Car (DMC)			Trailer Car (TC)/ Motor Car (MC)			3 Car Train			6 Car Train		
	Normal	Crush	Dense Crush	Normal	Crush	Dense Crush	Normal	Crush	Dense Crush	Normal	Crush	Dense Crush
Seated	43	43	43	50	50	50	136	136	136	286	286	286
Standing	103	205	273	110	220	293	316	630	839	646	1290	1718
Total	146	248	316	160	270	343	452	766	975	932	1576	2004

Normal - 3 Per/sqm of standee area, **Crush**- 6 Per/Sqm of standee area, **Dense Crush** – 8 Per/Sqm of standee area.

11.4 WEIGHT

The weight of motor cars and trailers are estimated in **Table 11.3**, considering an average passenger weight as 65 kg.

TABLE 11.3: WEIGHT OF MASS RAIL VEHICLES (TONS)

	DMC/MC	TC	3 Car Train	6 Car Train
TARE	42.502	40.852	125.86	251.712
Passenger				
(Normal)	9.49	10.40	29.38	60.58
(Crush @ 6)	16.12	17.55	49.79	102.44
(Dense Crush @ 8)	20.54	22.30	63.38	130.26
Gross				
(Normal)	51.992	51.25	155.24	312.292
(Crush @ 6)	58.622	58.402	175.65	354.152
(Dense Crush @ 8)	63.042	63.15	189.23	381.972
Axle Load @ 6 persons/ m^2	14.655	14.60		
Axle Load @ 8 persons/ m^2	15.76	15.79		

The axle load @ 6persons/m^2 of standees works out in the range of 14.60T to 14.65T per coach. Heavy rush of passengers with loading @8 standees per sq.

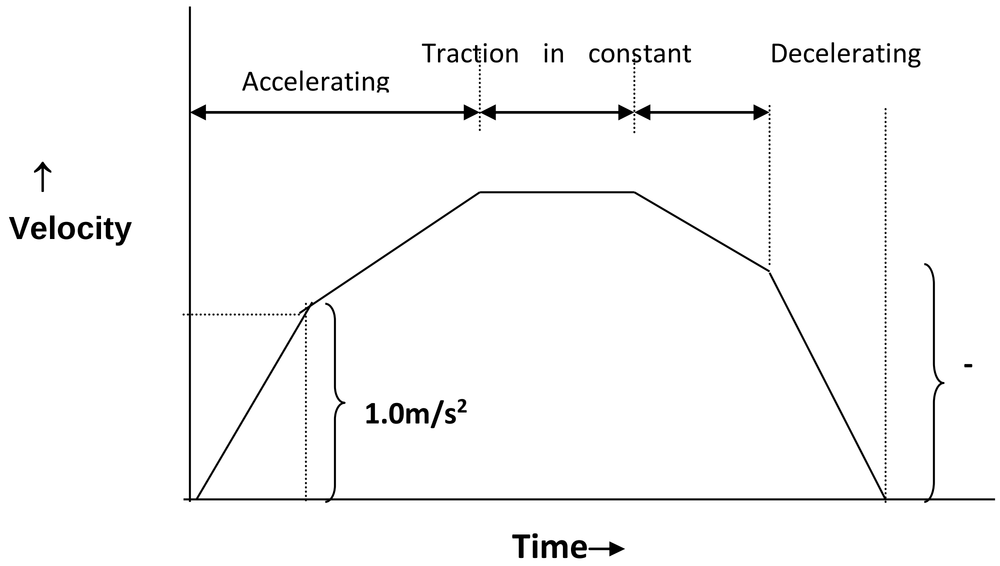
meter can be experienced occasionally during peak hours. It is recommended to design the coaches with sufficient strength so that even with this overload, design will not result in over stresses. Coach and bogie should therefore be designed for 16 T axle load.

11.5 PERFORMANCE PARAMETERS

To achieve desired schedule speed and running time between stations, the following values of acceleration and deceleration are recommended in consideration of riding comfort, adhesion and requirement of makeup time.

- Max. Speed : 80 kmph
- Max. Acceleration :1.0 m/s^2
- Max. Deceleration :1.1 m/s^2 (Normal brake)
  More than 1.3 m/s^2 (Emergency brake)

FIGURE 11.1: SIMPLIFIED VELOCITY – TIME OPERATION CURVE



11.6 SELECTION OF TECHNOLOGY

Following important criteria is proposed for selection of rolling stock:

- Passenger comfort and safety
- Proven equipment with high reliability
- Energy efficiency
- Light weight equipment and coach body
- High rate of acceleration and deceleration
- Optimized scheduled speed
- Flexibility to meet increase in traffic demand
- Aesthetically pleasing Interior and Exterior
- Low Life cycle cost

Low life cycle cost is achieved by the way of reduced scheduled and unscheduled maintenance and high reliability of sub-systems. It is possible to achieve these objectives by adopting state of art proven technologies. The selection of following technologies is proposed to ensure low life cycle cost.

(i) Car body

In the past, carbon high tensile steel was invariably used for car bodies. In-fact almost all coaches built by Indian Railways are of this type. These steel bodied coaches need frequent painting and corrosion repairs which may have to be carried out up to 4-5 times during the service life of these coaches. It is now standard practice to adopt stainless steel or aluminium car bodies.

(ii) Bogies

Bolster less light weight bogies with rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 4,20,000 km. The use of air spring at secondary stage may be considered with a view to keep floor level of the cars constant irrespective of passenger loading unlike those with coil spring. A smooth curving performance with better ride index will be ensured by provision of above type of bogies.

(iii) Braking System

The brake system shall consist of –

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

Regenerative braking will be main brake power of the train and will regain maximum possible energy and pump it back to 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.

(iv) Propulsion System Technology

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

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

For Chennai Metro Phase-II, three phase AC traction drive with VVVF control is recommended for adoption.

(v) Interior and Gang Ways

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

(vi) Passenger Doors

For swift evacuation of the passenger in short dwell period, four doors of adequate width, on each side of the coach may be considered. These doors shall be of such dimensions and location that all the passengers inside the train are able to evacuate within least possible time without conflicting movement. Automatic door closing mechanism is envisaged from consideration of passenger safety.

(vii) Air Conditioning

With passenger loading of 6 persons /m^2 for standee area and doors being closed from consideration of safety and with windows being sealed type to avoid transmission of noise, the air conditioning of coaches is considered essential. Each coach shall be provided with two air conditioning units capable of automatically controlling interior temperature throughout the passenger area at all times under varying ambient condition up to full load. For emergency situations such as power failure or both AC failures etc ventilation provision supplied from battery may be made.

(viii) Cab Layout

Modern stylish driver panel shall be FRP moulded which give maximum comfort and easy accessibility of different monitoring equipments to driver along with clear visibility. It is intended that at some point of time, the train operation can be completely driverless. Signalling system and rolling stock shall be procured accordingly.

(ix) Broad Features of Rolling Stock

Rolling Stock proposed for the Phase II corridors will be similar to that of Phase I. The specifications of rolling stock and its procurement may be decided on the basis of the project implementation mechanism. Broad features of Rolling Stock which may be followed are indicated in **Table 11.4**.

TABLE 11.4: BROAD FEATURES OF ROLLING STOCK

S. No.	Parameter	Rolling Stock
1	Basic Unit	3 Car basic unit 2DMC and 1 TC. Every coach should be fully interchangeable with any other coach of same type.
2	Train Composition	3- Car: DMC+TC+DMC 6 –Car: DMC +TC +MC + MC + TC + DMC Capable of GoA4 operation
3	Coach construction	Light weight stainless steel/Aluminum body
4	Axle load	≤16 T
5	Braking System	Regenerative Braking
6	Propulsion system	3 phase drive system with VVVF control
7	Type of traction supply	25kV AC OHE system

3 coach trains can be converted to 6 coach trains by procuring additional trailer coaches and motor coaches compatible with the existing one in communication protocol and dimensions and other performance requirements. Rolling Stock shall be capable of unattented train operation (UTO).

11.7 ROLLING STOCK REQUIREMENT

Based on the train operation plan, the rolling stock requirement for the different horizon years has been calculated. The total coach requirement for the Phase II Corridors is given in **Table 11.5.**

TABLE 11.5: TOTAL COACH REQUIREMENT

Year	2025	2035	2045	2055
Total Coach Requirement	414	537	633	762

12. POWER SUPPLY SYSTEM

12.1 INTRODUCTION

Power supply system is required for operation of MRTS for running of trains, station services including illumination of buildings, lifts, escalators, signaling, telecommunication, firefighting etc., workshops, depots & other maintenance infrastructure within the premises of metro system.

There are two types of Traction systems which are being used in different metro rail projects across India. These are 750 V DC Third Rail System and 25 kV AC Overhead Catenary System.

750V DC Traction System

25 kV AC Overhead Catenary System

The selection of proper traction system has a significant impact on capital cost, operational cost, traffic growth, operational flexibility and expandability of the system in future. It is also linked to the ultimate capacity being planned. Appropriate selection of traction system at design stage is essential to achieve optimum performance of a MRTS system. Phase I of Chennai Metro has been operational with 25 kV AC overhead traction. Thus, in order to maintain the uniformity of the system, it is proposed that ***25 kV AC traction*** shall be adopted for Chennai Metro Phase II corridors. 25 kV AC traction system offers several advantages like lower losses and more regeneration and thus is energy efficient in comparison to 750 V DC Third Rail Traction system.

12.2 POWER REQUIREMENT

Electricity is required for operation of system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting etc) and workshops, depots & other maintenance infrastructure within premises of metro system. The power requirements are determined by peak-hour demands of power for traction and auxiliary applications. Power supply system is proposed to be designed for peak PHPDT for different sections of Phase II.

Power Supply System design has been conceptualized considering 6 car rake and headway at peak period for different sections. The designed system shall ensure high reliability and adequacy of the system to meet unforeseen growth in traffic demand. The system shall be free from harmonic and power factor issues.

The ultimate (design) power requirement for this corridor will be conceptualized considering following norms, directives/guidelines,

- Train operation with 6 car rakes with carrying capacity of 1576 passengers (standing @ 6 passengers/ m²)
- Specific energy consumption of rolling stock – 70 KWh / 1000 GTKM
- Regeneration @ 30%
- At grade/ Elev. station load – initially 200kW, ultimate design 300 kW
- Underground station load – initially 1000 kW, ultimate design 1500kW
- Madhavaram Depot Aux. load – initially 1500kW, ultimate design 3000 KW
- SIPCOT Depot Auxiliary load – 500kW
- Power factor of load – 0.9
- Transmission losses @ 5%
- Voltage and current harmonics with in utilities statutory limit

Keeping in view of the above norms, the corridor wise power demand estimation is given in **Table 12.1**, **Table 12.2** and **Table 12.3**

TABLE 12.1: POWER DEMAND ESTIMATION (MVA) FOR CORRIDOR 3

(A)	TRACTION LOAD: Corridor 3: MMC- Adyar-Sholinganallur (35 km)					
			2025 (3,6 Car)	**2035 (3,6 Car)**	**2045 (3,6 Car)**	**Design (6 Car)**
1	Average speed (KMPH)	S	32	32	32	32
2	Headway (Sec.)	F	277	277	277	277
3	Mean distance between two trains (Km)	H	2.5	2.5	2.5	2.5
4	Nos of trains per hour	N	13(10,3)	13(8,5)	13 (6,7)	13
5	Specific energy consumption (KWh/Thou GTKM)	SEC	70	70	70	70
6	Gross tonnage of rakes	T	225	254	282	368

7	Corridor length (km)	D	35.0	35.0	35.0	35.0
8	Power factor of load	PF	0.9	0.9	0.9	0.9
9	Max. demand on TSS (KW)		14333	16180	17963	23442
10	Energy Saving on the account of Regeneration @30%		4300	4854	5389	7032
11	Net Demand		10033	11326	12574	16409
12	Depot Traction Load		1300	1500	1500	2000
13	Total Traction Load		11333	12826	14074	18409
	Max. demand on TSS in KVA		12592	14251	15638	20455
Max. demand on TSS in MVA assuming 5% energy losses and 0.9 pf			**13.22**	**14.96**	**16.42**	**21.48**
(B)	**TRACTION LOAD: Corridor 3: Sholinganallur-SIPCOT (9.6 km)**					
			2025 (3 Car)	**2035 (3 Car)**	**2045 (3 Car)**	**Design (6 Car)**
1	Average speed (KMPH)	S	32	32	32	32
2	Headway (Sec.)	F	600	600	600	600
3	Mean distance between two trains (Km)	H	5.3	5.3	5.3	5.3
4	Nos of trains per hour	N	6	6	6	6
5	Specific energy consumption (KWh/Thou GTKM)	SEC	70	70	70	70
6	Gross tonnage of car rake	T	182	182	182	368
7	Distance	D	9.60	9.60	9.60	9.60
8	Power factor of load	PF	0.9	0.9	0.9	0.9
9	Max. demand on TSS (KW)		1468	1468	1468	2968
10	Energy Saving on the account of Regeneration @30%		440	440	440	890
11	Net Demand		1027	1027	1027	2077
Max. demand on TSS in KVA			1142	1142	1142	2308
Max. demand on TSS in MVA assuming 5% energy losses and 0.9 pf			**1.20**	**1.20**	**1.20**	**2.42**
(C)	**AUXILIARY LOAD Corridor 3: MMC- Adyar-Sholinganallur- Sipcot (Corridor 3)**					
			2025	**2035**	**2045**	**Design**
1	Load of each elevated stations (KW)		200	235	275	300
2	Nos of elevated/ at grade station		20	20	20	20
3	Load of each U/G stations (KW)		1000	1250	1400	1500
4	Nos of U/G stations		30	30	30	30
5	Load of shed at Madhavaram (KW)		1800	2100	2600	3000
6	Load of shed at SIPCOT (KW)		500	500	500	500
7	Total load of the stations & Depot (KW)		36300	44800	50600	54500
8	Power factor of the load		0.9	0.9	0.9	0.9

A	Total max. power demand of Stations and Depot (KVA)	40333	49778	56222	60556
B	**Total max. power demand of Stations and Depot (MVA) assuming 5% energy losses and 0.9 pf**	**42.35**	**52.27**	**59.03**	**63.58**
C	Total Max. power Demand Traction + Aux. (MVA)	54.07	65.17	73.00	83.32
D	**Net demand (MVA) considering 5% distrbution loss**	**56.77**	**68.43**	**76.65**	**87.48**

TABLE 12.2: POWER DEMAND ESTIMATION FOR CORRIDOR 4

(A)	**TRACTION LOAD**					
			2025 (3 Car)	**2035 (3,6 Car)**	**2045 (3,6 Car)**	**Design (6 Car)**
1	Average speed (KMPH)	S	32	32	32	32
2	Headways (Sec.)	H	277	277	257	240
3	Mean distance between two trains (Km)		2.5	2.5	2.3	2.1
4	No. of trains per hour (Frequency)	N	13	13	14	15
5	Specific energy consumption (KWh/Thou GTKM)	SEC	70	70	70	70
6	Gross tonnage of rakes	T	182	282	328	368
7	Corridor length (km)	D	25.4	25.4	25.4	25.4
8	Power factor of load	PF	0.9	0.9	0.9	0.9
9	Max. demand on TSS (KW)		8413	13036	16329	19629
10	Energy Saving on the account of Regeneration @30%		2524	3911	4899	5889
11	Net Demand		5889	9125	11430	13740
12	Depot Traction Load		1300	1500	1500	2000
	Total Traction Load		7189	10625	12930	15740
	Max. demand on TSS in KVA		7988	11806	14367	17489
	Max. demand on TSS in MVA assuming 5% energy losses and 0.9 pf		**8.39**	**12.40**	**15.09**	**18.36**
(B)	**AUXILIARY LOAD**					
			2025	**2035**	**2045**	**2055**
1	Load of each elevated stations (KW)		200	235	275	300
2	Nos of elevated/ at grade station		18	18	18	18
3	Load of each U/G stations (KW)		1000	1250	1400	1500
4	Nos of U/G stations		12	12	12	12

5	Load of shed at Poonamllee (KW)		1500	1700	1800	2000
6	Total load of the stations & Depot (KW)		17100	20930	23550	25400
7	Power factor of the load		0.9	0.9	0.9	0.9
Total max. power demand of Stations and Depot (KVA)			19000	23256	26167	28222
Total max. power demand of Stations and Depot (MVA) assuming 5% energy losses and 0.9 pf			19.95	24.41	27.47	29.62
Total Max. power Demand Traction + Aux. (MVA)			26.99	35.06	40.53	45.71
Net demand (MVA) considering 5% distribution loss			**28.34**	**36.81**	**42.56**	**48.00**

TABLE 12.3 : POWER DEMAND ESTIMATION (MVA) FOR CORRIDOR 5

(A)	**TRACTION LOAD: Corridor 5: MMBT-CMBT- Sholinganallur**					
			2025 (3,6 Car)	**2035 (3,6 Car)**	**2045 (6 Car)**	**Design (6 Car)**
1	Average speed (KMPH)	S	32	32	32	32
2	Headway (Sec.)	F	240	240	240	212
3	Mean distance between two trains (Km)	H	2.1	2.1	2.1	2.1
4	Nos of trains per hour	N	15 (11,4)	15 (5,10)	15	17
5	Specific energy consumption (KWh/Thou GTKM)	SEC	70	70	70	70
6	Gross tonnage of car rake	T	232	306	368	368
7	Distance	D	42.00	42.00	42.00	42.00
8	Power factor of load	PF	0.9	0.9	0.9	0.9
9	Max. demand on TSS (KW)		20462	26989	32458	36785
10	Energy Saving on the account of Regeneration @30%		6139	8097	9737	11036
11	Net Demand		14324	18892	22720	25750
	Max. demand on TSS in KVA		15915	20992	25245	28611
	Max. demand on TSS in MVA assuming 5% energy losses and 0.9 pf		**16.71**	**22.04**	**26.51**	**30.04**
(A)	**TRACTION LOAD: Corridor 5: MMC-MMBT**					
			2025 (3,6 Car)	**2035 (3,6 Car)**	**2045 (6 Car)**	**Design (6 Car)**
1	Average speed (KMPH)	S	32	32	32	32
2	Headway (Sec.)	F	514	514	514	514
3	Mean distance between two trains (Km)	H	4.6	4.6	4.6	4.6
4	Nos of trains per hour	N	7(4,3)	7(2,5)	7	7

5	Specific energy consumption (KWh/Thou GTKM)	SEC	70	70	70	70
6	Gross tonnage of car rake	T	262	315	368	368
7	Distance	D	4.30	4.30	4.30	4.30
8	Power factor of load	PF	0.9	0.9	0.9	0.9
9	Max. demand on TSS (KW)		1104	1327	1551	1551
10	Energy Saving on the account of Regeneration @30%		331	398	465	465
11	Net Demand		773	929	1086	1086
12	Depot Traction Load		0	0	0	0
Total Traction Load			773	929	1086	1086
Max. demand on TSS in KVA			859	1032	1206	1206
Max. demand on TSS in MVA assuming 5% energy losses and 0.9 pf			**0.90**	**1.08**	**1.27**	**1.27**
(B)	**AUXILIARY LOAD MMC-CMBT- Sholinganallur (Corridor 5)**					
			2025	**2035**	**2045**	**2055**
1	Load of each elevated stations (KW)		200	235	275	300
2	Nos of elevated/ at grade station		42	42	42	42
3	Load of each U/G stations (KW)		1000	1250	1400	1500
4	Nos of U/G stations		6	6	6	6
6	Total load of the stations (KW)		14400	17370	19950	21600
7	Power factor of the load		0.9	0.9	0.9	0.9
Total max. power demand of Stations (KVA)			16000	19300	22167	24000
Total max. power demand of Stations (MVA) assuming 5% energy losses and 0.9 pf			**16.80**	**20.27**	**23.28**	**25.20**
Total Max. power Demand Traction + Aux. (MVA)			32.77	41.32	48.62	53.82
Net demand (MVA) considering 5% distrbution loss			**34.41**	**43.39**	**51.05**	**56.51**
Total Power Demand for all the three corridors			**119.52**	**148.63**	**170.26**	**191.99**

This requirement has been worked out based on the conceptual design and therefore, needs to be reaffirmed and fine-tuned by conducting necessary simulation study during detailed design stage of project implementation.

12.3 NEED FOR HIGH RELIABILITY OF POWER SUPPLY

Proposed MRTS corridors are being designed to cater to a large traffic demand when trains are expected to run at high frequency. 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. Effect on signal and communication may affect train operation and passenger safety as well. Therefore, uninterrupted power supply is mandatory for efficient metro operations.

In order to ensure high reliability of power supply, feed from more than one Receiving Sub Station (RSS) have been planned for the proposed corridors. Under normal circumstances, each RSS will feed specific sections of the corridor. In case of emergency condition i.e. when one RSS fails, the other RSS will feed the section of the RSS under outage. Therefore, it is essential that all the sources of supply and connected transmission & distribution networks are reliable and have adequate built in redundancies.

12.4 SOURCES OF POWER SUPPLY

Chennai City has 230kV, 110kV, 33kV power transmission and distribution network to cater to various types of demand in the vicinity of the proposed corridor. Keeping in view of the reliability requirements and considering the complete length of corridors, twelve (12 nos) Receiving Substations (RSS) are proposed to avail power supply for traction as well as auxiliary services from the Tamil Nadu Transmission Corporation Limited grid sub-stations at 110kV voltage through transmission lines or cable feeders for proposed corridors.

M/s TANGEDCO has confirmed the availability of supply vide letter no. CE/Plg&RC/SE/SS/EE1/AEE2/F.Metro Rail Coridor/D.417/16 dated 18.11.16. The copy of the confirmation letter has been attached as **Annexure 12.1.**

The Receiving substations (110/33/25 kV) planned for the power requirements of Chennai Metro Phase II corridors with the respective feeding zones and the length of cables of from the Grid Substations is shown in **Table 12.4**.

TABLE 12.4 : SOURCES OF POWER SUPPLY

Grid Sub-Station	RSS of Metro Authority	Approx. Distance from GSS to RSS
Manali GSS (230/110kV)	Madhavaram RSS (110/33/25kV)	3.5 km
GMR Vasavi GSS (230/110 kV)	Vasanthi RSS (110/33/25kV)	2 km
Mylapore GSS (230/110 kV)	YMCA RSS (110/33/25kV)	1 km

Grid Sub-Station	RSS of Metro Authority	Approx. Distance from GSS to RSS
Tharamani GSS (230/110 kV)	Tharamani RSS (110/33/25kV)	0.5 km
Siruseri GSS (230/110 kV)	Siruseri RSS (110/33/25kV)	2.0 km
Korattur GSS (230/110 kV)	Nadhamuni RSS (110/33/25kV)	1 km
Thiruverkadu GSS (230/110 kV)	Mugalivakkam RSS (110/33/25kV)	7 km
Alandur GSS (230/110 kV)	St. Thomas RSS (110/33/25kV)	1.5 km
Kadaperi GSS (230/110 kV)	Medavakkam RSS (110/33/25kV)	6 km
Mambakkam GSS (230/110 kV)	Perubakkam RSS (110/33/25kV)	5 km
Koyambedu GSS (230/110 kV)	Avicii School RSS (110/33/25kV)	1 km
Kilpauk GSS (230/110 kV)	Panagal RSS (110/33/25kV)	2 km

In the case where the proposed location for Phase II RSS is very close to the existing phase I RSS, the possibility of catering to the supply to phase II sections from the existing phase I RSS may be explored at detailed design stage. The HT power supply from grid substations at 110 kV will be stepped down to 25kV single phase supply for traction purpose and 33kV supply for auxiliary power supply at the Receiving cum Traction Substations (RSS/ TSSs) of MRTS authority. The traction power will be fed to 25kV OHE system through cable feeders and the auxiliary power will be distributed along the alignment through 33kV Ring main cable network for feeding auxiliary loads. These cables will be laid in dedicated ducts/ cable brackets along the viaduct/ tunnel. These cables shall not have effect on Power Factor and the pf shall be maintained between 0.9 and 1.0. The summary of expected power demand at various sources is given in **Table 12.5**.

TABLE 12.5 : POWER DEMAND PROJECTION FOR VARIOUS SOURCES

Name of RSS	Peak Demand- Normal (MVA)				Peak Demand – Emergency (MVA)			
	2025	2035	2045	2055	2025	2035	2045	2055
Manali GSS- Madhavaram RSS Chainage C3 0 to 5966 (5.966 km)								
Traction	3.51	4.00	4.25	5.60	4.88	5.78	6.38	7.97
Auxiliary	10.27	12.66	14.47	15.75	19.60	24.33	27.53	29.75
Total	13.78	16.66	18.72	21.35	24.48	30.10	33.91	37.72

Name of RSS	Peak Demand- Normal (MVA)				Peak Demand – Emergency (MVA)			
	2025	2035	2045	2055	2025	2035	2045	2055
GMR Vasavi GSS -Vasanthi RSS- C3 Chainage 5966 to 12362 (6.396 km)								
Traction	2.14	2.41	2.68	3.50	5.65	6.42	6.93	9.09
Auxiliary	9.33	11.67	13.07	14.00	19.60	24.33	27.53	29.75
Total	**11.47**	**14.08**	**15.75**	**17.50**	**25.25**	**30.74**	**34.46**	**38.84**
Mylapore GSS- YMCA RSS - C3- Chainage 12362- 19974 (7.612km)								
Traction	2.55	2.87	3.19	4.16	6.70	7.56	8.40	10.96
Auxiliary	9.33	11.67	13.07	14.00	18.67	23.33	26.13	28.00
Total	**11.88**	**14.54**	**16.26**	**18.16**	**25.37**	**30.90**	**34.53**	**38.96**
Tharamani GSS- Tharamani RSS - C3 - Chainage 19974- 32393 (12.419 km)								
Traction	4.15	4.69	5.21	6.79	6.70	7.56	8.40	10.96
Auxiliary	9.57	11.85	13.36	14.35	18.90	23.52	26.43	28.35
Total	**13.72**	**16.54**	**18.56**	**21.14**	**25.60**	**31.08**	**34.82**	**39.31**
Siruseri GSS – Siruseri RSS - C3 - Chainage 32393-44671 (12.278 km)								
Traction	2.20	2.33	2.44	4.05	6.35	7.02	7.65	10.84
Auxiliary	3.85	4.42	5.08	5.48	13.42	16.28	18.43	19.83
Total	**6.05**	**6.75**	**7.52**	**9.53**	**19.77**	**23.30**	**26.08**	**30.68**
Korattur GSS- Nadhamuni RSS - C5- Chainage 0-7186 (7.186 km)								
Traction	1.36	1.77	2.12	2.37	4.88	5.78	6.38	7.97
Auxiliary	3.97	4.84	5.51	5.95	14.23	17.49	19.98	21.70
Total	**5.33**	**6.61**	**7.64**	**8.32**	**19.11**	**23.27**	**26.35**	**29.67**
Thiruverkadu GSS – Mugalivakkam RSS - C5- Chainage 7186- 13366 (6.180km)								
Traction	2.46	3.24	3.90	4.42	6.34	8.36	10.05	11.39
Auxiliary	5.13	6.38	7.18	7.70	7.70	9.40	10.70	11.55
Total	**7.59**	**9.62**	**11.08**	**12.12**	**14.04**	**17.75**	**20.75**	**22.94**
Alandur GSS - St. Thomas RSS- C5 - Chainage 13366-23109 (9.743 km)								
Traction	3.88	5.11	6.15	6.97	8.59	11.33	13.62	15.44
Auxiliary	2.57	3.02	3.53	3.85	5.13	6.03	7.06	7.70
Total	**6.44**	**8.13**	**9.68**	**10.82**	**13.72**	**17.36**	**20.68**	**23.14**
Kadaperi GSS – Medavakkam RSS - C5- Chainage 23109-34947 (11.838 km)								
Traction	4.71	6.21	7.47	8.47	9.22	12.16	14.62	16.57
Auxiliary	2.57	3.02	3.53	3.85	5.13	6.03	7.06	7.70
Total	**7.28**	**9.23**	**11.00**	**12.32**	**14.35**	**18.19**	**21.68**	**24.27**
Mambakkam GSS-Perubakkam - C5- Chainage 34947-46272 (11.325 km)								
Traction	4.51	5.94	7.15	8.10	9.22	12.16	14.62	16.57
Auxiliary	2.57	3.02	3.53	3.85	5.13	6.03	7.06	7.70

Name of RSS	Peak Demand- Normal (MVA)				Peak Demand – Emergency (MVA)			
	2025	2035	2045	2055	2025	2035	2045	2055
Total	**7.07**	**8.96**	**10.68**	**11.95**	**14.35**	**18.19**	**21.68**	**24.27**
Kilpauk GSS - Panagal Park RSS – C4 - Chainage 0 to 7436 (7.691 km)								
Traction	2.45	3.62	4.40	5.36	8.39	12.41	15.10	18.38
Auxiliary	11.67	14.58	16.32	17.49	19.95	24.40	27.46	29.62
Total	**14.12**	**18.20**	**20.72**	**22.85**	**28.34**	**36.81**	**42.56**	**48.00**
Koyembedu GSS- Avicii School RSS – C4- Chainage 7436-25829 (18.38 km)								
Traction	5.94	8.79	10.70	13.02	8.39	12.41	15.10	18.38
Auxiliary	8.28	9.82	11.14	12.13	19.95	24.40	27.46	29.62
Total	**14.22**	**18.61**	**21.84**	**25.15**	**28.34**	**36.81**	**42.56**	**48.00**

Since, the power fed from the two adjacent substations is normally from different phases, it is essential to segregate the supply from these substations using neutral sections. It is proposed that Chennai Metro Phase II corridors shall have Short Neutral sections (SNS).

The equipment rating of the RSS cum TSS will be determined considering the normal as well as emergency situation. When one RSS fails, the traction supply will be maintained by extending feed from adjoining RSS. The main and standby power supply sources for different sections of the corridors of Chennai Metro Phase II are given in **Table 12.6.**

TABLE 12.6: MAIN AND STANDBY SOURCES FOR DIFFERENT SECTIONS

S.No.	Zone	Main Source	Standby Source
1.	(Corr.-3) 0 to 5966	Madhavaram RSS	Vasanthi RSS or Nadhamuni RSS
2.	(Corr.3) Ch 5966 to 12362	Vasanthi RSS	Madhavarm RSS or YMCA RSS
3	(Corr.3) Ch. 12362- 19974	YMCA RSS	Vasanthi RSS or Tharamani RSS
4.	(Corr.3) Ch. 19974- 32393	Tharamani RSS	YMCA RSS or Siruseri RSS
5.	(Corr.3) Ch. 32393-44671	Siruseri RSS	Tharamani RSS or Perubakkam RSS
6.	(Corr.5) Ch.0 – 7186	Nadhamuni RSS	Madhavaram RSS or Mugalivakkam RSS
7.	(Corr.5) Ch. 7186- 13366	Mugalivakkam RSS	Nadhamuni RSS or St. Thomas RSS
8.	(Corr.5) Ch. 13366-23109	St. Thomas RSS	Mugalivakkam RSS or Medavakkam RSS

S.No.	Zone	Main Source	Standby Source
9.	(Corr. 5) Ch. 23109-34947	Medavakkam RSS	St. Thomas RSS or Perubakkam RSS
10.	(Corr. 5) Ch. 34947-46272	Perubakkam RSS	Medavakkam RSS or Siruseri RSS
11.	(Corr.4) Ch. 0 - 7436	Panagal Park RSS	Avicii School RSS
12.	(Corr.4) Ch. 7436 - 25829	Avicii School RSS	Panagal Park RSS

However, in case of total grid failure, all trains may come to a halt but emergency lighting, fire, hydraulics and other essential services can be catered to by stand-by UPS/ DG sets.

The Receiving Sub Stations (RSS) for the corridors of Chennai Metro are proposed to be provided in phases. Initially, the traction and auxiliary power supply of the corridors will be provided with nine (09 Nos) RSS. These substations will cater to the power requirement of the corridors till year 2035. Thereafter, the remaining three RSS will handle the power requirement long with other nine RSS provided during inception. The feeding zones of different RSS till year 2035 are given in **Table 12.7.**

TABLE 12.7: FEEDING ZONES TILL YEAR 2035

Name of RSS	Peak Demand- Normal (MVA)		Peak Demand- Emergency (MVA)	
	2025	**2035**	**2025**	**2035**
Manali GSS/ Madhavaram RSS C5 chainage 0 to 9284 C3 0 to 3421				
Traction	3.56	4.13	7.78	9.69
Auxiliary	9.10	11.11	23.10	28.61
Total	**12.66**	**15.24**	**30.88**	**38.31**
GMR Vasavi GSS (Chainage 3421 – 13207) 9.786 km				
Traction	3.27	3.69	6.84	7.82
Auxiliary	14.00	17.50	26.83	33.54
Total	**17.27**	**21.19**	**33.67**	**41.36**
Tharamani GSS (chainage 13207- 23994) 10.787 km				
Traction	3.61	4.07	8.50	9.44
Auxiliary	12.83	16.04	26.83	33.54
Total	**16.44**	**20.11**	**35.33**	**42.98**
Siruseri GSS (chainage 23994-44671) 20.677 km				
Traction	4.89	5.37	8.50	9.44
Auxiliary	8.75	10.44	21.58	26.48
Total	**13.64**	**15.81**	**30.08**	**35.93**

Thiruverkadu GSS (chainage 4307-14915) 10.608 km				
Traction	4.22	5.57	7.78	9.69
Auxiliary	7.23	8.94	10.27	12.50
Total	**11.45**	**14.50**	**18.05**	**22.19**
Alandur GSS (chainage 14915-27809) 12.894 km				
Traction	5.13	6.77	12.48	16.46
Auxiliary	3.03	3.56	10.27	12.50
Total	**8.16**	**10.33**	**22.74**	**28.96**
Mambakkam GSS (chainage 27809-46272) 18.463 km				
Traction	7.35	9.69	12.48	16.46
Auxiliary	4.20	4.94	7.23	8.50
Total	**11.55**	**14.62**	**19.71**	**24.96**
Kilpauk GSS (Chainage 0 to 7436) 7.691 km				
Traction	2.45	3.62	8.39	12.41
Auxiliary	11.67	14.58	19.95	24.40
Total	14.12	18.20	28.34	36.81
Koyembedu GSS (Chainage 7436-25829) 18.38 km				
Traction	5.94	8.79	8.39	12.41
Auxiliary	8.28	9.82	19.95	24.40
Total	14.22	18.61	28.34	36.81

The high voltage transmission lines or cables will be laid through public pathways from TANTRANSCO Sub-stations to RSS of Metro Authority. Each RSS shall be provided with 2 nos. (one as standby) 110/ 25kV single phase transformers having 21.6 MVA or 30/42 MVA capacity for peak traction demand and three phase transformers of 31.6 MVA (ONAN)/40 MVA (ONAF) capacity to meet peak auxiliary demand in case of outage of adjoining RSS. To avoid unbalance to the system, Scott connection transformers are proposed.

FIGURE 12.1 : GAS INSULATED SWITCHGEAR

Indoor type Gas Insulated Substation (GIS), which offers the advantage of considerable saving in space requirement as well as reduced maintenance, is proposed for each Receiving cum Traction substation. Each RSS/TSS would require land plot of about size 50m x 60m (3000 m^2). Power factor correction at RSS shall be installed to ensure that after charging of substation, the power factor will be above 0.9 lag at TNEB metering point and will not go leading. All the receiving substations shall have necessary provisions for unmanned operation.

12.5 AUXILIARY POWER ARRANGEMENTS

The auxiliary power will be required for

- Lights & fans for station
- Service Buildings
- Foot over Bridges/Subways.
- Maintenance Depots
- Air-conditioning
- Lifts & Escalators
- Water Supply Pumping Stations – for washing, toilets as well as fire protection measures.
- Equipment – Signalling, Telecom, Automatic Fare Collection etc.

Auxiliary sub-stations (ASS) are envisaged to be provided at each station for stepping down 33kV supply to 415V for auxiliary applications. The ASS will be located at mezzanine or platform level inside a room. The demand of power at each elevated station is expected to be about 200 kW in the initial years and is likely to reach 300 kW in the horizon year. Similarly, for the underground stations, the auxiliary load requirements have been assessed at 1000 kW for the initial years which is expected to increase to 1500 kW in the horizon year. The average load considered for elevated station and underground station will have to be fine tuned to suit station requirement at the time of detailed design.

The proposed Auxiliary substation shall be Gas insulated type. This will reduce the maintenance requirements. Each elevated station shall be provided with an Auxiliary Substation with two 33kV/415V, 3-phase, 500 kVA dry type cast resin transformers and the associated HT & LT switchgear. In addition, provision shall be made for one DG set at each station for emergency loads. Two transformers (33kV/415V, 3-phase) of 3.2 MVA at each underground ASS for the underground stations are proposed to be installed (one transformer as standby)

Apart from stations, separate ASS is required at depot with 2x2500 kVA auxiliary transformers to cater to depot cum workshop load.

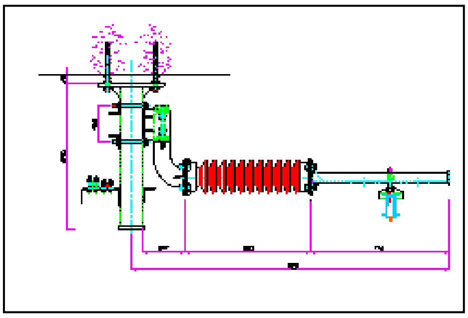
FIGURE 12.2: TYPICAL INDOOR AUXILIARY SUB-STATION (ASS)

12.6 25 KV RIGID OHE SYSTEM

The proposed 25kV Rigid OHE system in underground section is similar to the one installed in underground sections of Delhi Metro. 25kV Rigid OHE 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 and single cantilever arrangement attached to drop-down supports fixed to tunnel roof. The supports are located at maximum of 10 metre and there is no tension in the conductors and hence, no tensioning equipment is required in tunnel. The design of 25kv rigid OHE system shall be in accordance to electrical clearances and contact wire height as per IEC 60913 and EN50122, which is summarized below:

- Contact wire height = 4324mm (with Panto locked down height of 4048mm)
- Structure to Live parts clearances = 270/170/150mm (Static/Dynamic/Abs. min dynamic)
- Vehicle to Live parts clearances = 290/190/150mm (Static/Dynamic/Absolute/ min dynamic)

FIGURE 12-3 : 25KV RIGID OHE ARRANGEMENT



12.7 25 KV FLEXIBLE OVERHEAD EQUIPMENT SYSTEM

25 kV ac Flexible Overhead equipment system shall comprise 150 sq mm HD-copper contact wire and 65sqmm Cd-copper catenary wire. For tensioning of the OHE conductors, Auto-Tensioning Device (ATDs) shall be used. The type of ATDs shall be confirmed after the finalization of viaduct design. No Booster Transformer/Return Conductor shall be proposed and DOT clearance shall be obtained. Section insulators shall be provided only at turnouts, crossovers and depot entry.

12.8 RATING OF MAJOR EQUIPMENTS

Based on emergency demand expected at each RSS (**Table 12.3**), 2 traction transformers of 110/25 kV , 21.6 MVA or 30/42MVA capacity each are proposed for the RSS of Chennai metro corridors. Similarly, 2 nos. Auxiliary transformers (110/33 kV) of 31.6(ONAN)/40 MVA (ONAF) capacity each are proposed to be provided at all the RSSs. In order to reduce the maintenance requirements, it is proposed that all the switchgears at 25kV, 33kV & 110kV voltage levels shall be of GIS type.

Since, the power fed from the two adjacent substations is normally from different phases, it is essential to segregate the supply from these substations using neutral sections. It is proposed that Chennai Metro Phase II corridors shall have Short Neutral sections (SNS). The sectioning and paralleling post shall be equipped with lightning arresters and potential transformers.

33kV XLPE insulated FRLSOH cable ring network is proposed for Aux. ring main network, which shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations. The bus bar rating shall be in accordance to the transformer capacity.

The above capacities of transformers, switchgear, etc. have been worked out based on the conceptual design. Therefore, these may be required to be revised and fine-tuned during detailed design stage of project implementation.

12.9 STANDBY DIESEL GENERATOR (DG) SETS

In the unlikely event of simultaneous tripping of all the RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby DG set of 250 kVA at all elevated stations and 2 x 910 kVA capacity at underground stations to cater to the following essential services,

- Lift operation
- Essential lighting
- Signalling & telecommunications
- Firefighting system
- Fare Collection system

Silent type of DG sets, which have low noise levels and do not require separate room for installation, are proposed. In addition, UPS with adequate power backup may be installed for the very essential lighting load.

12.10 ELECTROMAGNETIC INTERFERENCE (EMI) & ELECTROMAGNETIC COMPATIBILITY (EMC)

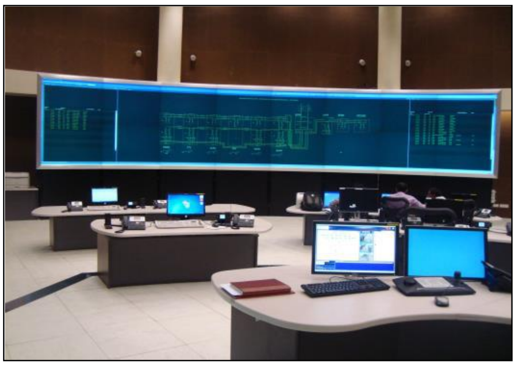
Earthing & Bonding of the power supply & traction system shall be designed in accordance with the latest standards EN50122-1, IEEE80, IS3043 etc. Two earth conductors – Overhead Protection Cable (OPC) and Buried Earth Conductor (BEC) are proposed to be laid along with track. All the concrete and metallic structures, structural reinforcement, running rails etc. will be connected to these conductors to form an equiv-potential surface & a least resistance path to the fault currents. The overhead protection cable will also provide protection against lightning to the 25kV OHE on the section.

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, signalling & 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 and Earthing& Bonding plan require to be developed during design stage.

12.11 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 fibre cables provided for telecommunications will be used as communication carrier for SCADA system. Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 33kV ac switchgear, transformers, 25kV ac switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system. Integrated SCADA system for all the subsystems is proposed for Chennai Metro. The software for SCADA shall be open source.

FIGURE 12.4: SCADA SYSTEM



12.12 STATION E&M SYSTEMS

12.12.1 LT Power Distribution

33 kV ring main cables running all along route shall feed each ASS by loop in loop out arrangement. 33 kV power supply is stepped down to 415V, 3 phase for distribution to consumption points (service utilities) viz. Elevators, Escalators, Light & power sockets, Fire system, HVAC system and S & T system.

The power distribution system shall be designed by using low voltage power cable run on the cable tray, raceway and conduit as suitable to supply power to various loads within station and buildings. The low voltage power distribution cables shall comply with IEC 60502 or other applicable international standard. Fire resistant cables shall be used for safety purpose and comply with the performance requirements of IEC60331 and BS 6387.

12.12.2 Illumination System

For Illumination generally, all lighting fixtures shall be applied with 240V, single phase 50Hz power supply. The type and quality of fittings and their luminous intensity shall relate to the space being illuminated and will take into account the effect of architectural space concept and colour scheme as per IS 3646.

The LED lights offer advantages over conventional fluorescent lighting on account of Energy savings, lower life cycle cost, longer life span, rugged nature etc. Considering the benefits of LED light fixtures over the conventional/fluorescent fixtures, the use of LED light fixtures is recommended at elevated and underground stations of the corridor and the office buildings of the depot. However, the conventional fluorescent light fittings may be adopted at selected locations wherever payback period for additional cost of LED light is much higher or non-availability of efficient and proven LED light fixtures such as Medium/High Bay lighting of high wattage (250W – 400W) in depot.

12.12.3 Fire Detection and Alarm System

The Fire Detection & Alarm System shall be in conformance to the applicable NFPA standard or Other International Standards &also comply with the codes of practice, standards, regulations and requirements of the Statutory Authorities. The coordination of Fire Detection & Alarm System with the following services should be verified, tested, and validated as a complete system before implementation

i. Fire Detection & Alarm System,
ii. Public Address & Voice Alarm System,
iii. Emergency Lighting System,
iv. Conveying Systems (Lifts & Escalators),
v. HVAC systems (AHUs / fire dampers / staircase pressurization fans / chillers, motorized dampers / exhaust fans etc),
vi. Fire Fighting Systems (Fire Pumps / Sprinkler Valves),
vii. Automatic Doors,
viii. Traction SCADA,
ix. E&M SCADA,
x. Rolling Shutters,
xi. Networking of main fire alarm system, at station to the station control room, and backnet Interface on TCP/IP for third party systems.
xii. Systems not listed above but that requires interfacing with the Main Fire Alarm System.

12.12.4 Fire Suppression

a) Portable Fire Extinguishers

The portable fire extinguishers shall be installed at all the stations in compliance with relevant BS EN Codes and codes of practice, standards, regulations & requirements of the Statutory Authorities. All the covered areas should be provided with suitable type of fire extinguishers. In the Concourse and Platform areas, Fire Extinguishers shall be provided in a central location inside a suitably sized cabinet of approved construction. The location and design of the extinguisher cabinets provided shall comply fully to the local fire authority requirements. Extinguishers shall be conspicuously located in positions where they will be readily accessible and immediately available in the event of fire. They shall be located near to room exits, corridors, stairways, lobbies and landings. Extinguishers shall be installed at a height of 1 metre above the floor level and shall be placed in a manner such that the extinguisher operating instructions face outward.

b) Wet Mains System

The Fire Fighting wet mains system shall be based on BS- 9990: 2006, BS-9999: 2008 & National Building Code. The system shall comprise pipe work, breeching inlets, landing valves, automatic air release valves, fire hose cabinets and fire hose reels etc. The wet mains system is charged by the Fire pumps set. The fire pump set shall have dual power supply and the system shall be designed to achieve a pressure of 3.5 Bar at the remote fire hydrant point. The system will draw water from the fire water storage tank provided near station building based on the NBC requirements.

- **Fire Hose Cabinets**

  The Fire Hose Cabinets shall be provided as per NBC and fire authority regulations in internal and external public areas of the station.

- **Fire Hose Reels**

  The hose reels shall meet the requirements of BS 5306.1: 2006 & BS EN 671 – 3:2004. Hose-reel shall be provided in such a way that it covers the entire Concourse / Platform areas with suitable number of fire hose cabinets. The hose reels system will be based on direct feed from the Fire Water Wet mains.

  Hose-reels shall be of the swing-recessed type. Each hose-reel shall be an integral unit consisting of a stop valve, reel, hose, and shut-off assembly. It shall be designed so as to facilitate the swift withdrawal of the hose in any direction with the reel axis horizontal.

12.12.5 Gas Flooding System

Gas Flooding System is proposed to be provided for protection of the equipments in electrical Auxiliary sub-stations and S&T equipments in Depot Control Centre/ Operational Control Centre. The design of the system shall be in conformance to NFPA standards.

12.12.6 Lifts and Escalators

Lifts and escalators shall be provided at each station for the convenience of the passengers. The lifts and escalators shall be energy efficient. The power supply for the operation of lifts and escalators is fed from the Auxiliary substation at each station. The design details of the lifts and escalators provided have been discussed in Chapter for station planning.

12.13 SOLAR ENERGY HARNESSING SYSTEM

The solar mission, which is part of the National Action Plan on Climate Change has been set up by Govt. of India to promote the development and use of solar energy for power generation and other uses with the ultimate objective of making solar energy competitive with fossil-based energy options.

Considering the futuristic technology and potential for solar power generation, Delhi Metro has recently implemented roof top grid connected solar power systems at selected locations of elevated stations and maintenance depot. Metro Railways under implementation in different cities of the country viz. Jaipur, Lucknow, Nagpur etc are also exploring the possibilities of harnessing solar photovoltaic energy.

With the downward trend in the cost of harnessing solar energy and appreciation for the need for development of solar power, provision of a grid connected solar photovoltaic power plant utilizing all possible areas viz. roof top of stations/sheds and buildings is proposed for Chennai MRTS.

12.13.1 Solar PV Power Generation Potential

The roof top on the elevated stations of Chennai Metro corridors and the different sheds and buildings of the depot viz. Stabling, Inspection and Heavy Repair Shed, Administrative Building, DCC/OCC Building etc is proposed to be used for SPV installation at suitable orientation and inclination to optimize the solar energy potential. The roof of the sheds should be south facing to maximize the Solar power generation in depot. The solar power would be used locally to the extent of load in the building and the generation over and above the requirement of the building would be fed into the grid.

The average raw sunshine available which can be harnessed for the power generation depends on the geometrical coordinates of the place. The intensity of solar radiation varies with time of the day The combined effect of these factors and the additional complication of the wobble of the seasons is that the average raw power of sunshine per square meter of south-facing roof in India is roughly 100 to 120W/m^2. Based on the solar radiation intensity in the city of Chennai, the peak solar power generation of Chennai Metro corridor is expected to be about 50 kWp for the elevated stations and about 2000kWp for maintenance depot.

The power generation depends upon various factors such as the intensity of the solar radiation, the net useable area available on the roof top, the obstructions due to shadow or the shading factor, the orientation of the solar panels, efficiency of the solar cells etc. The solar power generation potential in Chennai metro corridors is required to be reviewed and finalized during detail design stage.

It is proposed that the solar PV installation for Chennai metro shall be done on the basis of RESCO model which is also being followed by other metros in India. In the RESCO model, the CMRL shall sublet the rooftop to the project developer who will be responsible for the solar PV installation. The power shall be purchased by CMRL on the basis of the unit rate specified by Power Purchase Agreement (PPA).

12.14 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 includes the following energy saving features:

i. Modern rolling stock with 3-phase VVVF drive and lightweight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor.

ii. Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 25kV OCS 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 (operation or maintenance hours etc). Use of energy efficient LED lights is proposed.

iv. Machine-room less type lifts with gearless drive and 3-phase VVVF drive. These lifts are highly energy efficient.

v. The proposed heavy-duty public services escalators 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.

vi. The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc) which are free from harmonics and higher degree of power factor equipments.

vii. Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.

Annexure 12.1

TANGEDCO

From
Er.R.S.USHA, B.E.,
Chief Engineer,
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To
The Group General Manager
Urban Transport Division
RITES Bhawan
No.1 Sector 29
Gurgaon-122001

Lr.No. CE/Plg&RC/SE/SS/EE1/AEE2/F.Metro Rail Corridor /D. 417 /16,Dt. 18.11.16

Sir,

Sub: Elecy – Metro Rail Phase II Corridor -Availability of power supply for Metro Rail Corridors in Chennai- Regarding.

Ref : Letter No. RITES/UT/CMRL/DPR/Phase II/2016 dated 06.10.2016.

*****

In the letter under reference cited, it was requested to confirm the availability of the power supply for Chennai Metro Rail, Phase-II.

2.0 In this connection, the following details are furnished.

i. The demand as furnished by RITES can be accomodated initially from the existing 230/110 kV grid substations that are situated along the corridors subject to the availability of 110 KV bays in the above substations.

ii. If 110 kV bays are not available, this will be taken care of by accomodating the demand at the nearest feasible 110 KV substations at the time of receiving the application from CMRL during the corresponding periods.

iii. The application for extension of new supply at the required voltage level shall be furnished to the concerned territorial Superintending Engineer Chennai North/West/Central/South I & II circles as the case may be.

18/11/16
(D.Ravichandran)
Superintending Engineer/System studies
For Chief Engineer/Planning & RC

2/2

Sh. A K Mahatha,
GM/E/UT

28/11/16

c/- GGM/UT

13. VENTILATION & AIR CONDITIONING SYSTEM

13.1 INTRODUCTION

Underground stations of Chennai Metro Phase II corridors are proposed with full height Platform screen doors. The use of full height Platform screen doors will reduce air conditioning requirements of stations. Thus, ventilation and air conditioning system is proposed in following two parts:

- Environment Control System (ECS)
- Tunnel Ventilation System (TVS)

Use of Platform Screen Doors will improve climate control within the station (heating, ventilation, and air conditioning are more effective when the station is physically isolated from the tunnel).

13.2 NEED FOR VENTILATION AND AIR CONDITIONING

The underground stations are generally built in a confined space. A large number of passengers occupy concourse halls and 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 forced ventilation in underground stations for the purpose of:

- Supplying fresh air for the physiological needs of passengers and authority's staff;
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the station;
- Removing vapour and fumes from battery and heat emitted by light fittings, water coolers, Escalators, Fare Gates, etc. working in stations;
- Removing heat from air conditioning plant and sub-station and other equipment, if provided inside the underground station.

This large quantity of heat generated in underground stations cannot be extracted by simple ventilation, especially when outdoor air temperature and humidity is high. It is, therefore, essential to provide mechanical cooling in order to remove heat to maximum possible extent. As passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered appropriate.

13.3 ENVIRONMENT CONTROL SYSTEM

13.3.1 Design Parameters

Chennai has a hot and humid climate. The city lies on the thermal equator and is also on the coast, which prevents extreme variation in seasonal temperature. The hottest part of the year is late May to early June.

The design parameters shall be considered as per NBC 2016 and mandatory guidelines issued by Ministry of Housing and Urban Affairs, Govt. of India. The following VAC system design parameters are assumed to be provided for underground sections of proposed corridors of Chennai Metro Phase-II

(i)	Outside ambient conditions:		
	Summer:	:	37.2°C (DB), 25.8°C (WB)
	Monsoon:	:	32.3°C (DB), 28.0°C (WB)
(ii)	Inside design conditions:		
	Platform and concourse public areas	:	27°C (DB) at 55 % RH
	Technical/S&T equipment room, Back of house rooms	:	24±1°C (DB) and RH not exceeding 60%
(iii)	Minimum fresh air	:	10 % or 18 CMH/ person (in station public area) 2.5 l/s per person + 0.3 l/s per sqm (for air conditioning rooms)
(iv)	System Water Temperature		
	Chilled Water System	:	7°C Flow/12°C Return
	Condenser Water System	:	32°C Flow/ 36.5°C Return

13.3.2 System Components for VAC

Ventilation & Air conditioning (VAC) system includes

- Concourse & Platform public area Air-conditioning
- Technical & office rooms Air conditioning
- Ventilation of Ancillary spaces & plant rooms
- Smoke Management system
- VAC Electrical system
- VAC SCADA system

Platform area and Ancillary spaces such as staff room, equipment plant room, will be mechanically ventilated or air conditioned in accordance with desired air change rates and temperatures/humidity.

(i) Concourse & Platform Public Area Air-conditioning & Ventilation

Concourse & Platform Public areas shall be provided with VRF (Variable Refrigerant Flow) Air conditioning system with AHUs or modern type air cooled chillers with higher Coefficient of Performance and less noise level.

The platform and concourse areas will be air-conditioned using supply 'air handling units' located in VAC equipment rooms at both ends of the concourse in station. There shall be four number of air handling units proposed i.e. two AHU's in each equipment room in concourse level. LHS side AHU's (2 nos) shall serve LHS side concourse and platform levels and RHS side AHU's (2 nos) shall serve the RHS side concourse & platform levels.

These air conditioning systems mix return air with a desired quantity of outside air using fresh air fan. Heat/ Energy recovery wheel shall be considered for energy efficient system. The outside air requirement is based on occupancy, with a minimum of 5 litres per second per person or 10% of circulated air volume, whichever is higher. This mixture of outside and return air is cooled by a cooling coil and then filtered by means of suitable primary and secondary filters and then cooled by a cooling coil before being distributed as supply air via high level insulated ductwork to grilles/diffusers, discharging air into serviced space in a controlled way to minimize draughts. AHU's shall be provided with UVC emitter and drift eliminator. Return air to the platform areas is extracted via return air/smoke exhaust fans and either returned to AHUs during air conditioning/normal mode or exhausted via shaft during fire scenario.

Long entrances (more than 60 m in length) will be ventilated with dedicated supply/exhaust fan based on location and number of stairs in the particular entrances. Supply and exhaust fans will be installed in fan room. These fans are connected with ducts & diffusers/ grilles and will be used in case of fire to safe egress of passengers. Small & medium entrances shall be provided with return/smoke exhaust duct to extract smoke during fire mode.

Air Quality for the public areas shall be maintained. Demand control ventilation with Co2 sensor shall be provided. PM 2.5 and PM 10 sensors shall be provided for periodic monitoring. Free cooling mode/ventilation mode for public area shall be considered with enthalpy sensors. Air curtain will be provided at the entrances to prevent the conditioned air from the concourse public area. Infiltration and Exfiltration load through Platform Screen Doors (PSDs) shall be optimized by using SES and CFD simulation studies using software.

(ii) Technical and Office rooms Air Conditioning

All ancillary areas that require 24-hour air conditioning or the critical rooms will be provided with fan-coil units (FCU) and standby AC units. During the revenue hours when the main chilled water system is running the FCU will be used for air-conditioning and in non-revenue hours standby AC units (VRV/VRF) will be operated. Return air grilles will be fitted with washable air filters for the re-circulation of the air.

Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filter, common to a group of ancillary areas. Fresh air shall be provided in the backup house air conditioned areas via treated fresh air (TFA) unit. Temperature control will include an alarm setting, which is activated on attaining high temperature.

(iii) Ventilation of Ancillary Spaces & Plant Rooms

Ancillary building rooms will be ventilated through mechanical/natural ventilation supply and mechanical exhaust fan located in the corresponding plant/switchgear room. The fan will be sized based on Air changes per hour/heat dissipation load method. Dedicated ventilation exhaust fan with hydrogen sensors shall be provided for battery rooms. Proper ventilation shall be provided for toilets.

➢ **Staircase Pressurization**

For Staircase Pressurization System, Supply fan shall be used to pressurize the Fire Escape Staircase & Fire Man Staircase in case of fire mode for safe egress of passengers. These staircases will be pressurised by 50 Pa during door closed conditions and 1m/s velocity criteria shall be considered for door open condition in accordance with NBC 2005.

(iv) Smoke Management System

Smoke control systems will be provided for platform, concourse floors and back of house corridor. The Smoke control systems will be designed to satisfy the following criteria:

- To maintain a tolerable environment for all exits/egress and access paths to areas of refuge, for sufficient time to allow all occupants to reach an exit or area of refuge
- To prevent smoke layer entering the occupied zone in fire vicinity
- To prevent smoke from spreading to smoke/fire zone in other areas remote from the fire.

The design shall be complied with latest edition of SFSRTS and NFPA 130 whichever is stringent. In case of fire, the return fan will act like smoke exhaust fan. Smoke purging supply and exhaust shall be provided for the back of the corridor.

(v) VAC Electrical System

VAC equipment shall be fed through power supply from Main distribution board for panels in ancillary building chiller plant room. Main distribution board shall receive power supply from 2 transformers. VAC Panels in concourse area will be fed through Emergency Main Distribution Board (EMDB) which will receive power supply from MDB and standby Diesel Generator. All essential loads shall be supplied through fire-survival low smoke zero halogen cables and non-essential loads through flame retardant low smoke zero halogen cables.

Switch gear combination for the MCC panels shall be selected based on type-2 co-ordination chart. The panels shall be designed in accordance to IEC 61439 and form 4B/Type 7 with IP rating of IP55.

Damper control panel and FCU, air curtain and single phase fans control box/panel are available to control the dampers, FCU, air curtain and single phase fans. VFD drives shall be used to control the variable speed operating VAC equipments such as Chillers, primary chilled water pump, AHUs. Soft starters shall be used to reduce the inrush current, wear and tear of bearings, water hammering of the fans and pumps. All the motors shall be selected with IE3 rating.

(vi) VAC SCADA

VAC SCADA system shall include a Supervisory Control and Data Acquisition system (SCADA) to be able to control, monitor, and supervise Station VAC equipment during normal and emergency mode based on mode table operation. The station VAC SCADA systems control and monitoring includes the Air-conditioning Scheme for station, Smoke Management of public areas and back of house (BOH) areas, Stand-by air conditioning for certain operational/Technical rooms.

The system includes workstation with front-end HMI and two servers for storing alarms, trends etc. in station control room and Integrated back up panel in case of failure of workstation located in station control room. Three local control panels located in VAC equipment rooms/Chiller plant room and same shall be used during failure of IBP and workstation. Integrated SCADA shall be provided for VAC, TVS and MEP system.

13.3.3 Codes and Standards

Concept VAC design is guided by the following codes and standards:

a) SEDH – Subway Environment Design Handbook
b) ASHRAE – Handbook, current series.
c) CIBSE – relevant document.
d) NFPA – 130, 2003 edition.
e) ECBC – Energy Conservation Building Code

13.4 TUNNEL VENTILATION SYSTEM

13.4.1 Tunnel Ventilation System (TVS)

TVS is provided in a subway system essentially to carry out the following functions:

a) Train Pressure relief during normal operation
b) Ventilation during maintenance periods, if required
c) Removal of smoke during emergency conditions
d) Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies.

There are various operating modes (scenarios) for the Tunnel Ventilation system. These are described as under:

➢ **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. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements.

- **Congested Conditions**

Congested conditions occur when delays cause disruption to the movement of trains. It is possible that delays may result in idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures may result reduced performance of coach air conditioners that may lead to passenger discomfort. During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The 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. Nozzles or booster (jet) fans will be used to direct air into the desired tunnel, if required.

- **Emergency Conditions**

Emergency conditions are when smoke is generated in the tunnel or station trackway. 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 firefighting 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.

Tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be two fans in a fan room. Based on station design, fans can be horizontal or vertical. The fan capacity depends on the inter-station distances and may vary from 60 cum/s to 100 cum/s. The exact capacity will be obtained through the simulation during detailed design stage. If necessary, nozzle type structures made up of concrete or steel may also be constructed to achieve desired airflow and air velocity in the tunnel sections. Alternatively, booster fans (jet fans) may be installed to direct flow in desired direction. These fans may also be used for emergency ventilation at crossover locations. Tunnel Ventilation System Design shall be in accordance to the SEDH - Subway Environment Design Handbook, NFPA-130 and other relevant standards. Energy saving measures such as variable speed drives and bidirectional fans shall be considered during the design stage.

The trackway exhaust system will have two fans of each 30-45 cum/sec. for each platform. The connections to tunnels and shafts will be through damper units that may be electrically actuated.

13.4.2 Control and Monitoring Facilities

For the underground stations, 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.

14. MAINTENANCE DEPOT

14.1 DEPOT LOCATION AND APPROACH TO MAINTENANCE

The maintenance facilities will have infrastructure to maintain the rakes with necessary facilities viz stabling lines, scheduled inspection lines, workshop for overhaul, unscheduled maintenance including major repairs, wheel profiling, heavy interior/under frame/roof cleaning etc. for the rolling stock operational on the corridor as well as maintenance facilities for Civil – track, buildings, water supply; Electrical – Traction, E&M; Signaling & Telecomm.; Automatic Fare Collection etc.

The planning of the maintenance facilities is done considering the rolling stock requirement which is calculated on the basis of the proposed train operation plan. This chapter covers the following aspects related to planning of maintenance facilities setup for the Chennai Metro Phase II corridors:

- Conceptual design and layout of Servicing Shed and Workshop to provide maintenance facilities and stabling facilities for 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.

The details of the depot are provided on conceptual design basis and will work as a guideline for detailed design later.

The outline of the maintenance philosophy followed would be as below:

- Typical Maintenance schedules being followed by Delhi Metro have been considered for determining the requirement of lines in depot.
- Unit replacement and to get essential repairs to major equipments done by the OEMs.
- Automation with state-of-the-art machinery to ensure quality and reliability. Labour intensive procedures will be kept to the minimum.
- Maintenance staff shall be given special training to develop high-level skills in their trade to ensure quality and productivity in their performance.
- Adequate facilities for the stabling have been provided at the depot.
- To maintain high degree of cleanliness, Automatic washing plant has been proposed for cleaning of rakes.

14.2 MAINTENANCE PHILOSOPHY

The outline of the maintenance philosophy followed would be as below:

- Typical Maintenance schedules being followed by Chennai Metro Phase I and Delhi metro have been considered for determining the requirement of lines in depot.
- Unit replacement and to get essential repairs to major equipments done by the OEMs.
- Automation with state-of-the-art machinery to ensure quality and reliability. Labour intensive procedures will be kept to the minimum.
- Maintenance staff shall be given special training to develop high-level skills in their trade to ensure quality and productivity in their performance.
- Adequate facilities for the stabling have been provided at the depot.
- To maintain high degree of cleanliness, Automatic washing plant has been proposed for cleaning of rakes.

14.3 Rolling Stock Maintenance Needs

➢ **Maintenance schedule**

Servicing requirements shall be determined from the Rolling Stock manufacturer. Depending upon manufacturer's requirements, servicing facilities may be provided to include the ability to carry out the inspection, maintenance, overhaul and repair of the rolling stock fleet, including the following components:

- Body;
- Bogies;
- Wheels (Re-discing / re-axling is planned at workshop only);
- Traction motors;
- Electrical components;
- Electronics; PA/ PIS
- Mechanical components;
- Batteries;
- Rolling stock air conditioning;
- Brake modules;
- Vehicle doors, windows and internal fittings.

The modern, fully equipped facilities are to be provided that meet these requirements efficiently and in full. In meeting these requirements, it shall be assumed that the average daily distance travelled by each rolling stock unit is approximately 300 km.

The following maintenance schedule has been followed for the conceptual design:

TABLE 14.1: PROPOSED MAINTENANCE SCHEDULE

Type of Schedule	Interval	Work content	Locations
72 hours check	72 hours	Visual Inspection. The Train will stay on Main Line for Pilot train run and Early morning service	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)	A check Activities, visual Inspection, Cleaning, check system Operation, oil & greasing topup, Torque test of major components	Inspection Bays
C Service Check	30,000 Km (approx. 90 days)	B2 Check activities, Replacement of filters, measurements of height, Brake pad etc.	Inspection Bays
D Service Check	60,000 Km (approx. 180 days)	B4 Check activities, change oil, Bogie Inspection, measurements of wear, mechanical adjustments. Battery test, etc	Inspection Bays
Intermed iate Overhaul (IOH)	420,000 Km (approx. 3.5 years)	Check and testing of all sub-assemblies (Electrical + Mechanical). Overhaul of pneumatic valves, 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 (approx. 7 years)	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

Type of Schedule	Interval	Work content	Locations
Heavy Repairs	-	Changing of heavy item such as bogies, traction motor, axles, gear cases & axle boxes etc.	Workshop

In addition to the above schedule, the train may have a safety check daily before starting services on mainline. 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.

- **Washing needs of Rolling Stock**

The Metro trains are maintained to a high degree of cleanliness and therefore needs the maintenance schedule as mentioned in **Table 14.2.**

TABLE 14.2: SCHEDULE OF CLEANING

S.N	Kind of Inspection	Maint. Cycle	Time	Maintenance Place
1.	Outside Cleaning (wet washing on automatic washing plant)	3 Days	10 mins	Automatic washing plant of Depot Single Pass
2.	Outside heavy Cleaning (wet washing on automatic washing plant and Front Face, Vestibule/Buffer area, Floor, walls inside/outside and roof. Manually)	30 days	3 Hrs	Automatic washing Plant & washing line

14.4 DESIGN OF DEPOT FACILITIES AND DEPOT LAYOUT PLANS

- **Depot Layout Plans**

The major maintenance depot for Corridor- 3 & 5 is proposed at Madhavaram. Since, circular train operation is proposed between Corridor-3 and Corridor-5 i.e. from Madhavaram – MMBT – CMBT- Sholinganallur – Adyar – Madhavaram, the inspection and maintenance of the rakes of the two corridors can be done at Madhavaram Depot. The layout plan for the Madhavaram Depot is shown in **Annexure 14.1**. The depot will have infrastructure to maintain the rakes with necessary facilities viz stabling lines, scheduled inspection lines, workshop for overhaul, unscheduled maintenance including major repairs, wheel profiling, heavy interior/under frame/roof cleaning etc. for the rolling stock operational on the corridor as well as maintenance facilities for Civil – track, buildings, water supply; Electrical – Traction, E&M; Signalling & Telecomm.; Automatic Fare Collection etc. Since, the trains will operate in UTO mode (Unattended Train Operation), it is required that the signaling system should be compatible with the driverless train operation.

Minor Depot is proposed at SIPCOT with elevated stabling, inspection and washing facilities. The SIPCOT depot shall have a combined building which shall house the depot control centre and other office rooms. The inspection offices are proposed near the inspection shed. Other facilities such as underground water tank etc. shall be proposed below the depot and at the ground level. The layout plan for SIPCOT minor depot is shown in **Annexure 14.2**.

The major maintenance depot for Lighthouse to Poonamallee Bypass Corridor-4 is located at Poonamallee. The layout plan for the Poonamallee Depot is shown in **Annexure 14.3**.

The rake induction and withdrawal from depot to the open line will have to be so planned that the headway of open line is not affected. For this purpose, facilities for simultaneous receipt and dispatch of trains from depot to open line should be created. The stabling area should be interlocked with the open line so that the induction of train from the stabling can be done without loss of time. The rake washing can be done at automatic coach washing plant provided at the entry of depot i.e. before rake is placed on stabling lines.

The other movements in the depot, viz from the stabling to the inspection shed or workshop and vice versa may be non-interlocked. Two emergency re-railing lines have been provided from which emergency rescue vehicles can be dispatched to open line in the event of any emergency. To cater to the peak requirements, all trains would be in the service, only trains under maintenance would be in the shed. However, during the off-peak hour in daytime, approximately half of the trains will be withdrawn from the service. The scheduled inspections are envisaged to be carried out during the day off-peak hours and night. Tower wagon shall be housed inside the ETU cum emergency retailing building along with the Accident Relief Train.

14.5 INFRASTRUCTURE FACILITIES PLANNED AT DEPOT

A) Inspection Lines and Workshop Lines in Depot

To assess the number of lines required to maintain the rakes, following assumptions are made:

i. For Washing of rakes, an automatic washing plant is proposed. Hence, no separate washing line is needed exclusively for washing. However, one line is provided for heavy cleaning (Manual cleaning of Floor, walls inside/outside and roof).

ii. In a day, two rakes are taken for 'A check' on a pit line.

iii. In a day, one rake is taken for 'B check, C check, D check' on a pit line.

iv. Based on the number of holidays as given below, total numbers of working days are taken as 300 for calculating the requirement of lines.

- No. of days of Public holidays in a year : 13
- No. of Sundays in a year : 52
- No. of available working days in a year : 365 - 65 = 300 days.

As against the above requirement, infrastructure provided for schedule inspection of rakes is indicated in **Table 14.3.** and **Table 14.4**

TABLE 14.3: INSPECTION AND WORKSHOP LINES PROVIDED FOR C-3 & C-5

Schedule	Total visits per rake in 7 years	Average visits per year	Total Arising (96 rakes)	Line Occupancy	Lines Provided
Inspection Shed					
A Service Check	84	16	1536	2 rakes/ day	2.56
B Service Check	56	8	768	1 rake/ day	2.56
C Service Check	14	2.0	192	1 rake/ day	0.64
D Check	14	2.0	192	1 rake/ day	0.64
Lines required for Inspection					6
Adjustment line for minor repair/testing after POH					1
Unscheduled inspection for Madhavaram and SIPCOT depots					2
				Total Inspection Lines Provided	**9**
Workshop Shed					
IOH	1	0.14	13.44	1 rake 12 days	1.08
POH	1	0.14	13.44	1 rake 20 days	1.79
Lines required					4
Unscheduled Repair / Lifting /Wheel/Bogie sections etc.					2
Workshop Lines Provided					**6**

TABLE 14.4: INSPECTION AND WORKSHOP LINES PROVIDED FOR C-4

Schedule	Total visits per rake in 7 years	Average visits per year	Total Arising (31 rakes)	Line Occupancy	Lines Provide
Inspection Shed					
A Service Check	84	16	496	2 rakes/ day	0.83
B Service Check	56	8	248	1 rake/ day	0.83
C Service Check	14	2.00	62	1 rake/ day	0.21
D Check	14	2.00	62	1 rake/ day	0.21
Lines required for Inspection					3
				Total Inspection Lines Provided	**3**
Workshop Shed					
IOH	1	0.14	4.34	1 rake 12 days	0.35
POH	1	0.14	4.34	1 rake 20 days	0.58
Lines required					2
Unscheduled Repair / Lifting /Wheel/Bogie sections etc.					2
				Workshop Lines Provided	**4**

Madhavaram Depot proposed will have maintenance facility with an infrastructure to maintain 96 rakes of 6 car length. Based on the calculations indicated in **Table 14.3**, the depot is proposed to be planned with 6 workshop lines. The inspection facilities for the corridors are planned at Madhavarm depot as well as minor depot at SIPCOT. Madhavaram Depot will have 6 lines of 6 car length each and SIPCOT minor depot will have 3 lines of 6 car length each.

Poonamallee Depot proposed for the corridor-4 of Chennai Metro will have maintenance facility with an infrastructure to maintain 31 rakes of 6 car length. Based on the calculations indicated in **Table 14.4**, the depot is proposed to be planned with 4 workshop lines and 3 inspection lines of 6 car length each.

B) Stabling Facility for Rakes

The rake requirement for Phase II corridor-III and Corridor-5 is worked out to be 96 rakes of 6 car length for design year. Out of 96 rakes. Madhavaram Depot and minor depot at SIPCOT will cater to stabling requirements for Corridor-III and Corridor-5. Madhavaram Depot is planned with stabling facility for 37 rakes of 6 car each. Minor Depot at SIPCOT will have stabling facility for 20 rakes of 6 car each.

Stabling facility for 24 rakes is provided at enroute/ terminal stations viz. Madhavaram (8 rakes of 6 car length), MMBT (2 rakes of 6 car length), Sholinganallur (6 rakes of 6 car length), SIPCOT (6 rakes of 6 car length) and Medavakkam (2 rakes of 6 car length). Remaining rakes would remain under inspection at a given time.

The rake requirement for light house to Poonamallee Bypass Corridor-4 of Chennai Metro Phase II is worked out to be 31 rakes of 6car length for ultimate design year. Poonamllee Depot proposed on light house to Poonamallee Bypass Corridor-4 will have stabling facility for 24 rakes of 6 car. At a given time, three rakes would remain under inspection and the remaining rakes will be stabled at terminal/enroute stations for the start of early morning services.

14.6 DEPOT CUM WORKSHOP PLANNING

i. Stabling Lines in Depot

For the design of the stabling lines in the depot, following approximate lengths have been taken in consideration:

(i) Length of one 6-car rake= 135.6 m

(ii) Free length at outer ends of the rake (for cross pathway, Signal and Friction buffers)= 20m each side

(iii) Total length of Stabling line = (ii)+(i)+(ii)= 20+135.6+20= 175.6 m (say 180 m)

Looking to the car width of 2900 on Standard Gauge, 5m Track Centre is proposed for all the stabling lines. Thus, space between stabling shall be sufficient to include a pathway to be constructed between tracks to provide access for internal train cleaning and undercarriage inspection.

ii. Inspection Lines in Depot

For the design of the Inspection Bay Lines in the depot, following approximate lengths have been taken in consideration:

(i) Length of one 6-car rake= 135.6 m (approx)

(ii) Cross path at each end = 10 m

(iii) Total length of Inspection line = (ii)+(i)+(ii)= 10+ 135.6+10= 155.6m (say 160m)

The inspection bay in Poonamallee Depot shall be of 160 X 23.5m² size with three inspection lines having sunken floor and in Madhavaram Depot shall be of 160 X 43m² size with six inspection lines having sunken floor. SIPCOT minor depot shall have three inspection lines of 6 car length each. The track spacing between the adjacent inspection bay Lines shall be 6.25 m.

There would be lighting below the rail level to facilitate the under frame inspection. Ramps of 1:8 slopes, 3 meter wide should be provided with sunken floor system for movement of material for the cars. Further, 3.5 m 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.

Roof and walls shall be of such design that optimum natural air ventilation occurs all the time and sufficient natural light is also available. Each Inspection bay will also have arrangement close by for cleaning of HVAC filter under high pressure water jet.

iii. Workshop in Depot

The size of the workshop shed in Poonamallee Depot shall be 160 x 44.5 m²and in Madhavaram Depot shall be of 160 X 86m² two lines are provided with under floor train lifting system capable of lifting one train of six car in each line. An additional covered space of 160 x 8 m² and 160 x 15 m² shall be provided in the depots to cater for offices cum maintenance sections, costly item store, locker room, toilet etc. Following equipment repair/overhaul facilities are planned in the workshop.

- Body furnishing.
- Bogie.
- Wheels.
- Traction Motor
- Axle box and axle bearing
- Electrical equipment like transformer, converter/inverter, circuit breaker, relays.
- Battery.

- Air conditioning equipments.
- Brake equipment.
- Door actuators.
- Control and measuring equipments.
- Pneumatic equipments
- Dampers and Springs
- Couplers/ Gangways
- Cross track equipped with bogie turntables have been provided for movement between bays.

iv. Pit Wheel Lathe

A separate building is planned for housing pit wheel lathe (PWL) for Poonamallee Depot and Madhavaram Depot which is 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.

v. Auxillary Shed cum Emergency Re-railing Building

Since the workshop cum depot is designed optimally, it would not be wise to waste its capacity in maintaining the other than passenger Rolling Stock vehicles. Carrying these vehicles to the inspection shed affects the Rolling Stock maintenance as shunting is also involved. Therefore, other vehicles like rail cum road vehicle, tower wagons, etc. may be housed and given required inspection attention in a separate shed called Auxillary Shed cum Emergency Re-railing Building, for which 2 lines have been provided in the depots. However, for the heavy lifting needs, these vehicles may be taken to main workshop for required attention.

vi. Car Delivery Area

The newly procured coaches, which are transported by road, 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. 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.

vii. 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 six 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.

viii. Test Track

A test track of 1070m and 750 m length will be provided in Madhavaram and Poonamallee Depot respectively. 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. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized trespassing across or along the track.

ix. Internal 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.

x. 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 cycle/scooter/car stand facility for convenience of the train operating staff.

xi. 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.

xii. Operation Control Centre and Depot Control Centre

Control of train operation will be done centrally from Operations Control Center (OCC), which will house Traffic Control Centre, SCADA System for Traction Power Control & Monitoring, SCADA System for Auxiliary Power, VAC Control & Monitoring, Telecommunication, CCTV Control & Monitoring etc. Movement of trains inside depot shall be controlled from Depot Control Centre (DCC) located inside the depot.

xiii. Parking Facilities

a) Ample parking space shall be provided for the two wheelers and four wheelers at the following points.

i) Close to the depot entry.

ii) Close to the stabling lines.

iii) Close to the Workshop/ IBL.

b) Space for parking of road and re-railing equipments

Enough space for parking of road vehicle/ trailers/ trucks etc. Enough space will also have to be earmarked adjacent to workshops. Similarly, provision of space for parking of re-railing equipments will have to be made close to the main exit gate of the Depot.

xiv. Watch Towers

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

xv. Power Supply

An auxiliary substation of 2500 KVA capacity has been planned for catering to the power supply requirement of the depot. Details of connected load, feeder may be worked out during detailed designing stage.

xvi. Standby Power Supply

The standby power supply is proposed through silent DG set of 2X320 KVA adequate capacity to supply all essential loads without over loading.

xvii. 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 underground reserves.

xviii. Plant and Machinery

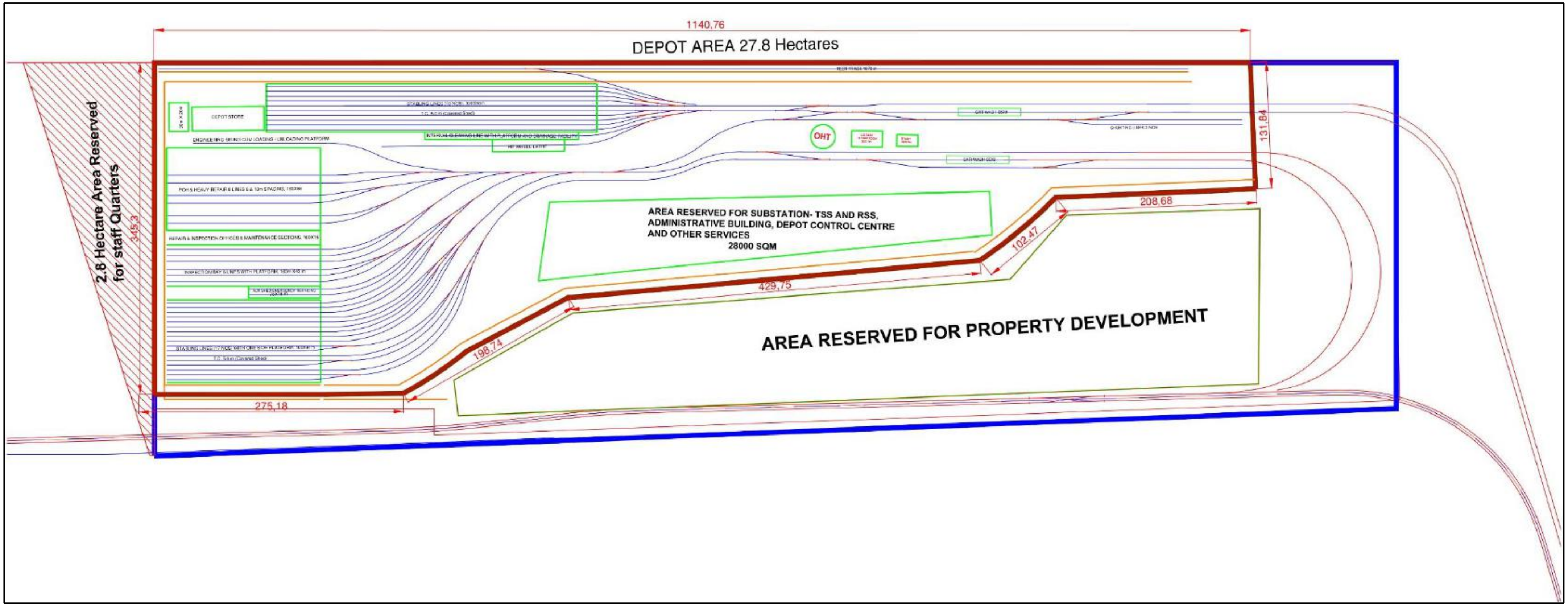
Plant and machinery proposed for the maintenance facilities at have been listed in **Annexure14.4.**

Synchronized Mobile Jacks

Synchronised Pit Jacks

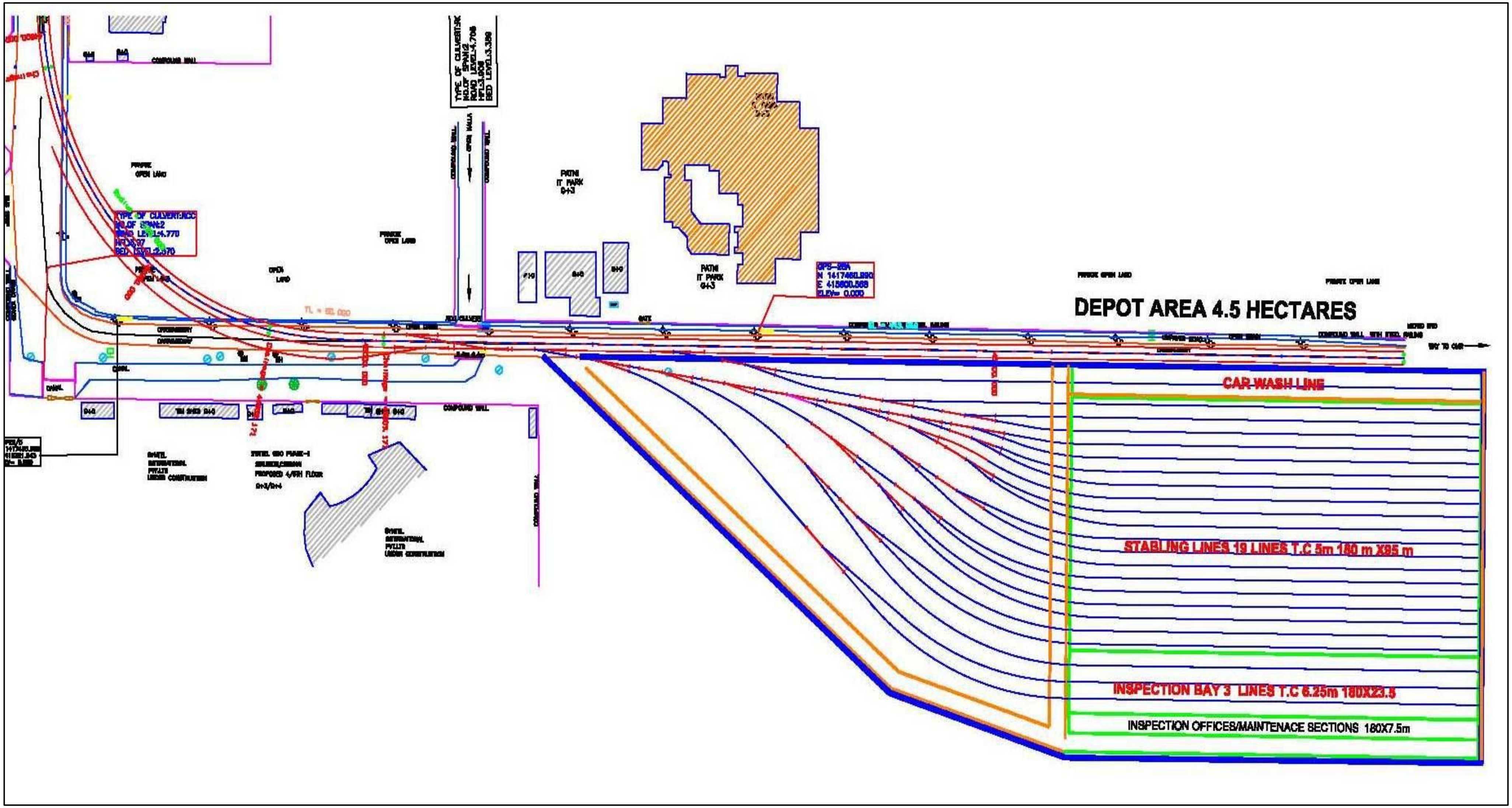
Annexure 14.1

LAYOUT PLAN – MAJOR DEPOT AT MADHAVARAM



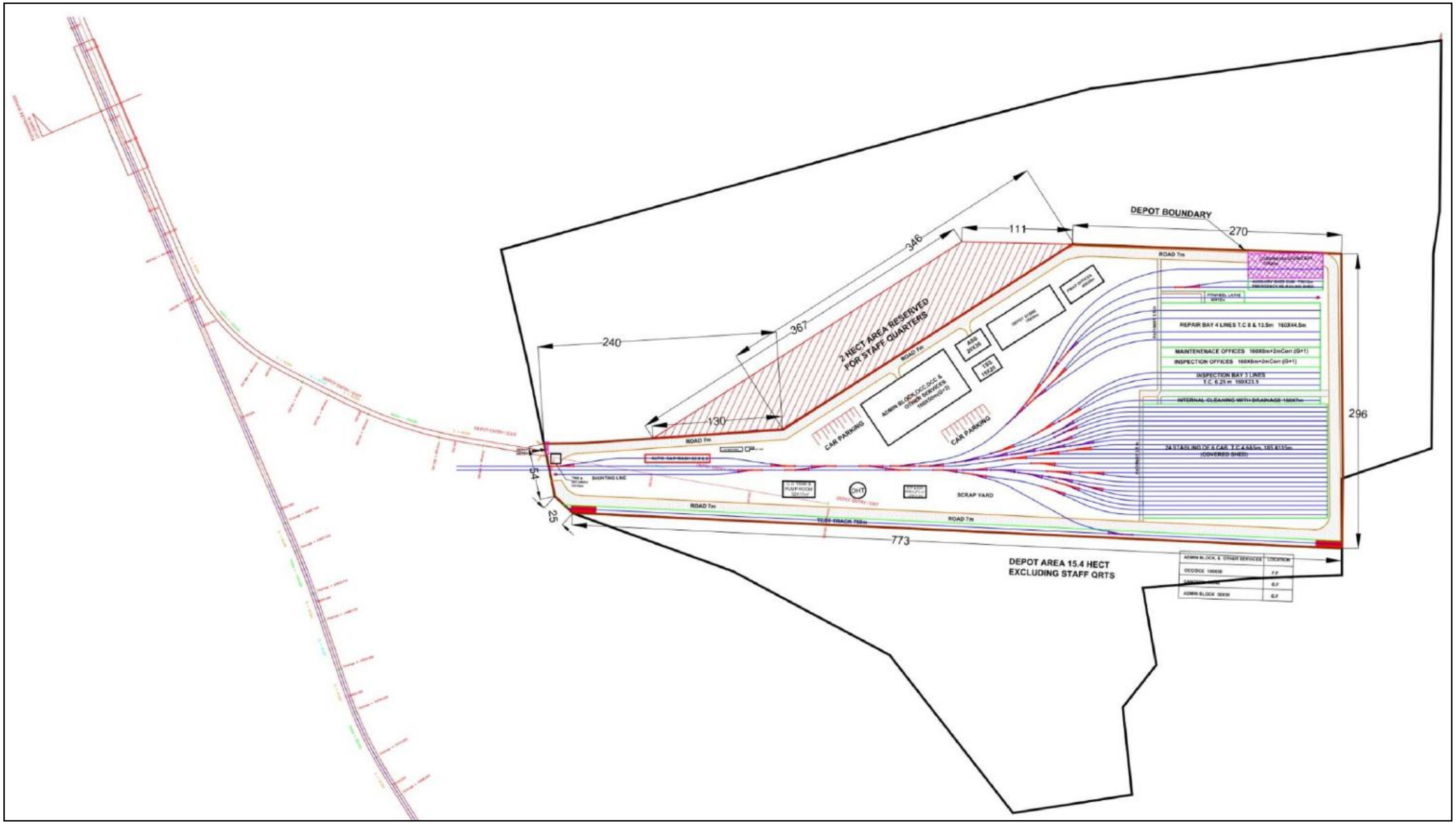
Annexure 14.2

LAYOUT PLAN – MINOR DEPOT AT SIPCOT



Annexure 14.3

LAYOUT PLAN FOR POONAMALLEE DEPOT



Annexure 14.4

LIST OF MAJOR PLANT AND MACHINERY FOR POONAMALLEE DEPOT

S.no.	PLANT & MACHINERY	Quantity
A.	**MATERIAL HANDLING**	
	Travelling over head EOT cranes for workshop 15/2T	2
	Travelling over head EOT cranes for workshop 3.2T	2
	Travelling over head EOT cranes for ETU shed 5T	1
	Jib crane for workshop 3 T	2
	Synchronized pit jacks system for car lifting (6 car unit)	1 set
	Car body stands for keeping 6 car shells	12
	Dummy bogies	2
	Mobile lifting jacks-15T (1 set= 12 Nos)	1 set
	Mobile lifting jacks 10T (1 set= 12 Nos)	1 set
	Battery powered locomotive	1
	Road mobile Crane 5T cap	1
	Fork lift truck 3T cap	2
	Fork lift trucks 2T cap	2
	Pallet trucks	2
	TATA Truck	2
	Scissors type lifting trolley - 2T capacity	2
	Hydraulic trolleys - 2T capacity	2
B.	**WHEEL SHOP**	
	Multipurpose Wheel Lathe	1
	Axle UST inspection machine	1
	Radial drill m/c	1
	Induction Heater	1
	Bearing/Coupling Extractor	1
C.	**BOGIE SHOP**	
	Bosch Tank : Bogie wash/cleaning plant	1
	Bogie static load testing m/c	1
	Shock absorber testing m/c	1
	Spring scragging&testing m/c	1
	Magnaflex crack detector	1
	Glowcheck crack detector	1
D.	**ROTATING M/CS**	
	Baking Oven	1
	Dynamic balancing	1
	Traction motor test console	1
	Motor compressor test bench	1
	Tan Delta testing instrument	1
E.	**OTHER M/CS**	
	Re-railing equipment	1
	Pit Wheel Turning Lathe	1
	Chip crusher and conveyor for pit wheel lathe	1

	Automatic Washing plant for Metro cars.	1
	High-pressure washing pump for front and rear end cleaning of cars.	1
	Turn table for one car	1
	Turntable for bogies	3
	Driving Cab Simulator	1
	Water de-mineralizing plant (Distillation plant)	1
	Painting booth for separate parts	1
	Floor cleaning machine	2
	Welding equipments	2
	DG set 320 KVA	1
	Battery charger	2
	Radial drill m/c	1
G.	**TEST BENCHES/INSTRUMENTS**	
	Pneumatic test bench	1
	Brake test bench	1
	SPM test bench	1
	Door test bench	1
	Inverter test bench	1
	Other test benches (MCB, RMPU etc.)	1
	Oscilloscope	1
H.	**FURNITURE/MATERIAL STORAGE/SMALL TOOLS**	
	Vertical storage system for DCOS store	1
	Computer MMIS with LAN connectivity	1
	Storage racks	LS
	Industrial furniture	LS
	Electric and pneumatic tools	LS
	Measuring and testing equipments	LS
	Tool kits	LS
	Mobile safety steps	6

PROPOSED PLANT AND MACHINERY AT MADHAVARAM DEPOT

S.No.	PLANT & MACHINERY	Quantity
A.	**MATERIAL HANDLING**	
	Travelling over head EOT cranes for workshop	2
	Travelling over head EOT cranes for workshop 3.2T	7
	Travelling over head EOT cranes for ETU shed 5T	1
	Jib crane for workshop 3 T	2
	Synchronized pit jacks system for car lifting (6 car	2 set
	Car body stands for keeping 6 car shells	36
	Dummy bogies	6
	Mobile lifting jacks-15T (1 set= 12 Nos)	1 set
	Mobile lifting jacks 10T (1 set= 12 Nos)	3 sets
	Battery powered locomotive	2
	Road mobile Crane 5T cap	1
	Fork lift truck 3T cap	2

S.No.	PLANT & MACHINERY	Quantity
	Fork lift trucks 2T cap	2
	Pallet trucks	4
	TATA Truck	2
	Scissors type lifting trolley - 2T capacity	3
	Hydraulic trolleys - 2T capacity	3
B.	**WHEEL SHOP**	
	Multipurpose Wheel Lathe	1
	Axle UST inspection machine	2
	Radial drill m/c	1
	Induction Heater	2
	Bearing/Coupling Extractor	4
C.	**BOGIE SHOP**	
	Bosch Tank : Bogie wash/cleaning plant	1
	Bogie static load testing m/c	1
	Shock absorber testing m/c	1
	Spring scragging&testing m/c	1
	Magnaflex crack detector	1
	Glowcheck crack detector	1
D.	**ROTATING M/CS**	
	Baking Oven	1
	Dynamic balancing	1
	Traction motor test console	1
	Motor compressor test bench	1
	Tan Delta testing instrument	1
E.	**OTHER M/CS**	
	Re-railing equipment	2
	Pit Wheel Turning Lathe	1
	Chip crusher and conveyor for pit wheel lathe	1
	Automatic Washing plant for Metro cars.	2
	High-pressure washing pump for front and rear end	2
	Turn table for one car	1
	Turntable for bogies	9
	Driving Cab Simulator	1
	Water de-mineralizing plant (Distillation plant)	2
	Painting booth for separate parts	1
	Floor cleaning machine	4
	Welding equipments	5
	DG set 320 KVA	3
	Battery charger	2
	Radial drill m/c	1
G.	**TEST BENCHES/INSTRUMENTS**	
	Pneumatic test bench	1
	Brake test bench	2
	SPM test bench	2
	Door test bench	2
	Inverter test bench	1
	Other test benches (MCB, RMPU etc.)	1
	Oscilloscope	1

S.No.	PLANT & MACHINERY	Quantity
H.	**FURNITURE/MATERIAL STORAGE/SMALL TOOLS**	
	Vertical storage system for DCOS store	1
	Computer MMIS with LAN connectivity	1
	Storage racks	LS
	Industrial furniture	LS
	Electric and pneumatic tools	LS
	Measuring and testing equipments	LS
	Tool kits	LS
	Mobile safety steps	10

15. ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

15.1 OBJECTIVE OF ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The objective of Environmental Impact Assessment (EIA) is to ascertain the baseline environmental conditions and then assess the impacts as a result of the proposed project during various pre-construction, construction and operation phases of the project cycle.

15.2 ENVIRONMENTAL LEGISLATION

The Acts, Rules and Norms relevant to the project are listed below:

- The Air (Prevention and Control of Pollution) (Union Territories) Rules 1982, 1983 (Consent for emission form)
- National Ambient Air Quality Standards 2009
- Guidelines for Ambient Air Quality Monitoring , CPCB, 2003
- The Water (Prevention and Control of Pollution) Act 1974 amended 1988
- The Water (Prevention and Control of Pollution) Rules 1975 (CTE or consent to discharge form)
- Guide Manual – Water and waste water analysis, CPCB
- Drinking water – Specifications IS 10500: 2012 and CPHEEO Manual 2012
- Noise Pollution (Regulation and Control) Rules, 2000 amendment in 2010
- Metro Rail Transit System, Guidelines for Noise and Vibrations, RDSO, Ministry of Railways, September 2015
- Construction and Demolition Waste Management Rules 2016
- Hazardous and Other Wastes (Management and Transboundary Movement) Rules 2016
- Solid Waste Management Rules 2016
- Coastal Regulation Zones Rules 2011
- Forest (Conservation) Act, 1980, amended 1988.
- Forest (Conservation) Rules 2003 and Forest (Conservation) Amendment Rules, 2014 (procedure for FC)
- The Indian Wild Life (Protection) Act 1972 and The Wildlife (Protection) Amendment Act 2002

- The Metro Railways (Operation and Maintenance) Act 2002 as amended vide The Metro Railways (Amendment) Act 2009 (disaster management)
- The Ancient Monuments and Archaeological sites and Remains (Amendment and Validation Act) 2010
- Chennai Metropolitan Area Groundwater (Regulation) Act, 1987 as amended till 2008 and Guidelines/Criteria for evaluation of proposals/requests for ground water abstraction (With effect from 16.11.2015), Central Ground Water Authority

15.3 ENVIRONMENTAL BASELINE DATA

Data on land environment has been collected and compiled from various sources and during field surveys. Information about geology, hydrology, natural hazards like earthquakes etc have been collected from literature reviews and authenticated information made available by government departments. Meteorological data was collected from Indian Meteorological Department (IMD). Water quality, soil quality, ambient air and noise environment in the surrounding areas were assessed primarily through monitoring and analysis of samples collected from field. The field study was carried out in the month of July 2016, May 2017, September 2018 and November 2018.

A scoping matrix was formulated to identify the attributes likely to be affected due to the development of proposed project and is presented in **Table 15.1**.

TABLE 15.1: SCOPING MATRIX

ASPECT	LIKELY IMPACTS
A. Land Environment	
Construction Phase	Increased soil erosion
	Pollution by construction spoils
	Solid waste from worker colonies and construction sites
B. Water Resources & Water Quality	
Construction Phase	Water quality impacts due to disposal of wastewater from worker camps and construction sites, spoils.
	Depletion of groundwater resources
Operation Phase	Drainage, Water requirement, and Disposal of waste water
C. Air Pollution	
Construction Phase	Impacts due to emissions generated by construction machinery/vehicles
D. Noise Pollution	
Construction Phase	Noise due to operation of various equipment

ASPECT	LIKELY IMPACTS
	Noise due to increased vehicular movement
Operation Phase	Noise from Metro operation
	Noise due to DG sets
E. Ecology	
Construction Phase	Removal of vegetation cover/loss of biomass
F. Socio-Economics	
Construction Phase	Loss of property, livelihood and community resources
	Improved employment potential during project construction phase
	Development of allied sectors leading to greater employment
	Pressure on existing infrastructure facilities
Operation Phase	Loss of property, livelihood and community resources
	Increase in Employment Opportunities in direct and indirect sectors
	Increased revenue from business development

15.3.1 Land Environment

Physiography: Chennai is located on the South–Eastern coast of India in the North–Eastern part of Tamil Nadu. It is situated on a flat coastal plain that's why it is also known as the Eastern Coastal Plains. It is bounded by the Bay of Bengal on the east. The study area is lies between Latitude of 13° 10' N to 12° 49' N and Longitude of 80° 10' E to 80° 14' E. Chennai is a low-lying area and the land surface is almost flat like a pancake. The average elevation of the city is not more than 22 ft above mean seal-level, while most of the localities are just at sea-level and drainage in such areas remains a serious problem.

Soil: The recent sandy soil (Entisols) is immature soils and is predominant in the city and it occurs in small patches. The major soil in this region belongs to Alfisols and Entisols **(Table 15.2)**. Inceptisols and Vertisols are found in a very limited area only. These soils are generally poor in soil nutrients. They have medium to high permeability. They have low water holding capacity except in patches of clayey soils.

TABLE 15.2: MAJOR SOIL TYPES IN CHENNAI DISTRICT

Sl. No	Name of Taluk	Major Soil Types
1	Saidapet	Alfisols
2	Ponneri	Inceptisols
3	Gummudipoondi	Inceptisols
4	Uthukottai	Inceptisols and Entisols
5	Pallipet	Inceptisols and Entisols
6	Thiruthani	Inceptisols

Sl. No	Name of Taluk	Major Soil Types
7	R.K. Pet	Inceptisols
8	Thiruvellore	Inceptisols and Altisols
9	Sriperumbudur	Inceptisols and Altisols
10	Kancheepuram	Alfisols
11	Walajapet	Inceptisols and Entisols
12	Arakanom	Inceptisols and Altisols

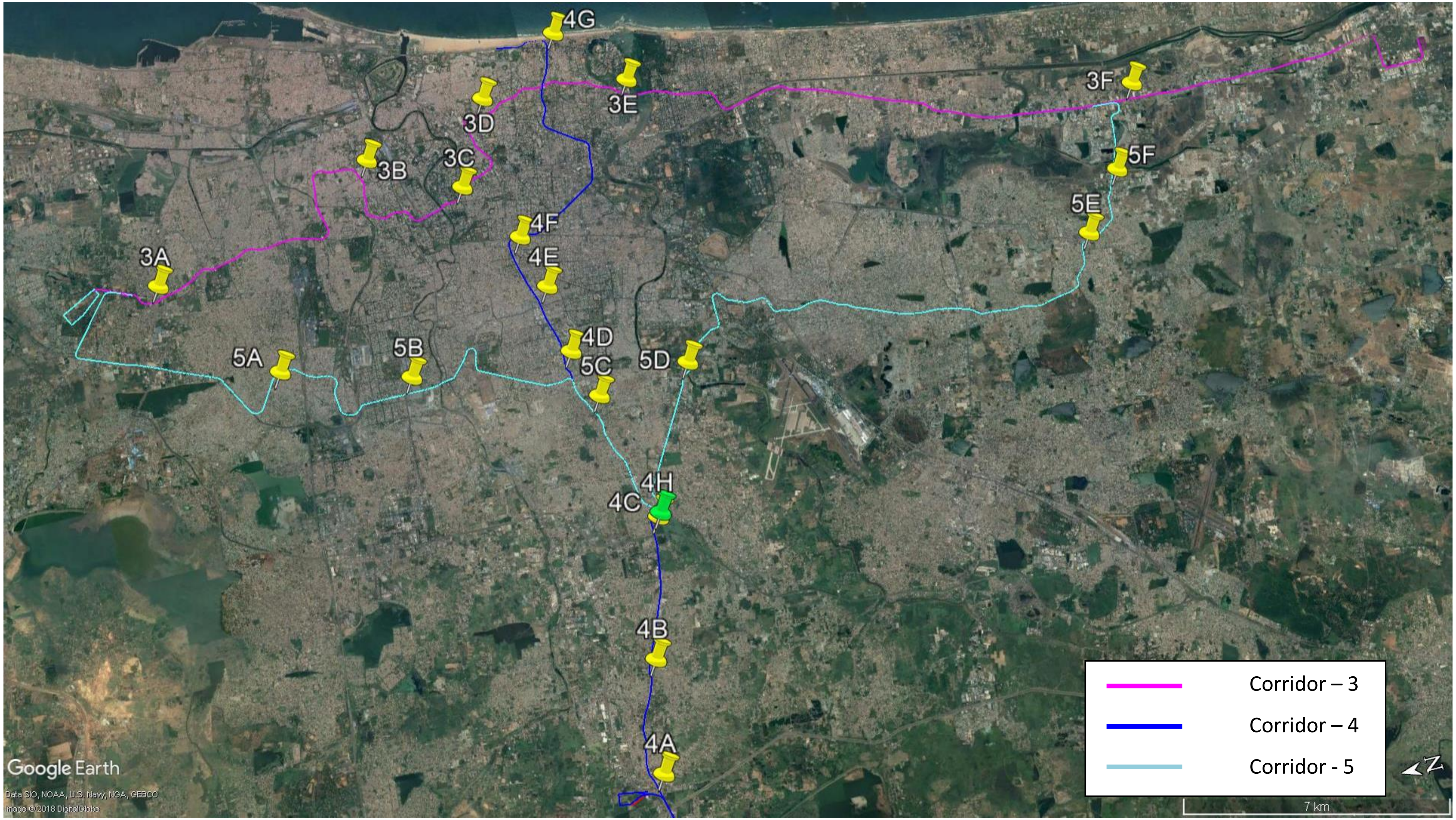
Source: cpheeo.nic.in

Soil samples were collected at 20 locations along the three proposed metro corridors as listed in **Table 15.3** and shown in **Figure 15.1**. The laboratory analysis results so obtained are reported in **Table 15.4**. The soils are slightly alkaline in nature. Organic matter content in soils varies from 1.02% to 1.29%.

TABLE 15.3: SAMPLING LOCATIONS FOR WATER, SOIL, AIR AND NOISE

S. No	Corridor – 3 Madhavaram to SIPCOT	Corridor – 4 Light House to Poonamallee Bypass	Corridor – 5 Madhavaram- CMBT- Sholinganallur
A	Mulakadai to Madhavaram Milk Colony (TapalPeti Bus stop)	At Crossing of NH 4 Bypass & Poonamalee Flyover	Srinivasa Nagar
B	Purasaivalkam (Tana Road)	Near Kumunanchavadi Bus Stop, MSS Nagar	Anna Nagar West
C	Good Shepherd school	Near Porur Lake, Padmavati Nagar	AlwarThiru Nagar junction
D	Royapettai Government Hospital	Permal Street, Shradha Nagar	MIOT Hospital
E	MGR Janaki College	Vadapalani Junction	Medavakkam Junction
F	Sholinganallur Junction	Kodambakkam Meenakshi College	Global Hospital
G	-	Santhome Church	-
H	-	Porur Lake (water & soil only)	-

FIGURE 15.1: MONITORING LOCATION MAP FOR AIR, NOISE, WATER AND SOIL



***Corridor 3**- Madhavaram to SIPCOT, **Corridor 4**- Light House to Poonamallee Bypass, **Corridor 5**- Madhavaram-CMBT-Sholinganallur (3, 4, 5 – Represents Corridor number and A to H monitoring location at respective corridors). (Refer Table 15.3)*

TABLE 15.4: RESULTS OF LABORATORY ANALYSIS OF SOIL SAMPLE

S. No.	Parameter	Unit	Result								
			Corridor 3						Corridor 4		
			3A	3B	3C	3D	3E	3F	4A	4B	4C
1	pH (at 25^0C)	-	7.96	7.97	7.27	7.17	7.19	7.66	8.24	8.2	8.05
2	Conductivity (1:2 soil water sus.)	mS/cm	0.21	0.17	0.11	0.15	0.13	0.16	0.36	0.32	0.24
3	Chloride	mg/kg	38.14	19.07	33.37	38.13	28.60	38.13	142.31	1223.09	359.93
4	Available Nitrogen	Kg/hec	30.92	23.82	21.05	30.13	28.72	25.92	28.46	23.55	24.60
5	Total Zinc as Zn	mg/kg	14.96	12.27	14.65	13.55	15.02	14.76	72.13	68.36	69.14
6	Manganese as Mn	mg/kg	201.97	176.21	166.32	173.85	199.57	177.92	262.50	108.56	141.38
7	Total Lead as Pb	mg/kg	8.45	8.24	9.57	10.31	10.72	10.38	BDL	BDL	BDL
8	Total Copper as Cu	mg/kg	16.23	18.69	18.21	17.49	16.19	20.06	19.50	15.10	14.80
9	Organic Carbon	%	0.66	0.66	0.74	0.73	0.68	0.73	0.35	0.33	0.35
10	Water Soluble Sulphate	mg/kg	25.04	21.88	20.77	20.39	20.44	26.15	36.45	26.58	40.16
11	Boron	mg/kg	1.33	1.74	1.64	1.29	1.61	2.07	1.48	1.84	1.66
12	Iron	mg/kg	256.81	378.36	379.21	456.0	369.56	436.21	1343.34	1258.05	1299.51
13	Nickel	mg/kg	12.63	15.98	12.36	20.01	20.37	18.64	BDL	BDL	BDL
14	Bicarbonate	mg/kg	92.16	142.08	126.47	141.30	138.47	148.52	168.40	135.63	168.44
15	Calcium	mg/kg	167.83	120.06	146.25	118.63	76.02	80.40	665.33	625.25	480.96
16	Magnesium	mg/kg	36.63	19.51	26.77	31.45	23.36	27.71	34.05	102.14	41.34
17	Sand	%	32.64	34.71	33.42	35.55	34.08	36.41	22.41	32.53	32.97
18	Silt	%	41.05	39.30	39.81	40.64	38.02	41.95	59.37	59.19	59.34
19	Clay	%	26.31	25.99	28.77	25.81	28.90	23.64	18.22	8.28	7.69
20	Sodium	mg/kg	53.05	57.20	234.10	51.05	46.20	76.05	23.70	2.97	129.33
21	Potassium	kg/hec	94.16	93.18	98.03	96.99	93.34	98.21	176.98	372.97	271.60
22	Sulphur	mg/kg	30.21	27.12	26.17	23.62	26.53	19.86	38.19	36.98	42.55
23	Organic Matter	%	1.03	1.14	1.29	1.28	1.26	1.15	0.60	0.57	0.60
24	Orthophosphate	mg/kg	73.58	72.64	75.03	70.65	72.08	73.20	12.40	10.12	5.80
25	Carbonate	mg/kg	4.12	4.92	3.98	5.01	5.02	4.28	5.65	16.54	10.20
26	Arsenic	mg/kg	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Mercury	mg/kg	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

28	Cadmium as Cd	mg/kg	1.20	1.39	1.27	1.07	1.69	1.62	BDL	BDL	BDL
29	Molybdenum	mg/kg	0.65	0.58	0.70	0.48	0.68	0.75	BDL	BDL	BDL
30	Available Nitrogen	Kg/hec	278.12	308.17	318.62	261.31	298.33	301.47	140.86	146.54	172.50

S. No.	Parameter	Unit	Result										
			Corridor 4					Corridor 5					
			4D	4E	4F	4G	4H	5A	5B	5C	5D	5E	5F
1	pH (at 25^{0}C)	-	7.98	7.23	7.10	7.02	8.14	7.56	7.02	7.11	7.75	7.86	7.28
2	Conductivity (1:2 soil water sus)	mS/cm	0.29	0.12	0.17	0.28	0.27	0.68	0.18	0.19	0.22	0.25	0.17
3	Chloride	mg/kg	262.50	33.37	29.87	47.67	97.67	57.20	38.13	24.79	33.37	19.11	47.67
4	Available Nitrogen	Kg/hec	29.60	28.01	26.91	29.31	26.50	27.82	28.12	28.24	25.83	23.97	22.16
5	Total Zinc as Zn	mg/kg	70.54	14.32	13.28	14.22	57.49	13.25	12.98	12.35	12.37	13.20	14.36
6	Manganese as Mn	mg/kg	196.43	200.01	199.12	179.42	52.79	177.55	188.62	166.32	190.32	118.37	197.08
7	Total Lead as Pb	mg/kg	BDL	10.75	10.69	10.23	BDL	9.78	9.89	9.65	10.77	11.40	8.78
8	Total Copper as Cu	mg/kg	16.20	20.02	18.27	19.25	13.20	15.38	17.85	14.82	19.45	16.23	16.88
9	Organic Carbon	%	0.36	0.59	0.62	0.69	0.40	0.63	0.58	0.73	0.63	0.59	0.66
10	Water Soluble Sulphate	mg/kg	36.48	27.29	20.88	20.23	38.50	22.12	22.57	20.12	18.99	22.53	27.64
11	Boron	mg/kg	1.86	2.38	1.98	2.66	1.78	1.98	2.16	1.86	2.27	1.76	1.33
12	Iron	mg/kg	1351.19	444.35	412.65	368.24	1210.29	424.5	442.61	420.37	448.5	428.23	455.64
13	Nickel	mg/kg	BDL	12.35	12.93	12.79	BDL	18.32	16.18	18.27	20.18	18.21	20.02
14	Bicarbonate	mg/kg	125.48	148.68	142.62	150.13	128.28	127.91	138.26	125.69	138.62	126.35	126.36
15	Calcium	mg/kg	384.77	108.16	145.06	136.29	436.87	176.04	155.55	140.09	160.24	86.82	76.28
16	Magnesium	mg/kg	89.98	28.12	20.36	28.13	38.91	35.97	19.88	27.28	27.98	22.36	20.36
17	Sand	%	38.86	34.09	34.45	33.45	36.54	34.44	38.46	34.93	31.97	35.17	35.78
18	Silt	%	56.04	39.67	38.88	40.05	59.56	39.97	39.10	38.88	39.05	39.06	37.66
19	Clay	%	5.10	24.27	26.67	26.50	3.90	26.59	22.44	28.19	28.98	26.77	28.56
20	Sodium	mg/kg	164.02	42.10	51.85	75.70	24.32	231.75	41.75	56.45	45.55	47.45	42.32
21	Potassium	kg/hec	249.50	97.16	88.38	98.92	200.49	98.68	110.22	70.18	78.03	98.53	92.76
22	Sulphur	mg/kg	48.55	22.87	30.23	29.56	36.22	30.18	28.02	29.18	26.78	26.27	19.27
23	Organic Matter	%	0.62	1.02	1.08	1.19	0.69	1.09	1.12	1.26	1.08	1.03	1.05

S. No.	Parameter	Unit	Result										
			Corridor 4					Corridor 5					
			4D	4E	4F	4G	4H	5A	5B	5C	5D	5E	5F
24	Orthophosphate	mg/kg	16.54	67.09	59.54	68.98	16.54	67.23	74.27	70.65	67.08	73.91	76.20
25	Carbonate	mg/kg	4.20	5.10	4.92	4.36	6.40	3.58	4.95	2.99	5.01	5.03	3.88
26	Arsenic	mg/kg	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
27	Mercury	mg/kg	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
28	Cadmium as Cd	mg/kg	BDL	1.72	1.32	1.68	BDL	1.08	1.22	1.24	1.66	1.31	1.36
29	Molybdenum	mg/kg	BDL	0.69	0.76	0.80	BDL	0.66	0.69	0.60	0.82	0.69	0.63
30	Available Nitrogen	Kg/hec	158.40	304.51	269.61	308.12	189.80	267.60	298.73	199.97	305.36	268.66	264.53

***Corridor 3**- Madhavaram to SIPCOT, **Corridor 4**- Light House to Poonamallee Bypass, **Corridor 5**- Madhavaram-CMBT-Sholinganallur (3, 4, 5 – Represents Corridor number and A to H monitoring location at respective corridors). (Refer Table 15.3)*

Geology and Minerals: The geological formations in the region are from the Archaeans to the recent Alluvium (**Table 15.5**). The geological formations can be grouped into three units, namely (i) the Archaean crystalline rocks, (ii) consolidated Gondwana with Tertiary sediments and (iii) the recent Alluvium. Most of the geological formations are concealed by the alluvial materials, except for a few exposures of crystalline rocks like charnockites along the railway track in Guindy area. The thickness of Gondwanashales is highly variable in the city. It is more than 130 m at Porur and Koyembedu whereas it exceeds 25 m in Ashok Nagar and 60 m in Sterling Road. The highly variable nature of Gondwana sediments indicated the irregularly eroded crystalline basement, over which the Gondwana sediments are deposited.

TABLE 15.5: GEOLOGICAL FORMATION IN THE PROJECT AREA

Geological succession in Chennai district Group	System	Age	Lithology	Aquifer Characteristics
1	2	3	4	5
Quarternary	Recent	Sub-Recent	Soils, Alluvium (sand & silt)	Moderate to good porous aquifer system
Tertiary	(Cuddalore Sandstone equivalents)	Eocene to Piliocene	Sandstone & and shale (fossiliferous)	Moderately Porous Aquifer
---UNCONFIRMITY---				
Mesozic	Upper Gondwana (Sri Perumbudur Beds)	Lower Cretaceous to Lower Jurassic	Brown Sandstone and siltstone; Grey shale; Black shale	Less Porous aquifer with minor fractures
---UNCONFIRMITY---				
Azoic	Archaean	--	Charnockites, Granites, Gneisses	Fractured Aquifer

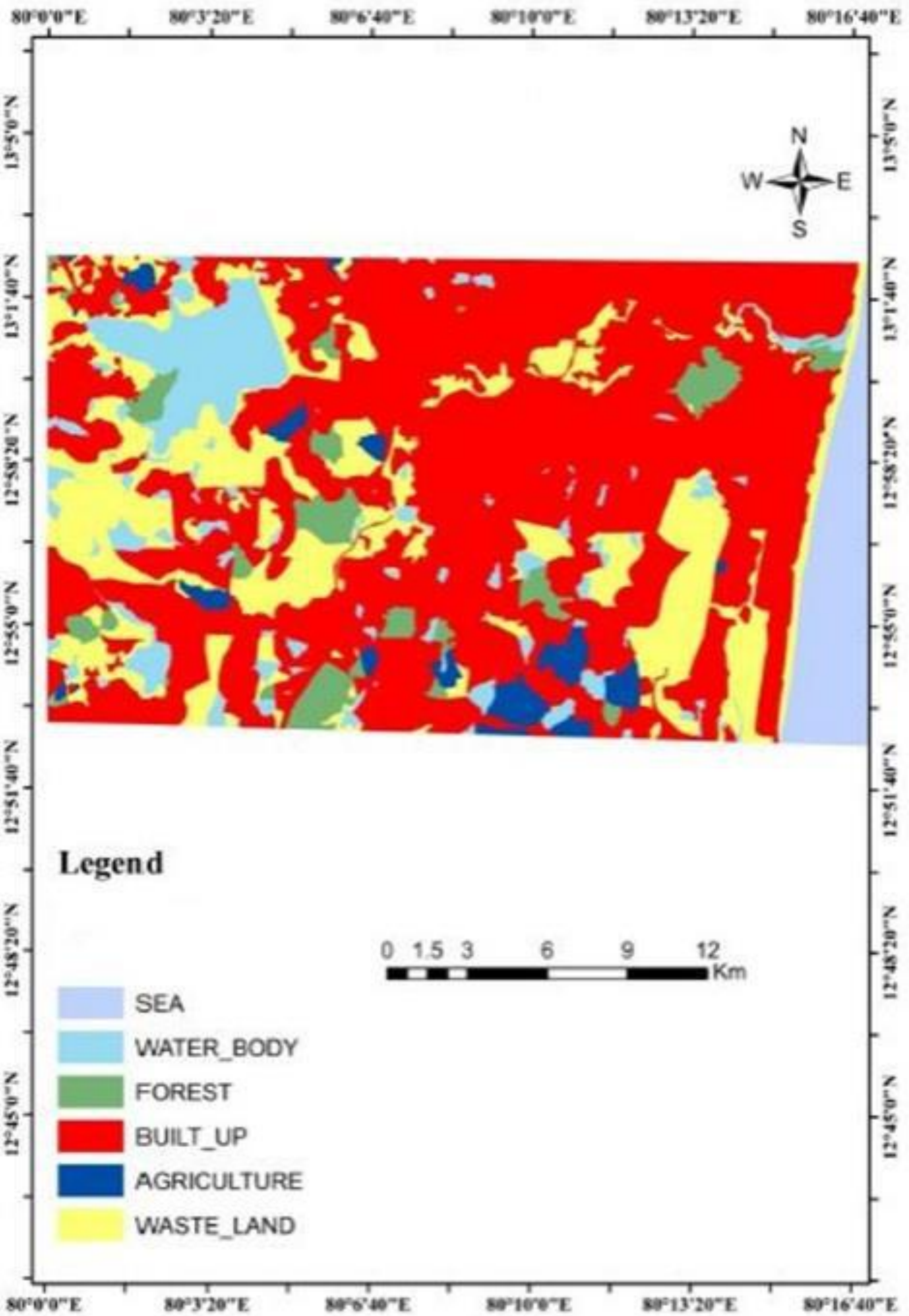
Source: cpheeo.nic.in

Land Use Land Cover: Land use distribution in the city is uneven. The north and west of the Fort and older city are most congested areas. During last three decades, the settlement density at outskirts of city is on increase.

The land use land cover map (**Figure 15.2**) was prepared with the help of satellite imagery of year 2006.It depicts that the built-up area is 58.05%, forest area 4.48%, water body 8.51%, agricultural land 2.75% and waste land is 20.27%.

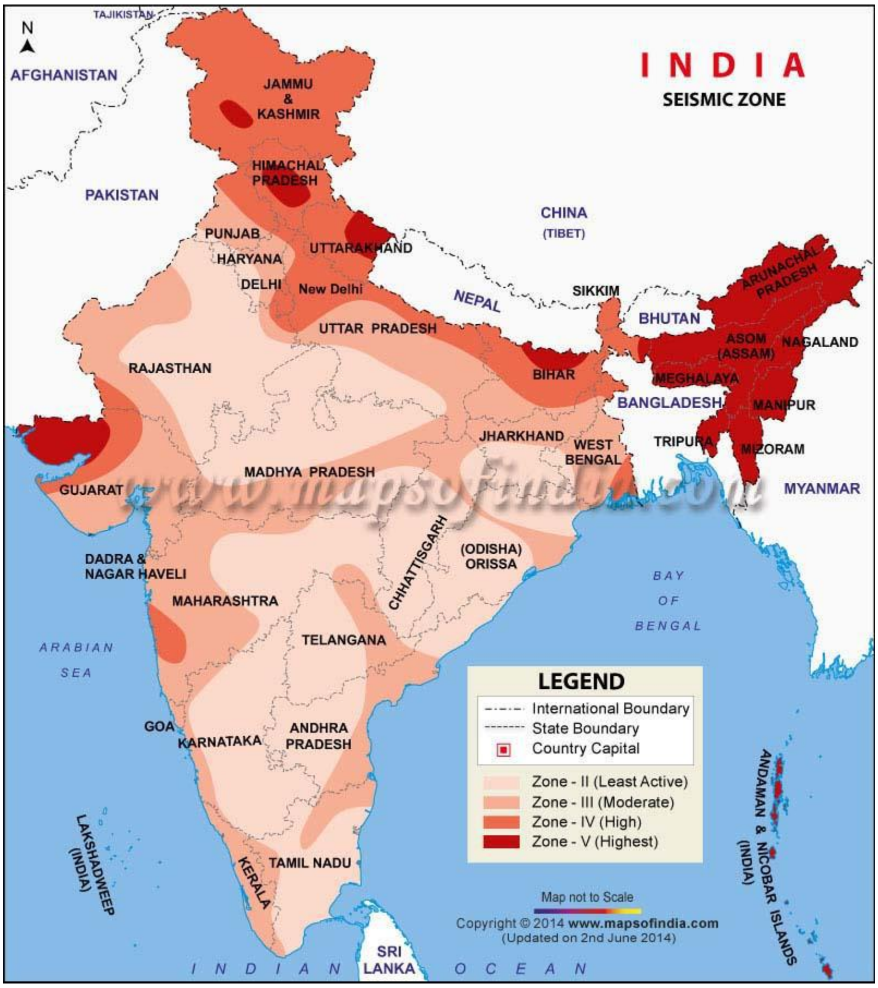
Seismicity: The Bureau of Indian Standard upgraded the seismic status of Chennai from Low Seismic Hazard (Zone II) to Moderate Seismic Hazard (Zone III) – (BIS: 1893 (2001)).The area of Chennai has experienced moderate earthquakes in the historical past. Suitable seismic coefficient needs to be adopted in the design of structures to commensurate with the Indian Standard seismic zoning of the country IS.1893-2002. The seismic zoning map of India is shown at **Figure 15.3**.

FIGURE 15.2: LAND USE LAND COVER MAP



Source: IJETT–Volume1, Issue2–May 2011

FIGURE 15.3: SEISMIC ZONE MAP OF INDIA



15.3.2 Water Environment

Water Resources: Ground water resources in Chennai are replenished by rain water and the city's average rainfall is 1,276 mm. Chennai Metropolitan Area (CMA) has 22 water sources, including three rivers, a canal, and four reservoir tanks. This also includes 16 minor waterways. Supply of ground water to the residents and sewage management in Chennai is taken care of by the Chennai Metropolitan Water Supply and Sewage Board (MetroWater). The city supplies 830 million litres of water per day. The city will get additional 880 mld from sources such as Minjur desalination plant (100 mld), Krishna water (500 mld), Nemeli desalination plant (100 mld), and Cauvery water from Veeranam Tank (180 mld).

Drainage: Adyar River originates at the confluence (Thiruneermalai) of two streams that drains theupstream area of Chembarambakkam tank. It drains the southern partof the district and remains flooded during monsoon. During the high tides, the back water from the Bay of Bengal enters inland up to 3 – 4 km.

Cooum is the other main river flowing through the central part of the district and carries only drainage water, which is highly polluted. It originates from the surplus waters from the Cooum tank in Tiruvalloretaluk and the tanks, which are in enroot, discharge their surplus water into the river during flood season. The flow of Cooum River at Korattur is 40.2 MCM/year for an average duration of 31 days in a year.

Otteri Nulla is another small stream flowing in the northern part of the city. Buckinghamcanal is the man made one for navigation purposes earlier, but now it acts as sewerage carrier in the city.

Water Quality: In order to assess the baseline water quality status of the study area, samples at 20 locations along the three proposed corridors were collected. Description of water sample locations is given in **Table 15.6** and geographical locations are shown in **Figure 15.1**. The analysis of water samples is presented in **Table 15.7**. Laboratory analysis of water sample depicts that all parameters are in acceptable limit except some parameters viz. turbidity, calcium, chloride, hardness, magnesium, mercury, lead are exceeded the permissible limit at 12 locations. Bacteriological contamination found at all locations except six locations on corridor 4. The water at six locations will be safe for drinking after proper treatment.

TABLE 15.6: SAMPLING LOCATIONS FOR WATER

S. No.	Location	Remark
Corridor 3		
A	Moolakadai to Madhavaram Milk Colony (Tapal Petti)	Bore water
B	Purasaivalkam (Tana Road)	Bore water
C	Good Shephered School	Bore water
D	Rayapetai Govt. Hospital	Supply water/Tap water
E	MGR Janki College	Bore water
F	Sholinganallur	Surface water
Corridor 4		
A	At Crossing of NH 4 Bypass & Poonamalee Flyover	Bore water
B	Near Kumunanchavadi Bus Stop, MSS Nagar	Bore water
C	Near Porur Lake, Padmavati Nagar	Bore water
D	Permal Street, Shradha Nagar	Bore water
E	Vadapalani Junction	Bore water
F	Kodambakkam Meenakshi College	Bore water
G	Santhome Church	Bore water
H	Porur Lake	Surface water
Corridor 5		
A	Srinivasa Nagar	Bore water
B	Anna Nagar West	Bore water
C	AlwarThiru Nagar Junction	Bore water
D	MIOT Hospital	Bore water
E	Medavakkam Junction	Bore water
F	Near Global Hospital	Surface water

TABLE 15.7: RESULTS OF LABORATORY ANALYSIS OF WATER SAMPLE

S. No.	Parameter	Unit	Result										Acceptable/Permissible Limit
			Corridor 3						Corridor 4				
			3A	3B	3C	3D	3E	3F	4A	4B	4C	4D	
1	pH at 25^{O}C	-	7.75	7.65	7.97	7.61	7.54	8.62	6.87	6.77	6.62	7.21	6.5-8.5/no relaxation
2	Turbidity	NTU	<1	<1	2.7	4.5	7.5	19.6	59.2	<0.1	<0.1	<0.1	1/5 max
3	Total Dissolved Solids	mg/l	928	845	561	365	811	2686	1186	1104	675	612	500/2000 max
4	Aluminium as Al	mg/l	BDL	BDL	0.121	0.07	BDL	0.063	BDL	BDL	BDL	BDL	0.03/0.02 max
5	Free Amonia (as NH3)	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	>0.1	<0.1	<0.1	-
6	Barium (as Ba)	mg/l	BDL	BDL	0.07	0.07	0.051	0.097	BDL	BDL	BDL	BDL	0.7 max/ no relaxation
7	Boran (as B)	mg/l	BDL	BDL	BDL	0.075	BDL	BDL	BDL	BDL	BDL	BDL	0.5/1
8	Calcium as Ca	mg/l	123.8	94.9	37.2	37.2	86.7	90.8	100.2	116.2	76.2	48.1	75/200
9	Chloride as Cl	mg/l	226.7	118.3	83.8	61.4	138	1261.5	207	182.3	123.2	98.6	250/1000
10	Copper as Cu	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.0021	0.0023	BDL	0.0021	0.05/1.5
11	Fluoride as F	mg/l	>1	>1	<1	<1	<1	>1	>1	>1	>1	>1	1.0/1.5
12	Iron as Fe	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.3/ no relaxation
13	Magnesium (as Mg)	mg/l	10	27.6	12.5	61.8	17.6	125.4	58.4	31.7	19.5	17	30/100
14	Manganese as Mn	mg/l	BDL	0.007	0.02	0.008	0.076	0.009	1.16	0.003	BDL	0.002	0.1/0.3
15	Nitrate as NO3	mg/l	10.1	2	BDL	BDL	2.7	1.8	BDL	70.8	21.6	1.2	45/ no relaxation
16	Phenolic Compounds	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001/0.002
17	Seleniem (as Se)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01/ no relaxation
18	Silver (as Ag)	mg/l	BDL	BDL	BDL	0.0026	BDL	0.007	BDL	BDL	BDL	BDL	0.01/ no relaxation
19	Sulphate as SO4	mg/l	22.2	29.5	25.9	37.8	37.4	78.2	312.7	196	50.8	85	200/400
20	Sulphide (as S)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05/ no relaxation
21	Total Alkalinity as CaCO3	mg/l	245	411.6	215.6	117.6	294	313.6	223.3	396	310	467	200/600
22	Total Hardness as CaCO3	mg/l	350.2	350.2	144.2	154.5	288.4	741.6	490	420	270	190	200/600
23	Zinc as Zn	mg/l	0.062	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5/15
24	Cadmium (as Cd)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.003/ no relaxation
25	Cynide (as CN)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05/ no relaxation
26	Lead as Pb	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01/ no relaxation
27	Mercury (as Hg)	mg/l	BDL	0.00025	BDL	0.0002	0.003	BDL	BDL	0.0008	0.00093	0.00025	0.001/ no relaxation

S. No.	Parameter	Unit	Result										Acceptable/Permissible Limit
			Corridor 3						Corridor 4				
			3A	3B	3C	3D	3E	3F	4A	4B	4C	4D	
28	Nickel	mg/l	0.0024	BDL	BDL	BDL	0.0024	0.003	BDL	BDL	BDL	BDL	0.02/ no relaxation
29	Total Arsenic as As	mg/l	BDL	0.015	0.006	BDL	BDL	0.005	BDL	BDL	BDL	BDL	0.01/0.05
30	Total Chromium (as Cr)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05 max/no relaxation
31	Total Suspended Solids	mg/l	4	4	7	5	6	37	29.0	9	7	7	-
32	Vanadium (as V)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-
33	Amonical Nitrogen (as N)	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	>0.1	<0.1	<0.1	0.5/No relaxation
34	Total Kjeldahl Nitrogen (as N)	mg/l	12.6	3.1	0.11	0.14	3.6	2.5	BDL	89	27.8	1.5	-
35	Chromium (as Hexavalent Cromium)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-
36	Oil and Grease	mg/l	<1	<1	<1	<1	<1	<1	<5	<5	<5	<5	-
37	Dissolved Oxygen	mg/l	5.3	5.5	5.5	5.4	5.3	3.9	6	6.8	6.6	6.7	-
38	Chemical Oxygen Demand	mg/l	28	12	20	20	28	100	32	24	16	20	-
39	Biochemical Oxygen Demand (3 day 27 deg C)	mg/l	11	6	7	7	11	35	13	9	6	8	-
40	Total Phosphate as P	mg/l	0.2	0.54	0.14	0.12	0.15	BDL	0.1	3.3	1.3	2.4	-
41	Dissolved Phosphate (as P)	mg/l	0.2	0.54	0.14	0.12	0.15	BDL	0.1	3.3	1.3	2.4	
42	Sodium as Na	mg/l	160	145	130	83.5	290	775	135	137.5	110	165	-
43	Potassium as K	mg/l	14.1	14.3	10.1	5.3	25	38	5.8	47	24.3	24.8	-
44	Nitrate Nitrogen	mg/l	2.3	0.45	BDL	BDL	0.61	0.41	BDL	16	4.9	0.27	-
45	Total Nitrogen	mg/l	12.6	3.1	0.11	0.14	3.6	2.5	BDL	89	27.8	1.5	-
46	Organic Phosphorus	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002 max
47	Coliform Count	MPN/100 ml	<1	<1	<1	<1	28	<1	160	20	40	90	Absent
48	Fecal Coliform	MPN/100 ml	<1	<1	<1	<1	<1	<1	50	10	10	30	Absent
49	Total Coliform Organism	MPN/100 ml	<1	<1	<1	<1	9	<1	250	69	80	230	Absent

RESULTS OF LABORATORY ANALYSIS OF WATER SAMPLE (Conti.)

S. No.	Parameter	Unit	Result										Acceptable/Permissible Limit
			Corridor 4				Corridor 5						
			4E	4F	4G	4H	5A	5B	5C	5D	5E	5F	
1	pH at $25^{O}C$	-	7.49	6.56	7.31	7.45	7.18	7.17	7.13	7.82	7.99	8.15	6.5-8.5/no relaxation
2	Turbidity	NTU	5.5	<1	<1	<1	<0.1	<0.1	67.3	<0.1	<0.1	76.5	1/5 max
3	Total Dissolved Solids	mg/l	1412	56	4510	418	818	656	1826	1528	1256	4386	500/2000 max
4	Aluminium as Al	mg/l	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.054	0.03/0.02 max
5	Free Amonia (as NH3)	mg/l	<0.1	<0.1	<0.1	<0.1	<1	<1	<1	<1	<1	>0.5	-
6	Barium (as Ba)	mg/l	0.058	BDL	0.099	BDL	BDL	BDL	0.13	0.146	0.046	0.23	0.7 max/ no relaxation
7	Boran (as B)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.004	BDL	0.04	BDL	0.5/1
8	Calcium as Ca	mg/l	57.8	2.1	289	32.1	123.8	61.9	82.6	210.5	206.4	123.8	75/200
9	Chloride as Cl	mg/l	409	14.8	2118.8	113.3	192.2	147.8	670.1	310.4	280.9	1995.7	250/1000
10	Copper as Cu	mg/l	BDL	BDL	0.007	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05/1.5
11	Fluoride as F	mg/l	>1	<0.1	>1	<1	<1	<1	>1	>1	>1	>1	1.0/1.5
12	Iron as Fe	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	0.15	BDL	BDL	0.14	0.3/ no relaxation
13	Magnesium (as Mg)	mg/l	42.6	1.3	95.3	14.6	12.5	25.1	52.7	32.6	27.6	188.1	30/100
14	Manganese as Mn	mg/l	0.35	BDL	0.137	0.003	0.13	0.006	0.54	0.02	BDL	0.21	0.1/0.3
15	Nitrate as NO3	mg/l	5	BDL	11.3	BDL	BDL	BDL	BDL	9.5	17.2	1.1	45/ no relaxation
16	Phenolic Compounds	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001/0.002
17	Seleniem (as Se)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01/ no relaxation
18	Silver (as Ag)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01/ no relaxation
19	Sulphate as SO4	mg/l	61.7	BDL	224.2	BDL	30	56.1	46.1	158.2	11.7	155.6	200/400
20	Sulphide (as S)	mg/l	BDL	BDL	BDL	27.4	BDL	BDL	BDL	BDL	BDL	BDL	0.05/ no relaxation
21	Total Alkalinity as CaCO3	mg/l	539	9.8	372.4	BDL	343	245	460.6	411.6	382.2	225.4	200/600
22	Total Hardness as CaCO3	mg/l	319.3	10.3	1112.4	152.3	360.5	257.5	422.3	659.2	628.3	1081.5	200/600
23	Zinc as Zn	mg/l	0.027	0.14	0.034	140	0.23	BDL	BDL	0.032	BDL	BDL	5/15

S. No.	Parameter	Unit	Result										Acceptable/Permissible Limit
			Corridor 4				Corridor 5						
			4E	4F	4G	4H	5A	5B	5C	5D	5E	5F	
24	Cadmium (as Cd)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.003/ no relaxation
25	Cynide (as CN)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05/ no relaxation
26	Lead as Pb	mg/l	0.045	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.009	0.050.01/ no relaxation
27	Mercury (as Hg)	mg/l	BDL	BDL	0.00045	BDL	BDL	BDL	0.006	0.006	0.0008	BDL	0.001/ no relaxation
28	Nickel	mg/l	0.0025	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002	0.004	0.02/ no relaxation
29	Total Arsenic as As	mg/l	BDL	BDL	0.004	BDL		0.0024	BDL	BDL	BDL	0.003	0.01/0.05
30	Total Chromium (as Cr)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05 max/no relaxation
31	Total Suspended Solids	mg/l	9	3	8	8	7	5	21	5	3	184	-
32	Vanadium (as V)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-
33	Amonical Nitrogen (as N)	mg/l	<0.1	<0.1	<0.1	<0.1	<1	<1	<1	<0.1	<1	>0.5	0.5/No relaxation
34	Total Kjeldahl Nitrogen (as N)	mg/l	11.6	0.1	14.2	1.12	0.56	0.73	0.2	11.8	21.5	3.2	-
35	Chromium (as Hexavalent Cromium)	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	-
36	Oil and Grease	mg/l	<1	<1	<1	<5	<1	<1	<1	<1	<1	1	-
37	Dissolved Oxygen		4.4	6.1	4.9	5.7	5.6	5.8	4.6	5.1	4.5	3.7	-
38	Chemical Oxygen Demand	mg/l	64	Nil	52	56	12	8	64	36	60	220	-
39	Biochemical Oxygen Demand (3 day 27 deg C)	mg/l	20	Nil	19	20	5	2	23	11	23	75	-
40	Total Phosphate as P	mg/l	1.2	BDL	1.4	0.18	0.24	1.8	0.9	0.3	1.1	0.27	-
41	Dissolved Phosphate (as P)	mg/l	1.2	BDL	1.4	0.18	0.24	1.8	0.9	0.3	1.1	0.27	

S. No.	Parameter	Unit	Result										Acceptable/Permissible Limit
			Corridor 4				Corridor 5						
			4E	4F	4G	4H	5A	5B	5C	5D	5E	5F	
42	Sodium as Na	mg/l	455	10.9	925	75	125	135	575	352.5	150	1010	-
43	Potassium as K	mg/l	29	BDL	61	12	2.8	13.5	15	3.4	6	30	-
44	Nitrate Nitrogen	mg/l	1.13	BDL	2.6	BDL	BDL	BDL	BDL	2.1	3.9	0.25	-
45	Total Nitrogen	mg/l	11.6	0.1	14.2	1.12	0.56	0.73	0.2	11.8	21.5	3.2	-
46	Organic Phosphorus	mg/l	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002 max
47	Coliform Count	MPN/100 ml	<1	<1	<1	90	<1	22	<1	35	<1	54	Absent
48	Fecal Coliform	MPN/100 ml	<1	<1	<1	20	<1	<1	<1	<1	<1	<1	Absent
49	Total Coliform Organism	MPN/100 ml	<1	<1	<1	200	<1	15	<1	12	<1	14	Absent

***Corridor 3**- Madhavaram to SIPCOT, **Corridor 4**- Light House to Poonamallee Bypass, **Corridor 5**- Madhavaram-CMBT-Sholinganallur (3, 4, 5 – Represents Corridor number and A to H monitoring location at respective corridors). (Refer Table 15.6)*

15.3.3 Meteorology and Air Environment

The air pollutants emitted by point and non-point sources are transported, dispersed or concentrated by meteorological and topographical conditions. The meteorological parameters regulate the transport and diffusion of pollutants into the atmosphere. In order to assess the impact on existing ambient environment due to the project, it is necessary to have baseline status of ambient environmental parameters. Meteorological data on rainfall, wind, humidity, and temperature were collected from Indian Meteorological Department (IMD) for last five years. The ambient air quality and noise level had been monitored during the month of July 2016 and May 2017.

Meteorology: Chennai has a tropical wet and dry climate. The city lies on the thermal equator and is also on the coast, which prevents extreme variation in seasonal temperature. Meteorological data like monthly total rainfall, maximum & minimum temperature, windrose and relative humidity of the Chennai for a period of Jan 2011 to Dec 2017 collected from Indian Meteorological Department (IMD). **Table 15.8** and **Table 15.9** depicts that the hottest part of the year is May with maximum temperature varies 41.7°C to 42.8°C. The coolest part of the year is January, with minimum temperature varies 17.7°C to 20.3°C. Mean Relative Humidity at 08:30 hrs and 17:30 hrs are given in **Table 15.10** and **Table 15.11** respectively. It depicts that it varies 56% to 88% at 08:30 hrs and 57% to 81% at 17:30 hrs. The monthly rainfall is given in **Table 15.12**. The city gets most of its seasonal rainfall from the north–east monsoon winds, from mid–October to mid–December. Cyclones in the Bay of Bengal sometimes hit the city. The highest annual rainfall recorded is 1049.3mm in November 2015. Prevailing winds in Chennai are usually south-westerly between April and October and north-easterly during the rest of the year.

TABLE 15.8: MONTHLY HIGHEST (MAXIMUM) TEMPERATURE (DEG C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	31.1	32.6	37.7	35.7	41.7	38.6	38.0	36.9	36.4	35.4	32.6	31.6
2012	31.2	33.6	36.3	35.6	42.5	42.4	38.8	37.3	36.8	36.0	33.6	31.0
2013	30.9	32.5	35.1	37.4	42.7	39.7	38.3	36.9	35.7	35.6	33.6	32.1
2014	30.6	32.3	36.6	38.6	42.8	41.8	39.2	38.5	36.7	36.2	32.5	31.8
2015	31.3	33.1	35.1	36.8	42.2	39.6	41.0	37.6	36.9	35.7	32.6	32.4
2016	33.0	34.0	39.0	41.0	41.0	39.0	37.0	38.0	37.0	37.0	34.0	31.0
2017	31.0	36.0	36.0	41.0	43.0	41.0	39.0	37.0	36.0	36.0	34.0	33

Source: Regional Meteorological Centre, Chennai

TABLE 15.9: MONTHLY LOWEST (MINIMUM) TEMPERATURE (DEG C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	18.7	17.7	20.1	23.5	23.1	22.7	23.1	20.5	21.6	22.6	18.7	19.0
2012	17.7	19.2	22.4	25.7	27.1	24.2	22.6	23.7	22.0	22.2	17.6	20.7
2013	19.0	19.5	20.4	25.3	24.8	24.7	23.2	23.6	23.0	23.8	22.0	19.1
2014	20.3	19.0	22.1	25.6	24.3	23.0	23.6	22.9	23.7	23.4	21.3	21.0
2015	19.0	20.8	23.2	23.5	25.6	24.6	23.9	23.1	23.5	24.3	22.4	21.5
2016	19.0	20.0	23.0	25.0	25.0	24.0	24.0	24.0	23.0	22.0	19.0	19.0
2017	19.0	19.0	22.0	26.0	27.0	25.0	24.0	24.0	24.0	23.0	23.0	21

Source: Regional Meteorological Centre, Chennai

TABLE 15.10: MONTHLY MEAN RELATIVE HUMIDITY AT 08:30 HRS (%)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	82	81	77	75	64	60	70	79	80	84	85	88
2012	83	77	76	72	65	56	68	73	76	83	80	84
2013	88	84	80	77	73	61	80	83	82	86	86	80
2014	78	79	72	72	67	64	70	78	77	82	82	83
2015	83	81	74	72	69	66	70	77	77	83	91	86
2016*	94	100	94	94	100	100	100	100	100	94	100	100
2017*	100	94	94	94	89	100	100	100	100	100	100	100

*Source: Regional Meteorological Centre, Chennai, * at 05.30 & 14.30 Hrs (www.timeanddate.com)*

TABLE 15.11: MONTHLY MEAN RELATIVE HUMIDITY AT 17:30 HRS (%)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	60	61	59	67	65	58	57	69	74	80	76	67
2012	68	61	68	70	65	59	61	70	73	77	73	78
2013	75	72	69	77	74	60	76	76	78	81	81	73
2014	69	67	64	68	68	66	65	74	75	80	77	76
2015	73	71	67	69	69	65	70	71	75	78	87	78
2016*	38	30	29	30	30	37	37	33	37	30	27	27
2017*	35	24	38	23	25	16	33	42	47	36	43	40

*Source: Regional Meteorological Centre, Chennai, *at 05.30 & 14.30 Hrs(www.timeanddate.com)*

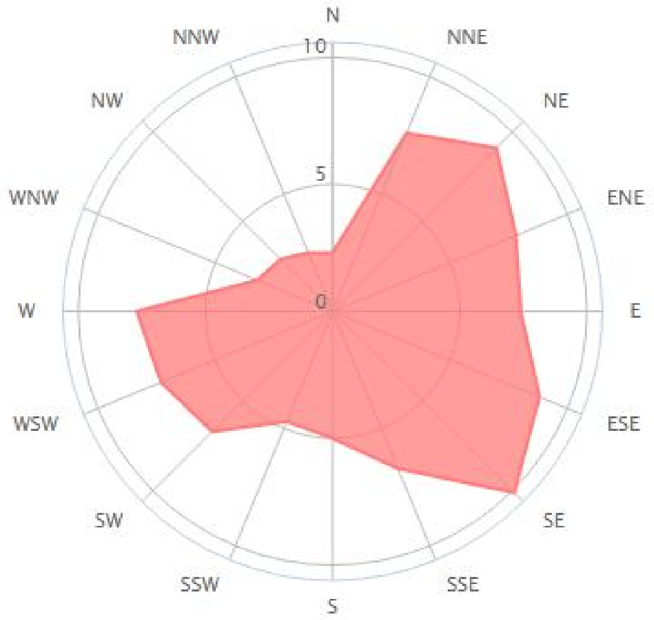
TABLE 15.12: MONTHLY TOTAL RAINFALL (MM)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	10.8	88.9	0.0	18.5	12.6	130.2	67.4	368.9	286.2	260	457.2	134.8
2012	16.3	0.0	1.6	0.2	0.0	24.7	79.9	89.5	214.1	422.6	47.0	125.5
2013	Trace	14.3	11.9	3.6	3.6	34.0	146.6	195.1	240.1	157.2	193.7	85.9
2014	0.1	9.9	0.0	0.0	13.5	96.2	69.7	222.6	130.8	405.5	196.9	149.9
2015	2.8	0.0	0.0	12.3	7.9	20.3	205.9	106.5	75.0	159.9	1049.3	454.7
2017*	0.0	5.0	2.5	0.0	0.5	60.0	55.0	90.0	65.0	160.0	155.0	9.0

*Source: Regional Meteorological Centre, Chennai, *www.meteoblue.com*

The wind rose diagram has been prepared based on the daily data for the period of 10/2009 to 08/2016. The prominent direction is NE, ESE and SE. Wind rose diagram for the Chennai is shown in **Figure 15.4.**

FIGURE 15.4: WINDROSE DIAGRAM FOR CHENNAI



Air Quality: Nineteen monitoring stations were selected strategically along three proposed metro corridors. The monitoring stations were selected to generate the representative samples for air quality covering residential, institutional and industrial area along the corridors. Location details are provided in **Table 15.3** and location map for air monitoring stations are shown in **Figure 15.1.** The monitoring results for ambient air quality of the study area are presented in **Table 15.13**. 24 hour air quality monitoring results indicates that SO_2, NO_2, PM_{10} and $PM_{2.5}$ were within the limits for residential, Industrial and rural areas. However, CO exceeds prescribed limits. The National Ambient Air Quality Standard (NAAQ) laid down by Central Pollution Control Board (CPCB) given in **Table 15.14.**

TABLE 15.13: AMBIENT AIR QUALITY OF THE STUDY AREA

Sl No	Parameters	Unit	Concentration of Pollution												
			Corridor–3						Corridor-4						
			3A	3B	3C	3D	3E	3F	4A	4B	4C	4D	4E	4F	4G
1	Sulphur Dioxide (SO_2)	µg/m^3	7.76	6.7	7.45	7.6	11.56	12.31	5.52	12.16	10.47	8.48	9.43	8.82	10.5
2	Nitrogen Dioxide (NO_2)	µg/m^3	15.21	9.3	9.9	9.84	10.20	14.85	11.52	18.03	17.53	23.64	17.53	12.17	17.71
3	Particulate matter (PM_{10})	µg/m^3	52.12	63.62	59.85	54.77	62.24	65.7	68.90	82.87	62.68	58.85	74.14	56.61	47.62
4	Particulate Matter ($PM_{2.5}$)	µg/m^3	37.5	29.17	37.72	29.62	29.25	25.1	36.67	48.75	38.33	34.64	24.74	29.28	33.33
5	Carbon Monoxide (CO)	mg/m^3	5	4	9	9	8	9	6.0	7.0	6.0	5.0	8.5	5.8	8

AMBIENT AIR QUALITY OF THE STUDY AREA (CONTINUED)

Sl No	Parameters	Unit	Concentration of Pollution					
			Corridor-5					
			5A	5B	5C	5D	5E	5F
1	Sulphur Dioxide (SO_2)	µg/m^3	6.54	10.34	9.58	10.8	8.82	6.23
2	Nitrogen Dioxide (NO_2)	µg/m^3	9.66	14.67	13.60	15.38	9.35	9.48
3	Particulate matter (PM_{10})	µg/m^3	55.3	54.47	84.12	73.34	69.97	62.37
4	Particulate Matter ($PM_{2.5}$)	µg/m^3	28.46	26.28	41.67	33.96	25.14	29.16
5	Carbon Monoxide (CO)	mg/m^3	4	9	6	9	6	4

Corridor 3*- Madhavaram to SIPCOT,* ***Corridor 4****- Light House to Poonamallee Bypass,* ***Corridor 5****- Madhavaram-CMBT-Sholinganallur (3, 4, 5 – Represents Corridor number and A to G monitoring location at respective corridors). (Refer Table 15.3)*

TABLE 15.14: NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Time weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural &Other Area	Ecological Sensitive Area
Sulphur Dioxide (SO_2) μg/m3	Annual	50	20
	24 Hours	80	80
Oxides of Nitrogen (NO_2) μg/m3	Annual	40	30
	24 Hours	80	80
Particulate Matter (size less than 10μm) or PM_{10}μg/m3	Annual	60	60
	24 Hours	100	100
Particular Matter (size less than 2.5μm) or $PM_{2.5}$μg/m^3	Annual	40	40
	24 Hours	60	60
Carbon Monoxide (CO) mg/ m^3	8 Hours	02	02
	1 Hour	04	04
Ozone (O_3) μg/m^3	8 Hours	100	100
	1 Hour	180	180
Lead (Pb) μg/m^3	Annual	0.5	0.5
	24 Hours	1.0	1.0
Ammonia (NH_3) μg/m^3	Annual	100	100
	24 Hours	400	400

Source: CPCB guidelines for AAQM

15.3.4 Noise Environment

The noise data was collected at noise monitoring stations at hourly interval during morning, afternoon and evening such that peak and off peak hours are covered. Most of the stretch is along the existing road. There are 19 locations identified strategically for carrying out Noise monitoring along 3 corridors and the details are given in **Table 15.3** and the location in map shown in **Figure 15.1**. The hourly noise monitoring was carried out for 24 hours in the month of July 2016. The noise monitoring results are given in **Table 15.15.**

TABLE 15.15: AMBIENT NOISE LEVEL MONITORING RESULTS

Location	Leq	L_{10}	L_{50}	L_{90}	L_{max}	L_{min}	L_{day}	L_{night}	L_{DN}
Corridor-3*Madhavaram to SIPCOT,*									
3A	82.42	85.49	77	67.45	99.4	66.3	80.16	69.35	74.76
3B	75.52	79.54	73.34	68.10	80.07	67.35	75.96	69.09	72.52
3C	79.33	80.25	77.99	71.29	81.14	68.86	78.50	73.62	76.06
3D	75.93	80.44	72.49	66.07	80.77	64.55	74.64	70.02	72.33
3E	75.88	77.25	74.97	69.87	80.19	66.54	75.88	71.10	73.49
3F	81.82	79.35	75.36	59.66	81.51	59.33	76.77	64.34	70.56
Corridor-4 *CMBT to Light House*									
4A	72.45	74.90	72.03	69.88	75.98	68.23	72.92	70.85	71.89
4B	62.90	66.22	61.12	55.87	67.06	52.36	62.79	57.32	60.06

Location	Leq	L_{10}	L_{50}	L_{90}	L_{max}	L_{min}	L_{day}	L_{night}	L_{DN}
4C	72.07	76.63	66.81	58.87	77.20	57.66	70.80	59.90	65.35
4D	78.44	78.82	75.13	64.72	78.94	63.03	76.11	68.14	72.12
4E	75.07	75.21	74.99	73.08	75.35	72.62	75.02	74.00	74.51
4F	73.19	76.01	72.73	70.76	76.27	69.84	73.65	71.37	72.51
4G	84.34	81.45	78.97	63.49	82.54	58.91	79.42	66.57	73.00
Corridor-5, *Madhavaram CMBT Sholinganallur*									
5A	80.20	80.88	77.48	68.10	81.04	66.16	78.81	71.91	75.36
5B	72.34	72.90	69.65	60.21	73.36	59.11	70.70	62.30	66.50
5C	81.19	80.55	76.27	63.35	81.60	61.26	77.66	66.61	72.13
5D	76.78	79.04	75.47	70.16	79.91	70.00	76.39	73.22	74.80
5E	71.00	72.59	67.78	58.70	73.79	56.49	69.37	60.91	65.14
5F	66.55	72.68	63.59	59.35	80.68	57.25	66.13	63.14	64.64

3, 4, 5 – Represents Corridor number and A to G monitoring location at respective corridors). (Refer Table 15.3)

The Ambient Noise Quality standards laid down by CPCB has been given in **Table 15.16.** The Noise Monitoring results shows that noise level at all locations are exceeding the noise level standards prescribed by CPCB either day or night or both for Residential Zone, Commercial Zone and Silence Zone as well except it is within permissible limit at Sholinganallur Junction at night.

TABLE 15.16: AMBIENT NOISE STANDARDS

Area Code	Category of Area	Limits in dB (A) Leq	
		Day time*	Night time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence Zone**	50	40

Source: CPCB guideline(as per The Noise Pollution (Regulation and Control) Rules, 2000)

** Day timeis from 6.00 AM to 10.00 PM, ****Silence Zone** is defined as an area up to 100m around premises of Hospitals, Educational Institutions and Courts.*

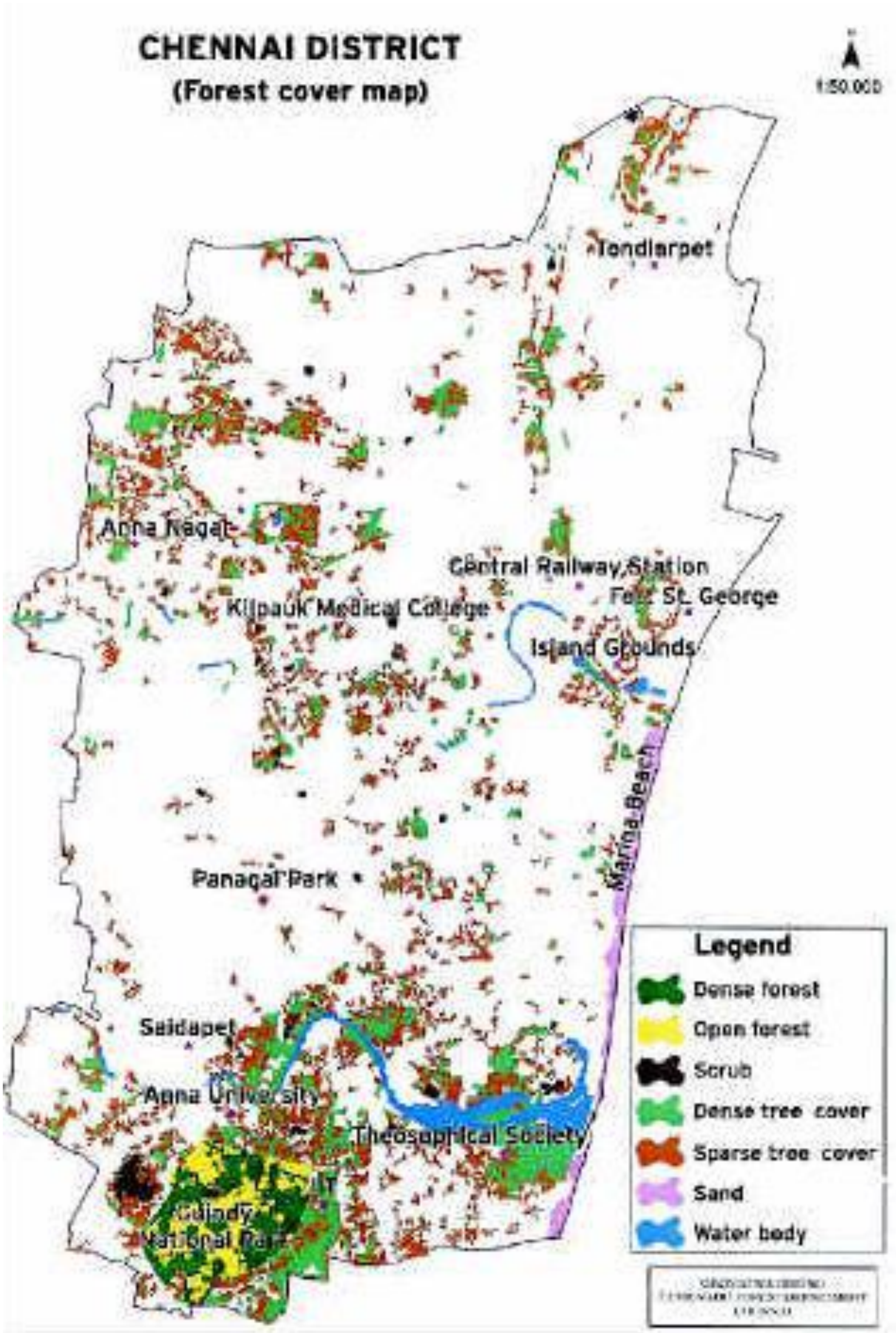
15.3.5 Ecological Environment

Forest: Chennai city today is devoid of any forest areas; however, many big parks are located in the city. Forest cover map of Chennai district is shown in **Figure 15.5**. About 662 m^2 (0.0662 hectare) area exists near proposed metro station Medavakkam Koot Road Bus Stop along Corridor-5.

Flora and Fauna: Tree survey was carried out along the proposed alignments. Most of the trees exist along the road on sides and median. The predominant tree species along the three corridors are given below (Local name- Botanical name);

1. Vembu- Azadirachta indica	*9.Vagai - Albizia lebbeck*
2. Vadam- Terminalia catapa	*10.Thennai - Cocos nucifera*
3. Nirkadambai - Neonauclea purpurea	*11. Shevaga - Morinda tinctoria*
4. Thoongu moonji - Albizia saman	*12. Nuna - Bombax malabarica*
5. Panei - Borassus flabellifer	*13. Arasu - Ficus religiosa*
6. Pungam - Pongamia pinnata	*14.Al - Ficus benghalensis*
7. Mayir Konnai - Delonix regia	*15. Ma - Mangifera indica*
8. Nettilingam- Polyalthia longifolia	

FIGURE 15.5: FOREST COVER MAP OF CHENNAI DISTRICT



An inventory of trees, along proposed three corridors is presented in **Table 15.17.**

TABLE 15.17: SUMMARY OF TREE INVENTORY

S. No	Description	Number of Trees
Corridor-3 (Madhavaram to SIPCOT)		
1	Alignment	376
2	SIPCOT Depot	10
	Sub-Total	**386**
Corridor-4 (Light House to Poonamalle Bypass)		
3	Alignment	140
	Poonamalle Bypass Depot	396
	Sub-Total	**536**
Corridor-5 (Madhavaram -CMBT -Sholinganallur)		
1	Alignment	580
2	Madhavaram Depot	541
	Sub-Total	**1121**
	Total	**2043**

Site construction activities will result in loss of trees about 2043. Trees of corridor 5 have been accounted in corridor 4 as some portion of which is overlapping on it. No rare or endangered species of trees were noticed during field studies. Common birds observed in the project area are pigeons, parrot, crows, and doves. The predominant mammals observed in the project area are mongoose, bat, Squirrel, monkey and mice etc. No rare or endangered species were noticed.

15.3.6 Archaeological Sites or Monuments

No archaeological monuments/sites are located on or along the proposed corridors.

15.3.7 Depots

Total three depots are proposed for the Chennai Metro Phase-II including extension of corridor 4. One depot is at Madhavaram of area 50 hectare including Property Development and staff quarters along corridor 5, minor depot at SIPCOT of area 4.5 hectare along corridor 3 and at Poonamalle Bypass having area of 15.4 hectare along corridor 4. Location of all these depots on google earth is shown in **Figure 15.6, Figure 15.7** and **Figure 15.8**.

FIGURE 15.6: LOCATION MAP OF MADHAVARAM DEPOT

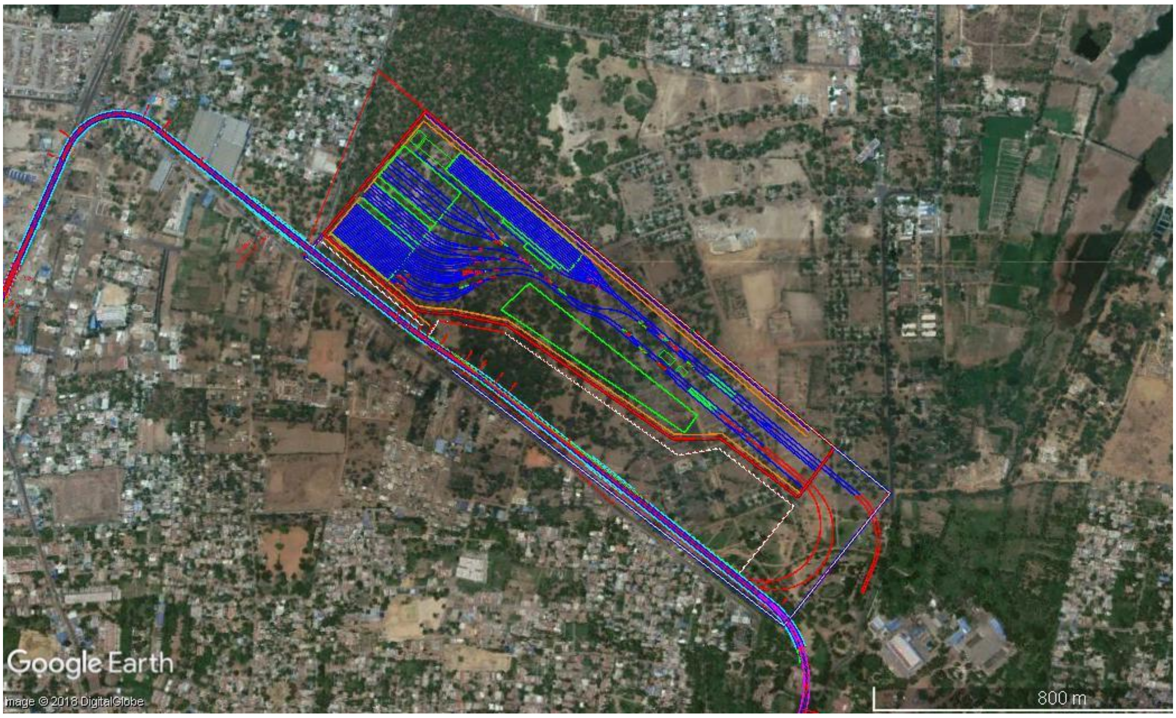


FIGURE 15.7: LOCATION MAP OF SIPCOT DEPOT

FIGURE 15.8: LOCATION MAP OF POONAMALLE BYPASS DEPOT

15.4 POSITIVE ENVIRONMENTAL IMPACT

Various positive impacts have been listed under the following headings:

- Employment Opportunities and benefits to Economy
- Direct benefits to passengers
- Traffic Noise Reduction
- Reduction of Traffic on Road
- Less Fuel consumption
- Reduced Air pollution

15.4.1 Employment Opportunities

During the period of construction manpower will be needed for various project activities. In post-construction phase, about 4165 people will be employed for operation and maintenance of the system. Thus, the project would provide substantial direct employment equal to the above number. In addition to these, more people would be indirectly employed in allied activities.

15.4.2 Benefits to Economy

The project will facilitate movement of people from different parts of Chennai. These corridors will yield benefits in terms of growth in economic activity due to better accessibility, savings in fuel consumption, corresponding reduction in cost of road construction and maintenance, reduction in vehicle operating costs, savings in travel time, and improvement in quality of life and reduction in loss of productivity due to health disorders resulting from pollution. However, in this study only savings in fuel consumption and resultant reduction in air pollution and GHG emissions have been quantified.

15.4.3 Direct Benefits to Passengers

The project will result in direct benefits to users of Metro and other modes: reduction in vehicle operating costs, savings in travel time, improvement in quality of life, reduction in loss of productivity due to health disorders resulting from pollution and reduction in road accidents.

15.4.4 Traffic Noise Reduction

A 50% reduction of the traffic volume may result in a 3 dB reduction in noise levels, regardless of the absolute number of vehicles. Reduction in traffic volume of 10% & 50%reduces noise at the tune of 0.5 dB & 3.0 dB respectively.

15.4.5 Reduction of Traffic on Road

The basis of reduction of vehicle is shift of ridership from road vehicle to the proposed system. The reduction in number of vehicles gives benefits to economy by reduction in Vehicle Operating Cost (VOC), Fuel Consumption, Pollution Load, Accidents and Travel Time etc. On implementation of the project, the consumption of petrol, diesel and CNG will get reduced significantly. The estimated daily vehicle-kilometer that will be reduced due to construction three corridors of metro rail are given in **Table 15.18.**

TABLE 15.18: REDUCTION IN DAILY VEHICLE KILOMETERS (IN LAKH)

Vehicle Type	2025	2035	2045	2055
Car	9.51	14.05	20.36	27.01
2 Wheeler	14.52	25.79	29.54	31.97
Auto Rickshaw (3W)	3.88	7.43	7.92	8.21
Bus	35.60	72.60	82.72	93.68

15.4.6 Less Fuel Consumption

Based on number of daily vehicle kilometre reduction, daily reduction in fuel (diesel and petrol) consumption is reported in **Table 15.19**. It is estimated that about 247.46 Million litres of diesel and 24.12 Million litres of petrol will be saved daily in year 2025. These reductions will increase to 652.30 Million litres of diesel and 61.13 Million litres of petrol in year 2055.

TABLE 15.19: DAILY REDUCTION IN FUEL CONSUMPTION (MILLION LITRES)

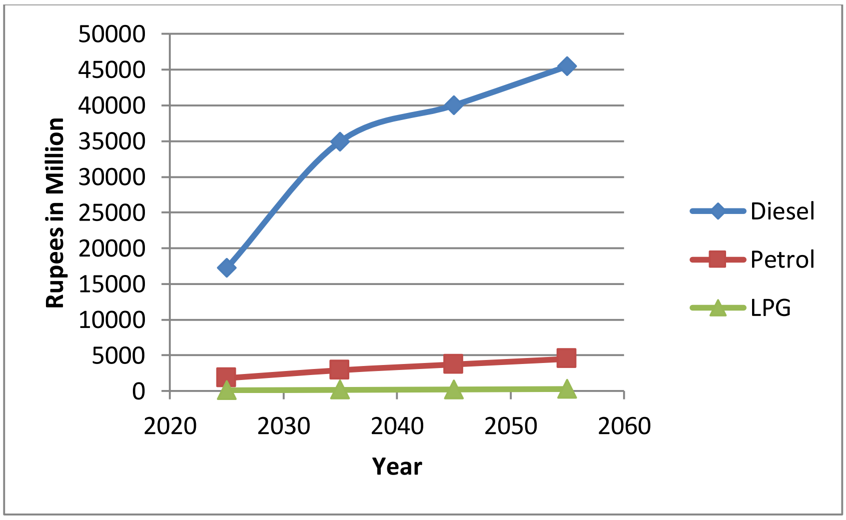
Fuel	2025	2035	2045	2055
Diesel	247.46	501.64	574.00	652.30
Petrol	24.12	39.40	50.48	61.13
LPG (Mkg)	1.95	3.02	4.13	5.29

The saving of Diesel and Petrol will directly benefit the country in monetary terms. Daily net saving on fuel expenditure at current price level is given in **Table 15.20** and graphically represented in **Figure 15.9**. The estimated total daily savings will be of about Rs 19117 Million in year 2025, Rs 38001 Million in year 2035, Rs 43918 Million in year 2045 and Rs 50219 Million in year 2055.

TABLE 15.20: DAILY NET SAVING ON FUEL EXPENDITURE (MILLION RS)

Fuel/Year	2025	2035	2045	2055
Diesel	17231	34929	39968	45420
Petrol	1785	2915	3735	4523
LPG	101	157	215	276
Total	19117	38001	43918	50219

FIGURE 15.9: NET SAVING ON FUEL EXPENDITURE (MILLION RS)



15.4.7 Reduced Air Pollution

Compared to other modes of transport, the metro is most environment friendly since no air emissions are involved in operating the metro trains. The major vehicular pollutants that define the ambient air quality are: Particulate matter, Nitrogen oxides, Carbon monoxide, Hydro Carbons and Carbon dioxide. In addition to the above pollution, un-burnt products like aldehydes, formaldehydes, acrolein, acetaldehyde and smoke are by products of vehicular emissions. The reduction of air pollutants with the present corridors are presented in **Table 15.21.**

TABLE 15.21: POLLUTION REDUCTION (TON/YEAR)

Pollutant	Year			
	2025	**2035**	**2045**	**2055**
CO	5966	11693	13489	15330
HC	687	1270	1459	1584
NOx	8106	16469	18781	21240
PM	332	666	761	855
CO2	1022903	2055788	2361557	2658221
Treatment cost (Rs)	20206	39794	46297	52300

15.5 NEGATIVE ENVIRONMENTAL IMPACTS

Negative impacts are 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.

15.5.1 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, and
- Impact on Historical and Cultural Monuments,

15.5.1.1 Project Affected People (PAPs)

People who have their properties along the alignment will be affected due to the acquisition of land for proposed metro corridors the details are given under head of Social Impact Assessment (SIA).

15.5.1.2 Change of Land use

Land will be required permanently for stations, depot, ramp and running sections. Both government and private land will be acquired for the project the detail of which is given in the section on civil engineering in the DPR. About 662m^2 forest land will be acquired near proposed metro station Medavakkam Koot Road Bus Stop on Corridor 5. This will be permanent land use change from forest land to non-forest use.

15.5.1.3 Loss of trees

The proposed corridors are in urban/city area except very small part of Corridor 5 which is passing through forest land. There are approximately 2043 trees which are likely to be cut during construction along the three proposed corridors and the three depot sites.

With removal of these trees, the process for CO_2 sequestration will get affected and the losses are reported below:

i.	Total number of Trees	:	2043
ii.	Decrease in CO_2 absorption due to loss of trees	:	6,129 kg/year
iii.	Decrease in Oxygen production due to tree loss	:	22,473 kg/year

The relative impact of urban forests and their management is much more significant for carbon dioxide than for oxygen (*Oxygen Production by Urban Trees in the United States, David J. Nowak, Robert Hoehn, and Daniel E. Crane, Arboriculture & Urban Forestry 2007*). From this study amount of oxygen produced per tree per year for urban forests was adopted as 11 kg. Based on model for tropical trees *(Tree allometry and improved estimation of carbon stocks and balance in tropical forests, J. Chave et al, Oecologia 2005)* and wood density for Asian species as per Food Agriculture Organization (FAO), CO2 sequestered per year per tree has been estimated for this report as 3 kg for typical tree of 30 cm girth.

15.5.1.4 Utility/Drainage Problems

The proposed Metro corridors are planned to run through the urban area above the ground i.e. elevated in less densely populated and underground in populated and sensitive areas. The alignment will cross drains, large number of sub-surface, surface and utility services, viz. sewer, water mains, storm water drains, telephone cables, overhead electrical transmission lines, electric pipes, 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.

15.5.1.5 Impact on Historical and Cultural Monuments

No archaeological monuments / sites are directly affected due to proposed project.

15.5.2 Impacts due to Project Design

Impacts due to project design are seen in following ways;

- Right of way
- Alignment and Architectural design
- Inter-modal integration
- Use of energy and water at stations
- Risk due to earthquake.

15.5.3 Impact Due to Project Construction

Environmental hazards related to construction works are mostly of temporary in nature; the most likely negative impacts are:

- Soil erosion
- Air pollution due to construction
- Noise Pollution and Vibration
- Impact due to land subsidence
- Impact due to Labour Camp
- Traffic diversions
- Vibration Impacts and Risk to existing buildings
- Muck disposal
- Transportation of construction material and soil
- Increased water demand
- Impact on Ground water and Surface water
- Impact due to Supply of Construction Material and
- Utility/Drainage Issues.

15.5.3.1 Soil Erosion

Run off from unprotected excavated areas, can result in excessive soil erosion, especially when the erodibility of soil is high. In general, construction works are stopped during monsoon season.

15.5.3.2 Air pollution due to construction

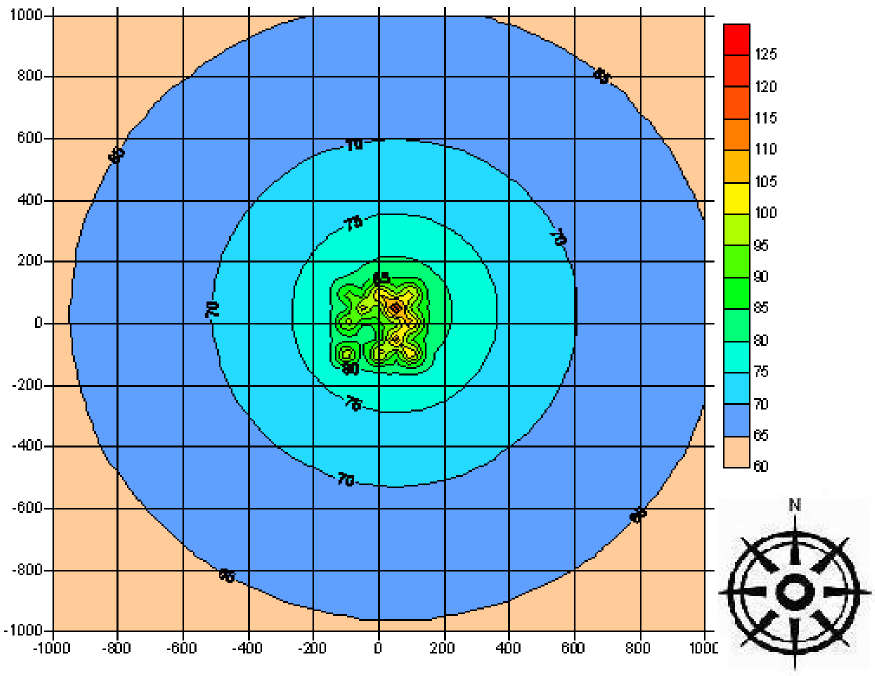
Air pollution occurs due to excavation, loading and unloading of construction materials, vehicular and construction equipment emissions and emission from the DG sets etc. Resulting pollution is short term.

15.5.3.3 Noise Pollution

Noise is a contributing factor to degradation of human health. The major sources of noise pollution during construction are movement of vehicles for transportation of material and equipment. Permitted number of impacts (example piling) at various noise levels are prescribed under Model Rules of the Factories Act, 1948. Actual noise from construction equipment (Lmax) measured at 50 feet distance (*Construction Noise Handbook August 2006, FHWA, USA*) ranged from 76 dB(A) to 84 dB(A); vibratory pile driver at 101 dB(A). The overall noise during construction will be for short-term (for day time).

Noise modelling during construction phase was carried out using CPCB/MoEFCC approved noise model "DHWANI" assuming that all the equipment emit noise simultaneously considering as worst-case scenario. The spatial variation of the predicted noise levels at an interval of 5 dB (A) without control around the project site on the area of 1 km x 1 km are shown in **Figure 15.10**.

FIGURE 15.10: SPATIAL VARIATION OF CONSTRUCTION EQUIPMENT NOISE LEVELS dB(A)



Modelling result shows that noise level meets the Ambient Noise Quality Standards (ANQS) 55 dB (A) (average between 6 am to 10 pm) at a distance of about 900 m. Uncontrolled noise levels generated from construction equipment, in the range of 94-124 dB (A) have been considered for prediction purpose. However, the CPCB standards specified for limited construction equipment reflect that noise emission specifications for such equipment should not exceed 75 dB (A). The noise levels predicted here is without mitigation measures. It is assumed that with the adoption of the mitigation measures noise levels will be further restricted within very short distances from the source. With respect to occupational exposure, the permissible threshold is 90 dB (A) (continuous exposure over 8 hours). Thus, based on the modelling results it can be concluded that all sensitive receptors (i.e. labour colonies) should be located beyond 125 meters from the noise generating source location during construction activities.

15.5.3.4 Impact due to Land Subsidence

Land subsidence is anticipated at stations which will be constructed by cut and cover method. Suitable measures including maintaining adequate distance of the trench from existing structures adjacent the trench, measures to support the walls of the trench as well strengthen soil underneath adjacent structures will be required.

15.5.3.5 Impacts due to Labour Camps

Improper disposal of municipal solid waste generated by labour camps can pollute surface water bodies and groundwater. Burning of waste can cause air pollution. Construction workers are more prone to infectious diseases due to unsafe sexual activity and lack of sanitation facilities (water supply and human waste disposal) and insect vectors. Problems could arise due to cultural differences between workers from outside and local residents.

Based on recent metro construction practices observed in India. It is estimated that about 12650 persons comprising skilled labour (7150) and unskilled labour (5500) will work during peak construction activity on 50% sections of the three Metro corridors on site, in casting yards and depots. Assuming that 30% labour are local (Chennai) and remaining 70% unskilled workers live at the labour camps and 80% of them are married of whom 80% have average family size as 4. Hence, total population in the labour camps will be 11242. The water requirement at camps will be 1517 KLD, waste water generation will be 1214 KLD & municipal solid waste generation will be 3373 kg per day. This will vary depending on the construction schedule during construction.

15.5.3.6 Traffic Diversions

During construction period, complete/partial traffic diversions on road will be required, as most of the construction activities are on the road. Preparation of traffic diversion plans and cost of their implementation form part of the section on Engineering.

15.5.3.7 Vibration Impacts and Risk to Existing Buildings

As per *RDSO (Research Designs and Standards Organization) Guidelines 2015*, vibration studies have to be conducted along the corridors to determine the extent of impacts. Pile driving for piers and tunnel driving generate vibrations. Vibration is pronounced in section of hard rock. Apart from distance from the alignment, age and condition of buildings adjacent to the alignment determines extent of damage to such buildings due to vibration. Continuous effect of vibration on the buildings can cause damage to buildings. Buildings subjected to the vibration of more than 150 VdB might be subjected to structural damage. Historic buildings are more susceptible to vibration effect due to type of building material and design. If significant impacts are expected, mitigation measures have to be implemented and building condition survey have to be conducted before and during construction. Cost of such building condition survey can be estimated after vibration study is conducted and structures falling within likely corridor of impacts are identified.

15.5.3.8 Muck Disposal

The metro lines are a mix of elevated and underground right of way. The construction activity involves cut and cover, tunnel, fill and embankment. All these activities will generate about 10.69 million cubic metre (Mm^3) of soil. Out of this, about 1.48 Mm^3 is likely to be reutilized in backfilling in underground stations and depots. The balance 9.21 Mm^3 shall be disposed of in environmental friendly manner. The soil disposal site will be identified by Project Authority/CMDA such that displacement of persons is not involved.

15.5.3.9 Pollution due to Transportation of Construction Material and Soil

Trucks and cranes are required to transport civil construction material from pre-cast yards and batching plants to construction site and between construction site and soil disposal site/source. These activities including muck disposal may generate dust due to vehicle movements which is estimated as 32 tons during total construction period for all three corridors. During the period of construction, an emission due to truck movement on account of transportation of civil construction material and disposal/backfill of earth is estimated for various parameters are given in **Table 15.22.**

TABLE 15.22: POLLUTION DURING CONSTRUCTION (TON)

Pollutant	Corridor 3	Corridor 4	Corridor 5
Carbon Monoxide (CO)	62.36	30.77	38.89
PM $_{2.5}$	2.78	1.37	1.73
Hydro-Carbons (HC)	2.78	1.37	1.73
Nitrogen Oxide (NOx)	129.53	63.91	80.78
VOC	20.36	10.05	12.70
Carbon dioxide (CO_2)	8049.53	3971.83	5020.07

15.5.3.10 Increased Water demand

The demand for water and energy will increase during construction phase. Water consumption during construction is of the order of 2198 KLD.

15.5.3.11 Impact on Ground and Surface Water

Ground water contamination can take place if chemical substances get leached by precipitation of water and percolate to the ground water table. Dumping of construction materials which could result in hazardous leachate percolating into ground water; dumping of used water from the RMC plant; oils and greases from construction sites and labour camp are sources of water pollution.

15.5.3.12 Impact due to Supply of Construction Material

The procurement source of the construction materials will be decided by the Contractor, but it will be from existing licensed supplier. Sites of material stockpile will be decided before start of construction. Stockpile site will be part of construction area which will be temporarily acquired from its owner like Municipal Corporation etc.

15.5.3.13 Utility/Drainage Issues

The alignment will cross utility services, viz. sewer, water mains, storm water drains, telephone cables, electrical transmission lines, etc. Lack of scheduled utility support and diversions during construction will damage utilities; lead to flooding due to disruption of drainage; lead to pollution of water supply with sewage and safety risks like electrocution etc.

15.5.4 Impacts Due to Project Operation

Along with many positive impacts the project may cause the following negative impacts during operation of the project:

- Noise pollution,
- Vibration,
- Energy supply at stations,

- Water supply and Sanitation at Stations,
- Pedestrian and Traffic Congestion around stations,
- Impacts due to Depot.

15.5.4.1 Noise Pollution

Noise radiated from train operations and track structures generally constitute the major noise sources. Airborne noise is radiated from at-grade and elevated structures, while ground-borne noise and vibration are of primary concern in underground operations. Basic sources of wayside airborne noise are:

- Wheel / Rail Noise: Due to wheel /rail roughness
- Propulsion Equipment: Traction motors, cooling fans for TM, reduction gears etc.
- Auxiliary Equipment: Compressors, motor generators, brakes, ventilation systems, other car mounted equipment

Predicted noise levels for the project area were modelled in accordance with the Federal Transit Administration (FTA) guidelines. Predicted future noise levels in the project area were based on existing measured sound levels and future daily metro rail operations. To provide a baseline for the analysis of potential noise effects caused by the metro operations, 24-hour measurements were conducted at 19 sites along the metro corridors, which include residences and other buildings. For the calculation purpose monitoring locations has been considered as receptor on each corridor (Ref Figure 15.1).

Table 15.23 lists the factors of Metro Rail operations considered for predicting noise level at the 19 identified receptor locations.

The predicted noise levels were compared to norms to determine if there would be No Effect, Moderate Effect, or Severe Effect. The status is presented in **Table 15.23**.

TABLE 15.23: OPERATIONAL FACTORS FOR NOISE PREDICTION

Corridor	Train Type	Train Speed (Kmph)	Length of Train (m)	Length of Power Unit (m)	Length of Leading unit (m)	Track Configuration	Trains per Hour per direction	Trains per day (7Am-10Pm)	Trains per Night (10Pm-7 Am)
Corridor-3	Electric	34	150	25	25	Viaduct	6	90	Nil
Corridor-4	Electric	34	150	25	25	Viaduct	10	150	Nil
Corridor-5	Electric	34	150	25	25	Viaduct	8	120	Nil

TABLE 15.24: NOISE LEVELS AT RECEPTORS DUE TO METRO TRAIN OPERATIONS

S No.	Receptor Location	Receptor Distance from Corridor (m)	Existing Ld	Project Noise Exposure (Ld)	Combined Noise Exposure (Ld)	Project Noise Effect
Corridor-3						
1	Mulakkadai to Madhavaram Milk colony (Tapalpetti Bus stop)	40	80.16	52.52	80.17	Low
2	Purasaivalkam (Tank Bus stop	469	75.96	36.49	75.96	Low
3	Good Shepherd school	67	78.50	49.17	78.51	Low
4	Royapetai Government Hospital	266	74.64	40.18	78.50	Low
5	MGR Janaki College	65	75.88	49.35	75.89	Low
6	Sholinganallur Junction	92	76.77	47.09	76.77	Low
Corridor-4						
7	At Crossing of NH 4 Bypass & Poonamalee Flyover	25	72.92	58.55	73.08	Low
8	Near Kumunanchavadi Bus Stop, MSS Nagar	12	62.79	61.74	65.31	Low
9	Near Porur Lake, Padmavati Nagar	27	70.80	58.22	71.03	Low
10	Permal Street, Shradha Nagar	14	76.11	61.07	76.24	Low
11	Vadapalani Junction	50	75.02	50.02	75.03	Low
12	Kodambakkam Meenakshi College	22	73.65	55.34	73.73	Low
13	Santhome Church	48	79.42	51.83	79.43	Low
Corridor-5						
14	Srinivas Nagar	22	78.81	56.96	78.33	Low
15	Anna Nagar West	197	70.70	42.72	70.71	Low
16	Alwar Thirunagar Junction	99	77.66	47.19	77.66	Low
17	MIOT Hospital	38	76.39	53.46	76.41	Low
18	Medavakkam Junction	90	69.37	47.19	69.40	Low
19	Global Hospital	529	66.13	36.28	66.13	Low

Based on the noise modelling results it can be inferred that the effect of predicted day-time noise level has low impact with respect to the existing ambient noise environment.

15.5.4.2 Vibration

Passing of trains on elevated section as well as underground section causes vibrations. The dominant component of vibration due to passing on elevated section is horizontal while in tunnel vertical component is dominant. Impact is more in solid rock.

15.5.4.3 Energy Supply at Stations

- Disaster management, and
- Emergency measures.

Use of full height platform screen doors in underground stations has been proposed. This is estimated to result in savings of about 40% in expenditure on energy consumption in underground stations.

15.5.4.4 Water Supply and Sanitation at Stations

The water demand at station comprising drinking, toilet, cleaning and air conditioning in Chennai will be of the order of magnitude indicated in **Table 15.25.** The water requirement for the stations will be met through the public water supply system. Municipal water supply will be supplemented by rain water harvesting along viaduct and at elevated stations.

TABLE 15.25: WATER REQUIREMENT

S. No.	Particular	Water Demand at Each Station (KLD)	Total Water Demand (KLD)
1	In Underground stations with softening plant	85	4080
2	In Elevated stations	16.6	1328
		Total	**5408**

Solid waste generation from operational staff at stations is likely to be 38 ton per month. Sewage at stations is estimated to be 4948 KLD. This will be led into the municipal network.

15.5.4.5 Pedestrian and Traffic Congestion

Commencement of metro services results in passenger rush at stations which in turn results in congestion around stations. Essentially, the decongestion scheme should involve setting up of taxi and auto rickshaw stands, a halting space for public buses and other such facilities.

15.5.5 Impacts Due to Depot

The earth from underground metro corridor tunnelling and cut & cover will be utilised to fill the depot sites. Issues to be addressed at depot sites are water supply, sewage and effluent disposal, oil pollution, noise pollution, surface drainage, solid waste disposal, and felling of trees.

Water Supply: As per the Indian Railway Works Manual, the water demand for train washing (Departments, workshop and Contractor office) is 3600 liter per day. A three day cycle is assumed for train washing at depot. The water demand at Madhavaram and Poonamalle Bypass Depot would be about 742 KLD, 216 KLD for train washing and 59 KLD, 70 KLD for domestic purpose including staff quarters respectively. Water demand will be about 1.5 KLD for office use at SIPCOT minor depot.

Sewage and Effluent: About 53 KLD, 63 KLD sewage from domestic activities and 593 KLD, 173 KLD effluent from train washing will be generated at Madhavaram Depot and Poonamalle Bypass Depot respectively. About 1.4 KLD sewage from office activities is estimated to be generated at SIPCOT minor Depot.

Oil Pollution: Oil spillage during change of lubricants, cleaning and repair processes, in the maintenance Depot cum workshop for maintenance of rolling stock, is very common. The spilled oil should be trapped in oil and grease trap. The collected oil would be disposed off to authorised collectors, so as to avoid any underground/ surface water contamination.

Noise Pollution: The main source of noise from depot is the operation of workshop. The roughness of the contact surfaces of rail and wheel and train speed is the factors, which influence the magnitude of rail - wheel noise.

Surface Drainage: Due to the filling of the low-lying area for the construction of depots, the surface drainage pattern may change specially during monsoon. Suitable drainage measures form part of the engineering cost.

Solid Waste: Sludge will be generated from ETP/STP, oil, grease and metal shavings will be produced from car maintenance. It is estimated that municipal solid waste of about 3.6 ton per month, 0.72 ton per month and 0.27 ton per month will be generated from Madhavaram Depot, Poonamallee Bypass Depot and SIPCOT Depot respectively.

Felling of Trees: About 541 numbers of tree are observed at Madhavaram Depot, 396 at Poonamalle Bypass Depot and about 10 trees at SIPCOT DEPOT. These trees are tree likely to be cut; afforestation cost is given in the Environmental Management Plan.

Loss of livelihood: Loss of livelihood if any is dealt in SIA section.

15.6 ENVIRONMENTAL MANAGEMENT PLAN (EMP)

The aim of mitigation measures is to protect and enhance the existing environment of the project. This section includes measures for:

- **Location and Design:** Compensatory Afforestation, Diversion of Forest Land, Right of Way, Alignment and Architecture, Spatial Planning of stations and Inter-Modal Integration, Provision of Green Building, Use of Energy and Water, and Risk Due to Earthquake.

- **During Construction:** Construction Material Management and Housekeeping, Hazardous Waste Management, Construction and Demolition Waste management, Energy Management, Labour Camp, Welfare and Safety of Labour, Utility Plan, Air Pollution Control Measures, Noise Control Measures Vibration Control Measures, Traffic Diversion/Management, Soil Erosion Control, Muck Disposal and dewatering of underground works.

- **During Operation:** Noise Management, Water Supply and Sanitation at stations, Electromagnetic Interference, Rain Water Harvesting, Management Plan for Depot and Training & Extension

15.6.1 For Location and Design

15.6.1.1 Compensatory Afforestation

Removal of air pollutants: Particulate matter in the atmosphere is intercepted by tree canopy. The particulates are retained on the plant surface or washed off by rain or dropped to ground with leaf fall. Urban trees have been found to remove PM10 and PM2.5 particulates from the atmosphere. Benefits in terms of reduced mortality. Removal of PM2.5 is lower than removal of PM10 but the health benefits are higher. *(Modeled PM2.5 removal by trees in ten US cities and associated health effects, David J Nowak, Satoshi Hirabayashi, Allison Bodine, Robert Hoehn, Elsevier, Environmental Pollution 178 (2013) 395-402).*

Ambient concentrations of SO2 was found to reduce by 39%, NOx by 40%, SPM by 37%, THC by 86%, CO by 93%, VOCs by 87.1% across the green belt and the overall air pollutant removal efficiency was calculated as 63% *(Assessment of Carbon Sequestration Ability of Trees for Adopting in Green Belt of Cement Industries in Karnataka, March 2016, Central Pollution Control Board Zonal Office South.*

Location for afforestation will be decided by CMRL in consultation with owner of the land as well Forest Department such that displacement does not become necessary.

Increase in groundwater recharge : Quantity of rainfall percolating to a specified depth of soil was found to decrease with distance from canopy edge towards with minimum percolating quantity in open area. Soil infiltration is improved near trees due to litter and tree roots promoting activity of earthworms, insects etc. resulting in increased soil macro porosity. Under conditions where surface runoff of rain water is redistributed towards trees, net water stored in soil near trees increases. In case of trees in which at least 25% of their water intake from soil is from depth greater than 1.5m, 10 trees per hectare with canopy cover 5% provide the highest groundwater recharge: tree density greater than this optimal cover showed reduced groundwater recharge. *(Intermediate tree cover can maximize groundwater recharge in the seasonally dry tropics, U. Llstedtetal, February 2016, www.nature.com).*

The Department of Forests, Government of Tamil Nadu is responsible for the conservation and management of trees/forests in the project area. According to the results of the present study, it is found that about 2043 trees are likely to be lost along the three corridors and three depots. It is proposed to plant twelve saplings for each tree to be cut. Hence 24516 trees need to be planted. Estimated compensatory afforestation cost is about **Rs 72.95 Lakh** for Corridor-3, **Rs 101.30 Lakh** for Corridor-4 and **Rs 211.87 Lakh** for Corridor-5. The afforestation cost for SIPCOT Depot is considered in Corridor 3, Poonamalle Bypass Depot in Corridor 4 and Madhavaram Depot is in Corridor 5. Native plant species are recommended for afforestation.

15.6.1.2 Diversion of Forest Land

Forest area of 0.066 Ha (662 m^2) needs to be diverted for the construction near proposed metro station Medavakkam Koot Road Bus Stop on Corridor-5. The cost to be provided for in case of diversion of forest land for non-forest purposes comprises three components i.e. a) NPV value of forest land, b) cost of non-forest land transferred to forest department and c) cost of development of non-forest land for forest purpose.

a) Net Present Value (NPV): The net present value of 0.066 Ha of forest land diverted falls in category Tropical and Subtropical Dry Evergreen Forests & which is open forest. NPV of 0.066 Ha of forest land diverted was calculated *(Revision of rates of NPV applicable for different class/category of forests- November 2014)* as **Rs 0.68 Lakh**.

b) As per norms, two times of diverted land is to be made available to forest department for development of forest. Thus, the land of 0.132 Ha will be given to forest department, cost of which is not included in the project cost because this transfer of land will be done on intra-government basis.

c) The estimated cost of development of 0.132 Ha non forest land for forest purpose is **Rs 2.50 Lakh**.

The Department of Forests is responsible for the conservation, maintenance and management of trees/forests/wildlife in the project area for which a total amount of **Rs 3.18 Lakh** will be transferred to CAMPA Fund for forest land diversion.

15.6.1.3 Right of Way, Alignment and Architecture

Alignment is kept elevated where adequate width of right of way on roads is available. Viaduct and elevated stations shall be shaped to minimize visual intrusion.

15.6.1.4 Spatial Planning of Stations and Inter-Modal Integration

Adequate and well-laid out space shall be designed for concourses and platforms, escalators, elevators and staircases, lighting, turnstiles for normal and abnormal operating conditions; optimal height / depth of the stations, forced ventilation shall be provided. Physical and operational integration of metro with other modes shall be planned. Adequate design of stations and multimodal integration prevents and mitigates congestion at stations. Safety is improved.

15.6.1.5 Provision for Green Buildings

In accordance with the *GRIHA (version 2015)* norms, the following measures shall be implemented to a feasible degree in the stations and depots.

- Control annual heat gain through favorable orientation and design of facades and trees

- Site planning according to contours
- Site plan designed to preserve existing vegetation/ existing water bodies /other topographical features like boulders etc.
- Manage storm water on site through rain water harvesting

Mitigate heat island effect by ensuring that building surface visible to sky is shaded by trees. Ensure zero SWD post-construction by means of ground water recharge and recharge of groundwater aquifers by rainwater. The building shall be designed to incorporate low ODP materials, indoor air quality and comfort, low-VOC paints and adhesives, reduced landscape water demand, sustainable building materials and renewable energy utilization etc.

For the utilization of renewable energy, wherever feasible, installations for solar power can be implemented on roof of elevated stations. Solar energy generation per year is estimated to be 15.69 Giga-watt-hr for Corridor 3, be 4.91 Giga-watt-hr for Corridor 4 and 7.18 Giga-watt-hr for Corridor 5. The installation cost for solar system is about **Rs 885 Lakh**, Rs 277 Lakh and **Rs 405 Lakh** for Corridor 3, Corridor 4 and Corridor 5 respectively. However this cost is not included in the estimated cost of EMP and thereby in cost estimate of the project since installation and maintenance of solar power infrastructure is proposed to be awarded to developer along with Power Purchase Agreement (PPA). The power shall be purchased by CMRL on the basis of the unit rate specified by Power Purchase Agreement (PPA).

15.6.1.6 Use of Energy and Water

Requirement of electrical energy for climate control, lighting and other facilities at stations shall be optimized by proper use of natural day/night light and design of passenger flow inside stations and on streets outside stations. Timer circuits and occupancy sensors that switch lamps off during room vacancy times, photoelectric sensors that sense the amount of daylight in the room and either switch lamps on or off or adjust the lamp brightness can be used where appropriate.

The water requirement for stations will be met through the municipal water supply system; in depots water will be sourced from municipal supply and recycled sewage. Municipal water supply will be supplemented by rain water harvesting along viaduct and at elevated stations and in depots. Sewage from stations will be led into municipal network; in depots sewage will be recycled for horticulture.

15.6.1.7 Risk Due to Earthquake

Station design shall be done to facilitate quicker emergency evacuation. Stipulation of Bureau of Indian Standards codes shall be met while designing the structures. It is understood that such measures have already been taken in construction of Phase I Metro.

15.6.2 During Construction

Measures to mitigate impacts observed during construction shall be implemented by Contractor and duly monitored by Owner in accordance with approved method statements. Their cost forms part of engineering and track cost.

15.6.2.1 Construction Material Management and Housekeeping

Procedures for storage, handling and transport of construction material shall be prescribed in SH&E method statement approved for construction.

Some of the housekeeping measures are listed below:

- Full height fence, barriers, barricades etc. shall be erected around the site in order to prevent the surrounding area from excavated soil, rubbish etc,
- 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.
- Proper and safe stacking of material at yards, stores and such locations 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.

15.6.2.2 Hazardous Waste Management

Classification of waste as Hazardous shall be in accordance with the Hazardous and Other Wastes (Management, Handling & Trans-boundary movement) Rules 2016. The contractor shall file Application for obtaining authorization. Hazardous waste would mainly arise from the maintenance of equipment which may include used engine oils, hydraulic fluids, waste fuel, spent mineral oil/cleaning fluids from mechanical machinery, scrap batteries or spent acid/alkali, spent solvents etc.

It shall be the responsibility of the contractor to ensure that hazardous wastes are labeled, recorded, stored in impermeable containment and for periods not exceeding mandated periods and in a manner suitable for handling storage and transport. The contractor shall approach only Authorized Recyclers for disposal of Hazardous Waste, under intimation to the Project Authority.

15.6.2.3 Construction and Demolition Waste Management

C&D waste generated from metro construction has potential use after processing and grading. The construction contractor is required to take the following measures in accordance with Construction and Demolition Waste Management Rules 2016.

- Segregation and temporary storage of reusable and recyclable materials at identified locations. Transport recyclable materials to construction sites.
- sale of metal scrap and other saleable waste to authorized dealers
- The construction and demolition waste generated should be disposed at site identified by CMRL away from any water body or river bank.
- Identification of intended transport means and route.
- Obtaining permission, where required, for disposal.

Sites for waste disposal will be decided by CMRL before start of construction in consultation with respective authority like Municipal Corporation etc. such that the sites are away from residential areas and do not require displacement.

15.6.2.4 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 the request of officer of the Project Implementation Unit.

Measures to conserve energy include the following:

- Use and maintenance of energy efficient lamps, tools, plants and equipment.
- Engine of DG set to comply with CPCB norms
- Promoting employees awareness and training on energy conservation.

15.6.2.5 Labour Camp

The Contractor during the progress of work will provide, erect and maintain necessary (temporary) living accommodation and ancillary facilities for labour.

Water supply, waste water and sewage treatment: Uncontaminated water for drinking, cooking and washing, health care, latrines and urinals, system for conveyance, treatment and disposal of sewage and solid waste shall be provided. Adequate washing and bathing places shall be provided, and kept in clean and drained condition. Water required for drinking, washing and other uses will be procured from municipal authorities. Wastewater will be discharged to the existing sewage network.

Solid Waste Management: Garbage bins must be provided in the camp and regularly emptied and the garbage disposed of in a hygienic manner. Solid waste generated will be collected and transported to local municipal bins for onward disposal to disposal site by municipality.

Shelter at Workplace: At every workplace, shelter shall be provided free of cost, separately for use of men and women labourers. The height of shelter shall not be less than 3m from floor level to lowest part of the roof. Sheds shall be kept clean and the space provided shall be on the basis of at least $0.5m^2$ per head.

Canteen Facilities: A cooked food canteen on a moderate scale shall be provided for the benefit of workers. The contractor shall conform generally to sanitary requirements of local medical, health and municipal authorities.

First aid facilities: At every workplace, a readily available first-aid unit will be provided. Suitable transport will 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 made so as to enable women workers to leave behind their children. At construction sites where 20 or more women are ordinarily employed, there shall be provided at least one temporary structure with sufficient openings for light and ventilation for use of children under the age of 6 years belonging to such women. There shall be adequate provision of sweepers and maidservants to keep the places clean. Size of crèches shall vary according to the number of women workers employed.

Health care awareness and clinics: Construction workers are more prone to Infectious diseases such as HIV/AIDS. It should be prevented by following actions: Counselling, community events, clinic, co-ordination with local health authorities.

15.6.2.6 Welfare and Safety of Labour

Construction works shall be executed as laid down in the Safety Health and Environment (SHE) manual prepared by the Contractor and approved by CMRL.The construction works shall be undertaken in accordance with all applicable legislation and Indian statutory requirements and guidelines-OHSAS 18001-1999: Occupational Health and Safety Management System and ISO 14001-2004: Environmental Management Systems.

Workplace safety and occupational health shall be ensured with special focus on the areas like Housekeeping, Lighting, Ventilation and illumination, Exposure of worker to use of exhaust or harmful gases in confined locations, Fire prevention, protection and fighting system, Demolition, Excavation and Tunnelling, Medical Facilities on site : Occupational Health Centre, Ambulance van and room HIV/ AIDS prevention and control, Exposure to Noise – prevention measures and Welfare measures for workers: latrine, canteen, drinking water, living accommodation, crèches etc.

15.6.2.7 Utility Plan

Prior to the execution of work at site, detailed investigation of all utilities will be undertaken and plans for their retention in situ with precautions or temporary/permanent diversions prepared and got approved by respective agencies. Utility services shall be kept operational during the entire construction period and after completion of project.

15.6.2.8 Air Pollution Control Measures

During the construction period, the impact on air quality will be mainly due to increase in Particulate Matter (PM) along haul roads and emission from vehicles and construction machinery. Mitigation measures which shall be adopted to reduce the air pollution are presented below:

- The Contractor shall take all necessary precautions to minimize 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.

- 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.
- To extent feasible site shall be wetted during excavation and demolition
- Dust screens will be used 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.

15.6.2.9 Noise Control Measures

There will be an increase in noise level in the ambient air due to construction and operation of the Metro corridors. Exposure of workers to high noise levels need to be minimized by measures such as the following:

- Placing of temporary noise barriers
- Use of electric instead of diesel powered equipment and hydraulic tools instead of pneumatic tools
- Acoustic enclosures for construction equipment like DG sets
- Scheduling work to avoid simultaneous activities that generates high noise levels
- Job rotation and protective devices
- Sound proof control rooms etc.

15.6.2.10 Vibration Control Measures

Vibration can be reduced by minimizing surface irregularities of wheel and rail by welding and grinding, improving track geometry, providing elastic fastenings, and separation of rail seat assembly from the concrete plinth with insertion of resilient and shock absorbing pad.

For locations where the alignment is close to sensitive structures, it shall be ensured that pre-construction structural integrity inspections of historic and sensitive structures and monitoring during construction are conducted.

15.6.2.11 Traffic Diversion/Management

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, traffic segregation, one-way movements, traffic diversions, acquisition of service lanes, etc. Various construction technologies like cut and cover can be employed to ensure that traffic impedance is minimized.

15.6.2.12 Soil Erosion Control

The surface area of erodible earth material exposed by clearing and grubbing, excavation shall be limited to the extent practicable. Works such as construction of temporary berms, slope drains and use of temporary mulches, fabrics, mats, seeding, or other control devices or methods as necessary to control erosion shall be implemented. Mitigation measures include careful planning, timing of cut and fill operations and re-vegetation. In general, construction works are stopped during monsoon season.

15.6.2.13 Muck Disposal

Owing to paucity of space and for safety reasons, measures need to be adopted for collection, transfer, temporary storage/dumping and disposal of excavated muck. Dumping areas are essential to store the excavated earth temporarily for back filling at later date and final disposal. Sites for muck disposal will be decided by CMRL before start of construction in consultation with respective authority like Municipal Corporation etc. such that the sites are away from residential areas and do not require displacement.

To mitigate these problems following mitigation measure are proposed to be adopted:

- The disposal sites will be cleaned and then treated so that leached water does not contaminate the ground water.

- Material will be stabilised each day by watering or other accepted dust suppression techniques. The muck shall be filled in the dumping site in layers and compacted mechanically.
- Stock piling of earth with suitable slopes.
- Once the filling is complete, the entire muck disposal area shall be provided with a layer of good earth on the top and covered with vegetation.
- Before excavation, the Contractor will be required to test the soil quality including heavy metals and the results will be compared with US EPA standards. If the soil is contaminated, the polluter will be responsible for treatment and disposal.

15.6.2.14 Dewatering of underground works

Problems of water flow associated with tunnelling are bound to take place where water table is low. The dewatering can be achieved by drains, sumps and wells. The pumped water from sump wells will be put into storm water drain. Seepage water will be drained along the side of walls into sumps. It can be either re-used for construction purposes or discharged to the drainage system or used to recharge the ground water.

15.6.3 During Operation

15.6.3.1 Noise management

The ballast-less track supported on two layers of rubber pads can reduce track noise and ground vibrations. In addition, providing skirting of coach shell covering the wheel will screen any noise coming from the rail wheel interaction as of propagating beyond the viaduct.

Screening of noise can be ensured by providing parabolic noise barriers on each side of the track along the curved portion of the viaduct and at stations during operation. Polycarbonate noise barriers 15 mm to 25 mm are known to reduce noise level by between 30 dB to 33 dB. The estimated cost of noise barriers is about **Rs 117.60 Lakh** for Corridor-3 and **Rs 387.03 Lakh** for Corridor-5.

15.6.3.2 Water Supply and Sanitation at Stations

Water supply for drinking, washing of stations, air conditioning and other uses will be procured from municipal authorities. Municipal water supply will be supplemented by rain water harvesting along viaduct and at elevated stations. Wastewater from station will be discharged to the existing sewage network. Toilets will be provided for staff as part of station layout. Non-hazardous solid waste generated in stations will be collected and transported to local municipal bins for onward disposal to disposal site by municipality.

15.6.3.3 Rain Water Harvesting

To conserve and augment the storage of groundwater, it is proposed to construct roof top rainwater harvesting structure of suitable capacity at the elevated stations and in the elevated alignment. Each pillar can have inbuilt downpipes to collect the rainwater from the viaduct and into the underground tanks; a recharge tank shall be constructed at suitable distance; water collected will percolate down to the subsoil through layers of sand, gravel and boulders. Average annual rainfall of Chennai is 1541 mm. Considering a runoff coefficient of 0.85 the annual rainwater harvesting potential of elevated stations and viaduct for all three corridors is estimated as 12,57,618 cubic meter per year. Estimated cost for rainwater harvesting for viaduct and elevated stations is **Rs 336.60 Lakh** for Corridor-3, **Rs 343.27 Lakh** for Corridor 4 and **Rs 749.64 Lakh** for Corridor-5.

15.6.3.4 Electromagnetic Interference

Detailed specification of equipment e.g. power cables, rectifiers, transformer, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a complete vehicle (trains, signalling & telecommunication, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121-3-1, EN50123, IEC61000 series etc. EMC requirements of international standards for whole railway system to the outside world shall comply with EN50121-2.

15.6.3.5 Management Plan for Depot

Three maintenance depots are planned for Chennai Metro Phase-II. These are i) Madhavaram Depot, ii) Poonamalle Bypass Depot and iii) SIPCOT Depot which is minor depot. The management plan for depot site includes: Water Supply, Sewage/Effluent Pollution Control, Recycling of treated waste water, Oil Pollution Control, Solid waste disposal, Surface Drainage and Noise pollution mitigation.

Water Supply: Water will be required for operation of depot which will be sourced from municipal supply. This will be supplemented by rain water harvesting and recycled sewage.

Sewage Treatment and Effluent Treatment: Sewage will be generated from Madhavaram and Poonamalle Bypass depots where maintenance staff work and their families reside. Sewage will be generated from depots which could be treated up to the level so that it could be used for horticulture purpose in the campus; sludge from STP will be used as fertilizer. For Madhavaram and Poonamalle Bypass depots cost of Sewage Treatment Plant (STP) is estimated as **Rs 78.11 Lakh** and **Rs 33.79 Lakh** respectively.

The waste water from depots will have oil, grease and, detergent as main pollutants. This has to be treated as per requirement of Tamil Nadu State Pollution Control Board. Cost of Effluent Treatment Plant (ETP) is estimated as **Rs 95.70 Lakh** and **Rs 45 Lakh** for Madhavaram and Poonamalle Bypass depots respectively**.** No train washing is required in case of SIPCOT minor depot. Staff strength will be small; sewage generated is proposed to be discharged into the nearest municipal sewerage line.

Rain water Harvesting: To conserve and augment the storage of groundwater, it has been proposed to construct roof top rainwater harvesting structure of suitable capacity in the proposed depots. Most of the area in depot will be open to sky and it is estimated that approximately 10% area will be covered. Rainwater harvesting potential of depots is calculated as 76,125 cubic meter per year for all three depots. The estimated cost for rainwater harvesting for all three depots is **Rs 43.94 Lakh**.

Oil Pollution Control: Oil spilled in Depot should be trapped in oil and grease trap and disposed of to authorised collectors so as to avoid any underground/ surface water contamination. Oil that is mixed in water shall be removed in the ETP. Capital and operating cost are included in engineering cost and therefore is not included in EMP.

Solid Waste Disposal: The solid waste generated from the Depot will be taken by the cleaning contractor weekly and disposed to the municipal waste disposal sites in accordance with relevant National and State laws and regulations. Cost is not included in EMP.

Surface Drainage: The Storm water will be collected through the drains and led to rain water harvesting pits and the drainage system. Capital and operating cost are included in engineering cost and therefore is not included in EMP.

Green Belt Development: The greenbelt development/ plantation in the depot area not only functions as landscape features resulting in harmonizing and amalgamating the physical structures of proposed buildings with surrounding environment but also acts as pollution / noise barrier. The estimated cost of afforestation is inclusive of cost of green belt development at three depots.

15.6.3.6 Training and Extension

The training for engineers and managers will be imparted by Project Authority on regular basis to implement the environmental protection clauses of the tender document and to implement the best environmental practices during the construction phase. Apart from training, programme should include guidelines for safety, methods of disaster prevention, action required in case of emergency, fire protection, environmental risk analysis etc. The cost involved for such programme is estimated to be **Rs 12.60 Lakh** each for Corridor-3 and Corridor-5, and **Rs 6.40 Lakh** for Corridor-4. Details are listed in **Table 15.26.**

TABLE 15.26: COST FOR TRAINING PROGRAMME

S. No	Item	Cost (Rs)		
		Corridor-3	Corridor-4	Corridor-5
1	Curriculum Development and course preparation 1 months Rs.50000/month	50,000	50,000	50,000
2	Extension Officer (1 year) Rs. 20,000/month	7,20,000	2,40,000	7,20,000
3	Instructor total 22 sessions of 10 days each	2,40,000	1,80,000	2,40,000
4	Demonstration/Presentation Aids	1,00,000	70,000	1,00,000
5	Material etc LS	1,50,000	1,00,000	1,50,000
Total		**12,60,000**	**6,40,000**	**12,60,000**

15.6.4 Disaster Management

The main activities are:

- Identify the causes which develop/ pose unexpected danger to the structural integrity of Metro tunnel or overhead rail
- Identify sources of repair equipments, materials, labour and expertise for use during emergency
- Prepare Reporting Procedures taking into account provisions contained in Metro Railways (Operation and Maintenance) Act, 2002
- Put in place efficient communication system with local authorities.

- Constitute Emergency Action Committee comprising members from Metro, local Civic and transport authorities
- Put in place Emergency Action Plan comprising Emergency Lighting, Fire Protection, Fire Prevention and Safety Measures

15.6.5 Emergency Measures

The emergency measures are adopted to avoid any failure in the system such as lights, fire, means of escape, ventilation shafts etc. The aim of Emergency Action Plan is to identify areas, population and structures likely to be affected due to a catastrophic event of accident. The action plan should also include preventive action, notification, warning procedures and co-ordination among various relief authorities. The emergency lights operated on battery power should be provided at each station. Fire protection and safety measures like fire alarm, emergency exit, ventilation shafts, access for fireman etc. to be provided.

15.7 ENVIRONMENTAL MONITORING PLAN

15.7.1 Pre-Construction Phase

The environmental monitoring programme helps in signalling the potential problems resulting from the proposed project activities and will allow for prompt implementation of corrective measures. 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
- 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. The estimated environmental monitoring cost during construction and operation phases for all three corridors is **Rs 296.10 Lakh** and **Rs 117 Lakh** respectively.

15.7.2 Construction Phase

During construction stage environmental monitoring will be carried out for air quality, noise levels, vibrations, water quality, and ecology. At this stage it is not possible to visualize the exact number of locations where environmental monitoring must be carried out. However keeping a broad view of the sensitive receptors and also the past experience an estimate of locations has been made and are summarized in **Table 15.27**. These numbers could be modified based on need when the construction actually commences.

TABLE 15.27: CONSTRUCTION STAGE MONITORING SCHEDULE

Parameter	Frequency	Locations	Years
Air	2x24 hours in a week for each season, four season in a year	20	5
Noise	2x24 hours in a week for each season, four season in a year	20	5
Vibration	24 hours, once a two months	11	5
Water	Once in a season, four season in a year	17	5
Soil	Once in a season, four season in a year	17	5

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 Accredited/MoEFCC recognized private or Government agency. Water quality should be analyzed following the procedures given in the standard methods. Parameters for monitoring will be as per BIS: 10500. The monitoring points could be ground and surface water.

Air Quality: Air quality is regularly monitored by Central Pollution Control Board at number of places in Chennai. In addition to these, air quality should be monitored at the locations of baseline monitoring. The parameter recommended is Particulate Matter ($PM_{2.5}$ and PM_{10}), SO_2, NO_X, CO and HC. 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 and vibration will be monitored at construction sites for entire phase of construction by the site contractor and under the supervision of Project Authority.

Ecological Monitoring: The Project Authority in coordination with the Department of Forest shall monitor the status of ecology/trees along the project corridors at least 4 times in a year during construction phase in order to maintain the ecological environment. The plantation/afforestation of trees by Department of Forest, Government of Tamil Nadu will be reviewed four times a year during construction phase.

Workers Health and Safety: Epidemiological studies at construction sites 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 recurrence of health incidents shall be recorded and appropriate mitigation measures shall be taken. Contractor will be responsible to take care of health and safety of workers during construction and project proponent is responsible to review/audit the health and safety measures/plans.

15.7.3 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, vibration, water and ecology during operation phase of the project. The parameters monitored during operation will be Particulate Matter ($PM_{2.5}$ and PM_{10}), SO_2, NO_X, CO and HC for air. Water quality parameters that will be monitored will be as per BIS 10500. The monitoring schedule is presented in **Table 15.28**. Monitoring should be carried out by NABL Accredited/MoEFCC recognized private or Government agency under the supervision of Project Authority during operation phase.

The results of air quality, water quality, waste water, vibration will be submitted to management quarterly during construction phase and bi-annually during operation phase.

TABLE 15.28: OPERATION STAGE MONITORING SCHEDULE

Parameter	Frequency	Locations	Years
Air Quality	2x24 hours in a week for each season, four season in a year	17	3
Noise	2x24 hours in a week for each season,	17	3

Parameter	Frequency	Locations	Years
	four season in a year		
Vibration	24 hours, once a two month	10	3
Water	Once in a season, four season in a year	11	3
Waste Water	Once in a season, four season in a year	3 (Depots)	3
Solid Waste	Once a year	3 (Depots)	3

15.7.4 Establishment of Environmental Division

It is recommended that Project Authority establishes an Environment Division at the initial stage of the project itself. This division should have an Environmental Officer and an Environment Engineer. The task of the division would be to supervise and coordinate studies, environmental monitoring and implementation of environmental mitigation measures, and it should report directly to Chief Engineer of the Project Authority. Progress of the division should be reviewed by an Environmental Advisor once in a year. The environmental Advisor should be an experienced expert familiar with environmental management in similar projects. Cost for the first ten years (including 10% annual increase) is given in **Table 15.29.** The estimated cost for each corridor is **Rs 171.46 Lakh**.

TABLE 15.29: ENVIRONMENTAL DIVISION COST

S No	Head	Cost (Rs Lakh)
A	**Capital Cost**	**For Each Corridor**
	Office Furnishings (Computer, furniture etc) LS	2.50
B	**Recurring Cost**	
	Man Power Cost (For 12 months)	
	Environmental Engineer @ Rs. 40,000/month	4.80
	Environmental Assistant @30000/month	3.60
	Office Maintenance @ Rs. 10,000/month	1.20
C	**Sub Total (A+B)**	**12.10**
	Miscellaneous and unforeseen expenses, LS (10 % of C)	1.21
Total cost for 1 Year		**13.31**
	Total cost for 10 years with 10% annual increase	**171.46**

15.8 ENVIRONMENTAL MANAGEMENT SYSTEM (EMS)

Environment Management System is intended to facilitate implementation, tracking and reporting of mitigation and monitoring measures proposed for the project. Roles and responsibilities are summarized in **Table 15.30** and **Table 15.31.**

TABLE 15.30: ROLES AND RESPONSIBILITIES - SECURING APPROVALS/CLEARANCES

S. No.	Issue	Provision of Laws & Regulations	Due Date	Approving Authority
Pre-Construction Phase				
1.	Permission for felling of trees and compensatory afforestation	Tamil Nadu Forest Act 1882, The Tamil Nadu Preservation of Private Forest Act, 1949	Before Construction	Tree authority, Municipal Corporation
2.	Prior Environmental Clearance: Metro Railway is not listed among activities requiring prior Environmental Clearance in EIA Notification 2006.	EIA Notification 2006 and its amendments		SEIAA
3.	Building Permissions for Depot, stations, property development	EIA Notification 2006 and its amendments		Municipal Corporation
4.	Utility / traffic diversion	Respective Acts and Rules		Local Offices of respective Agencies.
5.	Consent to Establish construction yards, labour camps, stations and depots (since non-residential)	Water (Prevention and Control of Pollution) Act 1974, Air (Prevention and Control of Pollution) Act, 1981		State Pollution Control Board; Development Authority for landuse clearance
6.	Sites to establish labour camps, pre-casting and material yards	Land use Master Plan and DC&PR		Municipal Corporation
Construction Phase				
7.	• Consent to Establish and Operate hot mix plant, crushers, batching plant etc and • Consent to Establish labour camps	Air (Prevention and Control of Pollution) Act, 1981	Before Construction	• State Pollution Control Board • MunicipalCorporation
8.	Permission for drawal of groundwater for construction **(not recommended)**	Environment (Protection) Act, 1986	Before Construction	Regional Director, Central Ground Water Board and Municipal Corporation
9.	Authorization for Disposal of Hazardous Waste	Hazardous Waste (Management and Handling and trans boundary movement) Rules 2016	Before Construction	State Pollution Control Board
10.	Consent for disposal of waste water from construction sites and sewage from labour camps	Water (Prevention and Control of Pollution) Act 1974	Before Construction	State Pollution Control Board
11.	Labour employment, safety, welfare measures	The Building and Other Construction Workers	Before Construction	District Labour Commissioner

S. No.	Issue	Provision of Laws & Regulations	Due Date	Approving Authority
		(Regulation of Employment and Conditions of Service) Act, 1996		
12.	Permission for management of C&D waste and muck	Construction and Demolition Waste Management Rules 2016	Before Construction	Municipal Corporation and State Pollution Control Board
Operation Phase				
13.	Consent to Operate Depot	Environment Protection Act , 1986	After Construction	State Pollution Control Board
14.	Installation and operation of DG sets at stations	Air (Prevention and Control of Pollution) Act, 1981	After construction	State Pollution Control Board

TABLE 15.31: ROLES AND RESPONSIBILITIES –PREPARATION AND IMPLEMENTATION OF ENVIRONMENTAL MANAGEMENT PLAN AND ENVIRONMENTAL MONITORING PLAN (EMOP)

S. No.	Environmental Impact	Mitigation Measure	Implementing Entity	Responsible Entity
Location and Design Phase				
1	Displacement and private property acquisition, impact of environmentally sensitive areas.	Alignment design to avoid or minimize impact.	DPR and design consultant	PIU
2	Loss of trees and water bodies		DPR and design consultant	PIU
3	Visual intrusion	Capital and operating cost and vibration impact of underground line in trade off with visual intrusion. To design aesthetic structures of viaduct and stations on elevated sections.	DPR and design consultant	PIU
4	Archaeological monuments	Alignment design to avoid or minimize impact.	DPR and design consultant	PIU
Pre-construction Phase				
5	Displacement and private property acquisition.	Implement R&R Plan	PIU	PIU
6	Loss of trees and water bodies	Implement compensatory afforestation	Municipal Corporation	Municipal Corporation
7	Site measures	Prepare Safety, Health and Environment (SH&E) Manual and secure approval.	Contractor	PIU
8	Water supply; sewage and solid waste disposal	Requirement for construction to be planned so as to avoid use of ground water.	Contractor	PIU

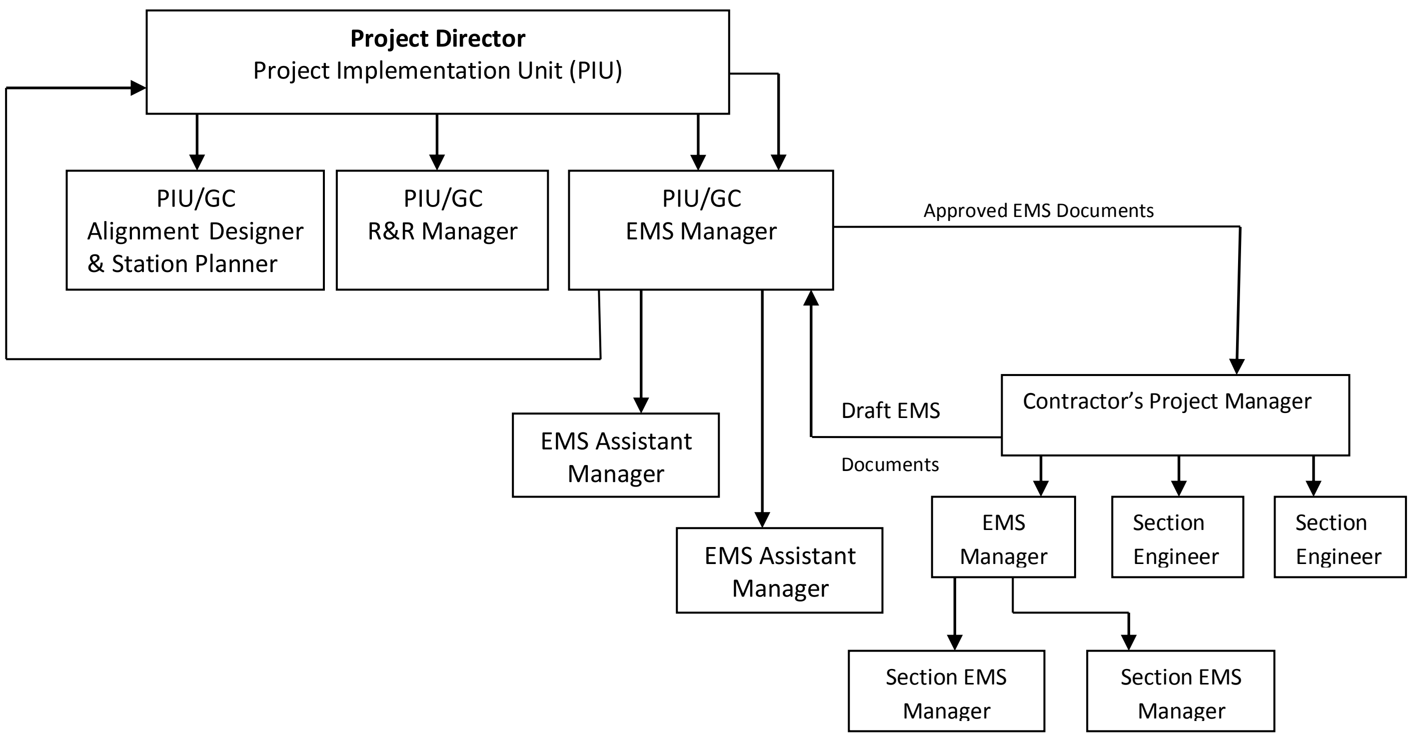
S. No.	Environmental Impact	Mitigation Measure	Implementing Entity	Responsible Entity
9	Environmental Management and Monitoring	Implement institutional requirements for implementation of EMP and EMoP.	Contractor	PIU
Construction Phase				
10	Soil erosion, fugitive dust generation, muck disposal and C&D waste management	Implement suitable construction methods and as per SHE Manual	Contractor	PIU
11	Air and noise Pollution	Vehicles and machinery are to be maintained to emission standards; machinery noise muffles etc and personal protective gear to workers.	Contractor	PIU
12	Vibration	Implement vibration monitoring and building condition surveys at sensitive structures	Contractor	PIU
13	Water pollution	Implement measures such as precipitation tanks on site	Contractor	PIU
14	Soil pollution	Implement measures to prevent ingress of toxic / heavy metals	Contractor	PIU
15	Labour camp: water supply; sewage and solid waste disposal; health	Implement measures as per SHE Manual	Contractor	PIU
16	Facilities on site and workplace safety		Contractor	PIU
17	Incident Management	Prepare Incident Management Plan with reporting formats.	Contractor	PIU
18	Environmental Monitoring	Prepare Environmental Monitoring Plan.	Contractor	PIU
19	Availability of institutional capacity	Implement training and establish environment unit.	Contractor	PIU
Operation Phase				
20	Noise Pollution	Implement and maintain noise barriers on viaduct	PIU	PIU
21	Vibration	Implement vibration monitoring and building condition surveys at sensitive structures.	PIU	PIU
22	Water supply, sanitation, sewage and solid waste disposal at stations and depots	Implement prescribed measures including rain water harvesting at stations and depots; green belt and water recycling at depots.	PIU	PIU
23	Sewage and effluent disposal	Implement STP and ETP at depots.	PIU	PIU
24	Incident Management	Implement Incident Management Plan.	PIU	PIU
25	Environmental Monitoring	Implement Environmental Monitoring Plan.	PIU	PIU

The range of documentation required to be generated and maintained as part of EHS before and during construction and during operation is as follows:

- Controlled documents of mandatory environmental Approvals and clearances along with record extensions thereof
- Controlled documents of approved SHE Manual, EMP and EMoP with revisions thereof and time schedule of such revisions if any.
- Controlled documents of formats of site inspection checklists with revisions thereof and time schedule of such revisions if any
- Reports of site inspections, monitoring data, reports of internal or external audit, observations of PIU and local statutory agency if any like Pollution Control Board, local municipal authority, Forest Department etc. and subsequent remedial action taken by Contractor, if any
- Records of coordination meetings of PIU/GC and Contractor with subsequent remedial action taken by Contractor, if any
- Records of incident reporting and remedial action taken by Contractor if any and follow up of such incidents

A typical EMS organization is depicted in **Figure 15.11.** One indicative activity i.e., approval of EMS documents is shown in this organisation chart.

FIGURE 15.11: EMS ORGANIZATION



* GC: General Consultant as Project Management Consultant

15.9 COST ESTIMATE OF ENVIRONMENTAL MANAGEMENT PLAN

The total cost involved in Environmental mitigation, management and monitoring are summarized in **Table 15.32.** The cost of STP, ETP, afforestation and Green belt development of Madhavaram Depot is included in Corridor-5, Poonamallee Bypass Depot in Corridor 4 and afforestation & green belt development at SIPCOT Depot in Corridor-3. The total estimated environmental management cost for the proposed project is about **Rs 4869.07 Lakh.**

The environmental management plan should be implemented in phases so that optimum benefit could be achieved and should be synchronized with the construction schedules.

TABLE 15.32: ESTIMATED COST OF ENVIRONMENTAL MANAGEMENT PLAN

S No	Item	Amount (Rs in Lakh)		
		Corridor-3	Corridor-4	Corridor-5
1	Compensatory Afforestation	72.95	101.30	211.87
2	Diversion of Forest Land	0	0	3.18
3	Noise Barriers	117.60	0	387.03
4	Rainwater Harvesting including Depot	350.29	359.84	763.33
5	Sewage Treatment Plant (STP)	0	33.79	78.11
6	Effluent Treatment Plant (ETP)	0	45.00	95.70
7	Environmental Monitoring	149.85	115.29	147.96
8	Training and Extension	12.60	6.40	12.60
9	Environment Division	171.46	171.46	171.46
10	Solar System	885.00	0	405.00
	Total	**1759.75**	**833.07**	**2276.24**

15.10 SOCIAL IMPACT ASSESSMENT

15.10.1 Project Description

The Study area is the area along the Metro corridors and depot locations which have been decided by the Client Chennai Metro Rail Limited (CMRL). The corridor is described in Engineering Chapter of this DPR.

Land Requirement and Resettlement

The proposed project shall require land for different purposes. Land is mainly required for route alignments of rail tracks, station buildings, platforms, entry/exit structures, traffic integration, car shed, power sub-stations, ventilation shafts, property development, depots and work sites etc. Acquisition of land may make affected families landless. Therefore, every effort has been made to keep land requirements to the barest minimum by realigning the alignments away from private property / human habitation.

For different components of the proposed corridor, a total 120.9882 (27.1931 ha Private land and 93.7951ha Government land) land will be required. Corridor wise details of land requirement are presented in **Table 15.33**.

TABLE 15.33: LAND REQUIREMENT AND ACQUISITION (in ha.)

Corridor	Type of Land (ha)		Total Land (ha)
	Private land	Govt.land	
Corridor-3 - MMC to SIPCOT-2	10.905	66.827	77.732
Corridor-4 - Light House to Depot Area near Virugambakkam St.)	5.7008	22.4398	28.1406
Corridor-5 - MMC to Sholinganallur	10.5873	4.5283	15.1156
Total land required	**27.1931**	**93.7951**	**120.9882**

15.10.2 Social Impact Assessment (SIA)– Scope and Objectives

Scope of SIA

The loss of private assets resulting in loss of income and displacement has made social impact assessment an important input into the project design while initiating and implementing developmental interventions. An understanding of the issues related to social, economic and cultural factors of the affected people is critical in the formulation of an appropriate rehabilitation plan. As per requirement of Detailed Project Report (DPR) preliminary social impact assessment (SIA) was carried out.

Objectives of SIA

The specific objectives of the SIA are as follows:

- Identify PAPs by type and extent of loss;
- Identify the possible adverse effects of the project on the people and the area
- Suggest culturally and economically appropriate measures for mitigation of adverse effects of the project
- Provision of institutional mechanism for implementation of RAP, grievance redress; Monitoring and Evaluation (M&E) of implementation of RAP
- A time frame for implementation of RAP
- Budgetary cost estimate

15.10.3 Approach & Methodology for preparation of SIA

The present SIA study is for the requirement of DPR and has been prepared in accordance with the guidelines of Government of India and general guidelines of multilateral funding agencies. The study is primarily based on field data generated by the Social Development Experts of RITES during social survey and secondary data where necessary. The study was conducted in phases.

15.10.3.1 Phase – I: Pre Survey Activities

Based on review of alignment drawings key stakeholders were identified. Team comprising of social scientists, engineers and environmental planners of RITES undertook reconnaissance of proposed corridors to cross verify the issues identified through the review of alignment drawings and also provided the basis for field research preparation and helped in developing and testing survey questionnaires and checklists. Both the review and rapid reconnaissance survey helped in finalizing the study tools and techniques.

15.10.3.2 Phase II: Survey Activities

The structures (i.e. residential, commercial and common properties) that were likely to be affected by the project were identified and were enumerated on basis of alignment drawings was conducted during October and November 2016, May 2017 and November-December 2018. Qualitative survey comprising consultation at project level was conducted to elicit their expectations and suggestions. Relevant national and funding agency guidelines pertinent to rehabilitation and resettlement were reviewed.

15.10.4 General Requirements of Multilateral funding agencies

As per General guidelines of multilateral/bilateral funding agencies for confirmation of Environmental and social Considerations, the proposed metro rail project is classified as 'Category A'. It includes projects in sensitive sectors or with sensitive characteristics and projects located in or near sensitive areas and the project is considered to have likely significant impacts on sensitive zones. Metro rail is similar to the "Road, Railways and Bridge" category project which is indicated in the guidelines as 'Category A' project, which requires impact assessments of social settings of the project area. It is considered important to have a dialogue with the partners (the host country, local governments, borrowers and project proponents) for its confirmation of social considerations. The active participation of key stakeholders (local residents, project affected families and local NGOs) in all stages of the project is also desirable.

15.10.5 Social Impacts

The proposed project will have a number of positive and negative impacts. In general the project shall bring following positive impacts:

Generate Employment opportunities and economic growth; Mobility and safe travel; Traffic decongestion; Save fossil fuel; Reduce air pollution.

The anticipated negative impacts include:

Loss of Land; Loss of Residential Structures; Loss of Commercial Structures; Loss of Livelihood; Loss of Common Property Resources. Impacts on PAFs/PAPs have been assessed and presented here.

15.10.6 Inventory of Affected Structures

Quick updation of inventory has been carried out to incorporate impact due to modification in alignment of corridor C5. Stations and sections from Alwarthirunagar to Porur are common to corridors C5 and extended C4: their impact has been covered under C4 and therefore has not been duplicated in C5. Impact if any due to stations and sections from CMBT to Alwarthirunagar is covered under C5 of which it forms part. Before land acquisition is initiated, exact number of affected and displaced families/persons will have to be found out by detailed inventory including measurement with ownership/tenancy documents and Census/Baseline Socio-Economic Survey (BSES) after marking of alignment on the ground.

Table 15.34 indicates corridor wise impact of the proposed metro project on the different types of structures i.e. residential, commercial, residential cum commercial and other. Majority of affected structures are of commercial use.

TABLE 15.34: CORRIDOR WISE IMPACT ON STRUCTURES

Corridors	Type of Structures				
	R	C	R+C	Others	Total
Corridor -3(Madhavaram Milk Colony to SIPCOT 2)	18	281	41	34	374
Corridor-4(Light house to Depot Area near Virugambakkam St.)	42	353	42	37	474
Corridor-5(Madhavaram Milk Colony to Sholinganallur)	45	303	77	36	461
Total	**105**	**937**	**160**	**107**	**1309**

Source: Field Survey, November 2016, May, 2017 and November-December 2018
Note: R-Residential, C-Commercial, R+C: Residential cum Commercial
Other structures includes common properties such as bus stop, Govt. structures, temple, hospital, school, public toilet, community centre, police booth, playground, park etc.

Station/location wise number of residential, commercial, residential cum commercial and other structures which are coming along Corridors 3, 4 and 5 are presented in **Table 15.35, Table 15.36 and Table 15.37** respectively.

TABLE 15.35: AFFECTED STRUCTURES IN CORRIDOR-3

Station/Location	Total Structures				
	R	C	R+C	Others	Total
Madhavaram Milk Colony	0	4	0	2	6
Thapal Petti Bus Stop	0	6	0	0	6
Murari Hospital	0	1	0	3	4
Moolakkadai	0	29	0	0	29
Don Bosco	1	7	10	1	19
Revathi	2	20	6	4	32
Aynavaram Bus Depot	1	4	0	3	8
Otteri	1	10	3	1	15
Stranhans Road	0	22	2	1	25
Perambur Barracks Road	0	8	4	2	14
Purasaiwakkam	0	24	4	0	28
Miller's Road Junctio	0	7	0	2	9
Kelly's Junction	0	10	2	0	12
Chetpet	4	1	1	0	6
Numgambakkam	0	2	0	0	2
Haddows Road Jn	0	1	0	0	1
Thousand Lights East	0	18	0	1	19
Royapetta	0	9	0	1	10
Thirumilai East	0	41	0	1	42
Mandaveli Bus Stop	5	6	2	5	18
M.G.R Janki College	0	2	0	3	5
Adyar Avin Bus Stop	1	2	3	0	7
Adayar Bus Depot	0	18	1	1	20
Indira Road Junction	1	3	0	0	4
Tharamani Link Road	0	0	0	3	3
Mettukuppam Bus Stop	0	4	1	0	5
Ptc Colony	0	3	0	0	3
Sholinganallur Junction	0	5	0	0	5
Diamond Engineering	2	5	1	0	8
Satyabhama University	0	2	0	0	2
Navallur	0	2	1	0	3
Siruseri	0	4	0	0	4
Total	**18**	**281**	**41**	**34**	**374**

Source*: Field Survey,* November 2016, May, 2017. ***Note: R:****Residential;* ***C:****Commercial (includes kiosk),* ***R+C:*** *Residential+ Commercial;* ***Other structures*** *includes common properties such as Govt. offices, bus stop, temple, hospital, school, community center, playground, parks etc.*

TABLE 15.36: AFFECTED STRUCTURES IN CORRIDOR-4

Station/Location	Total Structures				
	R	C	R+C	Others	Total
Foreshore Road	0	42	0	0	42
Kutchery Road	0	22	3	0	25
Thirumalai Mrts	0	44	0	0	44
Anjennyar Temple	3	2	3	0	8
Alwarpeth Bus Stop	4	5	9	2	20
Adyar Gate Junction	1	4	5	2	12
Nandanam	1	8	3	3	15
Natesan Park	0	5	0	1	6
Panagal Park	0	0	0	1	1
Kodambakkam	24	0	3	2	29
Meenakshi College	0	11	1	4	16
Ramp	0	3	0	0	3
Power House	0	14	2	5	21
Vadapalani	0	6	0	5	11
Shaligramam	1	14	1	2	18
Avichi School	1	4	0	2	7
Alwarthuru Nagar	0	7	2	0	9
Valasaravakkam Station	0	19	1	0	20
Karapakkam Station	0	8	2	0	10
Alapakkam Junction	0	11	0	0	11
Porur Junction	0	18	4	0	22
Near Porur Jn.	0	11	0	0	11
Kumanan Chavadi	0	7	0	1	8
Karyan Chavadi	0	8	0	1	9
Mullaithottam Station	1	8	1	1	11
Poonamallee Bus Terminal	4	14	2	1	21
Lyappanthangal Bus Depot	0	4	0	1	5
Padmavati Nagar Station	0	0	0	1	1
Virugambakkam Station	1	11	0	1	13
Near Virugambakkam Station	0	6	0	0	6
Depot Area	1	37	0	1	39
Total	**42**	**353**	**42**	**37**	**474**

Source: *Field Survey,* November 2016, May, 2017 and November-December 2018.
R:*Residential (includes residential squatters);* ***C:****Commercial (includes kiosk),* ***R+C:*** *Residential+ Commercial;* ***Other structures*** *includes common properties such as Govt. offices, bus stop, temple, hospital, school, community center, playground, parks etc.*

TABLE 15.37: AFFECTED STRUCTURES IN CORRIDOR-5

Station/Location	Total Structures				
	R	C	R+C	Others	Total
Madhavaram to Venugopal Nagar Station	1	4	1	0	6
Venugopal Nagar Station	1	0	0	0	1
Assissi Nagar Station	0	3	1	0	4
Assissi Nagar to Manjambakkam Station	0	3	0	1	4
Manjambakkam Station	0	4	0	0	4
Velmurugan Nagar Station	1	3	0	0	4
Velmurugan Nagar Station to MMBT Station	0	2	0	0	2
MMBT Station to Shastri Nagar Station	0	4	0	0	4
Shastri Nagar Station	0	6	0	0	6
Srinivas Nagar Station	1	0	3	1	5
Villivakkam Bus Terminus	1	9	0	1	11
Nathamuni Station	0	10	0	5	15
Between Nathamuni Station to Anna Nagar Station	3	1	1	1	6
Thirumangalam Station	1	0	0	5	6
Kaliammankoil Street Junction	2	21	1	5	29
Sai Nagar Bus Stop Station	1	9	6	1	17
Elango Nagar Bus Stop Station	7	15	9	1	32
Between Elango Nagar to Alwarthirunagar Station	2	12	4	2	20
Between Porur Junction to Mugalivakkam Station	7	6	6	0	19
Mugalivakkam Station	0	3	0	0	3
CTC	0	13	0	0	13
Between CTC to Butt Road Station	3	2	3	1	9
Butt Road Station	2	0	0	0	2
Between Butt Road Station to Alandur Station	1	10	0	0	11
Between ST. Thomas Mount to Adambakkam Station	5	1	0	2	8
Between Adambakkam to Vanuvampet Station	0	3	1	0	4
Vanuvampet Station	1	12	7	1	21
Puzuthivakkam Station	0	13	6	0	19
Between Puzuthivakkam to Madipakkam Koot Road Station	0	4	2	1	7
Madipakkam Station	2	12	2	2	18
Kilkattalai Station	0	18	5	1	24
Echankadu Station	0	6	1	1	8
Kovilambakkam Station	0	6	1	2	9
Vellakkalu Station	2	11	2	0	15

Medavakkam Koot Road Station	0	14	1	0	15
Kamaraj Garden Station	1	17	6	0	24
Medavakkam Junction	0	31	7	0	38
Between Medavakkam Junction To Perumbakkam Station	0	3	0	0	3
Perumbakkam Station	0	3	1	1	5
Global Hospital Station	0	1	0	0	1
Elcot Stationto Sholinganallur Station	0	1	0	0	1
Sholinganallur Station	0	7	0	1	8
Total	**44**	**303**	**77**	**36**	**461**

Source*: Field Survey,* November 2016, May, 2017 and November-December 2018.
Source*: Field Survey, November, 2017;* ***R:****Residential;* ***C:****Commercial (includes kiosk),* ***R+C:*** *Residential+ Commercial;* ***Other structures*** *includes common properties such as Govt. structures, bus stop, temple, school, community centre, playground, parks etc.*

The magnitude of project impact on the structures, which is categorized as partially and fully affected structures, is presented in **Table 15.38**. On the basis of alignment drawings it was found during site visit that out of total 1309 structures, about 859 structures shall be fully affected and remaining about 450 structures shall be partially affected.

TABLE 15.38: MAGNITUDE OF IMPACT ON STRUCTURES

Corridor	Affected Structures		
	Partially	Fully	Total
Corridor 3	308	66	374
%	(82.3)	(17.6)	(100.0)
Corridor 4	262	212	474
%	(55.3)	(44.7)	(100.0)
Corridor 5	289	172	461
%	(62.6)	(37.3)	(100.0)
Total	**859**	**450**	**1309**
	(65.6)	**(34.3)**	**(100.0)**

Table 15.39 shows that majority of structures which are likely to be affected either partially or fully are commercial.

TABLE 15.39: CORRIDOR WISE PARTIALLY AFFECTED STRUCTURES

Corridor	Partially affected						
	R	C	R+C	Kiosk	squatter	Other	Total
Corridor 3	18	221	41	0	0	28	308
	(5.84)	(71.75)	(13.31)	(0.00)	(0.00)	(9.09)	(100)
Corridor 4	15	196	26	1	0	24	262
	(5.73)	(74.81)	(9.92)	(0.38)	(0.00)	(9.16)	(100)
Corridor 5	26	199	44	2	0	18	289
	8.99	68.85	15.22	0.69	0.00	6.22	100
Total	**59**	**616**	**111**	**3**	**0**	**70**	**859**
	6.86	**71.71**	**12.92**	**0.34**	**0.00**	**8.14**	**100**

TABLE 15.40: CORRIDOR WISE FULLY AFFECTED STRUCTURES

Corridor	Fully affected						
	R	C	R+C	Kiosk	squatter	Other	Total
Corridor 3	0	19	0	41	0	6	66
	(0.00)	(28.79)	(0.00)	(62.12)	(0.00)	(9.09)	(100)
Corridor 4	27	62	16	94	0	13	212
	(12.74)	(29.25)	(7.55)	(44.34)	(0.00)	(6.13)	(100)
Corridor 5	18	100	31	3	1	18	171
	10.52	58.47	18.12	1.75	0.58	10.52	100
Total	**45**	**181**	**47**	**138**	**1**	**37**	**449**
	10.02	**40.31**	**10.46**	**30.73**	**0.22**	**8.24**	**100**

Impact on PAFs/PAPs

About 2865 families consisting 9455 persons are likely to be affected due to the proposed metro project. Corridor wise number of PAFs and PAPs is presented in **Table 15.41**. Exact number of affected and displaced families/persons will be found out during detailed Census/Baseline Socio-Economic Survey (BSES) after peg marking of alignment on the ground.

TABLE 15.41: IMPACT ON PAFs AND PAPs

Corridor	Impact on PAFs and PAPs		
	Total PAFs	Average family size	Total PAPs
Corridor 3	890	3.2	2848
Corridor 4	832	3.2	2662
Corridor 5	1143	3.5	4001
Total	**2865**	**3.3**	**9455**

Out of the total families, majority (1960 PAFs) are in Non Title Holders (NTHs) category and remaining 905 PAFs are in the category of Title Holders (THs).The NTH category includes tenants, encroachers and kiosks. Among the non-title-holders there are 1808 tenants, 151 kiosks and one squatter. The kiosks are on public land without any legal permission. Corridor wise detail of title holders and non-title holders is given in **Table 15.42**.

TABLE 15.42: PROJECT AFFECTED FAMILIES - OWNERSHIP STATUS

Corridor	Type of PAFs						
	Title holder		Non-title holder				
	R	C	Tenant(R)	Tenant(C)	Kiosk	Squatter	Total
Corridor 3	26	279	103	441	41	0	890
Corridor 4	68	152	67	442	103	0	832
Corridor 5	79	301	65	690	7	1	1143
Total	**173**	**732**	**235**	**1573**	**151**	**1**	**2865**

Table 15.43 show that out of total affected families, majority of them (1924 PAFs) shall be affected partially and remaining 941 families shall be fully affected.

TABLE 15.43: PARTIALLY AND FULLY AFFECTED FAMILIES

Corridor	Partially affected families				Fully affected families			Total
	R	C	Total		R	C	Total	
Corridor 3	129	672	801		0	89	89	890
Corridor 4	38	418	456		97	279	376	832
Corridor 5	77	590	667		67	409	476	1143
Total	**244**	**1680**	**1924**		**164**	**777**	**941**	**2865**

Table 15.44 indicates that out of the total 2865 PAFs, residential units of 164 families are getting affected due to the proposed project.

TABLE 15.44: LOSS OF RESIDENCE

Name of the Location	Total PAFs	Residentially Affected Family	Percentage (%)
Corridor-3	890	0	0
Corridor-4	832	97	11.7
Corridor-5	1143	67	5.9
Total	**2865**	**164**	**5.7**

Table 15.45 indicates that out of total 2867 affected families, there are 777 PAFs whose business/livelihoods will be affected due to the loss of the commercial structures / business base.

TABLE 15.45: LOSS OF LIVELIHOOD

Name of the Location	Total PAFs	Commercially Affected Family	Percentage (%)
Corridor-3	890	89	10.0
Corridor-4	832	279	33.5
Corridor-5	1143	409	35.8
Total	**2865**	**777**	**27.1**

Impact on Community Structures

The community structures likely to be affected include religious structures, bus sheds, hospitals and public toilets. **Table 15.46** indicates that 107 community structures shall be affected. These common properties particularly religious structures, bus sheds, and hospital of the same size and type shall be redeveloped by the project developer at the desired place in consultation with local people.

TABLE 15.46: LOSS OF COMMON PROPERTY RESOURCES

Corridor	Religious Stru.	Public Toilet	Public booth	School	Hospital	Bus stop	Park	others	Total
Corridor 3	10	2	2	1	0	5	0	14	34
Corridor 4	12	1	1	0	1	7	2	13	37
Corridor 5	16	0	0	0	0	9	0	11	36
Total	**38**	**3**	**3**	**1**	**1**	**21**	**2**	**38**	**107**

15.10.7 Public Consultation

Preliminary public consultations and discussions were conducted by RITES study team through community meetings with Project Affected Persons (PAPs) as well as general public discussions at identified station locations in Chennai. The objectives of organizing public consultation are as follows:

- Disseminate information to the people about the project in terms of its activities and scope of work; and understand the views and perceptions of the people affected and local communities with reference to acquisition of land or loss of property and its due compensation.
- Understand views of affected people on land acquisition and resettlement options and generate idea regarding the expected demand of the affected people;
- Identify and assess major economic and social information and characteristics of the project area to enable effective social and resettlement planning and its implementation.
- Resolve issues related to impacts on community property and their relocation.
- Establish an understanding for identification of overall developmental goals and benefits of the project.

Public consultations were conducted in four locations in Corridor-3, six locations in Corridor-4 and three locations in Corridor-5.The consultation process involved various sections of affected persons such as traders, residential kiosks and other inhabitants.

The consultant briefed the participants about the objectives of the meeting regarding various social issues related to the project i.e., land acquisition, compensation, loss of livelihood, cost of travelling, employment and development of city etc. The participants were invited to give their valuable suggestions on the above issues and were assured for suitable incorporation of such suggestions in the project within the technical limitations and scope of the project.

A summary of outcome of public consultations is presented in **Table 15.47**.

TABLE 15.47: SUMMARY OF PUBLIC CONSULTATION

Place	Date	Number of participants	Issue	Suggestion/opinion
Corridor 3				
Moolakkadai	08.11.2016	09	Existing structure may get affected due to metro construction	Many people raised the concern of effect of metro construction on nearby buildings.
Otteri	08.11.2016	09	Easy transportation	Traffic jam is the regular phenomenon. The situation gets worse at peak time i.e. office hours, school hours. Participants suggest that Metro project will reduce traffic and commute by road will be easy.
Perambur	29.05.2017	10	High cost of metro ticket	It is difficult to afford high Metro fares.
			Accident due to tunnelling work	The accident happened in Anna Salai should not be repeated otherwise it is fine.
			Reduce Pollution	Metro will lessen the traffic and ultimately reduce the existing high level of pollution.
Thirumayilai	29.05.2017	08	Old area; building may collapse due to tunneling work	Underground track may not be suitable for Mylapore as it is a very old area with heritage buildings- temples, church etc. Many buildings/ residents are century old; therefore there is a great risk of collapse.
			Business loss due to construction activity	If construction activities go long more than expected, then it incurred loss to commercial/ shops.
			Solve traffic	Metro will reduce the

Place	Date	Number of participants	Issue	Suggestion/opinion
			issues and increase connectivity	traffic jam. The long distance travel will be easy and metro will increase the connectivity
Corridor 4*				
Alwarpet	03.112016	07	Compensation	Due to metro train, other facilities and infrastructure will develop, but participants strongly suggested that the affected structures/people should get adequate compensation in order to re-instate the life of people.
Vadapalani	11.112016	13	Loss of livelihood	Being a small shop owner, our livelihoods will totally loss. There has to be adequate provision of compensation.
			Reduction in pollution	Metro will reduce the existing traffic load and reduce the level of pollution.
			Metro reduce road side accidents	Metro will reduce the traffic and reduced in road accidents.
Stella Marys College	30-05-2017	10	Construction may resulting traffic jam	Construction activity will result traffic jam. As this place is fully commercial, metro construction may disrupt the traffic flow.
			Metro may reduce the green cover of city	In Chennai city, the greenery is as it is low and further infrastructure development will further reduce the green cover and need to take care of it.
			Reduce pollution with speedy travelling	Metro will reduce pollution and speedy up transportation.
			Metro will reduce traffic	The traffic is huge due to nearby colleges and commercial area nearby. Metro train will be helpful to reduce the traffic load.
Adyar Bus Depot	31/05/2017	14	Metro construction may affect nearby	People are apprehensive of tunnelling work for metro because it may affect nearby structures.

Place	Date	Number of participants	Issue	Suggestion/opinion
			structures	
			Low metro train fares are required	The existing transportation charges are too high, unless it is lessen metro will not be successful. Fare must be reasonable.
Corridor 5				
Madhavaram Milk Colony	12/11/2016	08	Cost of travelling by metro train is too high	The existing metro fare is too high and hardly people travel by it. Fare may be reduced.
Velakallu Bus Station	12/11/2016	11	Development of city	The proposed route will be helpful not only for better connectivity but to develop the local economy.
Villivakkam	26-05-2017	11	Low metro fares are required	The existing fare of metro is too high and in order to make it routine transportation for general public, the fare should be reduced.
			Reducing traffic with better connectivity	Metro may improve connectivity with speedy travelling.
			Area development	Due to metro train, other facilities will come such as infrastructure development. Local economy will boost up.

* Public consultations were also collected at Lyappanthangal and Poonamallee Bus Terminus for Corridor-4.

15.10.8 Resettlement Policy, Framework and Entitlement Matrix

Applicable Laws

The applicable law is Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013(RTFCTLARR Act, 2013). In addition, general guidelines of multilateral/bilateral funding agencies are also considered.

Entitlement Matrix for Chennai Metro Phase 2

An Entitlement Matrix has been developed in compliance with RTFCTLARR Act 2013 and usual Involuntary Resettlement Policy of Multilateral funding agency. The entitlement matrix summarizes the types of losses and corresponding nature and scope of entitlements. The matrix is just an approximate number which might change with the on-ground situation of the total number of entitled affected families. So, the final list of the Project Affected Families whether it is Titleholders or Titleholder claimants or the Non-Titleholders (squatters, kiosks, encroachers) of land and buildings shall be eligible for R&R if enumerated during the census survey. Once the peg marking is done, all the properties shall be identified, listed and photographed individually and there shall not be any change in the number of the affected properties later on.

a) Entitlement for titleholders/land owners consisting of
   (i) Loss of private land; (Residential/Commercial) – The owner
   (ii) Loss of private structure (Residential/commercial/mixed use)
   (iii) Loss of private land and structure (Residential/commercial/mixed use)
b) Entitlement to Non-Titleholders/ Affected family consisting of
   (i) Impact to the family who is sharing the shelter with the land/structure of land owners (Residential/commercial/mixed use) -
   (ii) Impact to tenants (Residential/commercial/mixed use)
   (iii) Impact to squatters/encroachers/Kiosks
c) Titleholder claimants of the land/structure
   (i) Claimant of Private land/structure
   (ii) Claimant of Government land/Government body
d) Loss of Employment to workers/employees
e) Loss of Livelihood
f) Assistance to affected and displaced vulnerable people
g) Common infrastructure and Common Property Resources(CPRs)

It is on this day that all impacted persons will be identified and the nature of the impact disclosed. Only Project Affected Persons who settle in the affected areas for preceding three years or prior to the acquisition of the land or whose primary source of livelihood for three years prior to the acquisition of the land affected by the acquisition of such land is eligible for compensation and/or other assistance. They, however, will be given sufficient advance notice, requested to vacate premises and dismantle affected structures prior to project implementation. Their dismantled structures will not be confiscated and they will not pay any fine or suffer any sanction. The entitlement matrix is presented in **Table 15.48.**

TABLE 15.48: ENTITLEMENT MATRIX

S.No	Type of Loss	Unit of Entitlement	R&R Entitlement Framework
1	**Loss of Private land**(agricultural/ homestead/commercial or otherwise	Titleholder/land owner	RTFCTLARR, Act 2013 **compensation award as per First and Second Schedule** **(or)** **Purchase through Mutual agreement and Negotiation**
2	**Loss of private structure**(Residential/commercial/mixed use)	Titleholder/land owner	RTFCTLARR, Act 2013 **compensation award as per First and Second Schedule** and For the owners, who have rented their structures (Residential/Commercial) would be given rental allowance for 6 months based on the ground assessment. **(or)** **Purchase through Mutual agreement and Negotiation**
3	**Loss of private land and structure** (Residential/commercial/mixed use)	Titleholder/land owner	RTFCTLARR, Act 2013 **compensation award as per First and Second Schedule** **(or)** **Purchase through Mutual agreement and Negotiation**
4	**Affected family** who is sharing the shelter with the land/structure of land owners (Residential/commercial/mixed use) **Note:** Affected family who are residing three years prior to the acquisition of land	Non-Titleholders/ Affected family	**RTFCTLARR, Act 2013 cash compensation award as per Second Schedule**
5	**Tenants** (Residential/commercial/mixed use) **Note:** Affected family which is	Non-Titleholders/ Affected family	RTFCTLARR, Act, 2013 **cash compensation award as per Second Schedule (i.e.)** • Monthly subsistence allowance of Rs.3000/- per month for a year. • One time Transportation allowance of 50,000/-. • One-time financial assistance of

S.No	Type of Loss	Unit of Entitlement	R&R Entitlement Framework
	without homestead land and who are residing three years prior to the acquisition of land.		Rs.25,000/- for loss of trade. • One-time Resettlement allowance of Rs.50,000/-
6	Squatters/encroachers/Kiosks	Non-Titleholders/ Affected family	RTFCTLARR, Act, 2013 **compensation award as per Second Schedule**
7	Mobile and ambulatory vendors	Vendor	RTFCTLARR, Act, 2013 **compensation award as per Second Schedule**
8	Loss of Employment	Workers/Employees	RTFCTLARR, Act, 2013 **compensation award as per Second Schedule**
9	Loss of Livelihood	Family	The affected family will be entitled with the loss of livelihood will be decided later accordingly.
10	Vulnerable family	Family	One adult member of the affected family whose livelihood is affected will be entitled for skill development. Training for skill development. This assistance includes cost of training and financial assistance for travel/conveyance and food.
11	Common infrastructure and common Property Resources	Community	a) Community properties will be replaced in consultation with the community. b) Civic infrastructure would be replaced in consultation with the affected community and the District/Urban/Rural administration
12	Any Unforeseen Impact	Affected community / persons	Any unforeseen impact would be mitigated/enhanced as per the RTFCTLARR Act 2013.

15.10.9 Institutional Arrangement

15.10.9.1 Executing Agency (EA)

The Government of Tamil Nadu created a Special Purpose Vehicle (SPV) for implementing the Chennai Metro Rail Project. This SPV named as "Chennai Metro Rail Limited" was incorporated on 03.12.2007 under the Companies Act. It has now been converted into a Joint Venture of Government of India and Government of Tamil Nadu with equal equity holding.

The Government of Tamil Nadu (GoTN) and Government of India (GoI) will be the executing agency of the proposed Chennai metro rail (Phase-2). The GoTN will be responsible for overall execution of the RAP. An independent Monitoring and Evaluation (M&E) Agency/Specialist will be hired by GoTN to monitor the implementation of the various provisions and activities planned in the RAP. The independent M&E Agency/Specialist will review the plan implementation in lights of targets, budget and duration that had laid down in the plan.

15.10.9.2 Implementing Agency (IA)

Chennai Metro Rail Limited (CMRL) shall be responsible for implementation of the proposed metro rail project. The Managing Director (MD) will be the in charge of the overall project activities and will facilitate land acquisition, capacity building and implementation of RAP. CMRL will be responsible for coordinating with other concerned government departments, NGO, and R&R Supervision Consultant for land acquisition, planning and implementation of RAP which will include the disbursement of compensation, assistance, shifting and relocation of affected people. CMRL will be accountable to the GoTN (i.e. the EA) for the implementation of the RAP.

15.10.9.3 Project Implementation Unit (PIU)

The PIU headed by the Project Director (PD) is responsible for the overall execution of the project and planning and implementation of resettlement and rehabilitation component during preparation, implementation and post implementation phase of the project. The PIU will coordinate with all implementing agencies and monitoring the progress of the project.

15.10.9.4 Social Management Unit (SMU)

CMRL shall set up a Social Management Unit (SMU) which shall look after land acquisition, resettlement and rehabilitation activities. A Social Development Officer (SDO) will be appointed on full time by CMRL. The SMU shall ensure that all land acquisition issues are handled according to the Land Acquisition and Rehabilitation & Resettlement policy/guidelines. It will also monitor that all the procedural and legal issues involved in land acquisition are fulfilled. The SMU will assist for getting all the necessary clearances and implementation of the resettlement activities prior to start of any civil work.

A Resettlement and Rehabilitation Officer (RRO) may be appointed in this SMU to supervise and monitor overall activities of RAP and he/she will report day to day progress to SDO. RRO will also work closely with the District Collector to expedite the payment of compensation for land acquisition and assistance to APs. The RRO will form Local Resettlement Committees (LRC) in each project affected areas consisting of local representatives and other stakeholders. Specific functions of the SMU in regards to resettlement management will include the following:

- Overall responsibility of planning, implementation and monitoring of land acquisition, resettlement and rehabilitation activities in the project;
- Ensure availability of budget for R&R activities;
- Liaison lined agencies support for land acquisition and implementation of land acquisition and resettlement;
- Coordinating with line Departments.

Moreover, the SMU will also look after the Corporate Social Responsibility (CSR) activities of CMRL on long term basis for sustainable development of affected communities.

15.10.9.5 Role of Non-Government Organization (NGO)

An NGO will be appointed by CMRL to extend implementation support to CMRL in the form of assisting affected families/persons during relocation and preparation of Income Restoration Plan (IRP). The NGO will help educating PAPs on proper utilization of compensation and rehabilitation grant and help them in getting financial assistance. The NGO will be supervised by SDO, SMU.

15.10.9.6 Implementation Support Consultant(R&R)

During implementation phase of RAP, CMRL will appoint a consultant(R&R) through General Engineering Consultancy (GEC) to assist CMRL in implementation of resettlement plan. The consultant will carry out due diligence in the implementation of resettlement and rehabilitation programmes through periodic monitoring. The consultant will be responsible for (i) preparation of database of affected structures, families, persons, (ii) verification of database through field survey,(iii)improve monitoring system,(iv)capacity building of implementation staffs ,(v)regular follow up implementation activities and other relevant activities.

15.10.9.7 Grievance Redress Committee (GRC)

Efficient grievance redressal mechanism will be developed to assist the PAPs resolve their queries and complaints. Grievances of PAPs will be first brought to the attention of field level staff of CMRL. Grievances not redressed by the staffs (field level) will be brought to the Grievance Redressal Committee (GRC). The proposed GRC will representatives from PAPs, women, NGO and local body; Project Director (PIU), SDO, SMU of CMRL and Land Acquisition Officer (LAO). The main responsibilities of the GRC are to: (i) provide support to PAPs on problems arising from land/property acquisition; (ii) record PAPs grievances, categorize, and prioritize grievances and resolve them; (iii) immediately inform the SMU of serious cases; and (iv)report to PAPs on developments regarding their grievances and decisions of the GRC. have

Other than disputes relating to ownership rights under the court of law, GRC will review grievances involving all resettlement benefits, compensation, relocation, replacement cost and other assistance.

15.10.9.8 Training and Capacity Building

Establishing sufficient implementation capacity to launch and carry out those components of project resettlement that must be completed before civil works. Exposure visits and training through specialists in the field will be arranged for SMU staff.

15.10.9.9 Implementation Schedule of Resettlement Action Plan

The implementation of RAP will consist of four major stages:

1 Identification of Cut-off Date (CoD) and notification for land acquisition as per Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013(thereafter land will be purchased).For non-titleholders the cut-off date for each corridor shall be from the start of Census Survey.

2 Verification of properties of PAFs/PAPs and estimation of their type and level of losses.

3 Preparation of list of PAFs/PAPs for relocation/rehabilitation.

4 Relocation and rehabilitation of the PAPs.

Timing of Resettlement

The resettlement process must be completed by the start of civil works on the particular corridor. Requisite procedure will be developed by the CMRL to carry out resettlement of PAPs located within Corridor of Impact (CoI), before the civil work starts on any section of the project road. All activities related to the land acquisition and resettlement shall be planned to ensure that 100% compensation is paid prior to displacement and the affected people will be given at least four months of notice to vacate their property before civil work begins. Stretches which are free of encroachment and other encumbrances will be handed over first to the contractor.

15.10.9.10 Implementation Schedule

The period for implementation of RAP has been taken as two and half years. However, monitoring and evaluation will continue beyond the period of implementation. The R&R activities of proposed project are in three phases: project preparation, RAP implementation and Monitoring and Evaluation (M&E).

- **Project Preparatory Stage (Pre-Implementation Stage)**

Setting up relevant institutions for the resettlement activities will be the major task during the preparatory stage which is pre implementation phase. The major activities to be performed in this period include establishment of SMU and additionally, the GRC needs to be appointed at this stage.

- **RAP Implementation Stage**

The RAP, at this stage, needs to be approved and will be disclosed to the PAPs. Upon the approval of RAP, all the arrangements for fixing the compensation and the disbursement needs to be done which includes payment of all eligible assistance; relocation of PAPs; initiation of economic rehabilitation measures; site preparation for delivering the site to contractors for construction and finally commencement of the civil work. Internal monitoring will be the responsibility of CMRL which will start in early stage of the project when implementation of RAP starts and will continue till the completion of the implementation of RAP. CMRL will be responsible for carrying out the monitoring on half yearly basis.

- **RAP Implementation Schedule**

RAP implementation schedule for R&R activities in the proposed project including various sub tasks and time line matching with civil work schedule is prepared and presented in **Figure 15.12.**

FIGURE 15.12: RAP IMPLEMENTATION SCHEDULE

	Description	2018	2019	2020	2021	2022	2023
A	**Project Implementation**						
1	Identification of required land for acquisition in DPR						
2	Preliminary Socio-economic survey for SIA in DPR						
3	Community /Public Consultation						
4	Preparation of Detailed SIA by Government after Notification						
6	Review/Approval of SIA						
7	Establishment of Grievance Redress Committee						
8	Census survey after peg marking on the ground						
9	Finalization of updated RAP						
10	Disclosure of SIA and RAP						
B	**RAP Implementation**						
11	Notification of Land Acquisition						
12	Joint Measurement Survey						
13	Suggestion & Objection of PAPs						
14	Hearing by Competent Authority						
15	Declaration of Award of Compensation as per RTFCTLARR,Act						
16	Resettlement and Rehabilitation provisions						
17	Shifting of PAPs						
18	Grievance Redress						
19	Schedule of Civil Work (Contd...)						
C	**Monitoring and Evaluation**						
20	Internal Monitoring						
21	External Monitoring						

15.10.10 R&R Cost Estimate

This budgetary R&R cost is indicative and needs to be updated and adjusted to the inflation rate as the project continues. The compensation amount for the land acquisition and structures will be finally determined by the Competent Authority. However, the cost for land and structure is presented in capital estimate of DPR. The cost for R&R implementation plan for three corridors of proposed metro rail is INR **29130.0 lakh.** Corridor wise R&R cost estimate is given in **Table 15.48**.

TABLE 15.49: COST FOR RESETTLEMENT & REHABILITATION

S.No	Metro Corridor	Amount (In Lakh)
1	Corridor-3	7553.0
2	Corridor-4	7576.0
3	Corridor-5	14001.0
	TOTAL	**29130.0**

15.10.11 Monitoring and Evaluation

Monitoring & Evaluation are critical activities in involuntary resettlement. Monitoring involves periodic checking to ascertain whether activities are progressing as per schedule while evaluation is essentially to assess the performance of PAPs at the end of the project.

15.10.11.1 Internal Monitoring

The internal monitoring for RAP implementation will be carried out by CMRL. The main objectives of internal monitoring are to:

- measure and report progress against the RAP schedule;
- verify that agreed entitlements are delivered in full to affected people;
- identify any problems, issues or cases of hardship resulting from the resettlement process, and to develop appropriate corrective actions, or where problems are systemic refer them to the management team;
- monitor the effectiveness of the grievance system
- periodically measure the satisfaction of project affected people.

Internal monitoring will focus on measuring progress against the schedule of actions defined in the RAP. Activities to be undertaken by the CMRL will include:

- Liaison with the Land Acquisition team, construction contractor and project affected communities to review and report progress against the RAP;
- Verification of land acquisition and compensation entitlements are being delivered in accordance with the RAP;
- Verification of agreed measures to restore or enhance living standards are being implemented;
- Verification of agreed measures to restore or enhance livelihood are being implemented;
- Identification of any problems, issues, or cases of hardship resulting from resettlement process;
- Through household interviews, assess project affected peoples' satisfaction with resettlement outcomes;
- Collection of records of grievances, follow up that appropriate corrective actions have been undertaken and that outcomes are satisfactory;

Monitoring is a continuous process and will be carried out by field level officers of Social Management Unit on regular basis to keep track of the R&R progress.

15.10.11.2 Independent Evaluation

An Independent Evaluation Agency (IEA) will be hired by CMRL for mid and end term evaluation. The external evaluation will be carried out to achieve the following:

- Verify results of internal monitoring,
- Assess whether resettlement objectives have been met, specifically, whether livelihoods and living standards have been restored or enhanced,
- Assess resettlement efficiency, effectiveness, impact and sustainability, drawing lesions as a guide to future resettlement policy making and planning, and
- Ascertain whether the resettlement entitlements were appropriate to meeting the objectives, and whether the objectives were suited to affected persons' conditions,
- This comparison of living standards will be in relation to the baseline information available in the BSES. If some baseline information is not available, then such information should be collected on recall basis during the evaluation.

Reporting Requirements

CMRL shall be responsible for supervision and implementation of the RAP. CMRL shall prepare quarterly progress reports on resettlement activities. The Independent Evaluation Agency will submit draft and final reports of their assignment to CMRL.

16. DISASTER MANAGEMENT & SECURITY MEASURES

16.1 NEED FOR DISASTER MANAGEMENT MEASURES

World Health Organization (WHO), defines disaster as "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."

Metro systems will carry thousands of passengers daily, therefore the effect of any disaster spread over in operational area (station, tunnels, viaducts etc.) is likely to be considerable.

Disaster brings about sudden and immense misery to humanity and disruptions to normal human life in established social and economic patterns. It has the potential to cause large scale human suffering. There is a need to provide efficient disaster management plan to tackle above mentioned emergency situations at metro system.

The main objectives of Disaster Management Measures are as follows:

- Save life and alleviate the sufferings.
- 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 as early as possible.
- Lay down the actions required to be taken by staff in the event of a disaster in Chennai Metro Rail Corporation in order to ensure prompt handling of crisis situation in a 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.

16.2 SERIOUS INCIDENTS REQUIRING DISASTER MANAGEMENT MEASURES

Metro specific disasters can be classified into two broad categories e.g.: Man-made and Natural.

a. Man Made Disaster

i. Terrorist attack
ii. Bomb threat/ Bomb blast
iii. Hostage Situations
iv. Release of Chemical or biological gas in trains, stations or tunnels
v. Fire in metro buildings, underground/ elevated infrastructures, power stations, train depots etc.
vi. Train accident and train collision/derailment of a passenger carrying train
vii. Sabotage
viii. Stampede

b. Natural Disaster

i. Earthquakes
ii. Floods

16.3 PROVISIONS UNDER DISASTER MANAGEMENT ACT, 2005

According to 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.

A. National Disaster Management Authority (NDMA)

Establishment of National Disaster Management Authority:

i. 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.

ii. 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.

iii. The Chairperson of the National Authority may designate one of the members nominated under clause (b) of sub-section (ii) to be the Vice-Chairperson of the National Authority.

iv. 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:-

i. 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.

ii. 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 Chairperson of State Authority;
c. The Chairperson of State Executive Committee, ex officio.

iii. The Chairperson of State Authority may designate one of the members nominated under clause (b) of sub-section (ii) to be the Vice- Chairperson of the State Authority.

iv. The Chairperson of the State Executive Committee shall be Chief Executive Officer of the State Authority, the Chief Minister shall be the Chairperson of the Authority established under this section.

v. 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 chairmanship of Cabinet Secretary
2. Crisis Management Group (CMG) under chairmanship of Union Home Secretary.
3. State Level Committee under the chairmanship of Chief Secretary.
4. District Level Committee under the Chairmanship of District Collector.

All agencies of Government at National, State and district levels will function in accordance with 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:

i. Prepare a disaster management plan setting out following, namely:-
   a. Provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;
   b. Provisions for taking measures relating to capacity-building and preparedness as laid down in the District Plan;
   c. The response plans and procedures, in the event of, any threatening disaster situation or disaster;

ii. 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;

iii. Regularly review and update the plan; and

iv. Submit a copy of its disaster management plan, and of any amendment thereto, to the District Authority.

16.4 PROVISIONS AT METRO STATIONS/OTHER INSTALLATIONS

An effective system needs to be provided which includes Fire Detection and Suppression System, Smoke Management, Environmental Control System (ECS), Tunnel Ventilation System, Track-way Exhaust System (TES), Lighting System, Station Power Supply System, DG Sets & UPS, Seepage system, Water Supply and Drainage System, Sewage System, Station Area Lights and other facilities which may be deemed necessary.

The above said provisions are suggestive and an exhaustive set of facilities have to be provided based on site conditions, location and other internal and external factors.

16.5 MEASURES IN CASE OF FIRE

Fire has been recognized as one of the most dreaded accidents on metros primarily because of large concentration of passengers at stations and in trains. Fire prevention and prompt response to any incident of fire or smoke emission is therefore the most important component of disaster management on Metros.

Universally accepted measures for fire prevention include:

i. Rigid observance of non smoking regulations
ii. Total ban on carriage of inflammable/ explosive substance within metro premises and in trains
iii. Non accumulation of garbage in the metro station premises and inside trains
iv. All staffs posted at stations must ensure instructions are rigidly enforced by regular checks.

A. Fire and Smoke

In the event of fire and / or smoke either in train , station premises, right of way including the tunnel or other metro premises, every Metro Rail official whether on duty or not shall,

i. Report the occurrence to the nearest Station Controller (SC) or Chief Controller (OCC)
ii. Take all possible steps to extinguish fire
iii. Disconnect electric supply, if required
iv. Prevent the fire from spreading
v. Seek assistance of Fire services.

B. Fire in a Train

The guidelines set out below are based on the content analysis of past accidents on other Metros and are in the nature of best practices. Since every fire incident is unique, the train operator is to exercise quick judgment based on:

i. The nature of fire whether localized or widespread in passenger area.
ii. The extent of occupation of the train-number of passengers-if the number is manageable he will ask passengers of the affected coach to move away to other coaches.
iii. Proximity of the next station – passenger evacuation and handling of emergency is much easier at station than in between stations. Train Operator (TO) has to exercise his judgment about those extreme cases where the train has to be stopped forthwith to save life by prompt evacuation or taken to the next station expeditiously.

C. Fire in Train at the Station Platform

The Train Operator shall open all train doors on the platform side and ask passengers to vacate the train. He will inform OCC and Station Controller and take assistance from station staff as required.

D. Special Instructions for underground sections

Entire underground Metro network is equipped with Tunnel Ventilation system, capable of Centralized operation from OCC and also local operation from Station Control Rooms.

In the event of a 'fire incident' the system is designed to:

- Provide smoke free evacuation route
- Make available adequate fresh air
- Remove smoke and heat
- Cut off supply to the fire affected area during emergency.

A water pipeline should run along the entire underground Metro corridor. These pipelines have hydrants fixed every 15 m where hose pipes can be connected. The pipes are of great help to quickly extinguish any fire outbreak. Each underground section should equip with one to three cross passages between the up and down tunnels. These passages can be used for speedy evacuation of commuters in case of emergency. There is a Fire Detection and Suppression system equipped to automatically activate alarms for Vents, Fans and Dampers & Suppression equipments. The system is operated from a panel located in the Station Control Room.

E. Fire Suppression System

A wet Fire Main System covers the station area as well as the entire length of the tunnels. In addition there are automatic sprinklers, inert gas based suppression systems and portable fire extinguishers at various locations. Immediately on receipt of information about a train with fire incident held up between stations – Auxiliary System Controller (ASC) will

- Identify the location of fire (front/rear of the train)
- Identify affected ventilation zone/s
- Other trains held up needing increased ventilation
- Help OCC to decide the correct direction of passenger evacuation.
- Identify the appropriate TVS Master mode and operate TVS system.
- Inform TO through TC the direction of evacuation.

Before starting evacuation, ASC/ Traction Power Controller (TPC) shall check for the adequacy of Tunnel Lighting and correct Operation of TVS & ECS and Tunnel lights can be switched on from Station control room by BMS controller/ nominated E&M staff.

F. Fire at Metro Station Premises

The fire can be at the following locations:

i. In areas, where the passengers enter for purchasing tickets or leave the station after performing their train journey including lifts, staircases and escalators.

ii. Concourse

iii. Auxiliary electrical substations.

In case of fire in areas where passengers enter/leave the station premises, the endeavor of station staff should be to cordon off the area so that it is not approachable for intending Metro users or by Metro passengers leaving the station area.

16.6 MEASURES IN CASE OF COLLISION OF TRAINS

In the event of a train collision involving Metro trains, any employee witnessing, discovering or being involved in a train collision shall inform the Operations Control Center (OCC) and provide the following information-

- Callers name and identification,
- Reason for the call,
- Train identification,
- Location of the collision (Line identification, track (UP/DN), OHE mast no., nearest station if not at station),
- Need for medical assistance,
- Presence of smoke or fire

If the employee making the first report is a Train Operator (TO), Traffic Controller (TC) shall instruct the Train Operator to secure the train, inform the passengers about the incident, check if any passenger or employee needs medical attention. The TO will inform TC accordingly. If the other TO has not communicated with OCC, TC will ask TO to collect similar information about the second train and report.

A. Train Operator (TO) shall

i. Look for presence of smoke or fire. Furnish details of visible damage, if any coaches are derailed or

ii. If the other track is obstructed.

iii. The OCC /TC shall instruct Train Operators of trains in approach of the collision site, in both directions, to stop their trains at stations and report their positions.

B. Duties of Train Operator:

i. In the event of collision taking place involving his train, the train operator shall inform OCC by giving as many details as possible.

ii. In case of adjacent track is infringed, he will first protect the adjacent track to avoid multiple accidents as per prescribed procedure.

iii. He will inform passengers about the incident advising them about rescue and relief arrangements being made.

iv. He shall quickly assess the situation particularly in respect of passenger's injury and again inform OCC with as much details as available seeking medical and other assistance as required.

v. He will render first aid to passengers and check for injury and damage to the train (both his train and other train).

vi. Shall seek OCC's permission for passenger evacuation.

vii. Shall await further instructions from OCC.

C. Duties of Station Controller:

i. The Station Controller on receipt of information about collision at his station shall inform OCC.

ii. Arrange for immediate medical assistance as required.

iii. Inform Metro rail police/Local police.

iv. Mobilize the staff for evacuation of passengers and rendering of first aid to the injured and their hospitalization as required.

v. Inform passenger awaiting at the station of the likely delays.

vi. Station controller will evacuate passengers as per instructions of OCC.

D. Duties of Traffic Controller:

i. On receiving information about train collision the Traffic Controller shall block all movement on both the tracks to protect the site of accident.

ii. Inform CMRL Disaster Management Team members.

iii. And other designated CMRL departments and Personnel.

iv. Mobilize medical assistance as required.

v. Inform the train depot to be in readiness to move rescue and relief train.
vi. Instruct Station Superintendent to depute staff for evacuation of passengers and providing medical aid to the injured.
vii. Regulate train services and inform all stations on the route about the likely dislocation in train services.
viii. Activate ventilation system based on condition of the scene (tunnel section only).
ix. Arrange for Public Address announcements to be made to passengers in trains and at stations.
x. Initiate operating procedure to relieve train congestion at collision site by: a) Single track operation (Single Line Working), b) Turning trains on both sides of collision site (Short Loop Operation) etc.
xi. The OCC Chief Controller shall inform the Disaster Management Team, ED/OP, GM/OP and all controllers in OCC, the Police/Metro Police and Security Controller to secure the accident scene and Station Superintendent/Station Controllers on the affected line. Chief Controller shall also inform emergency services. All controllers in OCC shall inform their respective officers, maintenance/emergency team and others as applicable.

E. Medical Assistance

The TO/SC requesting medical assistance to OCC shall provide an estimate of the likely number of people requiring medical assistance and also indicate the most convenient access point for medical personnel to enter. (The names and addresses of person requiring/receiving medical assistance and the names of medical agencies and personnel shall be recorded in the Accident Log book maintained at site/at OCC).

16.7 MEASURES IN CASE OF TRAIN DERAILMENT

A. Duties of Train Operator:

i. The TO becoming aware that his train has derailed shall stop the train immediately if not, already stopped and secure the train.
ii. Inform passengers of the problem and action being taken.
iii. Inform OCC providing following information:
- Train Operator identification
- Location (line identification, Track (UP/DN), & Mast No.)
- Train description (Train no. & train set no.)
- Adjacent track obstructed or clear.
- Passenger injury or presence of smoke or fire.
- Seek instruction for passenger evacuation.

B. Duties of Traffic Controller:

i. TC shall instruct TOs of trains approaching the derailment site on both tracks to stop their trains and report their positions.

ii. TC shall immediately notify DMT and all concerned Metro departments, Police/Metro Police and Security Controller to secure the accident site and Station Superintendents on the affected line for informing waiting passengers at stations about the likely delay. OCC/TC will also arrange to inform passengers aboard trains held up.

iii. Mobilize medical assistance as required.

iv. Inform the depot to be in readiness to move the rescue and relief train.

v. Instruct Station Managers to depute staff for evacuation of passengers and providing medical aid to the injured in case of derailment between stations.

vi. Regulate train services and inform all stations on the route about the likely dislocation in train services.

vii. Activate ventilation system based on condition of the scene (for tunnel section only).

viii. Arrange for Public Address announcements to be made to passengers in trains and on stations.

ix. Request assistance of Police / Metro Police / Security/ Watch & Ward for crowd control at critical stations.

x. Initiate operating procedure to relieve train congestion at derailment site by:

- Single track operation (Single Line Working),
- Turning trains on both sides of derailment site (Short Loop Operation) etc.

C. Medical Assistance:

The employee requesting medical assistance to OCC shall provide an estimate of likely number of people requiring medical assistance and will also indicate the most convenient access point for medical personnel to enter. (The names and addresses of passengers requiring medical assistance and the names of medical agencies and personnel shall be recorded in the Accident Log book maintained at site/in OCC).

16.8 MEASURES IN CASE OF TERRORIST ACTIONS

Increase in terrorist actions against public transport worldwide, indicates that public transport systems are becoming more vulnerable and potential targets for terrorist.

It is clear that preventing terrorist activities is the primary responsibility of security agencies and state police.

However, concern for passenger well being and their security and adverse effects of such mishaps on the public image of transport systems itself, requires best possible level of preparedness for prevention of such threats within Metro premises. Key components of such preparatory and preventive action include:

- Encouraging and guiding passengers to be cautious themselves.
- An awareness program – appealing users to be on the alert and report any suspect package.
- Well thought out crisis communication to prevent misinformation, confusion, panic and shock.
- Clear procedures and systems of communications need to be established for emergencies and regularly tested, in order to ensure a working communication during crisis situation.
- Frequent mock drills to test effectiveness of passenger evacuation systems including the collaboration and response of passengers.
- Training all frontline staff to prevent dangerous situations and handle incidents.
- Once they have happened act with courage, promptitude and alertness, reassuring passengers and providing regular information for their guidance.
- Terrorist attack may take place anywhere in the metro rail's jurisdictions, however when it takes place, on the right of way particularly underground section, at metro station and in running trains it may have serious impact in terms of human distress and restoration of normal operation. On receipt of information of any terrorist act on Metro Trains, stations or on the Right of Way, OCC will take prompt action to get the entire metro network cleared of all passengers.

A. Terrorist attack at Station

Duties of Station Superintendent/Station Controller:

i. Shall visit the affected spot, assess the extent of impact on human life and also how it may affect train services.
ii. Shall inform the OCC about details of incident.
iii. Sound the hooter and get the station premises vacated of all the passenger
iv. Depute staff to announce at 5-minute interval, through the station PA system what has happened and what the passengers are expected to do without getting panic.

v. Mobilize resources to render first aid and evacuate the injured.
vi. In case any person is seen moving in a suspicious manner, he may be detained for interrogation with the help of security staff.
vii. Passengers found near the affected area may also be asked about their first hand knowledge of the occurrence and their statement with name and addresses recorded.
viii. Inform Police/Metro Police and depute station security staff to protect and cordon the site to preserve the clues and leave the site undisturbed for police investigation.

Duties of Traffic Controller/Chief Controller:

Immediately on receipt of the information about terrorist attack, Chief Controller shall:

i. Inform Police/Metro Police and security personnel and ask them to rush to the spot of occurrence.
ii. Mobilize Medical Assistance and/ or Fire Services to reach the spot.
iii. Inform the DMT and other CMRL departments and personnel.
iv. Hold trains at stations. Train movement shall only be resumed after confirming that the running of train through the affected station is safe, till the position becomes clear regular announcement to be made to passengers in train and at station of the likely delay and evacuation procedures started. The entire Metro network shall remain closed till rescue and search operations have been completed. Revenue operations shall only be started after ensuring that the system is fully safe and secure.

B. Terrorist Attack in Train:

Of all the cases of terrorist attack, those within a train will have most disastrous consequences and very prompt action will be necessary to restrict the damage to men and material. Such a situation may include:

i. A Bomb on the track which detonates under a train.
ii. Detonation of Bomb / igniting of inflammable material inside a train.
iii. Release of chemical / biological gases in a train.
iv. Criminal interference with train running equipments which causes fire in the coaches while on run.
v. Other terrorist activities incapacitating the train on run.

C. Bomb Blast on Track:

There may be derailment of the train with large scale damage to the train and fixed structures as well as injury to the passengers in the train. In case of derailment, the train will immediately come to a stop. The Train Operator shall immediately inform Traffic Controller about the occurrence and ask for immediate assistance as required. TO shall seek permission for evacuation of passengers. In case the situation does not permit detrainment from one end, it may be arranged from both ends. The injured passengers should be evacuated as soon as the Medical Team arrives on the spot.

D. Bomb Blast inside the Train:

The Train operator shall:

i. Inform Traffic Controller
ii. Inspect the impact of explosion and if the train is in a position to move, he will try to take the train to the next station at reduced speed.
iii. In case he is not able to take the train to the next station, Shall stop the train and inform the Traffic Controller about the incident.
iv. Shall seek assistance of fire services and medical services as required, take the permission of the TC to detrain the passengers.
v. Shall make an on the spot assessment of the situation including the injury/death of passengers and inform the Traffic Controller for immediate appropriate action.
vi. The TO shall make announcement to the passengers through the train PA system about the situation and ask them to remain calm indicating that action has already been taken to arrange for detrainment of passengers.
vii. The TO will arrange evacuation of the passenger when authorized by OCC.
viii. This will help in reaching prompt assistance to the injured and disabled passengers on arrival of the Security and Medical Team.
ix. Train Operator will thereafter arrange to detrain the injured passengers with the help of security and medical staff.

E. Release of Chemical Poisonous or biological gases in tunnels, trains or at stations

Whenever other terrorist activities described above produce loud noise, explosion, fire and smoke, release of lethal or harmful gases works silently and can only be generally inferred from-

- Unusual smell
- Passengers or employees complaining of Breathing problems- including choking/fainting, Severe eye/Skin irritation and Vomiting etc.

Receiving any such complaint the Train Operator or Station Controller/ Station Manager will take serious note of it and immediately inform OCC to take prompt action to handle the emergency as case of suspected release of poisonous gases. If gas release is detected in a train, TO will inform OCC and expeditiously bring the train to the next station, open train doors and request all passengers to detrain. He will personally check with station staff, security and Police/Metro Police that the train has been completely vacated.

To prevent further spreading of gas in platform area and to help Police and Medical teams to investigate and identify the gas he will close the train doors. In the event of gas release in station premises, the station should be fully vacated and kept closed unless certified free of contamination by medical authorities.

Whereas, release of gases on the Right of Way in Rail corridors may not have serious impact, with gas spreading into atmosphere. In tunnel sections it will be necessary to

- Locate the presence of gas in specific ventilation zones.
- Activate appropriate TVS modes to dilute the gas.
- Degasify the tunnel portion or the entire tunnel, depending upon the severity of the case informing civil authorities of the likely discharge of gas in certain areas which may require to be protected.
- Pending this, the affected portion or the entire tunnel will have to be vacated of all passengers and staff.

Normal operation should only be resumed after running of a trial train with Police, Medical and metro authorities confirming that the section has been made free of contamination.

16.9 MEASURES IN CASE OF NATURAL CALAMITIES

On being informed about an earthquake in the city of Chennai or experiencing the same, OCC Traction Power Controller (TPC) will switch off Traction power Supply in a manner which does not shut down station supplies informing the Traffic Controller who will instruct the TOs to stop their trains and report their position.

In the event of a significant earthquake, TO experiencing the impact or being informed by passengers or OCC will bring his train to a stop and inform OCC the location of the train.

- If at station, he will not move the train, inform OCC and advice passengers to remain inside the train.

- After receiving OCC instructions that the earthquake has subsided, the trains waiting at stations will detrain passengers.
- For the trains held up between stations, TOs to visually check the track. If the track is unaffected and there are no visible obstruction after informing OCC/TC, train can be moved at walking speed up to the next station where passengers shall be detrained.
- Train Operator (TO) will keep passengers informed of the problem and request them to maintain calm.

In case of any doubt, OCC will arrange for passenger evacuation on the right of way as per procedure. Normal operation of revenue trains shall only be resumed after the track and structures department issuing of a certificate of fitness for normal operations which will be issued after detailed physical inspection. OCC and Station Superintendent/Station Controllers will continuously inform passengers of the situation and likely time for commencement of train services.

16.10 PREPAREDNESS FOR DISASTER MANAGEMENT

Being a technologically complex system with a new set of staff, intensive mock drills for the staff concerned is very essential to train them to become fully conversant with the actions required to be taken up while handling emergencies. They also need to be trained in appropriate communication skills while addressing passengers during incident management to assure them about their well being seeking their cooperation. Since learning can only be perfected by ‘doing’ the following Mock Drills are considered essential:

A. Fire Drill - This shall include

- Making announcements
- Protecting the area
- Summoning assistance
- Using fire fighting equipments locally available
- Passenger evacuation in case of need

B. Rescue of a disabled train

- Identifying causes, isolating fault.
- Announcement to passengers
- Passenger evacuation
- Coupling / Uncoupling of trains for clearing a failed train by an assisting train.
- Driving from an intermediate cab with Cab to Cab telephone communication from front cab.

C. Detrainment of passenger between stations

- Blocking adjacent line
- Announcement to passengers.
- Use of emergency doors.
- Guiding passengers to next station.

D. Passenger evacuation from station

- Announcement to passengers.
- Closing of booking offices.
- Opening of AFC gates/ Emergency exits
- Changing the direction of escalators.
- Crowd control with assistance of security staff and Police/Metro Police.
- Working of TVS system.
- Working of fire suppression and detection system

E. Drill for use of rescue & relief train

The following items need to be noted

- Time taken by the staff to report for duty from the time of first information.
- Departure time of rescue and relief train.
- Testing of all vital systems like generators, control panel.etc.
- Demonstrating a few key functions

F. Hot line telephone communication with state disaster management authority.

16.11 SECURITY MEASURES - BACKGROUND

Metro Rail System has emerged as the most reliable mode of urban transportation system in India. The inherent characteristics of metro system make it an ideal target for terrorists and miscreants. Metro systems are typically open and dynamic systems which carry thousands of commuters. Moreover, high cost of infrastructure, its economic impacts to the society, being the life line of city with high news value pose greater threat to its security. Security is a relatively new challenge in the context of public transport. It addresses problems caused intentionally and 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 terror threat.

The public transportation system is increasingly becoming important for urban areas to prosper in the face of challenges such as reduction in congestion and pollution.

Therefore, security system for public transportation like metro rail plays an important role in helping the system to become the preferred mode choice for commuters. Therefore, provision of an excellent and reliable security system is a prerequisite for metro system for increasing its market share. Metro railway administration must ensure that security model keep pace with the rapid expansion of the metro and changing security scenario.

16.12 THREE PILLARS OF SECURITY

Security means protection of human, intellectual assets and infrastructure either from criminal interference, destruction by terrorists or criminals or incidental to technological failures or natural hazardous events. Three important pillars of security are as follows:

i. The Human factor;
ii. Procedures; and
iii. Technology

Staff interaction with passengers create 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. The staff members should be skillful, trained, drilled and experienced. 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 tested in advance. There are number of technologies which can be used to enhance security e.g. surveillance systems. The objectives of the security systems differ i.e., detection of the plan before an attack, deny the access for carrying out an attack and mitigation measures after an attack.

16.13 DIFFERENT PHASES OF SECURITY

There are three different phases associated with the security system in metro. These phases are as under:

i. Prevention

These are the measures which can prevent a security breach from taking place. These can be identified by conducting risk assessment and gathering intelligence. Prevention begins with the daily operational security problems. Care has to be given in controlling unused, damaged properties which could otherwise prove to be a breeding ground for more serious crimes.

ii. Preparedness

Plans have to be prepared to respond to incidents and to mitigate the impacts. Staff have to be accordingly trained to carry out the exercises. The results of the risk assessment will give basis for such plans.

iii. Recovery

Urban transport system should have laid down procedures/instructions for quick recovery of normal service after an incident. Financial health is important for the recovery 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.

16.14 RESPONSIBILITIES AND PARTNERSHIPS

The responsibility of the Security lies with the state. Security in public requires clear governance. Responsibility should be clearly defined. In the present scenario, this is the responsibility of the State Government to ensure secured travel in Chennai Metro.

16.15 PROPOSED PROVISIONS FOR SECURITY SYSTEM

For providing an efficient security system in metro station areas the following provisions are suggested:

i. CCTV coverage of all metro stations with 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.

ii. 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.

iii. 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.

iv. 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.

v. 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.

vi. Bomb Blanket at least one per station and depot.

vii. Wireless sets (Static and Handheld) as per requirement of security agency.

viii. Dragon light at least one per metro station.

ix. Mobile phones, land lines and EPBX phone connections for senior security officers and control room etc.

x. Dog Squads (Sniffer Dog), at least one dog for 4 metro stations. Dog Kennels alongwith provision for dog handlers and MI room will also be provided by metro train depot administration including land at suitable places line wise.

xi. Bullet proof Morcha one per security check point (i.e. AFC array) and entry gate of metro train depot administration.

xii. Bullet proof jackets and helmets for Quick Response Team (QRTs) and riot control equipments including space at nominated stations. One QRT Team looks after 5-6 metro stations as per present arrangement. One QRT consist of 5 personnel and perform duty in three shifts.

xiii. 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 & office and one steel top table with two chairs for checking point.

xiv. Ladies frisking booth - 1 per security check point (AFC) Wooden Ramp - 1 per DFMD for security check points.

xv. Wall mounted/ pedestal fan at security check point, ladies frisking booth and bullet proof morcha, as per requirement.

xvi. Physical barriers for anti-scaling at Ramp area, low height of via duct by providing iron grill of appropriate height & design/concertina wire.

xvii. Adequate number of ropes. Queue managers, cordoning tapes, dragon search lights for contingency.

xviii. Iron grill at station entrance staircases, proper segregation of paid and unpaid areas by providing appropriate design grills etc.

xix. Proper design of emergency staircase and fireman entry to prevent unauthorized entry.

17. DETAILED PROJECT COST ESTIMATES

17.1 CAPITAL COSTS

17.1.1 Coverage

Cost estimate for Chennai Metro Phase II corridors has been prepared covering civil, electrical, signaling and telecommunications works, rolling stock, environmental protection, rehabilitation, etc. at December' 2018 price level.

While preparing the capital cost estimates, various items have generally been grouped under three major heads on the basis of (i) route km length of alignment, (ii) Number of units of that item and (iii) Item being an independent entity. All items related with alignment, construction, permanent way, OHE, Signaling & Telecommunication, whether in main lines or in maintenance depot, have been estimated at rate per route km/km basis.

Cost of station structures, other electrical services at these stations and Automatic Fare Collection (AFC) installations at all stations have been assessed. Similarly, for items like rolling stock, costs have been estimated in terms of number of units required for each item. In remaining items, viz. land, utility diversions, rehabilitation, etc. 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 recently awarded rates of Chennai Metro Phase I, Phase I extension, DPR for DMRC Ph-IV, DPRs for Lucknow and other Metros and suitable escalation factor has been applied to bring these costs to December' 2018 price level.

Basic cost is exclusive of taxes and duties. i.e. GST and Custom duty. Taxes and duties mainly comprising of latest prevalent GST & Custom duty are worked out separately. Current rates of Taxes have been taken into consideration.

17.1.2 Land Requirement

a) Finalization of alignment, location of stations, entry / exits etc. has been done with the objective of keeping land requirement to bare minimum. For this purpose, alignment & stations are planned on center of road and depots have been planned in the Govt. land to the extent possible. Out of three depots, Major Depot is planned in Madhavaram Milk Colony land. One Minor Depot for stabling purpose is planned in private land near SIPCOT and third depot is planned in HR&CE land near Poonamallee bypass

b) Stations sizes as mentioned in respective chapter are 190m / 150m long and 21.8m / 21.4m wide for Underground 2 level and 3 level, cut & cover construction. Elevated stations are 140m long and 21.95m wide. Working space required during construction is about 3m around the periphery of the station box Land requirement has been evaluated keeping buffer for variable station designs during construction. Additional land in station area shall be utilized for Traffic Integration & Property development. The summary of land requirement for Phase – II corridors is given **Table 17.1.**

c) Rate of Govt. Land required on permanent basis has been taken from Guideline value as provided by CMRL without solatium. In case, State Govt. is in a position to provide its land free of cost or at reduced rates, it will further improve the financial statistics of the project.

d) Rate of Govt. land required on temporary basis has been taken as 1% per annum on cost of Land for the period of Construction. No solatium has been applied to the basic land cost.

e) Rate of Private land is based on Guideline value with 100% solatium applied as per LARRA 2013. No administrative cost is added towards land acquisition activities, as it is understood that this activity shall be carried out by State Govt. from its own resources.

f) Property development have been proposed in Depot area including 29.4 Ha land in Madhavaram depot area and 1.8 Ha in SIPCOT depot area.

g) Rate of Govt. structures is taken as Rs. 20,000 per square meter for new construction. It is pointed out that relocation of certain structures is a condition precedent for dismantling the old structures and clearing the land piece for taking up of construction activities related to Chennai Metro.

TABLE 17.1: LAND & STRUCTURES REQUIREMENT (IN HA) FOR PHASE-II CORRIDORS

Ownership	Purpose	Corridor 3			Corridor 4			Corridor 5		
		Permanent Land	Temporary Land	Structures (Floor area)	Permanent Land	Temporary Land	Structures (Floor area)	Permanent Land	Temporary Land	Structures (Floor area)
Central Govt	Alignment / Stations, ancillary buildings & Misc.	1.942	0	0	0	0	0	0.0957	0	0
	Total	**1.942**	**0**	**0**	**0**	**0**	**0**	**0.0957**	**0**	**0**
State Govt	Alignment / Stations, ancillary buildings & Misc. etc	1.327	0	0.371	4.066	0	0.5579	3.1796	0	0.4367
	Depot	32.3	0	0	17.4	0	0.4008	0	0	0
	Parking cum PD	31.2	0	0	0.9738	0	0	1.253	0	0
	Casting Yard (Approx.)	0	50	0	0	20	0	0	50	0
	Total	**64.827**	**50**	**0.371**	**22.4398**	**20**	**0.9587**	**4.4326**	**50**	**0.4367**
Private	Alignment / Stations, ancillary buildings & Misc., RSS, etc	10.905	0	7.425	5.7008	0	20.3885	10.5873	0	11.5621
	Total	**10.905**	**0**	**7.425**	**5.7008**	**0**	**20.3885**	**10.5873**	**0**	**11.5621**
Grand Total		**77.674**	**50**	**7.796**	**28.1406**	**20**	**21.3472**	**15.1156**	**50**	**11.9988**

h) Rate of Private structures is taken as Rs. 20,000 per square meter for new construction. 100% solatium has been applied to the basic cost. No administrative cost is added towards land acquisition activities, as it is understood that this activity shall be carried out by State Govt. from its own resources.

i) Project involves acquisition of commercial structures in addition to land. 100% solatium has been applied to the basic land cost. No administrative cost is added towards land acquisition activities, as it is understood that this activity shall be carried out by State Govt. from its own resources.

j) The total cost of Land including contingencies works out to be **Rs. 4469.03 Crore** for Corridor-3, **Rs. 2990.73 Crore** for Corridor-4 and **Rs. 2133.20 Crore** for Corridor-5.

17.1.3 Items other than Land : Cost of items other than land is based upon LAR / DPR rates as under:-

TABLE 17.2: BASIS OF RATES

(December' 2018 Price Level, Rates in Rs. Crore)

S. No.	Item	Unit	Rate	Basis of Rates
2.0	**Alignment and Formation**			
a	Underground section by T.B.M excluding station length (190/150m each)	R. Km.	170.89	Based on Weighted mean for soil, rocky & mix area from Geotech report = Rs. 155 Cr. / Km at Jan'17 price level. Escalated to Rs. 167.45 Cr/km at December, 2018 price level.
b	U/G section by cut & cover for Ramp & Crossovers	R. Km.	165.38	As per LAR from CMRL Phase-I ext. & escalated to current price level.
c	U/G cross passages by NATM	No.	1.29	AEML C-6, 2010, 308 Cr. For 2.3 Km. With Taxes (20%) & one tunnel ventilation building. (308-8)/1.2/2.3+ Escalation @ 5% per year for current price level.
d	Elevated section excluding viaduct length in station (140m each)	R. Km.	44.10	Noida LAR rates plus escalation
e	Cost for additional height of viaduct pier to cross metro/flyover at double/triple height	R. Km.	5.00/10.00	12% additional for double elevated viaduct
f	Entry to Depot	R. Km.	44.10	same as 2.4
3.0	**Station Buildings**			
3.1	**Underground Station (190 m length and 2 levels) incl. EM works, VAC etc. by Cut & Cover**			
a	Underground Station-Structural Civil works	Each	152.145	CMRL UG station Tyagaraya College rate (150m x 21.8m in phase-1 ext) plus escalation for current price level

S. No.	Item	Unit	Rate	Basis of Rates
b	Underground Station- EM works etc.	Each	32.08	DMRC Ph-3 LAR CE-09 (lot 3) 06.08.13, Rs. 24.63 Cr. plus 5% per yr. esc.
c	Underground Station - VAC & TVS etc	Each	39.73	DMRC Ph-3 LAR CE-10&11 (lot 3) 08.05.13, Rs. 20.09 Cr. plus 5% per yr. esc. (Rs. 20 Cr. For TVS & Rs. 15 Cr. For VAC)
3.2	**Underground Station (150 m length and 2 levels with extended concourse) incl. EM works, VAC etc. by Cut & Cover**			
a	Underground Station-Structural Civil works	Each	140.44	CMRL UG station Kurkupet College rate (150m x 21.8m in phase-1 ext) plus escalation for current price level
3.3	**Underground Station (150 m length and 3 levels) incl. EM works, VAC etc. by Cut & Cover**			
a	Underground Station-Structural Civil works	Each	174.97	15% additional from 2 level station
3.4	**Underground Station-Architectural Finishes**	Each	11.86	LMRC accepted cost of 58.74 Cr. July'15 for 8 elevated Stations(140m). Cost per Station (140m) = 7.3425 Cr. And Cost per Station (190m) = 9.96 Cr. Escalated rate @ 5% = 11.86 Cr.
3.5	**Elevated Station (Type-I: 140m Length at Level 1)**			
a	Elevated station - Civil Works including Viaduct	Each	26.46	Noida LAR rates plus escalation @5%
b	Elevated station - EM Works etc.	Each	7.10	DMRC Ph-3 LAR CE-1 (lot 1&2) May'13, Rs. 5.17 Cr. plus 5% esc.
3.6	**Elevated Station (Type-II: 140m Length at Level 2)**			
a	Elevated station - Civil Works including Viaduct	Each	34.40	30% additional cost from level-1 station
b	Elevated station - EM Works etc.	Each	7.10	Same as level-1 station
3.7	**Elevated Station (Type-III: Common between C4 & C5)**			
a	Elevated station - Civil Works including Viaduct	Each	10.58	Corridor-4 & Corridor-5 will be one above the other with common pier arrangement for 5 stations with common concourse. Cost of level-1 station has been taken for Corridor-4. Corridor-5 will be at level-2. Hence, 40% of level-1 station is added to Corridor-5 = Rs. 10.58 Cr.
b	Elevated station - EM Works etc.	Each	2.84	40% cost of Level-1 station is added to C-5 for 5 common stations
3.6	**Elevated Station-Architectural Finishes**	Each	8.75	LMRC accepted cost of 58.74 Cr. July'15 for 8 elevated Stations(140m). Cost per Station (140m) = 7.3425 Cr. Escalated rate @ 5% = 8.75 Cr
3.7	**Lifts & Escalators (Elevated and UG stations)**			
a	Lifts	Each	0.51	Nagpur Metro awarded rates with escalation
b	Escalators	Each	0.78	Nagpur Metro awarded rates with escalation
4.0	**Maintenance Depot at Madhavaram**			
a	Civil works	Each	206.94	LMRC Depot April'15, Rs. 105.56Cr. for Civil works. 80% additional due to difference in

S. No.	Item	Unit	Rate	Basis of Rates
				size & civil works = Rs. 190.01 Cr. Escalated rate @ 5% esc. = Rs. 206.94 Cr.
b	EM works + Machinery & Plant + General Works	Each	186.0	LMRC Depot April'15, Rs. 18.44 Cr. for EM works. 100% additional due to difference in size & E&M works. Various LARs for Machinery & Plant = Rs.150 Cr. Total = Rs. 186 Cr.
4.1	**Maintenance Depot at SIPCOT**			
a	Civil works	Each	206.68	Rs. 15 crores for civil works & additional Rs. 191.68 Cr. For Elevated deck. Total = Rs. 206.68 Cr.
b	EM works + Machinery & Plant + General Works	Each	8.00	Minor E&M works like lighting & cabling etc.
4.2	**Maintenance Depot at Poonamallee**			
a	Civil works	Each	124.20	LMRC Depot April'15, Rs. 105.56Cr. for Civil works. Escalated rate @ 5% esc. = Rs. 124.20 Cr.
b	EM works + Machinery & Plant + General Works	Each	101.34	LMRC Depot April'15, Rs. 18.14 Cr. for EM works. Various LARs for Machinery & Plant = Rs.80 Cr. Total = Rs. 101.34 Cr.
5.0	**P-Way**			
a	Ballastless track for elevated & underground Section	Route Km.	9.38	Avg. Of Esc. Rates of DMRC Ph-4 DPR May'14 & LMRC DPR May'13 (Base rates are 7.26 Cr per Route Km & 7.26 Cr per Route Km respectively)
b	Ballastless track for Depot	Track Km.	4.69	Avg. Of Esc. Rates of DMRC Ph-4 DPR May'14 & LMRC DPR May'13 (Base rates are 7.26 Cr per Route Km & 7.26 Cr per Route Km respectively)
c	Ballastless track for entry to Depot	Route Km.	9.38	Avg. Of Esc. Rates of DMRC Ph-4 DPR May'14 & LMRC DPR May'13 (Base rates are 7.26 Cr per Route Km & 7.26 Cr per Route Km respectively)
6.0	**Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators**			
a	UG Section	R. Km.	18.61	DMRC Phase IV DPR, March 2014+ 60 lakh per km for GIS type ASS
b	Elevated section including SCADA	R. Km.	12.70	DMRC Phase IV DPR, March 2014+60 lakh each km for GIS type ASS
c	For Depots	Track Km.	6.05	Phase -IV DMRC DPR Mar'14, Rs. 9.56 Cr. for route Km. & Rs. 4.78 Cr. for Track Km. Plus 5% Esc
d	For 110kV GIS in RSS	Each	20.0	DMRC Ph-4 DPR rates. Cost of AIS substation is accounted in Traction cost.
7.0	**Signaling and Telecom**			
a	Signaling for corridors	R. Km.	8.82	DMRC Ph-III LAR June'13
b	Signaling for Depots	Track Km.	4.41	DMRC Ph-III LAR June'13
c	Telecommunication	Per Station	6.02	LMRC/System/S&T/Tele/LKS02/LOA Nov'15 with escalation
d	Automatic fare collection	Per station	5.04	CMRL Rates Phase I extension (based on phase 1-2011 rates)

S. No.	Item	Unit	Rate	Basis of Rates
e	Platform Screen Doors (Full height)	Per Platform	3.62	CMRL Rates Phase I extension (based on phase 1-2011 rates)
f	Platform Screen Doors (Half height)	Per Platform	2.70	CMRL Rates Phase I extension (based on phase 1-2011 rates)
g	UPS	LS		Rates devised from DMRC Ph-III Noida-G. Noida lines
h	Wifi for Corridor	R. Km.	0.55	As per discussions with DMRC
i	Wifi for Stations	Per Station	0.22	As per discussions with DMRC
8.0	**Rolling Stock**	Each	10.86	LMRC LAR
9.0	**Environment and R & R incl. Hutments etc.**			
a	Environmental Cost	Details in Chapter 15		As per details given in resp. chapter
b	R & R including hutments			As per details given in resp. chapter
10.0	**Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management**			
a	Civil works	R. Km.	4.68	As per DMRC DPR ph-4, Rs. 3.71 Cr. Plus Ecs.
b	Electrical Works	R. Km.	3.69	As per DMRC DPR ph-4, Rs. 2.93 Cr. Plus Ecs.
11.0	**Capital Expenditure on Security:** Estimated rates are based upon average of escalated rates of DMRC Ph-IV DPR May'14 & LMRC DPR May'13. The expenditure is required to cover the civil and Electrical items, equipments (X-Ray machine, Metal detector etc.)			
12.0	**Staff Quarters and OCC Building:** Estimated rates are based upon average of escalated rates of DMRC Ph-IV DPR May'14 & LMRC DPR May'13. OCC building is included in cost estimate for corridor-3 only and it will cover Corridor-4 & 5 also. As such, no separate OCC building will be required for corridor-4.			
13.0	**Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles:** As per LMRC DPR. As per LMRC DPR, it is taken @ 2% of total cost excluding land.			

17.1.4 Capital Cost Estimate

Detailed capital cost estimates for Corridor-3, 4 & 5 are given in **Table 17.3, Table 17.4** and **Table 17.5** respectively.

TABLE 17.3: CAPITAL COST ESTIMATE OF CORRIDOR - 3 FROM MADHAVARAM TO SIPCOT

Total Length = 45.813 Km, From = -383m to 45430.4m, UG = 26.723 Km & ELEV = 19.090 Km
UG Depot Entry = 0.412 Km

Stations = 49, Elevated = 20 No's, U/G by Cut & cover =29 No's,

December' 2018, Price Level (Rs. In Crores)

S. No.	Item	Unit	Rate	Qty.	Amount Without taxes
1.0	**Land**				
a	Central Govt. Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Misc., without Solatium)	**Ha**	104.30	1.942	202.55
b	Central Govt. Structures -Permanent	**Ha**	20.00	0.000	0.00
c	State Govt. Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Misc., without Solatium)	**Ha**	104.30	1.327	138.41

S. No.	Item	Unit	Rate	Qty.	Amount Without taxes
d	State Govt. Land -Permanent (for Depot without Solatium)	**Ha**	21.53	32.300	695.42
e	State Govt. Land -Permanent (for Parking cum PD in Depot)	**Ha**	21.53	31.200	671.74
f	State Govt. Structures -Permanent	**Ha**	20.00	0.371	7.42
g	State Govt. Land - Temporary (for Construction Yard)	**Ha**	6.26	50.000	312.90
h	Private Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Shafts, Misc., including Solatium)	**Ha**	196.57	10.905	2143.60
i	Private Land -Permanent (for Parking cum PD in Depot)	**Ha**	0.00	0.000	0.00
J	Private Structure - Permanent with Solatium	**Ha**	40.00	7.425	297.00
	Sub Total (1)				**4469.03**
2.0	**Alignment and Formation**				
2.1	Underground section by T.B.M excluding station length (190/150m each)	R. Km.	170.89	20.769	3549.16
2.2	U/G section by cut & cover for Ramp (0.216 Km) & Crossovers (0.598 Km)	R. Km.	165.38	0.814	134.62
2.3	U/G cross passages by NATM	No.	1.29	88	113.76
2.4	Elevated section excluding viaduct length in station (140m each)	R. Km.	44.10	16.290	718.41
2.5	Cost for additional height on OMR in lieu of Metro cum elevated road (this does not include road viaduct)	R. Km.	5.00	16.290	81.45
2.6	Entry for Depot (UG)	R. Km.	165.38	0.412	68.13
	Sub Total (2)				**4665.54**
3.0	**Station Buildings**				
3.1	**Underground Station (190 m length and 2 levels) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	152.15	16	2434.32
b	Underground Station- EM works etc.	Each	32.08	16	513.28
c	Underground Station - VAC & TVS etc	Each	39.73	16	635.68
3.2	**Underground Station (150 m length and 2 levels with extended concourse) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	140.44	4	561.76
b	Underground Station- EM works etc.	Each	32.08	4	128.32
c	Underground Station - VAC & TVS etc	Each	39.73	4	158.92
3.3	**Underground Station (150 m length and 3 levels) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	174.97	10	1749.67
b	Underground Station- EM works etc.	Each	32.08	10	320.80
c	Underground Station - VAC & TVS etc	Each	39.73	10	397.30
3.4	**Underground Station- Architectural Finishes**	Each	11.86	30	355.88
3.5	**Elevated Station Buildings (Type -I: 140mx21.95m)**				
a	Elevated station - Civil Works including Viaduct	Each	26.46	20	529.20

S. No.	Item	Unit	Rate	Qty.	Amount Without taxes
b	Cost for additional height on OMR in lieu of Metro cum elevated road	Each	5.29	20	105.84
c	Elevated station - EM Works etc.	Each	7.10	20	142.00
3.6	**Elevated Station- Architectural Finishes**	Each	8.75	20	174.91
3.7	**Lifts & Escalators (Elevated and UG stations)**				
a	Lifts	Each	0.51	172	87.72
b	Escalators	Each	0.78	541	421.98
	Sub Total (3)				**8717.58**
4.0	**Maintenance Depot at Madhavaram**				
a	Civil works	Each			206.94
b	EM works + Machinery & Plant + General Works	Each			186.00
4.1	**Maintenance Depot at SIPCOT**				
a	Civil works	Each			206.68
b	EM works + Machinery & Plant + General Works	Each			8.00
	Sub Total (4)				**607.62**
5.0	**P-Way**				
5.1	Ballastless track for elevated & underground Section	Route Km.	9.38	45.813	429.84
5.2	Ballastless track for Depot	Track Km.	4.69	23.000	107.90
5.3	Ballastless track for entry to Depot	Route Km.	9.38	0.412	3.87
	Sub Total (5)				**541.60**
6.0	**Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators**				
6.1	UG Section	R. Km.	18.61	26.723	497.32
6.2	Elevated section including SCADA	R. Km.	12.70	19.090	242.45
6.4	Entry for Depot (UG)	R. Km.	18.61	0.412	7.67
6.3	For Depots	Track Km.	6.05	23.000	139.15
6.5	For 110kV GIS in RSS	Each	20.00	3	60.00
6.6	Additional cost for 110 kv cables	LS			20.00
	Sub Total (6)				**966.58**
7.0	**Signalling and Telecom.**				
7.1	Signalling for corridors	R. Km.	8.82	46.225	407.71
7.2	Signalling for Depots	Track Km.	4.41	23.000	101.43
7.3	Telecommunication	Per Station	6.02	50	301.00
7.4	Automatic fare collection	Per station	5.04	50	252.00
7.5	Central Clearing House System (CCHS)	Each	16.54	1	16.54
7.6	Platform Screen Doors (Full height)	Per Platform	3.62	60	217.20
7.7	Platform Screen Doors (Half height)	Per Platform	2.70	40	108.00
7.8	UPS	LS			28.67
7.9	Wifi for Corridor	R. Km.	0.55	46.225	25.48
7.10	Wifi for Stations	Per Station	0.22	50	11.03
	Sub Total (7)				**1469.05**
8.0	**Rolling Stock**	Each	10.86	144	1563.84
	Sub Total (8)				**1563.84**
9.0	**Environment and R & R incl. Hutments etc.**				
a	Environmental Cost	--			17.60
b	R & R	--			75.53
	Sub Total (9)				**93.13**

S. No.	Item	Unit	Rate	Qty.	Amount Without taxes
10.0	**Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management**				
a	Civil works	R. Km.	4.68	46.225	216.22
b	Electrical Works	R. Km.	3.69	46.225	170.76
	Sub Total (10)				**386.99**
11.0	**Capital Expenditure on Security**				
a	Civil works	Per Station	0.334	50	16.71
b	EM works	Per Station	0.079	50	3.97
	Sub Total (11)				**20.68**
12.0	**Staff Quarters and OCC Building**				
a	Civil works	R. Km.	1.469	46.225	67.90
b	EM works	R. Km.	0.357	46.225	16.49
c	Cost of OCC Building - Civil Works	LS			48.03
d	Cost of OCC Building - E&M Works	LS			12.01
e	Cost for Green Building concept	LS			10.00
	Sub Total (12)				**154.43**
13.0	**Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land and R&R**				**382.23**
14.0	**Total of all items except Land and R&R**				**19493.73**
15.0	**General Charges including Design charges, incl. Metro Bhawan Building (Civil+EM works) @ 5% on all items except Land and R&R**				**974.69**
16.0	**Total of all items including G. Charges**				**20468.41**
17.0	**Contingencies @ 3 % on all items except Land and R&R**				**614.05**
18.0	**Total Cost including Contingencies & excluding Land and R&R Cost**				**21082.47**
19.0	**Total Cost including Contingencies & including Land and R&R Cost**			=	**25627.02**
20.0	**Central Taxes & Duties**				**1975.98**
21.0	**State Taxes & Duties**				**1589.04**
22.0	**Total Taxes & Duties**				**3565.02**
23.0	**Total Cost including Taxes & Duties**				**29192.05**
			Say	=	**29192.00**

TABLE 17.4: CAPITAL COST ESTIMATE OF CORRIDOR – 4 FROM LIGHTHOUSE TO POONAMALLEE BYPASS

Total Length = 26.085 Km, From = -255m to 25830m, UG = 10.071 Km & ELEV = 16.014 Km
Depot Entry = 1.00 Km

Stations = 30, Elevated = 18 No's, U/G by Cut & cover =12 No's,

December' 2018, Price Level (Rs. In Crores)

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
1.0	**Land**				
a	Central Govt. Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Misc., without Solatium)	**Ha**	0.00	0.0000	0.00
b	State Govt. Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Misc., without Solatium)	**Ha**	94.53	4.0660	384.36
c	State Govt. Land -Permanent (for Depot without Solatium)	**Ha**	4.33	17.4000	75.34
d	State Govt. Land -Permanent (for Parking cum PD)	**Ha**	4.33	0.9738	4.22
e	State Govt. Structures -Permanent	**Ha**	20.00	0.9587	19.17
f	State Govt. Land - Temporary (for Construction Yard)	**Ha**	5.67	20.0000	113.44
g	Private Land (for Alignment, RSS, Ancillary Bldgs., Shafts, Misc., including Solatium)	**Ha**	276.92	5.7008	1578.66
h	Private Land -Permanent (for Parking cum PD)	**Ha**	276.92	0.000	0.00
i	Private Structure - Permanent without Solatium	**Ha**	40.00	20.3885	815.54
	Sub Total (1)				**2990.73**
2.0	**Alignment and Formation**				
2.1	Underground section by T.B.M excluding station length (190/150m each)	R. Km.	170.89	7.484	1278.87
2.2	U/G section by cut & cover for Ramp (0.248 Km) & Crossovers (0.299 Km)	R. Km.	165.38	0.547	90.54
2.3	U/G cross passages by NATM	Each	1.29	32	41.37
2.4	Elevated section excluding viaduct length in station (140m each)	R. Km.	44.10	13.494	595.09
2.5	Additional cost for Double height Elevated section	R. Km.	5.00	1.750	8.75
2.6	Additional cost for Triple height Elevated section	R. Km.	10.00	1.160	11.60
2.7	Entry for Depot (Elevated)	R. Km.	44.10	1.000	44.10
	Sub Total (2)				**2070.31**
3.0	**Station Buildings**				
3.1	**Underground Station (190 m length and 2 levels) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	152.145	6	912.87

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
b	Underground Station- EM works etc.	Each	32.08	6	192.48
c	Underground Station - VAC & TVS etc	Each	39.73	6	238.38
3.2	**Underground Station (150 m length and 2 levels with extended concourse) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	140.44	1	140.44
b	Underground Station- EM works etc.	Each	32.08	1	32.08
c	Underground Station - VAC & TVS etc	Each	39.73	1	39.73
3.3	**Underground Station (150 m length and 3 levels) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	174.97	5	874.83
b	Underground Station- EM works etc.	Each	32.08	5	160.40
c	Underground Station - VAC & TVS etc	Each	39.73	5	198.65
3.4	**Underground Station- Architectural Finishes**	Each	11.86	12	142.35
3.5	**Elevated Station Buildings (Type -I: 140mx21.95m)**				
a	Elevated station - Civil Works including Viaduct	Each	26.46	18	476.28
b	Elevated station - EM Works etc.	Each	7.10	18	127.80
3.6	**Elevated Station- Architectural Finishes**	Each	8.75	18	157.41
3.7	**Lifts & Escalators (Elevated and UG stations)**				
a	Lifts	Each	0.51	101	51.51
b	Escalators	Each	0.78	276	215.28
	Sub Total (3)				**3960.50**
4.0	**Maintenance Depot at Poonamallee Bypass**	Each			
a	Civil works	LS			124.20
b	EM works + Machinery & Plant + General Works	LS			101.34
	Sub Total (4)				**225.54**
5.0	**P-Way**				
5.1	Ballastless track for elevated & underground Section	Route Km.	9.38	26.085	244.74
5.2	Ballastless track for Depot	Track Km.	4.69	11.000	51.60
5.3	Ballastless track for entry to Depot	Route Km.	9.38	1.000	9.38
	Sub Total (5)				**305.72**
6.0	**Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators**				
6.1	UG Section	R. Km.	18.61	10.071	187.42
6.2	Elevated section including SCADA	R. Km.	12.70	16.014	203.38
6.3	Entry to Depot (UG)	R. Km.	12.70	1.00	12.70
6.4	For Depot	Track Km.	6.05	11.00	66.55
6.5	For 110kV GIS in RSS	Each	20.00	2	40.00
6.6	Additional cost for 110 kv cables	LS			20.00
	Sub Total (6)				**530.05**
7.0	**Signalling and Telecom.**				

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
7.1	Signalling for Corridors	R. Km.	8.82	27.085	238.89
7.2	Signalling for Depot	Track Km.	4.41	11.000	48.51
7.3	Telecommunication	Per Station	6.02	30	180.60
7.4	Automatic fare collection	Per station	5.04	30	151.20
7.5	Platform Screen Doors (Full height)	Per Platform	3.62	24	86.88
7.6	Platform Screen Doors (Half height)	Per Platform	2.70	36	97.20
7.7	UPS	LS			13.23
7.8	Wifi for Corridors	R. Km.	0.55	26.085	14.38
7.9	Wifi for Stations	Per Station	0.22	30	6.62
	Sub Total (7)				**837.51**
8.0	**Rolling Stock**	Each	10.86	78	847.08
	Sub Total (8)				**847.08**
9.0	**Environment and R & R incl. Hutments etc.**				
a	Environmental Cost	--			8.33
b	R & R	--			75.76
	Sub Total (9)				**84.09**
10.0	**Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management**				
a	Civil works	R. Km.	4.68	27.085	126.69
b	Electrical Works	R. Km.	3.69	27.085	100.06
	Sub Total (10)				**226.75**
11.0	**Capital Expenditure on Security**				
a	Civil works	Per Station	0.334	30	10.02
b	EM works	Per Station	0.079	30	2.38
	Sub Total (11)				**12.41**
12.0	**Staff Quarters for O&M**				
a	Civil works	R. Km.	1.469	27.085	39.78
b	EM works	R. Km.	0.357	27.085	9.66
	Sub Total (12)				**49.45**
13.0	**Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land and R&R**				**181.47**
14.0	**Total of all items except Land and R&R**				**9255.13**

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
15.0	General Charges incl. Design charges, @ 5% on all items except Land and R&R				462.76
16.0	Total of all items including G. Charges				9717.89
17.0	Contingencies @ 3 % on all items except Land and R&R				291.54
18.0	Gross Total including Contingencies & excluding Land and R&R Cost				10009.42
19.0	Gross Total including Contingencies & including Land and R&R Cost			=	13075.91
20.0	Central Taxes & Duties				933.10
21.0	State Taxes & Duties				752.43
22.0	Total Taxes & Duties				1685.52
23.0	Total Cost including Taxes & Duties				14761.43
			Say	=	14761.00

TABLE 17.5: CAPITAL COST ESTIMATE OF CORRIDOR – 5 FROM MADHAVARAM TO SHOLINGANALLUR

Total Length = 47.008 Km, From = -386m to 46623m, UG = 5.835 Km, ELEV = 40.597 Km & At-grade = 0.577 Km. At-grade Depot Entry = 0.5 Km
Stations = 48, Elevated = 41 No's, At-grade = 1, & U/G by Cut & cover = 6 No's,

December' 2018, Price Level (Rs. In Crores)

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
1.0	**Land**				
a	Central Govt. Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Misc., without Solatium)	**Ha**	34.76	0.096	3.33
b	State Govt. Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Misc., without Solatium)	**Ha**	81.48	3.180	259.09
c	State Govt. Land -Permanent (for Parking cum PD)	**Ha**	81.48	1.253	102.10
d	State Govt. Structures -Permanent	**Ha**	20.00	0.437	8.73
e	State Govt. Land - Temporary (for Construction Yard)	**Ha**	4.89	50.000	244.45
f	Private Land -Permanent (for Alignment, RSS, Ancillary Bldgs., Shafts, Misc., including Solatium)	**Ha**	99.46	10.587	1053.01
g	Private Land -Permanent (for Parking cum PD)	**Ha**	99.46	0.000	0.00
h	Private Structure - Permanent without Solatium	**Ha**	40.00	11.562	462.48
	Sub Total (1)				**2133.20**

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
2.0	**Alignment and Formation**				
2.1	Underground section by T.B.M excluding station length (190/150m each)	R. Km.	170.89	3.864	660.24
2.2	U/G section by cut & cover for Ramp (0.612 Km) & Crossovers (0.299 Km)	R. Km.	165.38	0.911	150.66
2.3	U/G cross passages by NATM	R. Km.	1.29	17	21.98
2.4	Elevated section excluding viaduct length in station (140m each) & excluding 4 Km common section of C4 & C5 between Alwathirunagar & Porur jn)	R. Km.	44.10	30.857	1360.78
2.5	Additional cost for Double height Elevated section (including common section of C4 & C5 between Alwathirunagar & Porur jn.)	R. Km.	5.00	15.347	76.74
2.6	Additional cost for Triple height Elevated section	R. Km.	10.00	0.150	1.50
2.7	At-grade section including station length	R. Km.	10.00	0.577	5.77
2.8	Entry for Depot (At-grade)	R. Km.	10.00	0.500	5.00
	Sub Total (2)				**2282.66**
3.0	**Station Buildings**				
3.1	**Underground Station (190 m length and 2 levels) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	152.15	4	608.58
b	Underground Station- EM works etc.	Each	32.08	4	128.32
c	Underground Station - VAC & TVS etc	Each	39.73	4	158.92
3.2	**Underground Station (150 m length and 2 levels with extended concourse) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	140.44	1	140.44
b	Underground Station- EM works etc.	Each	32.08	1	32.08
c	Underground Station - VAC & TVS etc	Each	39.73	1	39.73
3.3	**Underground Station (150 m length and 3 levels) incl. EM works, VAC etc. by Cut & Cover**				
a	Underground Station- Structural Civil works	Each	174.97	1	174.97
b	Underground Station- EM works etc.	Each	32.08	1	32.08
c	Underground Station - VAC & TVS etc	Each	39.73	1	39.73
3.4	**Underground Station- Architectural Finishes**	Each	11.86	6	71.18
3.5	**Elevated Station (Type-I: 140m Length at Level 1)**				
a	Elevated station - Civil Works including Viaduct	Each	26.46	24	635.04
b	Elevated station - EM Works etc.	Each	7.10	24	170.40
3.6	**Elevated Station (Type-II: 140m Length at Level 2)**				
a	Elevated station - Civil Works including Viaduct	Each	34.40	12	412.78
b	Elevated station - EM Works etc.	Each	7.10	12	85.20

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
3.7	**Elevated Station (Type-III: Common between C4 & C5)**				
a	Elevated station - Civil Works including Viaduct	Each	10.58	5	52.92
b	Elevated station - EM Works etc.	Each	2.84	5	14.20
3.8	**At-grade Station Buildings (Type -IV: 140m Length)**				
a	At-grade station - Civil Works	Each	15.00	1	15.00
b	At-grade station - EM Works etc.	Each	7.10	1	7.10
3.9	**Elevated Station- Architectural Finishes**	Each	8.75	42	367.30
3.9	**Lifts & Escalators (Elevated and UG stations)**				
a	Lifts	Each	0.51	204	104.04
b	Escalators	Each	0.78	329	256.62
	Sub Total (3)				**3546.62**
4.0	**Maintenance Depot**				
a	Civil works	LS			0.00
b	EM works + Machinery & Plant + General Works	LS			0.00
	Sub Total (4)				**0.00**
5.0	**P-Way**				
5.1	Ballastless track for elevated, at-grade & underground Section	Route Km.	9.38	47.008	441.05
5.2	Ballastless track for Depot	Track Km.	4.69	0.000	0.00
5.3	Ballastless track for entry to Depot	Route Km.	9.38	0.500	4.69
	Sub Total (5)				**445.74**
6.0	**Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators**				
6.1	UG Section	R. Km.	18.61	5.835	108.58
6.2	Elevated section including SCADA	R. Km.	12.70	41.174	522.91
6.3	Entry for Depot (At-grade)	R. Km.	12.70	0.50	6.35
6.4	For Depot	Track Km.	6.05	0.00	0.00
6.5	For 110kV GIS in RSS	Each	20.00	4	80.00
6.6	Additional cost for 110 kv cables	LS			20.00
	Sub Total (6)				**737.84**
7.0	**Signalling and Telecom.**				
7.1	Signalling for corridors	R. Km.	8.82	47.508	419.02
7.2	Signalling for Depots	Track Km.	4.41	0	0.00
7.3	Telecommunication	Per Station	6.02	48	288.96
7.4	Automatic fare collection	Per station	5.04	48	241.92
7.5	Platform Screen Doors (Full height)	Per Platform	3.62	12	43.44

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
7.6	Platform Screen Doors (Half height)	Per Platform	2.70	84	226.80
7.7	UPS	LS			27.56
7.8	Wifi for Corridors	R. Km.	0.55	47.008	25.91
7.9	Wifi for Stations	Per Station	0.22	48	10.58
	Sub Total (7)				**1284.20**
8.0	**Rolling Stock**	Each	10.86	192	2085.12
	Sub Total (8)				**2085.12**
9.0	**Environment and R & R incl. Hutments etc.**				
a	Environmental Cost	--			22.76
b	R & R	--			140.01
	Sub Total (9)				**162.77**
10.0	**Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management**				
a	Civil works	R. Km.	4.68	47.508	222.22
b	Electrical Works	R. Km.	3.69	47.508	175.50
	Sub Total (10)				**397.73**
11.0	**Capital Expenditure on Security**				
a	Civil works	Per Station	0.334	48	16.04
b	EM works	Per Station	0.079	48	3.81
	Sub Total (11)				**19.85**
12.0	**Staff Quarters for O&M**				
a	Civil works	R. Km.	1.469	47.508	69.78
b	EM works	R. Km.	0.357	47.508	16.95
e	Cost for Green Building concept	LS			0.00
	Sub Total (12)				**86.73**
13.0	**Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land and R&R**				**218.19**
14.0	**Total of all items except Land and R&R**				**11127.44**
15.0	**General Charges including Design charges @ 5% on all items except Land and R&R**				**556.37**
16.0	**Total of all items including G. Charges**				**11683.81**
17.0	**Contingencies @ 3 % on all items except Land and R&R**				**350.51**
18.0	**Total Cost including Contingencies & excluding Land and R&R Cost**				**12034.33**
19.0	**Total Cost including Contingencies & including Land and R&R Cost**			=	**14307.53**

S. No.	Item	Unit	Rate	Qty.	Amount (Without taxes)
20.0	**Central Taxes & Duties**				**1150.57**
21.0	**State Taxes & Duties**				**923.63**
22.0	**Total Taxes & Duties**				**2074.20**
23.0	**Total Cost including Taxes & Duties**				**16381.73**
			Say	**=**	**16382.00**

17.1.5 Taxes and Duties

Taxes and duties are worked out for each corridor separately. Current rates of GST (i.e. 12% on Metro projects) have been taken into consideration and have been applied as per prevalent practice. Taxes & duties for Phase II corridors have been worked out in **Table 17.7, Table 17.8 and Table 17.9.**

TABLE 17.6: TAXES & DUTIES COMPONENTS

SN	Tax Component		%
1	Basic Customs duty	=	5.1500%
2	IGST (Central portion)	=	9.4635%
3	IGST (State portion)	=	9.4635%
4	**Total taxes & duties on Imported items**	**=**	**24.0770%**
5	General CGST	=	6.0000%
6	General SGST	=	6.0000%
7	**Total taxes & duties on Domestic items**	=	12.0000%

TABLE 17.7: DETAILS OF TAXES AND DUTIES FOR CORRIDOR-3

S. No.	Description	Total cost	Taxes and duties (in Crores)							
			Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
1	**Alignment & Formation**									
	Underground	3865.68	59.72	109.75	109.75	279.22	162.36	162.36	324.72	**603.94**
	Elevated	799.86	0.00	0.00	0.00	0.00	47.99	47.99	95.98	**95.98**
2	**Station Buildings**									
	Underground station-civil works	5101.63	78.82	144.84	144.84	368.50	214.27	214.27	428.54	**797.03**
	Underground station-EM works	2460.12	63.35	116.41	116.41	296.16	73.80	73.80	147.61	**443.77**

S. No.	Description	Total cost	Taxes and duties (in Crores)							
			Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
	Elevated station - civil works	809.95	0.00	0.00	0.00	0.00	48.60	48.60	97.19	**97.19**
	Elevated station-EM works	345.88	3.56	6.55	6.55	16.66	16.60	16.60	33.20	**49.86**
3	**Depot**									
	Civil works	413.62	6.39	11.74	11.74	29.88	17.37	17.37	34.74	**64.62**
	EM and M&P works	194.00	2.00	3.67	3.67	9.34	21.73	21.73	43.46	**52.80**
4	**P-Way**	541.60	22.31	41.00	41.00	104.32	6.50	6.50	13.00	**117.32**
5	**Traction & power supply**									
	Traction and power supply	966.58	19.91	36.59	36.59	93.09	34.80	34.80	69.59	**162.68**
6	**S and T Works**									
	S & T	810.14	33.38	61.33	61.33	156.05	14.58	14.58	29.16	**185.21**
	AFC	252.00	9.73	17.89	17.89	45.51	5.67	5.67	11.34	**56.85**
	CCHS	16.54	0.68	1.25	1.25	3.19	0.30	0.30	0.60	**3.78**
	PSD, UPS & Wifi	390.37	16.08	29.55	29.55	75.19	7.03	7.03	14.05	**89.25**
7	**Environmental works**	17.60	0.00	0.00	0.00	0.00	1.06	1.06	2.11	**2.11**
8	**Misc.**									
	Civil works	216.22	0.00	0.00	0.00	0.00	12.97	12.97	25.95	**25.95**
	EM works	170.76	0.00	0.00	0.00	0.00	23.91	23.91	47.81	**47.81**
9	**Security**									
	Civil works	16.71	0.00	0.00	0.00	0.00	1.00	1.00	2.00	**2.00**
	EM works	3.97	0.00	0.00	0.00	0.00	0.56	0.56	1.11	**1.11**
10	**Staff quarters**									
	Civil works	67.90	0.00	0.00	0.00	0.00	4.07	4.07	8.15	**8.15**
	EM works	16.49	0.00	0.00	0.00	0.00	2.31	2.31	4.62	**4.62**
11	**OCC Buildings**									
	Civil works	58.03	0.00	0.00	0.00	0.00	3.48	3.48	6.96	**6.96**
	EM works	12.01	0.12	0.23	0.23	0.58	1.34	1.34	2.69	**3.27**
12	**Intermodal Integration**	382.23	0.00	0.00	0.00	0.00	22.93	22.93	45.87	**45.87**
13	**Rolling stock**	1563.84	70.87	130.23	130.23	331.34	16.89	16.89	33.78	**365.12**
14	**Rent on**	312.90	0.00	0.00	0.00	0.00	28.16	28.16	56.32	**56.32**

S. No.	Description	Total cost	Taxes and duties (in Crores)							
			Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
	Temporary Land									
15	General Charges	974.69	0.00	0.00	0.00	0.00	87.72	87.72	175.44	**175.44**
16	**Total**	**20781.31**	**386.94**	**711.03**	**711.03**	**1809.01**	**878.00**	**878.00**	**1756.01**	**3565.02**
	Total taxes & Duties							**SAY**		**3565.02**
	Central Taxes & Duties		**A + B + E**							**1975.98**
	State Taxes & Duties		**C + F**							**1589.04**

TABLE 17.8: DETAILS OF TAXES AND DUTIES FOR CORRIDOR-4

S. No.	Description	Total cost	Taxes and duties (in Crores)							
			Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
1	**Alignment & Formation**									
	Underground	1410.77	21.80	40.05	40.05	101.90	59.25	59.25	118.51	**220.41**
	Elevated	659.54	0.00	0.00	0.00	0.00	39.57	39.57	79.14	**79.14**
2	**Station Buildings**									
	Underground station-civil works	2070.50	31.99	58.78	58.78	149.55	86.96	86.96	173.92	**323.48**
	Underground station-EM works	968.44	24.94	45.82	45.82	116.59	29.05	29.05	58.11	**174.69**
	Elevated station - civil works	633.69	0.00	0.00	0.00	0.00	38.02	38.02	76.04	**76.04**
	Elevated station-EM works	287.88	2.97	5.45	5.45	13.86	13.82	13.82	27.64	**41.50**
3	**Depot**									
	Civil works	124.20	1.92	3.53	3.53	8.97	5.22	5.22	10.43	**19.40**
	EM and M&P works	101.34	1.04	1.92	1.92	4.88	11.35	11.35	22.70	**27.58**
4	**P-Way**	305.72	12.60	23.15	23.15	58.89	3.67	3.67	7.34	**66.22**
5	**Traction & power supply**									
	Traction and power supply	530.05	10.92	20.06	20.06	51.05	19.08	19.08	38.16	**89.21**

S. No.	Description	Total cost	Taxes and duties (in Crores)							
			Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
6	**S and T Works**									
	S & T	468.00	19.28	35.43	35.43	90.14	8.42	8.42	16.85	**106.99**
	AFC	151.20	5.84	10.73	10.73	27.30	3.40	3.40	6.80	**34.11**
	CCHS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	PSD, UPS & Wifi	218.30	8.99	16.53	16.53	42.05	3.93	3.93	7.86	**49.91**
7	**Environmental works**	8.33	0.00	0.00	0.00	0.00	0.50	0.50	1.00	**1.00**
8	**Misc.**									
	Civil works	126.69	0.00	0.00	0.00	0.00	7.60	7.60	15.20	**15.20**
	EM works	100.06	0.00	0.00	0.00	0.00	14.01	14.01	28.02	**28.02**
9	**Security**									
	Civil works	10.02	0.00	0.00	0.00	0.00	0.60	0.60	1.20	**1.20**
	EM works	2.38	0.00	0.00	0.00	0.00	0.33	0.33	0.67	**0.67**
10	**Staff quarters**									
	Civil works	39.78	0.00	0.00	0.00	0.00	2.39	2.39	4.77	**4.77**
	EM works	9.66	0.00	0.00	0.00	0.00	1.35	1.35	2.71	**2.71**
11	**OCC Buildings**									
	Civil works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	EM works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
12	**Intermodal Integration**	181.47	0.00	0.00	0.00	0.00	10.89	10.89	21.78	**21.78**
13	**Rolling stock**	847.08	38.39	70.54	70.54	179.48	9.15	9.15	18.30	**197.77**
14	**Rent on Temporary Land**	113.44	0.00	0.00	0.00	0.00	10.21	10.21	20.42	**20.42**
15	**General Charges**	462.76	0.00	0.00	0.00	0.00	41.65	41.65	83.30	**83.30**
16	**Total**	9831.32	180.67	332.00	332.00	844.66	420.43	420.43	840.86	**1685.52**
	Total taxes & Duties							**SAY**		**1685.52**
	Central Taxes & Duties		**A + B + E**							**933.10**
	State Taxes & Duties		**C + F**							**752.43**

TABLE 17.9: DETAILS OF TAXES AND DUTIES FOR CORRIDOR-5

S.	Description	Total	Taxes and duties (in Crores)

No.		cost	Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
1	**Alignment & Formation**									
	Underground	832.88	12.87	23.65	23.65	60.16	34.98	34.98	69.96	130.12
	Elevated	1449.78	0.00	0.00	0.00	0.00	86.99	86.99	173.97	173.97
2	**Station Buildings**									
	Underground station-civil works	995.16	15.38	28.25	28.25	71.88	41.80	41.80	83.59	155.48
	Underground station-EM works	475.94	12.26	22.52	22.52	57.30	14.28	14.28	28.56	85.85
	Elevated station - civil works	1483.04	0.00	0.00	0.00	0.00	88.98	88.98	177.96	177.96
	Elevated station-EM works	592.48	6.10	11.21	11.21	28.53	28.44	28.44	56.88	85.41
3	**Depot**									
	Civil works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	EM and M&P works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	**P-Way**	445.74	18.36	33.75	33.75	85.86	5.35	5.35	10.70	96.55
5	**Traction & power supply**									
	Traction and power supply	737.84	15.20	27.93	27.93	71.06	26.56	26.56	53.12	124.18
6	**S and T Works**									
	S & T	707.98	29.17	53.60	53.60	136.37	12.74	12.74	25.49	161.86
	AFC	241.92	9.34	17.17	17.17	43.69	5.44	5.44	10.89	54.57
	CCHS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PSD, UPS & Wifi	334.30	13.77	25.31	25.31	64.39	6.02	6.02	12.03	76.43
7	**Environmental works**	22.76	0.00	0.00	0.00	0.00	1.37	1.37	2.73	2.73
8	**Misc.**									
	Civil works	222.22	0.00	0.00	0.00	0.00	13.33	13.33	26.67	26.67
	EM works	175.50	0.00	0.00	0.00	0.00	24.57	24.57	49.14	49.14
9	**Security**									
	Civil works	16.04	0.00	0.00	0.00	0.00	0.96	0.96	1.92	1.92
	EM works	3.81	0.00	0.00	0.00	0.00	0.53	0.53	1.07	1.07
10	**Staff quarters**									
	Civil works	69.78	0.00	0.00	0.00	0.00	4.19	4.19	8.37	8.37

S. No.	Description	Total cost	Taxes and duties (in Crores)							
			Basic Customs Duty	IGST (Central portion)	IGST (State portion)	Total Customs Duty	CGST	SGST	Total GST	Total Taxes & Duties
			A	B	C	D=A+B+C	E	F	G=E+F	H=D+G
	EM works	16.95	0.00	0.00	0.00	0.00	2.37	2.37	4.75	4.75
11	**OCC Buildings**									
	Civil works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	EM works	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	**Intermodal Integration**	218.19	0.00	0.00	0.00	0.00	13.09	13.09	26.18	26.18
13	**Rolling stock**	2085.12	94.50	173.65	173.65	441.79	22.52	22.52	45.04	486.83
14	**Rent on Temporary Land**	244.45	0.00	0.00	0.00	0.00	22.00	22.00	44.00	44.00
15	**General Charges**	556.37	0.00	0.00	0.00	0.00	50.07	50.07	100.15	100.15
16	**Total**	11928.26	226.95	417.04	417.04	1061.02	506.59	506.59	1013.18	2074.20
	Total taxes & Duties							**SAY**		**2074.20**
	Central Taxes & Duties		**A + B + E**							**1150.57**
	State Taxes & Duties		**C + F**							**923.63**

17.2 INOVATIONS PROPOSED TO REDUCE THE COST

All efforts have been made to reduce the capital cost. Rates for various components involved in Metro Rail Systems like Civil works, E&M works, Traction & Power supply, Signaling & Telecommunication etc. costs have been assessed comparing the awarded rates of Chennai Metro Phase I, Phase I extension, Lucknow Metro, DPR for DMRC Ph-IV and other Metro systems across the country.

The size of the tunnels proposed for Phase-II is similar to what is been constructed in Phase-I for optimal utilization of Tunnel Boring Machines. This shall encourage indigenous development and manufacturing of components that are being presently imported. Such steps shall induce progressive increase in local content in procurement, construction etc.

The costs of rolling stock have been assessed considering establishment of manufacturing / assembling units of major suppliers of rolling stock in India. The type / size of the rolling stock have been taken similar to Phase-I for optimal utilization.

17.3 SUMMARY OF CAPITAL COSTS

The summary of capital cost estimate of Corridor-3, 4 & 5 is given in **TABLE 17.10.**

TABLE 17.10: SUMMARY OF COST ESTIMATE OF CORRIDOR – 3, 4 & 5

Rs. in crore

SN	Item	Corridor-3	Corridor-4	Corridor 5	Total
1	Land	4469.03	2990.73	2133.20	9592.95
2	Alignment and Formation	4665.54	2070.31	2282.66	9018.51
3	Station Buildings incl. Civil works, EM works, ECS, TVS, Lift, escalators & Architectural Finishes etc	8717.58	3960.50	3546.62	16224.71
4	Depot including civil, EM, Machinery & plants, general works	607.62	225.54	0.00	833.16
5	P-Way for main line, depot and depot connectivity	541.60	305.72	445.74	1293.06
6	Traction & power supply for main line and depot incl. OHE, ASS, GIS etc.	966.58	530.05	737.84	2234.47
7	Signalling and Telecom. Incl. AFC, Platform screen doors, CCHS etc.	1469.05	837.51	1284.20	3590.76
8	Rolling Stock	1563.84	847.08	2085.12	4496.04
9a	Environment	17.60	8.33	22.76	48.69
9b	R & R incl. Hutments etc.	75.53	75.76	140.01	291.30
10	Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management	386.99	226.75	397.73	1011.47
11	Capital Expenditure on Security including civil and EM works	20.68	12.41	19.85	52.93
12	Staff Quarters and buildings including civil, electrical works and green building concept (Cost of OCC building is included in corridor-3 only)	154.43	49.45	86.73	290.61
13	Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land	382.23	181.47	218.19	781.89
14	Total of all items except Land and R&R	19493.73	9255.13	11127.44	39876.30
15	General Charges incl. Design charges, (Civil+EM works) @ 5% on all items except Land and R&R.	974.69	462.76	556.37	1993.81
16	Total of all items including G. Charges	20468.41	9717.89	11683.81	41870.11
17	Contingencies @ 3 % on all items except Land and R&R	614.05	291.54	350.51	1256.10
Total Cost including Contingencies & excluding Land and R&R Cost		21082.47	10009.42	12034.33	43126.21
Total Cost including Contingencies & including Land and R&R Cost		**25627.02**	**13075.91**	**14307.53**	**53010.47**
Central Taxes & Duties		1975.98	933.10	1150.57	4059.65
State Taxes & Duties		1589.04	752.43	923.63	3265.09
Total Taxes & Duties		**3565.02**	**1685.52**	**2074.20**	**7324.74**
Gross Total including Taxes & Duties		**29192.05**	**14761.43**	**16381.73**	**60335.21**

17.4 ESTIMATION OF OPERATION AND MAINTENANCE COSTS

Operation and Maintenance costs for Chennai Metro Phase II corridors are worked under three major heads:

- Staff cost
- Maintenance cost which includes expenditure towards upkeep and maintenance of the system and consumables and
- Energy cost

17.4.1 Staff Cost

O&M staff is assumed to be provided @ 35 persons per kilometre and the annual cost on this account is estimated considering average staff salary of Rs. 8.55 Lakhs per annum in the year 2018. The above assumption is based on experiences of operating metros in India viz. DMRC and BMRCL as stated in the Operations and Maintenance systems report, November 2013. The escalation factor used for staff costs is 9% per annum to provide for growth in salaries. The staff cost for is estimated to be **Rs 508.07** crore for Corridor 3 and Corridor 5 and **Rs 142.77** crore for Corridor 4 Line for the inception year i.e. 2025.

17.4.2 Maintenance Expenses

Maintenance expenses are taken @ Rs. 1.65 Crores/km in the year 2018. The figure is derived by considering maintenance expenses of DMRC and BMRCL as stated in Operations and Maintenance report, November 2013. Maintenance cost for the corridors is calculated considering escalation @5% p.a. for every year of operation. Since, the maintenance cost will be less during first few years of operation, the cost of first three years is reduced to 33%. Majority of the equipments during this period will be under the warranty. The cost for next two years is reduced to 66% due to low maintenance of new equipments. The maintenance cost for Corridor 3 and Corridor 5 would be **Rs 71.27** crore and **Rs. 20.03** crore in the inception year i.e. 2025.

17.4.3 Energy Charges

The cost of electricity is a significant part of O&M charges. Therefore, it is the key element for the financial viability of the project. The total energy consumption is the sum of traction and non traction/ auxiliary load. Energy consumption for the various years of operation is given in the **TABLE 17.11.**

TABLE 17.11: ENERGY CONSUMPTION FOR CORRIDORS 3, 4 & 5 (IN MILLION UNITS)

Year	Corridor 3 & 5			Corridor 4		
	Traction	Non traction	Total (KVAh)	Traction	Non traction	Total (KVAh)
2025	100.30	299.59	444.33	19.34	101.18	133.91
2035	116.40	329.55	495.50	30.58	111.30	157.64
2045	149.73	362.51	569.15	38.09	122.43	178.35
2055	179.96	398.76	643.02	45.71	134.67	200.42

Power tariff is taken @ Rs. 6.35 per kVAh for year 2016, which is escalated @ 5% every year of operation. Annual energy consumption charges have been estimated at Rs. 437.67 crore, Rs. 131.90 crore for Corridor 3 & Corridor 5 and Corridor 4 respectively in 2055.

It is proposed that the power shall be harnessed by the solar PV installation at rooftop of the elevated stations and depot shed and implementation shall be done through the RESCO model. There shall be saving in energy charges on account of solar power generated. For the purpose of calculation of energy savings, the tariff rate for the solar power purchased is considered to be Rs. 4.39 per unit.

The elevated stations in Corridor 3 & Corridor 5 and Madhavaram Depot are proposed with solar PV installation. Therefore, the savings due to solar installation will lead to lower energy charges for Corridor 3 and Corridor 5. The net energy charges after considering savings are Rs 432.80 crore in 2025, Rs 784.38 crore in 2035, Rs 1466.09 crore in 2045 for corridor 3 and corridor 5. For corridor 4, the net energy charges are Rs. 129.13 crore in 2025, Rs. 246.94 crore in 2035 and Rs. 454.46 crore in 2045.

17.4.4 Additional Investment

To cater to increased traffic demand, additional investment will have to be made for purchase of additional coaches. The additional investment in 2035 works out to be Rs. 1094.88 crore for purchase of 72 additional coaches for Corridor 3 and Corridor 5 and Rs. 775.54 crore for 51 additional coaches for Corridor 4. Also there will be requirement of additional three receiving substations in 2035. The additional investment for the RSS is Rs. 396.28 crore.

An investment of Rs. 1279.04 crore would be required for purchase of 69 additional coaches in 2045 for Corridor 3 and Corridor 5 and investment of Rs. 500.49 crore would be required for the purchase of 27 additional coaches for Corridor 4.

These additional investments have been worked out considering an escalation factor of 2% per annum.

17.4.5 Replacement Cost

The replacement costs are provided for meeting the cost on account of replacement of equipments due to wear and tear. With the nature of equipment proposed to be provided for the corridor, it is expected that about 25% of the equipment comprising Electrical, Rolling stock and 50% of Signalling & Telecom would require replacement/ rehabilitation after 20 years.

The replacement cost for the corridor works out to be Rs**.** 13705.20 crore for Corridor 3 and Corridor 5 and Rs. 3781.91 for Corridor 4. The replacement cost has been worked out considering an escalation factor of 5% per annum.

The year wise total operation and maintenance cost of Chennai Metro Phase II corridors is given in **TABLE 17.12** and **TABLE 17.13**.

TABLE 17.12: O & M COST CORRIDOR 3 & CORRIDOR 5

Year	Staff Cost Esc @9%	Maint. Cost Esc @5%	Energy Charges Esc @5%	Solar saving in Cr	Net Energy Charges	Total O&M cost	Addition/ Replace - ment Cost (Cr.)	
2025	508.07	71.27	437.67	4.87	432.80	1012.14		Maint. cost reduced to 33% for 3 years
2026	553.80	74.83	464.73	5.31	459.42	1088.05		
2027	603.64	78.57	493.66	5.77	487.89	1,170.10		
2028	657.97	165.01	524.04	6.26	517.78	1,340.76		Maintenance cost = 66%
2029	717.19	173.26	556.36	6.76	549.60	1,440.05		
2030	781.74	275.64	590.68	7.30	583.38	1,640.76		
2031	852.10	289.42	627.04	7.86	619.18	1,760.70		
2032	928.79	303.89	665.49	8.45	657.04	1,889.72		
2033	1012.38	319.08	706.06	9.07	696.99	2,028.45		
2034	1103.49	335.03	749.31	9.72	739.59	2,178.11		Addition of 3 RSS
2035	1202.80	351.78	794.78	10.4	784.38	2338.96	1491.16	**396.28**
2036	1311.05	369.37	846.82	11.12	835.70	2,516.12		Add. of 72 coaches
2037	1429.04	387.84	902.09	11.87	890.22	2,707.10		**1094.88**
2038	1557.65	407.23	960.66	12.65	948.01	2,912.89		
2039	1697.84	427.59	1023.15	13.48	1009.67	3,135.10		

Year	Staff Cost	Maint. Cost	Energy Charges	Solar saving in Cr	Net Energy Charges	Total O&M cost	Addition/ Replace - ment Cost (Cr.)	
	Esc @9%	Esc @5%	Esc @5%					
2040	1850.65	448.97	1089.14	14.35	1074.79	3,374.41		
2041	2017.21	471.42	1159.25	15.26	1143.99	3,632.62		
2042	2198.76	494.99	1233.61	16.22	1217.39	3,911.14		
2043	2396.65	519.74	1312.87	17.23	1295.64	4,212.03		
2044	2612.35	545.73	1396.60	18.28	1378.32	4536.40		Replacement of 25% of Elec. & 50% S&T assets
2045	2847.46	573.02	1485.48	19.39	1466.09	4886.57	**14984.24**	
2046	3103.73	601.67	1580.29	20.56	1559.73	5,265.13		Add. of 69 coaches
2047	3383.07	631.75	1680.53	21.78	1658.75	5,673.57		
2048	3687.55	663.34	1786.94	23.07	1763.87	6,114.76		
2049	4019.43	696.51	1899.67	24.42	1875.25	6,591.19		
2050	4381.18	731.34	2019.48	25.84	1993.64	7,106.16		
2051	4775.49	767.91	2146.54	27.33	2119.21	7,662.61		
2052	5205.28	806.31	2281.04	28.90	2252.14	8,263.73		
2053	5673.76	846.63	2423.77	30.54	2393.23	8,913.62		
2054	6184.40	888.96	2574.95	32.27	2542.68	9,616.04		

TABLE 17.13: O & M COST CORRIDOR 4

Year	Staff Cost	Maintenance Expenses	Energy Charges	Savings (solar)	Net Energy Charges	Total O&M cost	Addition/ Replace - ment Cost (Cr.)	
	Esc @9%	Esc @5%	Esc @5%	Tariff @Rs 4.399(2016)	Esc @5%			
2025	142.77	20.03	131.90	2.77	129.13	291.93		
2026	155.62	21.03	140.92	3.02	137.90	314.55		
2027	169.63	22.08	150.58	3.28	147.30	339.01		
2028	184.90	46.38	160.77	3.56	157.21	388.49		
2029	201.54	48.70	171.65	3.85	167.80	418.04		
2030	219.68	77.47	183.24	4.15	179.09	476.24		
2031	239.45	81.34	195.56	4.47	191.09	511.88		
2032	261.00	85.41	208.62	4.81	203.81	550.22		
2033	284.49	89.68	222.46	5.16	217.30	591.47		
2034	310.09	94.16	237.25	5.53	231.72	635.97		Addition of 51 coaches
2035	338.00	98.87	252.85	5.91	246.94	683.81	**775.54**	
2036	368.42	103.81	268.95	6.32	262.63	734.86		
2037	401.58	109.00	286.03	6.75	279.28	789.86		
2038	437.72	114.45	304.11	7.19	296.92	849.09		
2039	477.11	120.17	323.39	7.67	315.72	913.00		
2040	520.05	126.18	343.72	8.16	335.56	981.79		
2041	566.85	132.49	365.30	8.68	356.62	1,055.96		
2042	617.87	139.11	388.17	9.22	378.95	1,135.93		
2043	673.48	146.07	412.52	9.80	402.72	1,222.27		

Year	Staff Cost	Maintenance Expenses	Energy Charges	Savings (solar)	Net Energy Charges	Total O&M cost	Addition/ Replace - ment Cost (Cr.)	
	Esc @9%	Esc @5%	Esc @5%	Tariff @Rs 4.399(2016)	Esc @5%			
2044	734.09	153.37	438.23	10.40	427.83	1,315.29		Addition of 27 coaches & Replacement of 25% of Elec. & 50% S&T assets
2045	800.16	161.04	465.49	11.03	454.46	1,415.66	4282.40	
2046	872.17	169.09	494.91	11.69	483.22	1,524.48		
2047	950.67	177.54	525.99	12.39	513.60	1,641.81		
2048	1036.23	186.42	558.98	13.12	545.86	1,768.51		
2049	1129.49	195.74	593.92	13.89	580.03	1,905.26		
2050	1231.14	205.53	631.03	14.69	616.34	2,053.01		
2051	1341.94	215.81	670.38	15.54	654.84	2,212.59		
2052	1462.71	226.60	712.02	16.43	695.59	2,384.90		
2053	1594.35	237.93	756.19	17.37	738.82	2,571.10		
2054	1737.84	249.83	802.96	18.35	784.61	2,772.28		

18. TRANSIT ORIENTED DEVELOPMENT

18.1. NATIONAL TRANSIT ORIENTED DEVELOPMENT (TOD) POLICY

National Transit Oriented Development (TOD) Policy provides guidelines on development along transit corridors. TOD integrates land use and transport planning and aims to develop planned sustainable urban growth centers, having walkable and livable communes with high density mixed land-use. Citizens have access to open green and public spaces and at the same time transit facilities are efficiently utilized.

TOD focuses on creation of high density mixed land use development in the influence zone of transit stations, i.e. within the walking distance of (500-800 m) of transit station or along the corridor in case the station spacing is about 1km. TOD advocates pedestrian trips to access various facilities such as shopping, entertainment and work.

TOD increases the accessibility of the transit stations by creating pedestrian and Non-Motorised Transport (NMT) friendly infrastructure that benefits large number of people, thereby increasing the ridership of the transit facility and improving the economic and financial viability of the system. Since the transit corridor has mixed land-use, where the transit stations are either origin (housing) or destination (work), the corridor experiencing peak hour traffic in both directions would optimize the use of the transit system.

18.2. OBJECTIVES OF TRANSIT ORIENTED DEVELOPMENT

The objectives of TOD include:

- To promote the use of public transport by developing high density zones in the influence area, which would increase the share of transit and walk trips.
- To provide all the basic needs of work/ job, shopping, public amenities, entertainment in the influence zone with mixed land-use development
- To establish a dense road network within the development area for safe and easy movement and connectivity of NMT and pedestrians between various uses as well as to transit stations.
- To achieve reduction in the private vehicle ownership, traffic and associated parking demand.
- To provide all kinds of recreational/entertainment/ open spaces, required for a good quality of life in the influence area.

- To prevent urban sprawl by accommodating the growing population in a compact area with access to the transit corridor, this would also consolidate investments and bring down the infrastructure cost for development.
- To reduce carbon footprints by shifting towards environmentally friendly travel options for the line haul as well as for access and egress trips.

18.3. TOD GUIDELINES ALONG PHASE-II METRO CORRIDORS

18.3.1. Prevalent Control Regulations

The corridors of Phase II of the Metro line are spread across a total length of 119 km. As per the development regulations prevalent in the CMDA region, Floor Space Index is determined by the following factors:

- Extent of the site
- Frontage of the site along the public road
- Width of the abutting public road

The table below gives the prevailing development regulations prevalent in Chennai.

The development control regulations in Chennai vary with respect to the nature of development and the characteristics of the site. **Table 18.1** below shows the regulations that would be applicable for every building category:

TABLE 18.1: GUIDELINES ALONG PHASE-II METRO CORRIDORS

Type of Buildings	Category of Building	Min. Plot Extent (sq.m.)	Min. Plot Frontage (m)	Min. Road Width (m)	Allowable Height (m)	FSI Permissible	Plot Coverage
Residential	Ordinary	80	6	6	9	1.5	70%
Commercial	Ordinary	80	6	7.2	9	1.5	65-70%
Residential	Special Buildings	1100	15	9	9/12/15.25	1.5	
	Special Buildings	300/450	9/12/15	10	9/12/15	1.5	
Commercial	Special Buildings	200	8		15.25	1.5	
Residential & Commercial	Group Developments	660	12		15.25	1.5	
Residential & Commercial	Multistoried	1200	25	12	24	1.5	30%
		1200	25	15	30	1.75	30%
		1500	25	18	60	2.5	30%
		2500	40	18	60	2.25	30-40%
		2500	40	18	60	2	40-50%

** **Ordinary buildings:** Means a residential or commercial building with a floor area not exceeding 300 sq.m. and G+1 floor in height.*

*** **Special Buildings:** Means a residential building with more than six dwelling units and a commercial building exceeding a floor area of 300 square meters. Minimum width of the public road on which the site abuts or gains access shall be 10 mtrs.*

**** **Group Development:** Means accommodation for residential or commercial or combination of such activities housed in two or more blocks of buildings in a particular site irrespective of whether these structures are interconnected or not. Minimum width of the public road on which the site abuts or gains access shall be 10 m.*

***** **Multistoried Buildings:** Minimum extent of site for construction of multistoried buildings shall not be less than 1500 square meters, and shall have a road width of minimum 18 m. Provided further that multi-storied building may be permitted with limitations on maximum FSI and maximum height of the building on a site abutting or gaining access from a public road of min. 12 m/15 m in width, or gain access from public road not less than 12 m/15 meters in width through a part of the site which can be treated as an exclusive passage of not less than 12 m/15 meters in width, subject to compliance of the planning parameters mentioned in the Development Control Regulations*

18.3.2. Additional FSI Availability

In addition to the normally available FSI, higher FSI can be availed by means of Premium FSI and by developing IT parks.

a) Premium FSI

The Authority may allow premium FSI over and above the normally allowable FSI subject to a maximum of 1 (one) relating the same to the road width parameters as shown in **Table 18.2**.

TABLE 18.2: PREMIUM FSI ALLOWED

Road Width	Premium FSI (% of normally allowable FSI)
18 meters and above	40%
12 meters – below 18 meters	30%
9 meters – below 12 meters	20%

The Premium FSI shall be allowed in specific areas as may be notified, subject to Guidelines and on collection of charge at the rates as may be prescribed by the Authority with the approval of the Government. The amount collected towards the award of Premium FSI shall be remitted into Government account to be allotted separately for this purpose for utilizing it for infrastructure development in that area as may be decided by the Government.

b) IT Parks

Floor Space Index shall be allowed at 1.5 times of the Floor Space Index ordinarily permissible except in Primary Residential use zone within the Chennai City Corporation area provided that in case of developments where the site extent is not less than 2000 sq. meters and conforms to other regulations stated in the Development Control Regulations

18.4. SEGMENTATION OF PHASE-II METRO CORRIDORS

The Real Estate dynamics along the Phase II of the Metro corridor has been analyzed by segregating the corridor into various clusters based on Geographical extent, Location characteristics, Prevalent real estate scenario – Organized / unorganized real estate activity, prevalent pricing. A detailed analysis has been carried out considering Economic Activity, Physical & Social infrastructure, Key drivers for real estate, Supply-Demand and dynamics.

Figures 18.1 and **18.2** present the various clusters and stations under different clusters respectively. The detailed profiling of the clusters is provided in subsequent section.

FIGURE 18.1: SEGMENTATION OF CORRIDORS INTO CLUSTERS

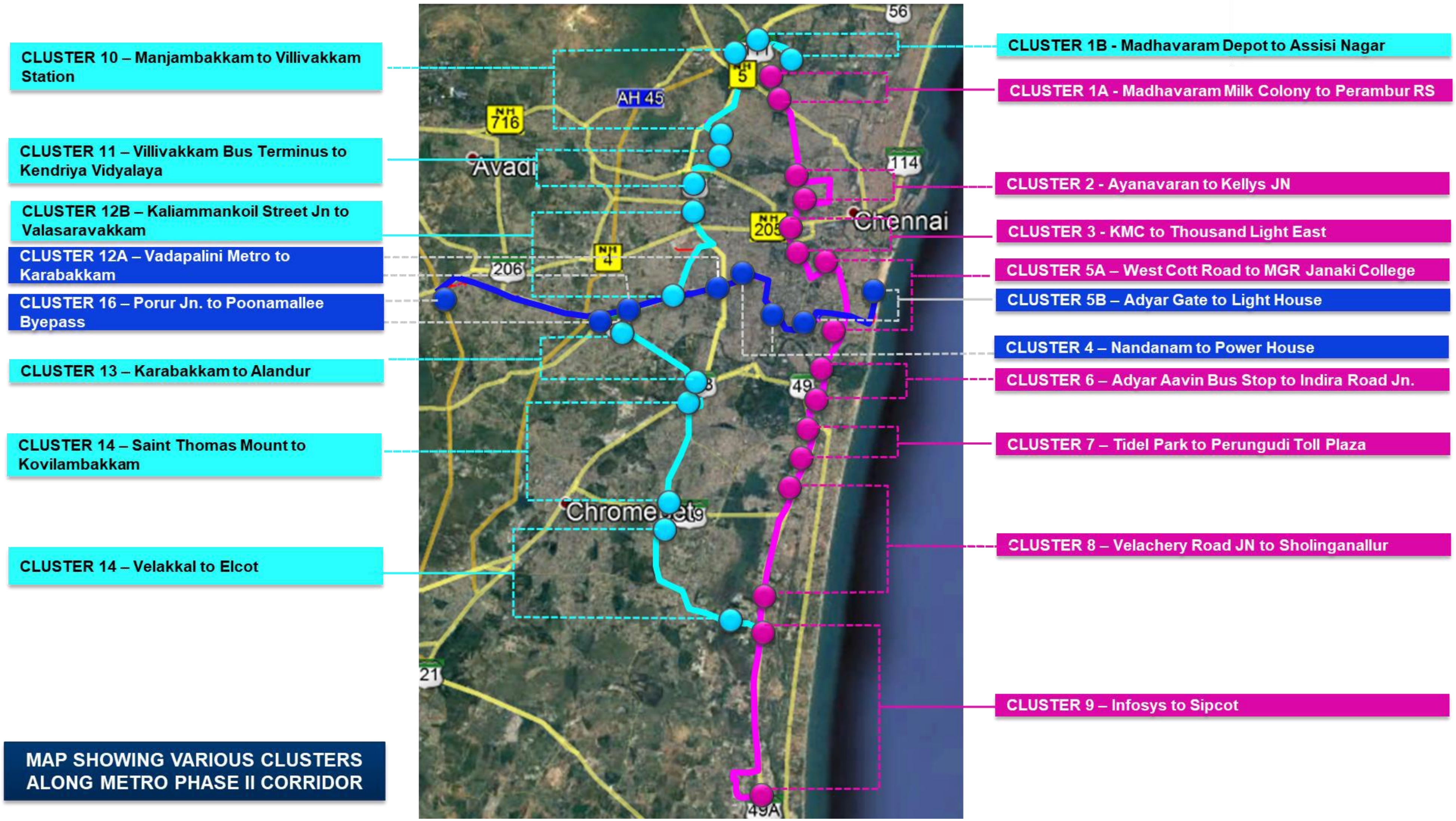


FIGURE 18.2: STATIONS UNDER DIFFERENT CLUSTERS

CLUSTERS	STATIONS IN CORRIDOR 3	STATIONS IN CORRIDOR 4	STATIONS IN CORRIDOR 5
CLUSTER 1	Madhavaram Milk Colony,Thapalpetti, Murari Hospital, Moolakadai, Donbosco, Revathi, Perambur Railway Station		Madhavaram Depot,Venugopal Nagar,Assisi Nagar
CLUSTER 2	Ayanavaram Bus Depot, Otteri,Strahans Road,Perambur Barracks Road, Purasaiwakkam Tank, Millers Road,Kellys Junction		
CLUSTER 3	KMC, Chetpet,Nungambakkam,Hadddows Road, Gemini, Thousand Light East		
CLUSTER 4		Nandanam, Natesan Park, Panagal park, Kodambakkam Metro, Meenakshi College,Power House	
CLUSTER 5	West Cott Road, Govt Hospital Royapettah, Thirumayilai East, Mandaveli Depot, MGR Janaki College	Adyar gate JN, Alwarpet, Thrumayilai Metro, Kutchery Road, Foreshore Road,Light House	
CLUSTER 6	Adyar Aavin Bus Stop, Adyar Depot, Indira Road Juction		
CLUSTER 7	Tidel park, Taramani Link road, Kandanchavadi, MGR Road Junction.Perungudi Toll Plaza,		
CLUSTER 8	Velachery Road JN,Mettukuppam Bus Stop,PTC Colony,Okkiyampet,karapakkam TCS,Tecci Park,Sholinganallur		
CLUSTER 9	Infosys,Diamond Engineering,Sathyabama University,Semmancheri,Gandhi Nagar point ,Navallur, Siruseri, Sipcot 1, Sipcot 2		
CLUSTER 10			Manjambakkam, Velmurugan Nagar, MMBT,Shastri Nagar,Retteri JN,Kolathur JN,Srivaasa nagar, Vilivakkam Metro
CLUSTER 11			Vilivakkam Bus Terminus,Nathamuni,Anna nagar Depot,Thirumangalam, Kendriya Vidyalaya
CLUSTER 12		Vadapalini Metro, Saligraman,Avichi School, Alwarthiru Nagar, Valasarawakkam,Karabakkam	Kaliammankoil Street Jn,CMBT,Grain Market,Sai Nagar Bus Stop, Elango Nagar Bus Stop, Alwartirunagar, Valasaravakkam
CLUSTER 13			Karabakkam, Alapakkam junction, Porur jn., Mugalivakkam, Dlf IT SEZ, Sathya Nagar, CTC, Butt Road, Alandur
CLUSTER 14			Saint Thomas Mount,Adambakkam, Vanuvampet, Puzhuthivakkam, Madipakkam, Kilkattalai, Echankadu, Kovilambakkam
CLUSTER 15			Velakkal,Medavakkam Koot Road,Kamaraj Garden Street, Medavakkam Jn,Perumbakkam,Global Hospital, Elcot,Sholinganallur
CLUSTER 16		Porur Junction, Ramchandra Hospital, Iyappanthangal Bus Depot, Kattupakkam, Kumanan Chavadi, Karyan Chavadi, Mullai Thottam, Poonamallee Bus Terminus, Poonamallee Byepass	

18.4.1 Snapshot of Real Estate Scenario across Various Clusters along TOD Corridor

METRO RAIL CLUSTER	DEMOGRAPHIC PROFILE	LAND USE	ALLOWABLE FSI	KEY REAL ESTATE DEMAND DRIVERS	REAL ESTATE STOCK (EXISTING)	UPCOMING REAL ESTATE SUPPLY	FUTURE OUTLOOK FOR REAL ESTATE GROWTH		
							RESIDENTIAL	OFFICE	RETAIL
Madhavaram Milk Colony to Perambur Railway Station & Madhavaram Depot to Assisi nagar	Population: 0.57mn Households: 0.15 mn Income segment : MIG, LIG	Mixed Residential, Institutional	Residential: 2.5 Institutional: 1.5	▪ Infrastructural development – New Bus Terminus ,Metro Rail ▪ Presence of MSME workforce and Government officials .	Residential: 1436 units Office: 0.057 Mn.sq.ft Retail: 0.07 Mn.sq.ft	Residential: 4790 units.	↑	→	↗
Aynavaram Bus Depot to CSI Bain school	Population: 0.55mn Households: No. of Households – 0.13 mn Income segment : MIG, HIG.	Institutional/Mixed Residential Commercial /Primary Residential.	Residential: 2 -2.5 Institutional: 1.5 Commercial : 2-2.5	▪ Well Established Social Infrastructure. ▪ Presence of different formats of retail ▪ Established Retail Destination – Known for High street retail Formats.	Residential: 394 units Office: 0.06 mn.Sq.ft. Retail: 0.16 mn. Sq.ft.	Residential: 1764 Units	↑	↗	↑
Kilpauk Medical College to Thousand Light East	Population: 0.21mn Households: No. of Households – 0.05 mn Income segment : HIG, HNI's	Institutional/Mixed Residential Commercial /Primary Residential.	Residential: 2 -2.5 Institutional: 1.5 – 1.75 Commercial : 2-2.5	▪ Advantage of being located in the CBD of the city. ▪ Located close to employment hubs. ▪ Accessibility and Connectivity. ▪ Desirable location for Commercial and Residential Activities	Residential: 367 units Office: 11.82 mn.sq.ft. Retail: 0.16 mn.sq.ft. Mall- 0.04 mn sq.ft.	Residential: 162 Units	↗	↑	↑

↑ *High Growth Potential*
↗ *Medium Growth*
→ *Low Growth*

METRO RAIL CLUSTER	POPULATION HOUSEHOLDS	LAND USE	ALLOWABLE FSI	KEY REAL ESTATE DEMAND DRIVERS	REAL ESTATE STOCK (EXISTING)	UPCOMING REAL ESTATE SUPPLY	FUTURE OUTLOOK FOR REAL ESTATE GROWTH		
							RESIDENTIAL	OFFICE	RETAIL
Panagal Park,Nandanam	Population: 0.23 mn Households: No. of Households – 0.05 mn Income segment : MIG, HIG	Institutional/Residential Commercial /Open space	Residential: 2 -2.5 Institutional: 1.5 Commercial – 2-2.5	▪ Well established social and Physical Infrastructure ▪ Presence of Established retail High street catering to all asset classes. ▪ Known for the presence of Substantial amount of Grade A office Space	Residential: 126 units Office: 9.96 mn. Sq.ft. Retail: 1.56 **mn. Sq.ft.**	Residential: 127 Units Office: 0.02 mn. Sq.ft.	→	↗	↑
CMBT to Kodambakkam sub urban station	Population: 0.62 mn Households: No. of Households – 0.16 mn Income segment : MIG, HIG	Institutional/Residential Commercial /Open space	Residential: 2 -2.5 Institutional: 1.5 Commercial : 2-2.5	▪ Located on the off-CBD region. Presence of Film studios - makes it the Hub of Film Industry ▪ Presence of Bus Terminus	Residential: 576 units Office: 1.04mn.sq.ft.	Residential: 1044 Units Office: 0.044 mn. Sq.ft.	↑	→	↑
Royapeetah Govt. Hospital to Greenways Metro	Population: 0.21 mn Households: No. of Households – 0.05 mn	Institutional/Residential Commercial /Open space, Light Industrial.	Residential: 2 -2.5 Institutional: 1.5 Commercial – 2-2.5 **Industrial – 1.25**	▪ Located in CBD region ▪ Presence of Landmark buildings and Government offices ▪ Well established physical and social infrastructure	Residential: 32 units Office: 1.52 mn.sq.ft. Retail: 0.16 mn.sq.ft.	Residential: 193 Units	↗	↑	↗

METRO RAIL CLUSTER	POPULATION HOUSEHOLDS	LAND USE	ALLOWABLE FSI	KEY REAL ESTATE DEMAND DRIVERS	REAL ESTATE STOCK (EXISTING)	UPCOMING REAL ESTATE SUPPLY	FUTURE OUTLOOK FOR REAL ESTATE GROWTH		
							RESIDENTIAL	OFFICE	RETAIL
Adyar Junction to Indira Nagar & Adyar gate to Light House	Population: 0.37mn Households: No. of Households – 0.02 mn. Income segment : MIG, HIG	Institutional/ Residential Commercial /Open space	Residential: 2 -2.5 Institutional: 1.5 Commercial – 2-2.5	▪ Well developed social and Physical Infrastructure ▪ Preferred location for Premium or High residential projects.	Residential: 246 units Office: 1.86 mn. Sq.ft.	Residential: 418 Units Office: 0.02 Mn sq.ft	↑	↑	↗
Thiruvanmiyur Metro to Perungudi	Population: 0.27 mn Households: No. of Households – 0.07 mn Income segment : MIG, HIG	Institutional/ Residential/Industrial	Residential: 2 -2.5 Institutional: 1.5 Industrial: 1.25	▪ Located on IT corridor ▪ well developed Physical and Social Infrastructure. ▪ Proximity to Employment Hubs.	Residential: 545 units Office: 17.6mn.sq.ft.	Residential: 1596 Units Office: 0.5 Mn. Sq.ft	↗	↑	→
Thoraipakkam to Shollinganallur	Population: 0.02 mn Households: No. of Households – 0.006 mn. Income segment : MIG, HIG	Institutional/ Residential Commercial /Open space, Light Industrial.	Residential: 2 -2.5 Institutional: 1.5 Commercial – 2-2.5 Industrial – 1.25 IT Corridor Benefits – Additional 1.5 times of the Ordinary FSI Permissible.	▪ Located on IT Corridor. ▪ Presence of Budget apartments and Villas ▪ Affordable Office and Retail Rentals.. ▪ Infrastructural developments	Residential: 2713 units Office: 10.37 mn.sq.ft. Retail: 0.03 mn.sq.ft.	Residential: 4266 Units Office: 1.08 Mn. Sq.ft	↑	↑	↗

METRO RAIL CLUSTER	POPULATION HOUSEHOLDS	LAND USE	ALLOWABLE FSI	KEY REAL ESTATE DEMAND DRIVERS	REAL ESTATE STOCK (EXISTING)	UPCOMING REAL ESTATE SUPPLY	FUTURE OUTLOOK FOR REAL ESTATE GROWTH		
							RESIDENTIAL	OFFICE	RETAIL
Sholinganallur to Sipcot 2	Income Group – MIG, HIG	Institutional/Residential/Industrial	Residential: 2 -2.5 Institutional: 1.5 Industrial: 1.25 IT Corridor Benefits – Additional 1.5 times of the Ordinary FSI Permissible	▪ Presence of SIPCOT IT Park ▪ Well Developed Commercial and Retail Corridor	Residential: 13,148 units Office: 5.7mn.sq.ft. Retail: 0.06**mn.sq.ft.**	Residential: 13,827 Units	↑	↑	↑
Vilivakkam Bus Terminus to Kendriya Vidyalaya	Population: 0.01 mn Households: No. of Households – 0.03 mn Income Group – MIG, HIG	Institutional/Residential/Industrial	Residential: 2 -2.5 Institutional: 1.5 Industrial: 1.25	▪ Most sought after residential locality for Premium Housing Units. ▪ Presence of Branded High streets (2nd and 4th Avenue) and Entertainment zones . ▪ Proximity to CBD and well developed Social Infrastructure.	Residential: 559 units Office: 6.6 mn.sq.ft. Retail: 3.15 **mn.sq.ft.**	Residential: 521 Units	→	↗	↑
Kaliammankoil Street to Valasaravakkam	Population: 0.02 mn Households: No. of Households – 0.05 mn. Income Group – MIG, HIG	Institutional/Residential Commercial , Light Industrial.	Residential: 2 -2.5 Institutional: 1.5 Commercial – 2-2.5 **Industrial – 1.25**	▪ Connected to Major Arterial roads of Chennai. ▪ Proximity to Industrial corridors.	Residential: 3280 units Office: 0.87 mn.sq.ft. Retail: 0.57 **mn.sq.ft.**	Residential: 4574 Units Office: 1.01 Mn. Sq.ft	↑	↑	↗

METRO RAIL CLUSTER	POPULATION HOUSEHOLDS	LAND USE	FSI	KEY DEMAND DRIVERS	REAL ESTATE STOCK	REAL ESTATE SUPPLY	FUTURE OUTLOOK FOR REAL ESTATE GROWTH		
							RESIDENTIAL	OFFICE	RETAIL
Karabakkam to Alandur	Population: 0.01 mn Households: No. of Households – 0.03 mn Income Group – MIG	Institutional/Residential/Industrial/ Commercial/Cantonment Area	Residential: 2 -2.5 Institutional: 1.5 Industrial: 1.25	▪ Proximity to Rajiv Gandhi Salai and Velachery ▪ Presence of DLF IT Park and other sectors related to construction and Manufacturing	Office: 12 mn. Sq.ft. Retail -0.03 Mn. Sq.ft	Residential: 2046 Units Office: 0.99Mn.sq.ft	↑	↑	↗
Saint Thomas Mount to Kovilambakkam	Income Group – MIG	Residential/Industrial	Residential: 2 -2.5 Institutional: 1.5 Industrial: 1.25	▪ Strategically located as a Suburban region to RGS corridor. ▪ Proximity to employment Hubs.	Residential: 491 units Office: 0.28 mn.sq.ft. Retail: 1.67 mn. Sq.ft.	Residential: 3091 Units Office: 2 Mn. Sq.ft	→	↑	↑
Velakkal to ELCOT	Income Group – LIG, MIG	Residential & Institutional	Residential: 2 -2.5 Institutional: 1.5	▪ Affordable Housing ▪ Upcoming Stretch dominated by LIG and MIG sectors.	Residential: 1372 units Office: 1.6 mn. Sq.ft.	Residential: 4372Units Office: 0.6 Mn. Sq.ft	↑	↑	↑
Manjambakkam to Vilivakkam Station	Population: 0.26 mn Households: No. of Households – 0.067 mn		Residential: 2 -2.5 Institutional: 1.5 Commercial – 2-2.5 **Industrial – 1.25**	▪ Established Industrial Hub ▪ Primary residential Zone		Residential: 2223 Units	↑	→	↗

18.4.2 Key Inferences - Real Estate Potential across TOD Corridor

- Majority of the TOD corridor falls along the central and suburban parts of Chennai covering the central, West, North and Southern parts of Chennai. The only peripheral zone falling under the TOD corridor in the Rajiv Gandhi Salai.
- The central, west and north zones are fairly established real estate markets in Chennai, while the Southern zone is one of the merging real estate corridor of Chennai
- Over a 38 year horizon we can expect the central and suburban parts of Chennai to witness several redevelopment projects. With the proposal of metro corridor along these areas, densification along the TOD corridors would be recommended in areas of low or medium density. The development should also focus of critical amenities like parking, open public spaces, last mile road connectivity to metro stations, etc.
- The Rajiv Gandhi Salai is expected to largely benefit from the TOD corridor, as the stretch is one of the most active and emerging real estate corridors of Chennai.

The following sections assesses the demand for various organized real estate asset classes:

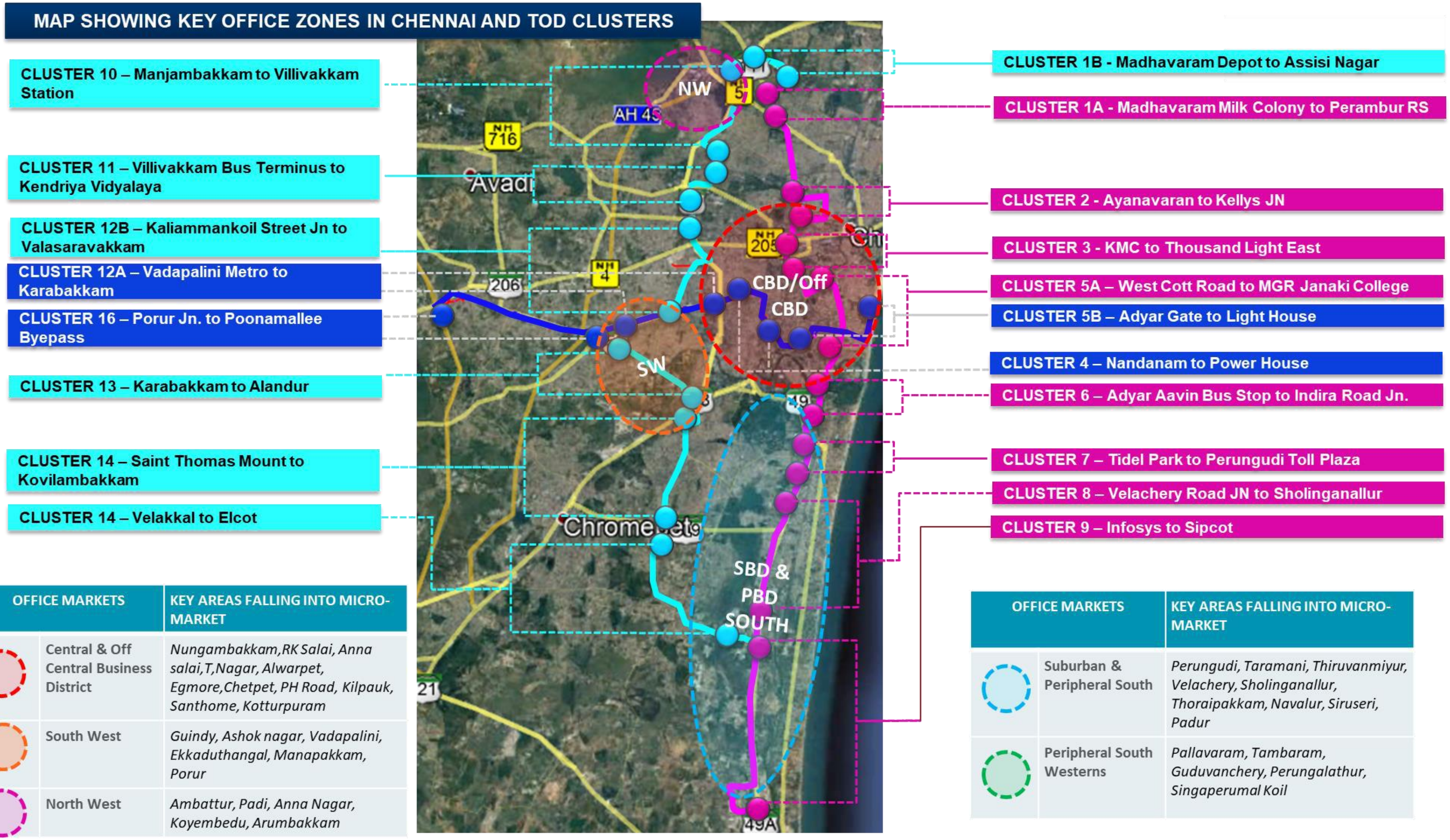
a) Office Segment
b) Residential Segment
c) Retail Segment

The demand for these segments have been assessed at a city level which is further classified into the various zones of the city and ultimately narrowed down to the TOD Corridor. The demand is estimated for a period of about 38 years.

Based on the net real estate demand estimated for the TOD Corridor and the rental escalation in various asset classes for the next 38 years, the potential revenue towards real estate demand along the TOD corridor has been estimated. This revenue estimation does not take into account the time value of money.

18.5. DEMAND ANALYSIS OFFICE SEGMENT

FIGURE 18.3 : KEY OFFICE ZONES IN CHENNAI AND TOD CLUSTERS



OFFICE MARKETS		KEY AREAS FALLING INTO MICRO-MARKET
	Central & Off Central Business District	*Nungambakkam, RK Salai, Anna salai, T, Nagar, Alwarpet, Egmore, Chetpet, PH Road, Kilpauk, Santhome, Kotturpuram*
	South West	*Guindy, Ashok nagar, Vadapalini, Ekkaduthangal, Manapakkam, Porur*
	North West	*Ambattur, Padi, Anna Nagar, Koyembedu, Arumbakkam*

OFFICE MARKETS		KEY AREAS FALLING INTO MICRO-MARKET
	Suburban & Peripheral South	*Perungudi, Taramani, Thiruvanmiyur, Velachery, Sholinganallur, Thoraipakkam, Navalur, Siruseri, Padur*
	Peripheral South Westerns	*Pallavaram, Tambaram, Guduvanchery, Perungalathur, Singaperumal Koil*

18.5.1 Past Trends in Office Space Absorption in Chennai

Demand for office Space in Chennai has been assessed based on the past office space absorption trends in Chennai over an 11-year period from year 2005 to year 2015 is presented in **Table 18.3**. The past 11 years considers various real estate cycles that a metropolitan city would witness ranging from peak demand to slowdown in the market. Thus, the demand for office space is projected based on a polynomial regression which estimates the potential office space demand by analyzing the fluctuations in the past absorption trends.

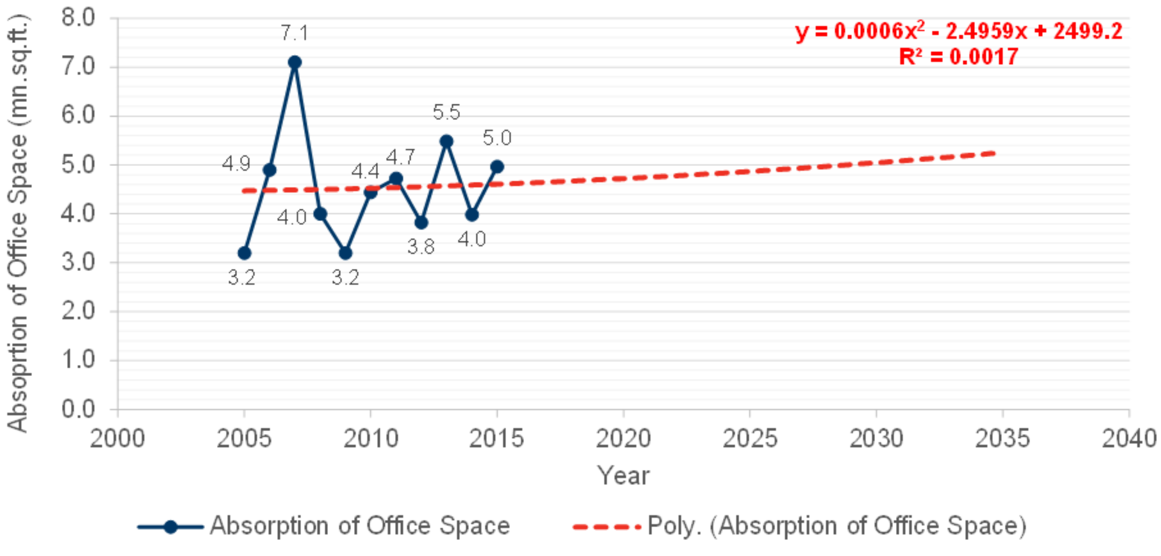
TABLE 18.3: PAST TRENDS IN OFFICE SPACE ABSORPTION IN CHENNAI

TRENDS IN ABSORPTION OF OFFICE SPACE IN CHENNAI (Million Sq.ft.)												
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	SOURCE
Year-on-Year Absorption of Office Space (mn.sq.ft.)	3.20	4.90	7.10	4.00	3.20	4.44	4.73	3.82	5.49	3.98	4.97	*C&W Research*

18.5.2 Projections in Absorption of Office Space in Chennai

The graph below indicates a polynomial regression which is a form of linear regression in which the relationship between the independent variable x and the dependent variable y is modelled as an nth degree polynomial. A polynomial trend line is a curved line that is used when data fluctuates. Based on the above absorption trends, the graph below indicates the potential future absorption potential in the Chennai Real estate market as in **Tables 18.4, 18.5** and **18.6**.

FIGURE 18.4: PROJECTION OF OFFICE SPACE ABSORPTION IN CHENNAI



Based on the Polynomial Regression trends the table below estimates the future demand for office space in Chennai over the next 20-year period.

TABLE 18.4: PROJECTIONS IN ABSORPTION FOR OFFICE SPACE

PROJECTIONS IN ABSORPTION OF OFFICE SPACE IN CHENNAI (Million Sq.ft.)																						
Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2055
Estimated Absorption of Office Space (mn.sq.ft.)	4.47	4.48	4.49	4.50	4.51	4.52	4.54	4.55	4.57	4.59	4.60	4.62	4.64	4.67	4.69	4.72	4.74	4.77	4.80	4.83	4.86	5.67

TABLE 18.5: PROJECTIONS IN ABSORPTION FOR OFFICE SPACE FOR FUTURE YEARS

Office Micro-Markets in Chennai	Key Areas falling into the micro-market	Current Office Space Inventory (mn.sq.ft.)	Current Share of Current Office Space Inventory across zones	Expected Share of Office Space across zones	Potential Demand for Office Space in various micro-markets (mn.sq.ft.)	Presence of TOD Corridor in the Zone	TOD Clusters Nos. falling in the Micro-markets
Central & Off-Central Business District	*Anna Salai, Nungambakkam, R.K. Salai, T.Nagar, Alwarpet, Kilpauk, Egmore, Chetpet, Royapettah, Kotturpuram*	25.24	33%	15.0%	28.86	Yes	3A,3B,5A,5B
South-west	*Guindy, Ashok Nagar, Vadapalani, Manapakkam, Ekkaduthangal, Porur, Poonamallee*	13.04	17%	20.0%	38.48	Yes	4,12,13
North-west	*Ambattur, Padi, Anna Nagar, Koyambedu, Arumbakkam*	5.01	6%	8.0%	15.39	Yes	11,
Suburban & Peripheral South	*Perungudi, Taramani, Thiruvanmiyur, Velachery, Sholinganallur, Thoraipakkam, Navalur, Siruseri, Padur*	31.18	40%	44.0%	84.65	Yes	6,7,8,9
Peripheral South-west	*Singaperumalkoil, Tambaram, Guduvanchery, Perungalathur, Pallavaram*	3.07	4%	13.0%	25.01	No	Non-TOD zone
Total		**77.55**	100%	100%	192.38		

TABLE 18.6: DISTRIBUTION OF PROJECTED OFFICE SPACE DEMAND ACROSS VARIOUS ZONES (YEAR 2017-55)

YEAR-ON-YEAR DEMAND FOR OFFICE SPACE IN CHENNAI (Million Sq.ft.)																						
Year	TOTAL	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2055
Central & Off Central Business District	28.86	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.69	0.69	0.69	0.69	0.70	0.70	0.70	0.71	0.71	0.72	0.72	0.72	0.73	0.85
South-west	38.48	0.90	0.90	0.90	0.90	0.90	0.91	0.91	0.91	0.92	0.92	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.96	0.97	0.97	1.13
North-west	15.39	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.45
Suburban & Peripheral South	84.65	1.97	1.97	1.98	1.98	1.99	2.00	2.00	2.01	2.02	2.03	2.03	2.04	2.05	2.06	2.07	2.09	2.10	2.11	2.12	2.14	2.49
Peripheral South-west	25.01	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.74
Total	**192.38**	**4.48**	**4.49**	**4.50**	**4.51**	**4.52**	**4.54**	**4.55**	**4.57**	**4.59**	**4.60**	**4.62**	**4.64**	**4.67**	**4.69**	**4.72**	**4.74**	**4.77**	**4.80**	**4.83**	**4.86**	**5.67**

18.5.3 Distribution of Office Space Demand Across various TOD Corridors

The "TOD Corridor" is defined as the 500 m region spread along either side of the Phase II corridor of Chennai Metro Rail. The area of the TOD Corridor is spread across a entire Phase-II length and a width of 1km.

The demand for office space estimated across the various zones of Chennai includes the TOD and Non-TOD Zones. In order to estimate the demand for office space in the TOD Corridor, the keys office areas falling within the TOD corridor are identified and the demand share in the TOD corridor is allocated. The basis of allocating the potential demand share in the TOD corridor considers key factors like -

- Presence of established office pockets within the TOD corridor
- Impact of the metro rail connectivity in the TOD corridor which would further impact the demand for office space development
- Upcoming areas within the TOD Corridor with potential for office space development in the next 38 years period.

Table 18.7 below segregates the office space demand into various TOD Zones in Chennai

TABLE 18.7: REVENUE ESTIMATION FROM OFFICE SPACE DEMAND IN TOD CORRIDOR

Office Micro-Markets in Chennai	TOD Clusters Nos. falling in the Micro-markets	Demand Share of Office Space within the TOD Zone	Demand Share of Office Space within the Non-TOD Zone	Potential Demand falling within TOD Cluster (Million sq.ft.)	Key Office Corridors in TOD Zone (Current and Future Potential areas)
Central & Off-Central Business District	3, 4, 5A, 5B	55%	45%	15.87	*Nungambakkam High Rd, Parts of Anna Salai, Royapettah High Rd, Poonamalee High Rd, Kodambakkam High Rd*
South-west	12A, 12B,13,16	75%	25%	28.86	*Arcot Road, Vadapalini, Koyembedu, Ramapuram, Porur, Manapakkam*
North-west	11	15%	85%	2.31	*100 feet Road (Thirumangalam to Villivakkam)*
Suburban & Peripheral South	6, 7, 8, 9, 15	75%	25%	63.49	*LB Road, RGS*
Peripheral South-west	Non-TOD zone	0%	100%	0.00	
Total				**110.52**	

The projected demand for Office Space within the TOD corridor is estimated at 110.52 mn.sq.ft. spread across a 38 year period (year 2017 to year 2055)

The estimated revenue from the office space demand along the TOD corridor is calculated based on the projected rentals and shown in **Table 18.8.**

TABLE 18.8: REVENUE ESTIMATION FROM OFFICE SPACE DEMAND ON PROJECTED RENTALS

PREVAILING RENTALS FOR OFFICE SPACE ACROSS VARIOUS MICRO-MARKETS IN CHENNAI	
Office Micro-Markets in Chennai	**Warm Shell Rentals (INR/sq.ft./Month)**
Central & Off-Central Business District	62
South-west	58
North-west	34
Suburban & Peripheral South	51

Escalation in Office Space Rentals *(As per prevailing terms in office leasing which is 15% at every 3 years)*	**5%**

PROJECTED RENTALS IN OFFICE SPACE (INR/SQ.FT./MONTH)																						
Office Micro-Markets	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2055
Central & Off-Central	62	65	68	72	75	79	83	87	92	96	101	106	111	117	123	129	135	142	149	157	165	416
South-west	58	61	64	67	70	74	78	82	86	90	94	99	104	109	115	121	127	133	140	147	154	389
North-west	34	36	37	39	41	43	46	48	50	53	55	58	61	64	67	71	74	78	82	86	90	228
Suburban & Peripheral South	51	54	56	59	62	65	68	72	75	79	83	87	92	96	101	106	111	117	123	129	135	342

18.5.4 Methodology for Estimation of Revenue from Office Space Demand in TOD Corridor

Year-on-Year Revenue Estimation in TOD Corridor = Office Space Demand in TOD Corridor (mn.sq.ft.) X Projected Office Space Rentals (INR/sq.ft.) X 12 months.

Table 18.9 gives the revenue estimation from the forecasted year-on-year demand for office space. The revenue is calculated on the incremental demand estimated year-on-year. The revenue estimation does not consider the impact of Time Value of Money.

TABLE 18.9: REVENUE ESTIMATION FROM OFFICE SPACE IN TOD CORRIDOR: INCREMENTAL (YEAR 2017-2055)

ESTIMATION OF INCREMENTAL REVENUE FROM THE YEAR-ON-YEAR OFFICE SPACE DEMAND IN TOD CORRIDOR (INR MILLION)																						
Office Micro-Markets	TOD Clusters Nos.	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2055	Total Revenue (INR Mn.)
Central & Off-Central	3, 4, 5A, 5B	289	304	320	336	354	373	393	414	437	460	485	512	540	570	602	635	671	709	749	791	2,333	37,678
South-west	12A, 12B,13,16	491	517	544	572	603	635	669	705	743	783	826	871	919	970	1,023	1,081	1,141	1,205	1,273	1,345	3,968	64,086
North-west	11	23	24	25	27	28	30	31	33	35	37	39	41	43	45	48	51	54	57	60	63	186	3,005
Suburban & Peripheral South	6, 7, 8, 9, 15	950	999	1,052	1,107	1,166	1,228	1,293	1,363	1,437	1,515	1,597	1,685	1,777	1,876	1,980	2,090	2,207	2,331	2,463	2,603	7,675	123,974
Total		**1,752**	**1,844**	**1,940**	**2,043**	**2,151**	**2,265**	**2,386**	**2,515**	**2,651**	**2,794**	**2,947**	**3,108**	**3,279**	**3,461**	**3,653**	**3,857**	**4,073**	**4,302**	**4,545**	**4,802**	**14,162**	**228,744**

Table 18.10 gives the Revenue estimation from the forecasted Cumulative demand for office space. The revenue is calculated on the cumulative demand for office space. This revenue estimation does not consider the impact of Time Value of Money.

TABLE 18.10: REVENUE ESTIMATION FROM OFFICE SPACE DEMAND IN TOD CORRIDOR (YEAR 2017 – 2055): CUMULATIVE

ESTIMATION OF YEAR-ON-YEAR REVENUE FROM OFFICE SPACE DEMAND IN TOD CORRIDOR (INR MILLION)

Office Micro-Markets	TOD Clusters Nos.	Year 2017	Year 2018	Year 2019	Year 2020	Year 2021	Year 2022	Year 2023	Year 2024	Year 2025	Year 2026	Year 2027	Year 2028	Year 2029	Year 2030	Year 2031	Year 2032	Year 2033	Year 2034	Year 2035	Year 2036	Year 2037
Central & Off-Central	3, 4, 5A, 5B	289	607	957	1,341	1,762	2,224	2,728	3,279	3,879	4,533	5,245	6,020	6,861	7,774	8,764	9,838	11,001	12,259	13,621	15,093	16,683
South-west	12A, 12B,13,16	491	1,032	1,627	2,281	2,998	3,782	4,640	5,576	6,598	7,711	8,922	10,239	11,669	13,223	14,907	16,733	18,711	20,851	23,167	25,671	28,376
North-west	11	23	48	76	107	141	177	218	262	309	362	418	480	547	620	699	785	877	978	1,086	1,204	1,331
Suburban & Peripheral South	6, 7, 8, 9, 15	950	1,997	3,148	4,412	5,799	7,316	8,976	10,787	12,763	14,916	17,259	19,807	22,574	25,579	28,837	32,370	36,195	40,336	44,816	49,660	54,893
Total		**1,752**	**3,684**	**5,808**	**8,141**	**10,699**	**13,500**	**16,561**	**19,904**	**23,550**	**27,522**	**31,845**	**36,545**	**41,652**	**47,195**	**53,208**	**59,725**	**66,784**	**74,425**	**82,691**	**91,627**	**101,284**

ESTIMATION OF YEAR-ON-YEAR REVENUE FROM OFFICE SPACE DEMAND IN TOD CORRIDOR (INR MILLION)

Office Micro-Markets	TOD Clusters Nos.	Year 2038	Year 2039	Year 2040	Year 2041	Year 2042	Year 2043	Year 2044	Year 2045	Year 2046	Year 2047	Year 2048	Year 2049	Year 2050	Year 2051	Year 2052	Year 2053	Year 2054	Year 2055	Total
Central & Off-Central	3, 4, 5A, 5B	18,401	20,256	22,257	24,415	26,741	29,248	31,949	34,857	37,987	41,355	44,978	48,875	53,064	57,566	62,404	67,600	73,181	79,173	**909,063**
South-west	12A, 12B,13,16	31,298	34,452	37,856	41,526	45,483	49,747	54,341	59,287	64,611	70,340	76,503	83,131	90,256	97,914	106,142	114,980	124,472	134,664	**1,546,206**
North-west	11	1,468	1,616	1,775	1,947	2,133	2,333	2,548	2,780	3,030	3,299	3,588	3,899	4,233	4,592	4,978	5,392	5,837	6,315	**72,512**
Suburban & Peripheral South	6, 7, 8, 9, 15	60,546	66,648	73,231	80,332	87,987	96,235	105,121	114,689	124,989	136,072	147,994	160,815	174,598	189,412	205,329	222,427	240,790	260,504	**2,991,110**
Total		**111,713**	**122,971**	**135,119**	**148,220**	**162,344**	**177,564**	**193,959**	**211,613**	**230,616**	**251,065**	**273,063**	**296,719**	**322,150**	**349,484**	**378,853**	**410,400**	**444,280**	**480,656**	**5,518,891**

The potential cumulative Rental Revenue generated from the Office Space demand of 110.52 mn.sq.ft. in the TOD corridor is estimated at INR 5,518,891 Million.
This revenue is a total of the revenue generated through renting of office space of 110.52 mn.sq.ft. between the years 2017 to 2055.

The total estimated revenue from Office space demand along the TOD corridor accounts INR 5,518,891 million. **Table 18.11** below gives a distribution of the revenue estimation from Office space demand across the 3 TOD corridors.

TABLE 18.11: DISTRIBUTION OF REVENUE ESTIMATION FROM OFFICE SPACE DEMAND ACROSS THE 3 TOD CORRIDORS

Office Micro-Markets	TOD Corridors & Cluster Nos.	Total Revenue Estimation - Year 2017 to 2036) (INR Million)	SHARE OF TOD REVENUE ACROSS VARIOUS METRO CORRIDORS		
			Corridor 3: Madhavaram to SIPCOT	Corridor 4: Lighthouse to Poonamallee Byepass	Corridor 5: Madhavaram to Sholinganallur
Central & Off-Central	Corridor 3: Cluster Nos. 3, 5A Corridor 4: Cluster No. 4, 5B Corridor 5: Nil	**909,063**	727,250	181,813	
South-west	Corridor 3 - Nil Corridor 4 - Cluster No. 12A, 16 Corridor 5 - Custer Nos. 12B, 13	**1,546,206**		1,082,345	463,862
North-west	Corridor 3: Nil Corridor 4: Nil Corridor 5: Cluster No. 11	**72,512**			72,512
Suburban & Peripheral South	Corridor 3: 6, 7, 8, 9 Corridor 4: Nil Corridor 5: 15	**2,991,110**	2,991,110		
Total		**5,518,891**	**3,718,360**	**1,264,157**	**536,374**

COST ESTIMATION FOR DEVELOPMENT OF ESTIMATED OFFICE SPACE DEMAND ALONG TOD CORRIDOR

The costs incurred towards the potential construction of office space demand of **110.52 mn. sq.ft**. is estimated based on the prevailing construction costs in Chennai market. It also considers an average annual escalation of 5% in construction costs. **Table 18.12** below gives an estimation of the costs incurred towards the development of 110.52 million sq.ft. of office space over the next 38-year period between year 2017 to year 2055.

Key Cost Assumptions

- Prevailing Construction Cost for Office Space in Chennai – **INR 2000/sq.ft. (Average)**
- Avg. escalation in Construction Costs – 5% per annum

TABLE 18.12: COST ESTIMATION FOR DEVELOPMENT OF ESTIMATED OFFICE SPACE DEMAND ALONG TOD CORRIDORS

ESTIMATION OF CONSTRUCTION COST FOR OFFICE SPACE DEMAND IN TOD CORRIDOR (INR MILLION) – YEAR –ON-YEAR

Office Micro-Markets	TOD Clusters Nos.	Year 2017	Year 2018	Year 2019	Year 2020	Year 2021	Year 2022	Year 2023	Year 2024	Year 2025	Year 2026	Year 2027	Year 2028	Year 2029	Year 2030	Year 2031	Year 2032	Year 2033	Year 2034	Year 2035	Year 2036	Year 2037
Central & Off-Central	3, 4, 5A, 5B	776	816	859	904	952	1,003	1,057	1,114	1,174	1,237	1,305	1,376	1,452	1,532	1,617	1,708	1,803	1,905	2,012	2,126	2,247
South-west	12A, 12B,13,16	1,411	1,484	1,562	1,644	1,732	1,824	1,921	2,025	2,134	2,250	2,372	2,502	2,640	2,786	2,941	3,105	3,279	3,463	3,659	3,866	4,086
North-west	11	113	119	125	132	139	146	154	162	171	180	190	200	211	223	235	248	262	277	293	309	327
Suburban & Peripheral South	6, 7, 8, 9, 15	3,104	3,266	3,437	3,618	3,809	4,012	4,227	4,454	4,695	4,950	5,219	5,505	5,808	6,130	6,470	6,831	7,213	7,619	8,049	8,505	8,989
Total		**5,403**	**5,685**	**5,983**	**6,298**	**6,632**	**6,985**	**7,359**	**7,754**	**8,173**	**8,617**	**9,087**	**9,584**	**10,112**	**10,671**	**11,264**	**11,892**	**12,558**	**13,264**	**14,013**	**14,807**	**15,649**

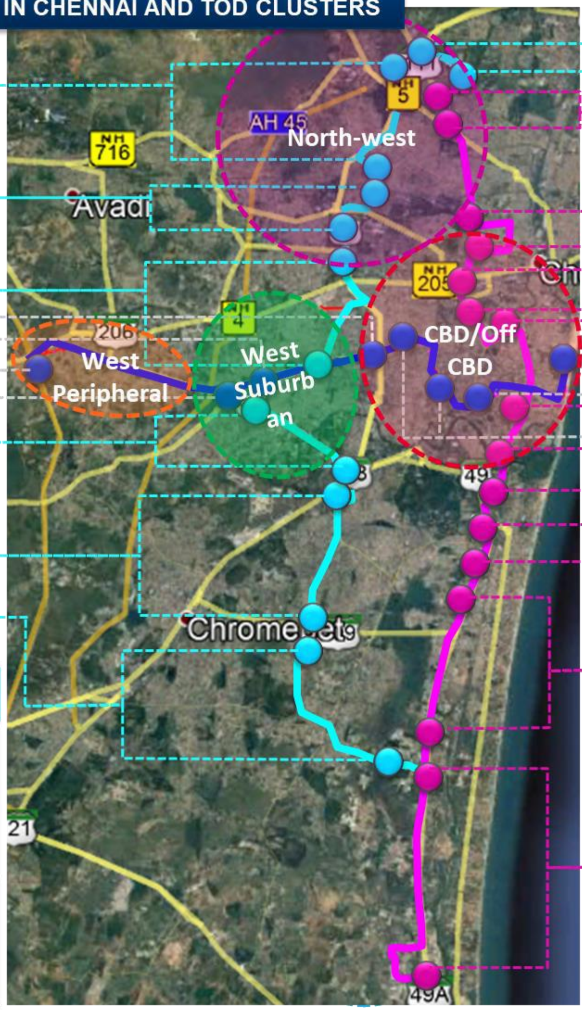
ESTIMATION OF CONSTRUCTION COST FOR OFFICE SPACE DEMAND IN TOD CORRIDOR (INR MILLION) – YEAR –ON-YEAR

Office Micro-Markets	TOD Clusters Nos.	Year 2038	Year 2039	Year 2040	Year 2041	Year 2042	Year 2043	Year 2044	Year 2045	Year 2046	Year 2047	Year 2048	Year 2049	Year 2050	Year 2051	Year 2052	Year 2053	Year 2054	Year 2055	Total
Central & Off-Central	3, 4, 5A, 5B	2,376	2,512	2,656	2,810	2,972	3,145	3,328	3,523	3,730	3,949	4,182	4,429	4,692	4,971	5,267	5,581	5,916	6,271	101,286
South-west	12A, 12B,13,16	4,319	4,567	4,830	5,108	5,404	5,718	6,052	6,405	6,781	7,180	7,603	8,053	8,530	9,038	9,576	10,148	10,756	11,401	184,156
North-west	11	346	365	386	409	432	457	484	512	542	574	608	644	682	723	766	812	860	912	14,733
Suburban & Peripheral South	6, 7, 8, 9, 15	9,503	10,047	10,625	11,238	11,889	12,580	13,313	14,092	14,918	15,796	16,727	17,716	18,767	19,883	21,067	22,326	23,663	25,083	405,144
Total		**16,543**	**17,491**	**18,497**	**19,565**	**20,698**	**21,901**	**23,177**	**24,533**	**25,971**	**27,499**	**29,121**	**30,843**	**32,672**	**34,614**	**36,677**	**38,867**	**41,195**	**43,666**	**705,319**

Total Construction Costs estimated towards the office Space demand in TOD Corridors – INR 705,319 Million

18.6. DEMAND ANALYSIS RESIDENTIAL SEGMENT

FIGURE 18.5 : KEY RESIDENTIAL ZONES IN CHENNAI AND TOD CLUSTERS



Housing Micro-Markets		Key Areas falling into the micro-market
	Central & Off-Central Business District	*Egmore, Kilpauk ,Nungambakkam, Anna Nagar, Boat Club, Gopalapuram, KK Nagar, MRC Nagar, Mylapore, Nandanam, Poes Garden, RA Puram, Royapettah, Saidapet, T.Nagar, Teynampet, Alwarpet*
	North-west	*Ambattur, Moolakadai, Padi, Perambur, Puraisawalkam, Washermanpet,Thiruvotriyur ,Kolathur, Madhavaram, NH-5, Surappattu, Tondiarpet*

Housing Micro-Markets		Key Areas falling into the micro-market
	Suburban & Peripheral South	*Adyar, Besant Nagar, Thiruvanmiyur, Velachery, East Coast Rd, Rajiv Gandhi Salai, GST Rd*
	West Suburban	*Porur, Poonamalle, Koyambedu, Inner Ring Road*
	West Peripheral	*NH 4, Oragadam*

KEY TARGET SEGMENTS FOR HOUSING IN CHENNAI

Residential demand in Chennai is largely end-user driven and typically generated by the following target segments

- Rented households living in Chennai looking to invest in own homes
- Investors living in Chennai investing in homes for rental income

While the above segments are primary demand drivers for housing in Chennai, secondary demand drivers for housing comprise of speculative investors and end-user generated as a result of nuclearization of families. The following aims to assess the demand from primary target segments of housing.

TABLE 18.13: HOUSING POPULATION OF CHENNAI METROPOLITAN AREA

Projected Population of Chennai																					
Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Population - Chennai Metropolitan Area – 2011 (in Millions)	8.65																				
Decadal Growth in Population (2001-2011)	7.77%																				
Projected population of Chennai based on past decadal growth (in Millions)	8.98	9.05	9.12	9.19	9.26	9.33	9.40	9.47	9.54	9.61	9.68	9.75	9.83	9.90	9.98	10.05	10.13	10.20	10.28	10.36	10.43
No. of Households in Chennai (Based on an average of 4 members per household) (in millions)	2.25	2.26	2.28	2.30	2.31	2.33	2.35	2.37	2.38	2.40	2.42	2.44	2.46	2.48	2.49	2.51	2.53	2.55	2.57	2.59	2.61

DISTRIBUTION OF HOUSEHOLDS W.R.T ANNUAL INCOME AND HOUSING AFFORDABILITY

The distribution of households in Chennai with respect to income and affordability category is presented in **Table 18.14.**

TABLE 18.14: DISTRIBUTION OF HOUSEHOLDS WITH RESPECT TO ANNUAL INCOME AND HOUSING AFFORDABILITY

Annual Income of Households (INR/annum)	% Share of Population	Housing Affordability	Source
No. of households earning Rs. 75,000 - Rs.150,000	22%	Upto 7.5 Lakhs	Annual Income of Households - Indicus Market Skyline of India
No. of households earning Rs.150,001 - Rs.300,000	20%	INR 7.6 to 15 Lakhs	Housing Affordability based on Housing Loan Eligibility
No. of households earning Rs.300,001 - Rs.500,000	15%	INR 16 to 25 Lakhs	
No. of households earning Rs.500,001 - Rs.1,000,000	16%	INR 26 to 50 Lakhs	
No. of households earning Rs. 1,000,001 - Rs.2,000,000	12%	INR 51 Lakhs to 1 Crore	
No. of households earning Rs. 2,000,001 - Rs.5,000,000	10%	INR 1 to 2.5 Crore	
No. of households earning Rs. 5,000,001 - Rs.10,000,000	4%	INR 2.5 to 5 Crore	

Distribution of Households wrt Housing Affordability (in millions)																					
Housing Affordability	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
Upto 7.5 Lakhs	0.50	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.53	0.53	0.53	0.54	0.54	0.55	0.55	0.55	0.56	0.56	0.57	0.57	0.58
INR 7.6 to 15 Lakhs	0.46	0.46	0.47	0.47	0.47	0.48	0.48	0.48	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.53	0.53	0.53
INR 16 to 25 Lakhs	0.34	0.34	0.34	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.39	0.39	0.39	0.39
INR 26 to 50 Lakhs	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.42	0.42	0.42	0.43
INR 51 Lakhs to 1 Crore	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32
INR 1 to 2.5 Crore	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25
INR 2.5 to 5 Crore	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
TOTAL	**2.25**	**2.26**	**2.28**	**2.30**	**2.31**	**2.33**	**2.35**	**2.37**	**2.38**	**2.40**	**2.42**	**2.44**	**2.46**	**2.48**	**2.49**	**2.51**	**2.53**	**2.55**	**2.57**	**2.59**	**2.61**

GROSS DEMAND FOR ORGANIZED HOUSING IN CHENNAI

As discussed earlier, the primary target segments for housing in Chennai are those who reside in Rented households (which comprise of end-users' segment), and investors who invest in homes for rental income. Eventually the occupiers of homes in both the above segments are the rented households. Hence, **Table 18.15** below calculates the demand for housing from the rented households based in Chennai.

TABLE 18.15: GROSS DEMAND FOR ORGANIZED HOUSING IN CHENNAI

Proportion of Rented Households in Chennai	51%	*(as per Census 2011)*

Demand for Housing in Chennai (in millions)																					
Housing Affordability	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Upto 7.5 Lakhs	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29
INR 7.6 to 15 Lakhs	0.23	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27
INR 16 to 25 Lakhs	0.17	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20
INR 26 to 50 Lakhs	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.22
INR 51 Lakhs to 1 Crore	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
INR 1 to 2.5 Crore	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13
INR 2.5 to 5 Crore	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
TOTAL	**1.15**	**1.15**	**1.16**	**1.17**	**1.18**	**1.19**	**1.20**	**1.21**	**1.22**	**1.23**	**1.23**	**1.24**	**1.25**	**1.26**	**1.27**	**1.28**	**1.29**	**1.30**	**1.31**	**1.32**	**1.33**

NET DEMAND FOR ORGANIZED HOUSING IN CHENNAI

The organized segment of housing in Chennai Metropolitan area presently caters to the ticket sizes of INR 25 lakhs and upwards. Hence the net demand for modern organized housing is estimated from the housing affordability of INR 25 lakhs and upwards and presented in **Table 18.16**.

TABLE 18.16: NET DEMAND FOR ORGANIZED HOUSING IN CHENNAI

Gross Demand for Organized Housing in Chennai (> INR 25 Lakhs) – No. of Units																					
Housing Affordability	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Cumulative Demand for Housing Units in Over 25 Lakhs Price Segment (in millions – No. of Units)	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.53	0.53	0.53	0.54	0.54	0.55	0.55	0.56	0.56	0.56
Incremental Demand for Housing Units in Over 25 Lakhs Price Segment (No. of Units)	485,335	3,645	3,672	3,700	3,728	3,756	3,784	3,812	3,841	3,870	3,899	3,928	3,958	3,987	4,017	4,047	4,078	4,108	4,139	4,170	4,202

Supply (Unsold Inventory) of Organized Housing in Chennai (> INR 25 Lakhs) – No. of Units																					
Housing Affordability	2016																				
Over 25 Lakhs Ticket Size	35,233																				

Demand-Supply Gap of Organized Housing in Chennai (> INR 25 Lakhs) – No. of Units																						
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2055
Net Demand for Housing Units in Chennai	450,102	3,645	3,672	3,700	3,728	3,756	3,784	3,812	3,841	3,870	3,899	3,928	3,958	3,987	4,017	4,047	4,078	4,108	4,139	4,170	4,202	4,843

Net Demand for Organized Housing in Chennai (2016-2055)	**614,548 units**

ZONE WISE DISTRIBUTION OF HOUSING DEMAND IN CHENNAI

Zone wise distribution of Housing demand across Chennai is presented in **Table 18.17.**

TABLE 18.17: DISTRIBUTION OF HOUSING DEMAND IN CHENNAI

Housing Micro-markets In Chennai	Share Of Housing Stock & Upcoming Supply (% Share)	Demand for Housing Units in Various Micro-markets (No. of Units)	Key Areas in the Micro-market
CBD	0.6%	3,739	*Egmore, Kilpauk ,Nungambakkam*
Off CBD	2.2%	13,714	*Anna Nagar, Boat Club, Gopalapuram, KK Nagar, MRC Nagar, Mylapore, Nandanam, Poes Garden, RA Puram, Royapettah, Saidapet, T.Nagar, Teynampet, Alwarpet*
North	14.2%	87,300	*Ambattur, Moolakadai, Padi, Perambur, Puraisawalkam, Washermanpet,Thiruvotriyur ,Kolathur, Madhavaram, NH-5, Surappattu, Tondiarpet*
South Sub Urban	6.2%	38,278	*Adyar, Besant Nagar, Thiruvanmiyur, Velachery*
South Peripheral	49.5%	303,982	*East Coast Road, Rajiv Gandhi Salai, GST Road*
West Sub Urban	11.6%	71,275	*Porur, Poonamalle, Koyambedu, Inner Ring Road*
West Peripheral	15.7%	96,260	*NH 4, Oragadam*
Total		614,548	

Net Demand for Organized Housing Units across various micro-markets in Chennai (2016-2055)	614,548 Units

PROJECTED HOUSING DEMAND ALONG TOD CORRIDOR (NO. OF UNITS)

The "**TOD Corridor**" is defined as the 500m region spread along either side of the Phase II corridors of Chennai Metro Rail.

The demand for housing estimated across the various zones of Chennai includes the TOD and Non-TOD Zones. In order to estimate the housing demand in the TOD Corridor, the keys residential areas falling within the TOD corridor are identified and the demand share in the TOD corridor is allocated. The basis of allocating the potential demand share in the TOD corridor considers key factors like:

- Presence of established housing pockets within the TOD corridor
- The improvement in connectivity through the metro rail project in the TOD corridor which would further enhance the demand for housing
- Upcoming areas within the TOD Corridor with potential for housing development in the next 38 years period.

TABLE 18.18: DISTRIBUTION OF HOUSING DEMAND INTO TOD AND NON-TOD ZONES

DISTRIBUTION OF HOUSING DEMAND INTO "TOD" AND "NON-TOD" ZONES

Housing Micro-Markets in Chennai	TOD Clusters Nos. falling in the Micro-markets	Share of Housing demand within the TOD Zone	Share of Housing demand within the Non-TOD Zone	Potential Housing Demand within TOD Cluster (No. of Units)	Key Housing Pockets falling in TOD Zone (Current and Future Potential areas)
CBD	3	50%	50%	1,870	Balfour Rd, Nungambakkam High Rd, Ormes Rd, Harrington Rd, Sterling Rd, Spurtank Rd, College Rd, Kodambakkam High Rd, Poonamallee High Rd, Village Rd
Off CBD	4 ,5A,5B,11	60%	40%	8,228	100 feet Rd, 18th Main rd annanagar, North Usman Rd, GN Chetty Rd, Pondy Bazaar, Thygaraya Rd, Venkanarayana Rd, ChamierS Rd, Boat Club, TTK Rd, Luz Church Rd, RK Mutt Rd, Kutchery Rd, Royapettah High Rd
North	1A,1B,2,10	50%	50%	43,650	100 feet Road, Madhavaram Milk Colony Road, Paper Mills Road, Millers Road, Purusaiwalkam Road, Perambur Barracks Rd, Strahans Rd, Medavakkam Tank Road
South Sub Urban	6,14	60%	40%	22,967	Adyar, Gandhi nagar, LB Road, Indra nagar, Sardar patel Road, Medavakkam Main Road, Pallavaram-Thoriapakkam Road,
South Peripheral	7,8,9,15	65%	35%	197,588	RGS, Pallavaram-Thoraipakkam Rd, Perumbakkam High Rd, Medavakkam Koot Rd, OMR ECR Link Road
West Sub Urban	12A,12B,13, 16	95%	5%	67,711	Arcot Road, Kodambakkam High Road, Mt.Poonamallee Rd, Ramapuram Main Rd, Porur, Poonamalee
West Peripheral	Non-TOD Zone	0%	100%		
Total				342,014	

The projected demand for Housing Units within the TOD corridor is estimated at **342,014 units** spread between **year 2016 to year 2055**

DISTRIBUTION OF HOUSING DEMAND ALONG TOD CORRIDOR (BUILT-UP-AREA)

The demand for housing units is further converted into Built-up Area space by identifying the average unit sizes prevailing in various micro-markets.

TABLE 18.19: DISTRIBUTION OF HOUSING DEMAND ALONG TOD CORRIDORS

DISTRIBUTION OF HOUSING DEMAND IN TOD ZONE

Housing Micro-Markets in Chennai	TOD Clusters Nos. falling in the Micro-markets	Potential Housing Demand within TOD Cluster (No. of Units)	Average Unit Sizes prevailing in the region (sq.ft.)	Total Demand for Housing in Built-up Area (Million sq.ft.)
CBD	3	1,870	2500	4.7
Off CBD	4 ,5A,5B,11	8,228	1800	14.8
North	1A,1B,2,10	43,650	900	39.3
South Sub Urban	6,14	22,967	1300	29.9
South Peripheral	7,8,9,15	197,588	1000	197.6
West Suburban	12A,12B,13, 16	67,711	1200	81.3
Total		342,014		**367.5**

YEAR-ON-YEAR DISTRIBUTION OF HOUSING DEMAND IN BUILT-UP AREA

Table 18.20 below gives a year-on-year distribution of Housing Demand across TOD Corridor in terms of Built-up Area (million sq.ft.)

TABLE 18.20: YEAR-WISE DISTRIBUTION OF HOUSING DEMAND IN TERMS OF BUILT-UP AREA

Housing Demand along TOD Corridor – Built-up Area (million sq.ft.)																					
TOD Areas within Housing Micro-markets	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2055**
CBD	3.4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04
Off CBD	10.8	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.12
North	28.8	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.31
South Suburban	21.9	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.24
South Peripheral	144.7	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.56
West Suburban	59.5	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.53	0.53	0.54	0.54	0.54	0.55	0.55	0.56	0.64
Total	**269.1**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.4**	**2.4**	**2.4**	**2.4**	**2.4**	**2.5**	**2.5**	**2.5**	**2.5**	**2.9**

The projected demand for Housing Space within the TOD corridor is estimated at **367.5 mn.sq.ft**. spread between **year 2016 to year 2055**

METHODOLOGY FOR ESTIMATION OF REVENUE FROM HOUSING DEMAND IN TOD CORRIDOR

Year-on-Year Revenue Estimation in TOD Corridor = Housing Demand in TOD Corridor (mn.sq.ft.) X Projected Housing Capital Values (INR/sq.ft.)

The potential revenue generated from the housing demand along the TOD corridor is estimated using the potential capital values forecasted across various zones. This revenue estimation does not consider the impact of Time Value of Money.

TABLE 18.21: REVENUE ESTIMATION FROM HOUSING DEMAND IN TOD CORRIDOR

Revenue Estimation towards Housing Demand along TOR Corridor – INR Million per sq.ft.

TOD Areas within Housing Micro-markets	Yr 2016	Yr 2017	Yr 2018	Yr 2019	Yr 2020	Yr 2021	Yr 2022	Yr 2023	Yr 2024	Yr 2025	Yr 2026	Yr 2027	Yr 2028	Yr 2029	Yr 2030	Yr 2031	Yr 2032	Yr 2033	Yr 2034	Yr 2035	Yr 2036
CBD	68,462	571	593	615	638	662	687	713	740	768	797	827	858	891	924	959	995	1,033	1,072	1,112	1,154
Off CBD	108,476	905	939	974	1,011	1,049	1,089	1,130	1,173	1,217	1,263	1,310	1,360	1,411	1,464	1,520	1,577	1,637	1,698	1,762	1,829
North	129,477	1,080	1,121	1,163	1,207	1,252	1,300	1,349	1,400	1,452	1,507	1,564	1,623	1,684	1,748	1,814	1,882	1,953	2,027	2,104	2,183
South Suburban	120,272	1,003	1,041	1,080	1,121	1,163	1,207	1,253	1,300	1,349	1,400	1,453	1,508	1,565	1,624	1,685	1,749	1,815	1,883	1,954	2,028
South Peripheral	578,864	4,828	5,010	5,199	5,396	5,599	5,811	6,030	6,257	6,493	6,739	6,993	7,257	7,530	7,815	8,110	8,416	8,733	9,063	9,405	9,760
West Suburban	327,312	2,730	2,833	2,940	3,051	3,166	3,286	3,409	3,538	3,672	3,810	3,954	4,103	4,258	4,419	4,585	4,758	4,938	5,124	5,318	5,518
Total	**1,332,864**	**11,117**	**11,537**	**11,972**	**12,424**	**12,893**	**13,379**	**13,884**	**14,408**	**14,952**	**15,516**	**16,101**	**16,709**	**17,339**	**17,994**	**18,673**	**19,377**	**20,108**	**20,867**	**21,655**	**22,472**

Revenue Estimation towards Housing Demand along TOR Corridor – INR Million per sq.ft.

TOD Areas within Housing Micro-markets	Yr 2037	Yr 2038	Yr 2039	Yr 2040	Yr 2041	Yr 2042	Yr 2043	Yr 2044	Yr 2045	Yr 2046	Yr 2047	Yr 2048	Yr 2049	Yr 2050	Yr 2051	Yr 2052	Yr 2053	Yr 2054	Yr 2055	Total
CBD	1,198	1,243	1,290	1,339	1,389	1,442	1,496	1,552	1,611	1,672	1,735	1,800	1,868	1,939	2,012	2,088	2,167	2,248	2,333	**117,493**
Off CBD	1,898	1,970	2,044	2,121	2,201	2,284	2,370	2,460	2,553	2,649	2,749	2,853	2,960	3,072	3,188	3,308	3,433	3,562	3,697	**186,164**
North	2,265	2,351	2,440	2,532	2,627	2,726	2,829	2,936	3,047	3,162	3,281	3,405	3,533	3,667	3,805	3,948	4,097	4,252	4,413	**222,205**
South Suburban	2,104	2,184	2,266	2,352	2,440	2,532	2,628	2,727	2,830	2,937	3,048	3,163	3,282	3,406	3,534	3,668	3,806	3,950	4,099	**206,408**
South Peripheral	10,128	10,510	10,907	11,318	11,745	12,188	12,648	13,126	13,621	14,135	14,668	15,222	15,796	16,392	17,011	17,653	18,319	19,010	19,728	**993,433**
West Suburban	5,727	5,943	6,167	6,400	6,641	6,892	7,152	7,422	7,702	7,992	8,294	8,607	8,932	9,269	9,619	9,982	10,358	10,749	11,155	**561,725**
Total	**23,320**	**24,200**	**25,113**	**26,061**	**27,044**	**28,065**	**29,124**	**30,223**	**31,363**	**32,547**	**33,775**	**35,049**	**36,372**	**37,744**	**39,169**	**40,647**	**42,180**	**43,772**	**45,424**	**2,287,428**

The potential Revenue generated from the Residential demand of 367.5 mn.sq.ft. in the TOD corridor is estimated at INR 2,287,428 Million. This revenue is spread between the years 2016 to 2055

DISTRIBUTION OF REVENUE ESTIMATION FROM HOUSING DEMAND ACROSS THE 3 TOD CORRIDORS

Table 18.22 gives a distribution of the revenue estimation from Housing demand across the 3 TOD corridors.

TABLE 18.22: DISTRIBUTION OF REVENUE ESTIMATION FROM HOUSING DEMAND

Zones	Cluster Nos.	Total Revenue Estimation	Corridor 3:	Corridor 4:	Corridor 5:
			Madhavaram to SIPCOT	Lighthouse to Poonamallee Bypass	Madhavaram to Sholinganallur
CBD	Corridor 3: Cluster No. 3 Corridor 4: Nil Corridor 5: Nil	117,493	117,493		
Off CBD	Corridor 3 – Cluster No. 5A Corridor 4 - Cluster Nos. 4, 5B Corridor 5 - Cluster No. 11	186,164	46,541	93,082	46,541
North	Corridor 3: Cluster Nos. 1A, 2 Corridor 4: Nil Corridor 5: Cluster No. 1B, 10	222,205	111,103		111,103
South Sub Urban	Corridor 3: Cluster No. 6 Corridor 4: Nil Corridor 5: Cluster No. 14	206,408	82,563		123,845
South Peripheral	Corridor 3: Cluster Nos. 7, 8, 9 Corridor 4: Nil Corridor 5: Cluster No. 15	993,433	695,403		298,030
West Sub Urban	Corridor 3: Nil Corridor 4: Cluster No. 12A, 16 Corridor 5: Cluster Nos. 12B, 13	561,725		477,466	84,259
Total		**2,287,428**	**1,053,103**	**570,548**	**663,777**

COST ESTIMATION FOR DEVELOPMENT OF ESTIMATED HOUSING DEMAND ALONG TOD CORRIDOR

The costs incurred towards the potential construction of housing demand of **367.5 mn.sq.ft**. is estimated based on the prevailing construction costs in Chennai market. It also takes into account an average annual escalation of 5% in construction costs. The table below gives an estimation of the costs incurred towards the development of 367.5 mn.sq.ft of housing space over the next 38 year time period between years 2017 to 2055.

Key Cost Assumptions

- Prevailing Construction Cost for Housing Space in Chennai – **INR 1500-2000/sq.ft. (Average)**
- Avg. escalation in Construction Costs – 5% per annum

TABLE 18.23: COST ESTIMATION FOR DEVELOPMENT OF ESTIMATED HOUSING DEMAND ALONG TOD CORRIDOR

Estimated Cost of Construction for the Projected Housing Demand (INR Mn.)

TOD Areas within Housing Micro-markets	Yr 2016	Yr 2017	Yr 2018	Yr 2019	Yr 2020	Yr 2021	Yr 2022	Yr 2023	Yr 2024	Yr 2025	Yr 2026	Yr 2027	Yr 2028	Yr 2029	Yr 2030	Yr 2031	Yr 2032	Yr 2033	Yr 2034	Yr 2035	Yr 2036
CBD	6,846	58	62	65	69	73	77	82	86	91	97	102	108	114	121	128	135	143	152	160	170
Off CBD	19,526	166	176	186	197	208	220	233	246	260	275	291	308	326	345	365	386	408	432	457	484
North	43,159	367	388	411	434	460	486	514	544	576	609	644	681	721	763	807	854	903	955	1,010	1,069
South Suburban	32,802	279	295	312	330	349	370	391	414	437	463	490	518	548	580	613	649	686	726	768	812
South Peripheral	217,074	1,846	1,953	2,066	2,185	2,312	2,445	2,587	2,737	2,895	3,063	3,240	3,428	3,626	3,836	4,058	4,293	4,541	4,804	5,082	5,377
West Suburban	89,267	759	803	849	899	951	1,006	1,064	1,125	1,191	1,259	1,332	1,410	1,491	1,577	1,669	1,765	1,868	1,976	2,090	2,211
Total	**408,673**	**3,475**	**3,676**	**3,889**	**4,114**	**4,352**	**4,604**	**4,870**	**5,152**	**5,451**	**5,766**	**6,100**	**6,453**	**6,827**	**7,222**	**7,640**	**8,082**	**8,550**	**9,045**	**9,568**	**10,122**

Estimated Cost of Construction for the Projected Housing Demand (INR Mn.)

TOD Areas within Housing Micro-markets	Yr 2037	Yr 2038	Yr 2039	Yr 2040	Yr 2041	Yr 2042	Yr 2043	Yr 2044	Yr 2045	Yr 2046	Yr 2047	Yr 2048	Yr 2049	Yr 2050	Yr 2051	Yr 2052	Yr 2053	Yr 2054	Yr 2055	Total
CBD	179	190	201	212	225	238	251	266	281	298	315	333	352	373	394	417	441	467	494	**14,868**
Off CBD	512	541	573	606	641	678	717	759	803	849	898	950	1,005	1,063	1,125	1,190	1,259	1,332	1,409	**42,403**
North	1,131	1,196	1,266	1,339	1,416	1,498	1,585	1,677	1,774	1,877	1,985	2,100	2,222	2,350	2,486	2,630	2,782	2,943	3,114	**93,727**
South Suburban	859	909	962	1,018	1,076	1,139	1,205	1,274	1,348	1,426	1,509	1,596	1,688	1,786	1,890	1,999	2,115	2,237	2,367	**71,234**
South Peripheral	5,688	6,017	6,365	6,734	7,124	7,536	7,972	8,434	8,922	9,438	9,985	10,562	11,174	11,821	12,505	13,229	13,995	14,805	15,662	**471,412**
West Suburban	2,339	2,474	2,618	2,769	2,929	3,099	3,278	3,468	3,669	3,881	4,106	4,344	4,595	4,861	5,142	5,440	5,755	6,088	6,440	**193,858**
Total	**10,708**	**11,328**	**11,984**	**12,677**	**13,411**	**14,187**	**15,009**	**15,877**	**16,797**	**17,769**	**18,797**	**19,885**	**21,037**	**22,254**	**23,542**	**24,905**	**26,347**	**27,872**	**29,485**	**887,502**

Total Construction Costs estimated towards the Housing Space demand in TOD Corridor – INR 887,502 Million

18.7. DEMAND ANALYSIS – RETAIL SEGMENT

FIGURE 18.6: KEY RETAIL ZONES IN CHENNAI AND TOD CLUSTERS

MAP SHOWING KEY RETAIL ZONES IN CHENNAI AND TOD CLUSTERS

CLUSTER 10 – Manjambakkam to Villivakkam Station

CLUSTER 11 – Villivakkam Bus Terminus to Kendriya Vidyalaya

CLUSTER 12B – Kaliammankoil Street Jn to Valasaravakkam

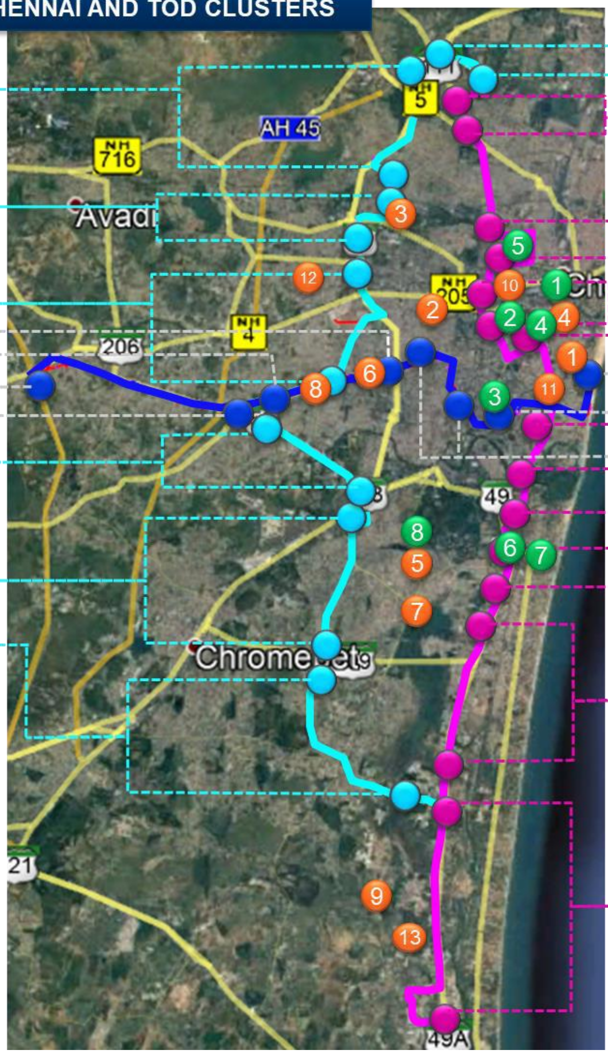
CLUSTER 12A – Vadapalini Metro to Karabakkam

CLUSTER 16 – Porur Jn. to Poonamallee Byepass

CLUSTER 13 – Karabakkam to Alandur

CLUSTER 14 – Saint Thomas Mount to Kovilambakkam

CLUSTER 14 – Velakkal to Elcot



CLUSTER 1B - Madhavaram Depot to Assisi Nagar

CLUSTER 1A - Madhavaram Milk Colony to Perambur RS

CLUSTER 2 - Ayanavaran to Kellys JN

CLUSTER 3 - KMC to Thousand Light East

CLUSTER 5A – West Cott Road to MGR Janaki College

CLUSTER 5B – Adyar Gate to Light House

CLUSTER 4 – Nandanam to Power House

CLUSTER 6 – Adyar Aavin Bus Stop to Indira Road Jn.

CLUSTER 7 – Tidel Park to Perungudi Toll Plaza

CLUSTER 8 – Velachery Road JN to Sholinganallur

CLUSTER 9 – Infosys to Sipcot

HIGHSTREET RETAIL	
1	Nungambakkam
2	T.Nagar
3	TTK Road
4	RK Salai
5	Purasaiwalkam
6	Adyar / Besant Nagar
7	Anna Nagar
8	Velachery

MALL RETAIL			
1	Citi Center-0.25mn.sft.	8	Chandra Mall-0.15mn.sft.
2	Sky Walk-0.45mn.sft.	9	Coramandal Plaza-0.18mn.sft.
3	Spectrum Mall- 0.16mn.sft.	10	Spencer-0.85mn.sft.
4	Express Avenue-0.90mn.sft.	11	Ramee Mall-0.15mn.sft.
5	Phoenix Market- 0.90mn.sft.	12	Ozone Mall-1mn.sft.
6	Forum Vijaya-0.65mn.sft.	13	Allied Mall-0.45mn.sft.
7	PS Grand -0.35mn.sft.	14	

TARGET SEGMENT FOR MODERN RETAIL IN CHENNAI

Demand for organized Retail in Chennai has been estimated based on 2 major factors - Retail Expenditure generated by the residing population in Chennai and the Real Estate Cost incurred by a Retailer in Chennai. **Table 18.24** below assesses the demand for modern organized retail in Chennai over a 38-year period, from year 2017 to year 2055.

TABLE 18.24: DEMAND FOR RETAIL SPACE IN CHENNAI

DEMAND FOR RETAIL SPACE IN CHENNAI BASED ON REAL ESTATE COST OF RETAILER																					
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Share of Real Estate Cost from the total Revenue generated by a Retailer (Rent as a percentage of Retail revenue) – *Based on Chennai Market Standards*	12%																				
Cost incurred towards Real Estate rentals (INR Million/Annum)	5,278	5,796	6,365	6,990	7,677	8,430	9,258	10,167	11,166	12,262	13,466	14,788	16,240	17,834	19,585	21,508	23,620	25,940	28,486	31,283	34,355
Projected Rentals in Chennai @ 5% escalation per annum (INR/sq.ft./Month)	75	79	83	87	91	96	101	106	111	116	122	128	135	141	148	156	164	172	180	190	199
Projected Rentals in Chennai (INR/sq.ft./Annum)	900	945	992	1,042	1,094	1,149	1,206	1,266	1,330	1,396	1,466	1,539	1,616	1,697	1,782	1,871	1,965	2,063	2,166	2,274	2,388
Gross Demand for retail Space in Chennai (Total Cost Incurred towards Retail Space Rentals ÷ Per sq.ft. Cost of Retail Space) - Cumulative (Million sq.ft.)	5.86	6.13	6.42	6.71	7.02	7.34	7.68	8.03	8.40	8.78	9.19	9.61	10.05	10.51	10.99	11.50	12.02	12.57	13.15	13.76	14.39
Stock of Modern Retail Space in Chennai (Million sq.ft.)	5.79																				
Cumulative Stock of Retail Space in Chennai (Million sq.ft.)	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79
Net Demand for Organized Modern Retail Space in Chennai – Cumulative (Million sq.ft.)	**0.08**	**0.35**	**0.63**	**0.92**	**1.23**	**1.55**	**1.89**	**2.24**	**2.61**	**3.00**	**3.40**	**3.82**	**4.26**	**4.72**	**5.21**	**5.71**	**6.24**	**6.79**	**7.37**	**7.97**	**8.60**

TABLE 18.25: DISTRIBUTION OF RETAIL DEMAND ACROSS VARIOUS RETAIL MICRO-MARKETS IN CHENNAI

DISTRIBUTION OF RETAIL SPACE DEMAND INTO VARIOUS ZONES (Million Sq.ft.)																					
Retail Zones in Chennai	**Share of Demand**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2055**
Central & Off-Central Business District	25%	0.09	0.16	0.23	0.31	0.39	0.47	0.56	0.65	0.75	0.85	0.96	1.07	1.18	1.30	1.43	1.56	1.70	1.84	1.99	2.15	6.99
South-West	20%	0.07	0.13	0.18	0.25	0.31	0.38	0.45	0.52	0.60	0.68	0.76	0.85	0.94	1.04	1.14	1.25	1.36	1.47	1.59	1.72	5.59
North-west	5%	0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.13	0.15	0.17	0.19	0.21	0.24	0.26	0.29	0.31	0.34	0.37	0.40	0.43	1.40
Suburban & Peripheral South	35%	0.12	0.22	0.32	0.43	0.54	0.66	0.79	0.91	1.05	1.19	1.34	1.49	1.65	1.82	2.00	2.18	2.38	2.58	2.79	3.01	9.79
Peripheral South-west	15%	0.05	0.09	0.14	0.18	0.23	0.28	0.34	0.39	0.45	0.51	0.57	0.64	0.71	0.78	0.86	0.94	1.02	1.11	1.20	1.29	4.19
TOTAL	100%	**0.35**	**0.63**	**0.92**	**1.23**	**1.55**	**1.89**	**2.24**	**2.61**	**3.00**	**3.40**	**3.82**	**4.26**	**4.72**	**5.21**	**5.71**	**6.24**	**6.79**	**7.37**	**7.97**	**8.60**	**27.96**

DISTRIBUTION OF RETAIL DEMAND ALONG TOD CORRIDOR

The "TOD Corridor" is defined as the 500m region spread along either side of the Phase II corridor of Chennai Metro Rail. The area of the TOD Corridor is spread across a total length of 119 km and a width of 1 km.

The demand for Retail space estimated across the various zones of Chennai includes the TOD and Non-TOD Zones. In order to estimate the demand for Retail space in the TOD Corridor, the keys Retail Pockets falling within the TOD corridor are identified and the demand share in the TOD corridor is allocated. The basis of allocating the potential demand share in the TOD corridor considers key factors like

- Presence of established Residential and retail pockets within the TOD corridor
- Impact of the metro rail connectivity in the TOD corridor which would enhance the demand for housing thereby impacting the demand for retail space development
- Upcoming areas within the TOD Corridor with potential for retail space development in the next 38 years period

TABLE 18.26: DISTRIBUTION OF RETAIL SPACE IN TOD AND NON-TOD ZONES

Retail Micro-Markets in Chennai	TOD Clusters Nos. falling in the Micro-markets	Demand Share of Retail Space within the TOD Zone	Demand Share of Retail Space within the Non-TOD Zone	Key Retail Corridors in TOD Zone (Current and Future Potential areas)
Central & Off-Central Business District	3, 4, 5A, 5B	70%	30%	Nungambakkam High Road, Annasalai, Royapettah High Road, T.Nagar, Alwarpet
South-west	12A, 12B, 13,16	90%	10%	Ambedkar Road, Arcot Road, Kodambakkam High Road, Mt.Poonamallee Road
North-west	11	30%	70%	Anna Nagar, Koyembedu, Poonamalee High Road, 100 Feet Road
Suburban & Peripheral South	6,7,8,9, 15	70%	30%	LB Road, Sardar Patel Road, Gandhi Nagar, RGS
Peripheral South-west	Non-TOD zone	0%	100%	
Total				

TABLE 18.27:DISTRIBUTION OF RETAIL DEMAND ALONG TOD CORRIDOR

DISTRIBUTION OF RETAIL DEMAND IN TOD ZONES (Million Sq.ft.)																					
Retail Zones in Chennai	**Share of Demand towards TOD Corridor**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2055**
Central & Off-Central Business District	70%	0.06	0.11	0.16	0.22	0.27	0.33	0.39	0.46	0.52	0.60	0.67	0.75	0.83	0.91	1.00	1.09	1.19	1.29	1.39	1.51	0.26
South-West	90%	0.03	0.05	0.07	0.10	0.12	0.15	0.18	0.21	0.24	0.27	0.31	0.34	0.38	0.42	0.46	0.50	0.54	0.59	0.64	0.69	0.27
North-west	30%	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.02
Suburban & Peripheral South	70%	0.09	0.15	0.23	0.30	0.38	0.46	0.55	0.64	0.73	0.83	0.94	1.04	1.16	1.28	1.40	1.53	1.66	1.80	1.95	2.11	0.36
Peripheral South-west	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL		**0.18**	**0.32**	**0.48**	**0.63**	**0.80**	**0.97**	**1.16**	**1.35**	**1.54**	**1.75**	**1.97**	**2.20**	**2.43**	**2.68**	**2.94**	**3.21**	**3.50**	**3.79**	**4.10**	**4.43**	**0.91**

The projected demand for Modern Retail Space within the TOD corridor is estimated at 17.20 mn.sq.ft. spread across a 38 year period (year 2017 to year 2055)

ESTIMATION OF REVENUE FROM RETAIL DEMAND ALONG TOD CORRIDOR

The potential revenue from the Retail Demand along the TOD corridor is estimated based on the Net demand for Retail space and the Rental towards retail space in Chennai and is provided in **Table 18.28**. This revenue estimation does not consider the impact of Time Value of Money.

TABLE 18.28: DISTRIBUTION OF RETAIL DEMAND ALONG TOD CORRIDOR

RETAIL REVENUE IN TOD ZONES (INR Million)

Retail Zones in Chennai	Yr 2017	Yr 2018	Yr 2019	Yr 2020	Yr 2021	Yr 2022	Yr 2023	Yr 2024	Yr 2025	Yr 2026	Yr 2027	Yr 2028	Yr 2029	Yr 2030	Yr 2031	Yr 2032	Yr 2033	Yr 2034	Yr 2035	Yr 2036	Yr 2037
Central & Off-Central Business District	58	109	169	236	312	399	497	608	732	872	1,030	1,206	1,403	1,623	1,870	2,145	2,451	2,792	3,172	3,595	4,064
South-West	59	113	173	243	321	411	511	625	753	897	1,059	1,240	1,443	1,670	1,923	2,206	2,521	2,872	3,263	3,697	4,180
North-west	5	9	14	20	27	34	43	52	63	75	88	103	120	139	160	184	210	239	272	308	348
Suburban & Peripheral South	81	153	236	330	437	559	696	851	1,025	1,221	1,441	1,688	1,964	2,273	2,618	3,003	3,431	3,909	4,441	5,032	5,690
Peripheral South-west	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	203	385	592	829	1,098	1,403	1,747	2,136	2,574	3,066	3,618	4,237	4,930	5,705	6,571	7,537	8,614	9,813	11,148	12,632	14,282

RETAIL REVENUE IN TOD ZONES (INR Million)

Retail Zones in Chennai	Yr 2038	Yr 2039	Yr 2040	Yr 2041	Yr 2042	Yr 2043	Yr 2044	Yr 2045	Yr 2046	Yr 2047	Yr 2048	Yr 2049	Yr 2050	Yr 2051	Yr 2052	Yr 2053	Yr 2054	Yr 2055	TOTAL
Central & Off-Central Business District	4,585	5,164	5,806	6,518	7,306	8,180	9,147	10,217	11,401	12,710	14,157	15,756	17,523	19,474	21,628	24,006	26,630	29,525	279,077
South-West	4,716	5,312	5,972	6,704	7,515	8,413	9,408	10,509	11,726	13,073	14,562	16,206	18,024	20,031	22,246	24,692	27,391	30,369	287,050
North-west	393	443	498	559	626	701	784	876	977	1,089	1,213	1,351	1,502	1,669	1,854	2,058	2,283	2,531	23,921
Suburban & Peripheral South	6,420	7,230	8,128	9,125	10,229	11,451	12,805	14,304	15,961	17,794	19,820	22,059	24,532	27,264	30,280	33,609	37,282	41,336	390,708
Peripheral South-west	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	16,114	18,148	20,404	22,905	25,676	28,746	32,144	35,905	40,065	44,666	49,752	55,372	61,581	68,438	76,008	84,365	93,587	103,761	980,756

The potential Cumulative Revenue from Retail space demand of 17.20 mn.sq.ft in the TOD corridor is estimated at INR 980,756 Million. This revenue would be spread over a 38 year period from Year 2017 to 2055.

DISTRIBUTION OF REVENUE ESTIMATION FROM RETAIL DEMAND ACROSS THE 3 TOD CORRIDORS

The tables below give a distribution of the revenue estimation from retail demand across the 3 TOD corridors for the period year 2017-2055.

TABLE 18.29: DISTRIBUTION OF REVENUE ESTIMATION FROM RETAIL DEMAND ALONG TOD CORRIDORS

Retail Zones in Chennai	Total Revenue Estimation (INR Million)	Corridor wise Distribution of Clusters	Corridor 3: Madhavaram to SIPCOT	Corridor 4: Lighthouse to Poonamallee Bypass	Corridor 5: Madhavaram to Sholinganallur
Central & Off-Central Business District	**279,077**	Corridor 3: Cluster Nos. 3, 5A Corridor 4: Cluster No. 4, 5B Corridor 5: Nil	209,308	69,769	
South-West	**287,050**	Corridor 3 - Nil Corridor 4 - Cluster No. 12A, 16 Corridor 5 - Custer Nos. 12B, 13		258,345	28,705
North-west	**23,921**	Corridor 3: Nil Corridor 4: Nil Corridor 5: Cluster No. 11			23,921
Suburban & Peripheral South	**390,708**	Corridor 3: 6, 7, 8, 9 Corridor 4: Nil Corridor 5: 15	390,708		
TOTAL	**980,756**		**600,015**	**328,115**	**52,626**

COST ESTIMATION FOR DEVELOPMENT OF ESTIMATED RETAIL SPACE DEMAND ALONG TOD CORRIDOR

The costs incurred towards the potential construction of retail demand of **17.20 mn.sq.ft**. is estimated based on the prevailing construction costs in Chennai market. It also takes into account an average annual escalation of 5% in construction costs.

The table below gives an estimation of the costs incurred towards the development of 17.20 mn.sq.ft of retail space over the next 38 year time period between years 2017 to 2055.

Key Cost Assumptions

- Prevailing Construction Cost for organized Retail Space in Chennai – **INR 2000/sq.ft. (Average)**
- Avg. escalation in Construction Costs – 5% per annum

TABLE 18.30: COST ESTIMATION FOR DEVELOPMENT OF RETAIL SPACE DEMAND ALONG TOD CORRIDOR

ESTIMATED COST OF CONSTRUCTION FOR RETAIL SPACE DEMAND IN TOD CLUSTERS (INR Million)																					
Retail Zones in Chennai	Yr 2017	Yr 2018	Yr 2019	Yr 2020	Yr 2021	Yr 2022	Yr 2023	Yr 2024	Yr 2025	Yr 2026	Yr 2027	Yr 2028	Yr 2029	Yr 2030	Yr 2031	Yr 2032	Yr 2033	Yr 2034	Yr 2035	Yr 2036	Yr 2037
Central & Off-Central Business District	128	109	119	131	144	158	173	191	209	230	252	277	304	334	367	403	443	486	534	586	644
South-West	132	112	123	135	148	162	178	196	215	236	260	285	313	344	377	415	455	500	549	603	662
North-west	11	9	10	11	12	14	15	16	18	20	22	24	26	29	31	35	38	42	46	50	55
Suburban & Peripheral South	179	152	167	183	201	221	243	267	293	322	353	388	426	468	514	564	620	681	747	821	901
Peripheral South-west	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	450	382	419	460	506	555	610	670	735	807	887	974	1,069	1,174	1,290	1,416	1,555	1,708	1,876	2,060	2,262

ESTIMATED COST OF CONSTRUCTION FOR RETAIL SPACE DEMAND IN TOD CLUSTERS (INR Million)																			
Retail Zones in Chennai	Yr 2038	Yr 2039	Yr 2040	Yr 2041	Yr 2042	Yr 2043	Yr 2044	Yr 2045	Yr 2046	Yr 2047	Yr 2048	Yr 2049	Yr 2050	Yr 2051	Yr 2052	Yr 2053	Yr 2054	Yr 2055	TOTAL
Central & Off-Central Business District	707	776	853	936	1,028	1,129	1,240	1,362	1,496	1,642	1,804	1,981	2,175	2,389	2,623	2,881	3,164	3,475	37,884
South-West	727	799	877	963	1,058	1,162	1,276	1,401	1,538	1,689	1,855	2,037	2,237	2,457	2,698	2,963	3,254	3,574	38,966
North-west	61	67	73	80	88	97	106	117	128	141	155	170	186	205	225	247	271	298	3,247
Suburban & Peripheral South	990	1,087	1,194	1,311	1,440	1,581	1,736	1,907	2,094	2,299	2,525	2,773	3,045	3,344	3,673	4,033	4,429	4,864	53,038
Peripheral South-west	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2,485	2,728	2,996	3,291	3,614	3,969	4,358	4,786	5,256	5,772	6,339	6,961	7,645	8,395	9,220	10,125	11,119	12,211	133,135

Total Construction Costs estimated towards the Retail Space demand in TOD Corridor – INR 133,135 Million

18.8. SUMMARY OF COST & REVENUE ESTIMATION OF REAL ESTATE DEVELOPMENT ALONG TOD CORRIDOR

The table gives a summary of the quantum of Real Estate Demand that could be developed along all the 3 TOD Corridors. The “TOD Corridor” is spread across the 500m region along either sides of the Phase II corridor of Chennai Metro Rail. The Revenue and Construction cost estimation from the TOD development is estimated based on the forecasted Rentals and Capital Values over a 38-year period (year 2017 to 2055) across Office, Residential and Retail asset classes. **Table 18.31** below represents the Revenue from the projected real estate demand from year 2017 to year 2055 along all 3 TOD corridors.

TABLE 18.31: COST & REVENUE FROM PROJECTED REAL ESTATE DEMAND ALONG ALL THREE TOD CORRIDORS

Asset Classes	Quantum of Real Estate Demand along the TOD Corridor (Year 2017 to 2055) Built-Up Area	Estimated Cumulative Revenue from the Projected Real Estate Demand along the TOD Corridor (Year 2017 to 2036)	Estimated Costs towards Construction of Real Estate Space along the TOD corridor (Year 2017 to 2036)
Office Space	192.38 Million sq.ft	Rental revenue : INR 5,518,891 Million	INR 705,319 Million
Residential Space	367.5 Million Sq.ft.	Sale revenue : INR 2,287,428 Million	INR 887,502 Million
Retail Space	17.2 Million Sq.ft.	Rental revenue : INR 980,756 Million	INR 133,135 Million

The year wise revenue from various asset classes along all the corridors are presented in **Table 18.32**.

TABLE 18.32: ESTIMATED REVENUE ALONG ALL TOD CORRIDORS

Year	Revenue (Rs. in Crores)			
	Revenue from Office Space	Revenue from Residential Space	Revenue from Retail Space	Total Revenue
2019	581	1,197	59	**1,837**
2020	814	1,242	83	**2,139**
2021	1,070	1,289	110	**2,469**
2022	1,350	1,338	140	**2,828**
2023	1,656	1,388	175	**3,219**
2024	1,990	1,441	214	**3,645**
2025	2,355	1,495	257	**4,107**
2026	2,752	1,552	307	**4,610**
2027	3,184	1,610	362	**5,156**
2028	3,655	1,671	424	**5,749**
2029	4,165	1,734	493	**6,392**
2030	4,720	1,799	571	**7,089**
2031	5,321	1,867	657	**7,845**

Year	Revenue (Rs. in Crores)			
	Revenue from Office Space	Revenue from Residential Space	Revenue from Retail Space	Total Revenue
2032	5,973	1,938	754	**8,664**
2033	6,678	2,011	861	**9,551**
2034	7,442	2,087	981	**10,511**
2035	8,269	2,165	1,115	**11,549**
2036	9,163	2,247	1,263	**12,673**
2037	10,128	2,332	1,428	**13,889**
2038	11,171	2,420	1,611	**15,203**
2039	12,297	2,511	1,815	**16,623**
2040	13,512	2,606	2,040	**18,158**
2041	14,822	2,704	2,290	**19,817**
2042	16,234	2,806	2,568	**21,608**
2043	17,756	2,912	2,875	**23,543**
2044	19,396	3,022	3,214	**25,633**
2045	21,161	3,136	3,590	**27,888**
2046	23,062	3,255	4,007	**30,323**
2047	25,107	3,377	4,467	**32,951**
2048	27,306	3,505	4,975	**35,786**
2049	29,672	3,637	5,537	**38,846**
2050	32,215	3,774	6,158	**42,148**
2051	34,948	3,917	6,844	**45,709**
2052	37,885	4,065	7,601	**49,551**
2053	41,040	4,218	8,436	**53,695**
2054	44,428	4,377	9,359	**58,164**

Net cash flow from TOD cannot be estimated without considering market costs of land, approvals, development of public infrastructure etc. Quantification of these variables requires a detailed study which is beyond the scope of this DPR. Further, the share and form of TOD revenue which will flow into the Metro Project is a matter of policy to be decided by GoTN. However, for present analysis this is taken as 10% and the summary based on this is given in **Table 18.33**.

TABLE 18.33: NET CASH FLOW FROM TOD

	Total Revenues (in Rs. Crore)				
	2019	**2025**	**2035**	**2045**	**2054**
Net Cash Flow from TOD	184	411	1155	2789	5816

19. FINANCIAL ANALYSIS

19.1 BACKGROUND

Project cost includes various associated costs in terms of:

- Capital cost of project
- Operation and Maintenance Costs
- Replacement and capital cost for capacity augmentation

Capital cost of project includes field investigations, design, civil works, electrical works of traction & power supply, signal and telecommunication, automatic fare collection, rolling stock and maintenance depot. O&M cost is based on costs of functioning of Delhi and Bangalore.

19.2 CAPITAL COST

The capital cost at December 2018 price level for Phase-II corridors has been worked out at Rs. 60335.2 crore. The capital cost for corridor 3, 4 and 5 is estimated at Rs. 29192.05 crore, 14761.43 crore, 16381.73 crore respectively. The block capital cost for an operation period of 30 years i.e. up to 2054-55 is given below in **Table 19.1**.

TABLE 19.1: CAPITAL COST INPUT

S. No.	Items	Capital Cost (Rs. in Crore)		
		Corridor 3 & 5	Corridor 4	Total
1	Total Capital Cost	45573.78	14761.43	60335.21
2	Addition of 3 RSS coaches and 72 coaches for Corridor 3&5 and 51 Coaches for Corridor 4 in 2035	1491.16	775.54	2261.70
3	Addition of 69 Coaches for Corridor 3&5 and 27 Coaches for Corridor 4 in 2045	1279.04	500.49	1779.53
4	Replacement of 25% of Equipment and 50% of S&T in 2045	13705.20	3781.91	17487.11

The Project is proposed to have a construction period of 6 years starting from the year 2019-20 but the payments are expected to spillover to seventh year as well. Hence capital expenditure is assumed to be in ratio of 5:15:20:20:20:15:5. The operation would start from the year 2025-26. Escalation is considered at 5% p.a. from Dec' 2018 onwards. The completed project cost (without IDC) is calculated as given in **Table 19.2**.

TABLE 19.2: COMPLETED PROJECT COST (WITHOUT IDC) FOR CORRIDOR 3, 4 & 5

(in Rs. Cr)

Particulars	2019	2020	2021	2022	2023	2024	2025	Total
Phasing of Const. Cost & Taxes	5.0%	15.0%	20.0%	20.0%	20.0%	15.0%	5.0%	100%
Phasing of Cost of Land	50%	50%						100%
Construction Cost	2156	6469	8625	8625	8625	6469	2156	43126
Central Taxes	203	609	812	812	812	609	203	4060
Cost of Central Land and R&R	105	105	0	0	0	0	0	210
Cost of State Land and R&R	4837	4837	0	0	0	0	0	9675
State Taxes	163	490	653	653	653	490	163	3265
Completed Cost of Project (w/o IDC)	**4942**	**14402**	**9460**	**9460**	**9460**	**9460**	**3153**	**60335**
Escalation Factor	1.01	1.06	1.12	1.17	1.23	1.29	1.36	-
Construction Cost (with escalation)	2183	6876	9626	10107	10613	8358	2925	50687
Central Taxes (with escalation)	205	647	906	951	999	787	275	4771
Cost of Central Land and R&R (no escalation on land)	105	105	0	0	0	0	0	210
Cost of State Land and R&R (no escalation on land)	4837	4837	0	0	0	0	0	9675
State Taxes (with escalation)	165	521	729	765	803	633	221	3838
Completed Cost of Project (w/o IDC)	**7496**	**12986**	**11261**	**11824**	**12415**	**9777**	**3422**	**69180**

19.3 REVENUE

Revenue has been estimated for two revenue streams viz. fare-box revenue and non-fare-box revenue i.e. from advertisement and commercial activities.

19.3.1 Fare-box Revenue

The revenue estimate and financial analysis is done on fare structure suggested by CMRL (**Table 19.3**). The projected ridership for Phase-II corridors is presented **Table 19.4.**

Fare box revenue has been worked out on the basis of daily ridership and fare structure. The fare is escalated by 7.5% annually. The fare-box revenue is given in **Table 19.5.**

TABLE 19.3: FARE STRUCTURE FOR YEAR 2021-22

Distance Slab (in Km)	Fare (in Rs.)
0-2	10
2-4	20
4-6	30
6-12	40
12-18	50
18-24	60
>24	70

TABLE 19.4: RIDERSHIP ASSESSMENT ALONG METRO CORRIDORS

Year	Daily Ridership (In Lakh)			Total Daily Trips
	C-3	C-4	C-5	
2025	6.03	5.09	6.61	**17.73**
2035	9.56	7.75	12.42	**29.73**
2045	10.66	9.33	14.14	**34.13**
2055	11.88	10.51	16.11	**38.50**

TABLE 19.5: FAREBOX REVENUE ESTIMATION

S.No.	Revenue Stream	Total Revenue (in Rs. Crore)			
		2025	2035	2045	2054
1	Revenue from Fare-box	3491	12197	28916	63795

19.3.2 Non-Fare-Box Revenue

Non-fare sources of revenue incorporated in financial analysis are as follows:

- Advertisement a) in stations, b) inside and outside trains and c) outside Stations and other prospective areas of advertisements are assumed @ 10% of the total advertisement revenue;
- Rental from Kiosks inside the stations
- Parking charges for 2 wheeler vehicles at stations;
- Cess on sales of private cars and taxis;
- Cess on employer firms;
- Film shooting Charges
- Telecom cable & Tower license fee

The unit rates and rates of increase are tabulated in **TABLE 19.6**.

TABLE 19.6: NON-FARE-BOX REVENUE

Type of Revenue	Unit Rate (Rs)	Rate of Increase (%)
Advertising panels inside stations	2,345 per sqm per month	5% every year
Train – interiors and external wrap	70,000 per train per month	5% every year
Kiosk rentals	2650 per sqm per month	20% every 3 years
Parking charges at stations	Average of 4 hrs. @ rate for 3-6 Hrs i.e. Rs. 10/- & 8 hrs for 6-12 Hrs i.e. Rs. 15/- Plus 20% for time slots and vehicle variations	10% every 5 years
Cess on sales of 4 wheelers	10000 per vehicle one time	6% per year on sales and 5% per year on cess amount
Cess on employer firms	500 per employee per month in firms employing average 200 employees per firm	5% per year in number of employees and cess amount upto year 2035 and 2.5% later
Film shooting charges	Rs. 4 Lakh/ hour for inside Train/Station assumed for 8 hrs and once in 4 months i.e. 24 hrs in a year	5% every year
Telecom Cable & Tower license fee	2500 per Km per month for entire track length, 75000 per Km per month for underground section Telecom Tower License fees @Rs. 15000 per month for elevated stations	7.5% every year

Advertising in stations is proposed at following locations with areas as mentioned in **TABLE 19.7**.

TABLE 19.7: ADVERTISING AREA

S. No.	Place of Advertisement	Area of Advertising in Sqm)
1	Under Ground Stations Advt. (48 Stations)	4800
2	Elevated Stations Advt. (80 Stations)	8000

The summary of non-fare revenue under the heads of advertisement receipts, rentals from kiosks, parking receipts, cess on 4 wheeler sales, cess on companies, Film Shooting, Telecom Cable & Tower (License fees), is presented in **TABLE 19.8**.

TABLE 19.8: NON-FARE-BOX REVENUE

Revenue Stream	Total Revenues (Rs. in Crore)			
	2025	**2035**	**2045**	**2054**
Advertisement Receipts	73	123	210	326
Rentals from Kiosks	23	44	85	152
Parking Receipts	26	39	57	69
4 Wheeler sales and cess thereon	324	1,403	5,533	12,454
Cess on Companies/ firms (on no. of employees)	160	452	1,207	2,761
Film Shooting	1	2	4	6
Telecom Cable & Tower (License fees)	9	19	39	75
Total	**617**	**2,082**	**7,136**	**15,843**

19.3.3 Revenue from TOD

The net cash flow from TOD as estimated in previous chapter is given in **TABLE 19.9**

TABLE 19.9: NET CASH FLOW FROM TOD

	Total Revenues (in Rs. Crore)				
	2019	**2025**	**2035**	**2045**	**2054**
Net Cash Flow from TOD	184	411	1155	2789	5816

The year wise revenue from non fare box sources including TOD up to 2054-55 is presented in **TABLE 19.10.**

TABLE 19.10: YEAR WISE REVENUE FROM NON FARE BOX AND TOD

Year	Total Revenue (Rs. In Cr)		
	Non Fare Box Revenue	**Net cash Flow from TOD**	**Total**
2019		184	184
2020		214	214
2021		247	247
2022		283	283
2023		322	322
2024		364	364
2025	617	411	1028
2026	734	461	1195
2027	851	516	1367
2028	969	575	1544

Year	Total Revenue (Rs. In Cr)		
	Non Fare Box Revenue	Net cash Flow from TOD	Total
2029	1087	639	1726
2030	1206	709	1915
2031	1325	785	2109
2032	1444	866	2310
2033	1564	955	2519
2034	1699	1051	2750
2035	2082	1155	3237
2036	2470	1267	3738
2037	2859	1389	4248
2038	3248	1520	4768
2039	3638	1662	5300
2040	4028	1816	5844
2041	4420	1982	6401
2042	4812	2161	6973
2043	5205	2354	7559
2044	5619	2563	8182
2045	7136	2789	9924
2046	8153	3032	11186
2047	9172	3295	12467
2048	10192	3579	13771
2049	11214	3885	15098
2050	12236	4215	16451
2051	13260	4571	17831
2052	14286	4955	19241
2053	15314	5369	20683
2054	15843	5816	21659

19.4 FIRR ANALYSIS

Based on the above, FIRR for a project operation period of 30 years including revenue from TOD and Non-fare box at constant and current prices is as given in **Table 19.11**. The details of FIRR at constant and current prices for both the scenarios is given in **Table 19.12** and **Table 19.13.**

TABLE 19.11: PROJECT FIRR WITH NON FARE BOX REVENUE INCLUDING TOD

Prices	FIRR
Constant Prices	4.01%
Current Prices	12.05%

TABLE 19.12: PROJECT FIRR ANALYSIS WITH TOD AND NON FARE BOX REVENUE AT CONSTANT PRICES (IN RS. CRORE)

Period		Capital Cost	O&M Expenses	Replacement Cost	Total Yearly Expenditure	Fare Box Revenue	Non Fare Box Revenue	Cash Flow from TOD	Total Revenue	Net Cash Flows
2019	2020	7465	0	0	7465	0		165	165	-7300
2020	2021	12510	0	0	12510	0	0	184	184	-12326
2021	2022	10090	0	0	10090	0	0	204	204	-9887
2022	2023	10090	0	0	10090	0	0	223	223	-9867
2023	2024	10090	0	0	10090	0	0	243	243	-9847
2024	2025	7568	0	0	7568	0	0	263	263	-7305
2025	2026	2523	822	0	3345	2614	230	283	3127	-217
2026	2027	0	827	0	827	2750	230	303	3283	2456
2027	2028	0	833	0	833	2894	230	324	3448	2615
2028	2029	0	903	0	903	3047	230	344	3622	2719
2029	2030	0	908	0	908	3210	230	365	3805	2897
2030	2031	0	980	0	980	3383	230	386	3999	3019
2031	2032	0	985	0	985	3567	230	407	4204	3219
2032	2033	0	991	0	991	3763	230	429	4422	3431
2033	2034	0	996	0	996	3971	230	451	4652	3657
2034	2035	0	1001	0	1001	4194	237	473	4904	3903
2035	2036	0	1006	1485	2491	4431	236	495	5162	2671
2036	2037	0	1013	0	1013	4477	236	517	5230	4217
2037	2038	0	1019	0	1019	4526	236	540	5302	4283
2038	2039	0	1026	0	1026	4580	236	563	5379	4353
2039	2040	0	1033	0	1033	4638	236	587	5460	4427
2040	2041	0	1039	0	1039	4700	236	610	5546	4507
2041	2042	0	1046	0	1046	4768	236	634	5638	4592

Period		Capital Cost	O&M Expenses	Replacement Cost	Total Yearly Expenditure	Fare Box Revenue	Non Fare Box Revenue	Cash Flow from TOD	Total Revenue	Net Cash Flows
2042	2043	0	1053	0	1053	4841	236	659	5736	4683
2043	2044	0	1059	0	1059	4920	236	684	5839	4780
2044	2045	0	1066	0	1066	5005	243	709	5957	4891
2045	2046	0	1072	5205	6277	5097	243	734	6074	-203
2046	2047	0	1079	0	1079	5150	243	760	6153	5074
2047	2048	0	1086	0	1086	5209	243	787	6238	5152
2048	2049	0	1092	0	1092	5275	243	814	6331	5239
2049	2050	0	1099	0	1099	5349	243	841	6433	5333
2050	2051	0	1106	0	1106	5432	243	869	6543	5437
2051	2052	0	1113	0	1113	5524	243	897	6663	5551
2052	2053	0	1119	0	1119	5626	243	926	6794	5675
2053	2054	0	1126	0	1126	5739	243	955	6937	5811
2054	2055	0	1133	0	1133	5866	243	985	7093	5960
Total		**60335**	**30630**	**6690**	**97656**	**134542**	**7101**	**19612**	**161255**	**4.01%**

TABLE 19.13: PROJECT FIRR ANALYSIS WITH TOD AND NON FARE BOX REVENUE AT CURRENT PRICES (IN RS. CRORE)

Period		Capital Cost	O&M Expenses	Replacement Cost	Total Yearly Expenditure	Fare Box Revenue	Non Fare Box Revenue	Cash flow from TOD	Total Revenue	Net Cash Flows
2019	2020	7496	0	0	7496	0		184	184	-7312
2020	2021	12986	0	0	12986	0		214	214	-12772
2021	2022	11261	0	0	11261	0		247	247	-11014
2022	2023	11824	0	0	11824	0		283	283	-11541
2023	2024	12415	0	0	12415	0		322	322	-12093
2024	2025	9777	0	0	9777	0		364	364	-9413
2025	2026	3422	1304	0	4726	3491	617	411	4519	-207
2026	2027	0	1403	0	1403	3948	734	461	5143	3740
2027	2028	0	1509	0	1509	4466	851	516	5833	4324
2028	2029	0	1729	0	1729	5055	969	575	6599	4870
2029	2030	0	1858	0	1858	5724	1087	639	7450	5592
2030	2031	0	2117	0	2117	6485	1206	709	8400	6283
2031	2032	0	2273	0	2273	7351	1325	785	9461	7188
2032	2033	0	2440	0	2440	8336	1444	866	10646	8207
2033	2034	0	2620	0	2620	9459	1564	955	11978	9358
2034	2035	0	2814	0	2814	10738	1699	1051	13488	10674
2035	2036	0	3023	2267	5289	12197	2082	1155	15434	10145
2036	2037	0	3251	0	3251	13246	2470	1267	16983	13732
2037	2038	0	3497	0	3497	14397	2859	1389	18645	15148
2038	2039	0	3762	0	3762	15659	3248	1520	20427	16665
2039	2040	0	4048	0	4048	17047	3638	1662	22347	18299
2040	2041	0	4356	0	4356	18573	4028	1816	24417	20060
2041	2042	0	4689	0	4689	20253	4420	1982	26655	21966

Period		Capital Cost	O&M Expenses	Replacement Cost	Total Yearly Expenditure	Fare Box Revenue	Non Fare Box Revenue	Cash flow from TOD	Total Revenue	Net Cash Flows
2042	2043	0	5047	0	5047	22106	4812	2161	29079	24032
2043	2044	0	5434	0	5434	24151	5205	2354	31710	26276
2044	2045	0	5852	0	5852	26412	5619	2563	34594	28743
2045	2046	0	6302	19267	25569	28916	7136	2789	38841	13272
2046	2047	0	6790	0	6790	31405	8153	3032	42590	35800
2047	2048	0	7315	0	7315	34147	9172	3295	46614	39299
2048	2049	0	7883	0	7883	37175	10192	3579	50946	43063
2049	2050	0	8496	0	8496	40524	11214	3885	55623	47127
2050	2051	0	9159	0	9159	44236	12236	4215	60687	51528
2051	2052	0	9875	0	9875	48359	13260	4571	66190	56315
2052	2053	0	10649	0	10649	52948	14286	4955	72189	61540
2053	2054	0	11485	0	11485	58068	15314	5369	78751	67267
2054	2055	0	12388	0	12388	63795	15843	5816	85454	73066
Total		**69180**	**153368**	**21533**	**244082**	**688668**	**198442**	**166683**	**67957**	**12.05%**

19.5 SENSITIVITY ANALYSIS

Sensitivity analysis with respect to decrease in expected ridership, increase in capital cost and delay in implementation (time overrun) is provided in **Table 19.14.**

TABLE 19.14: SENSITIVITY ANALYSIS

Parameter	Change in Parameter	Constant Prices	Current Prices
Base Case		4.01%	12.05%
Ridership	5% decrease	3.67%	11.73%
	10% decrease	3.32%	11.40%
Capital Cost	5% increase	3.72%	11.73%
	10% increase	3.43%	11.43%

19.6 FINANCIAL PLAN

19.6.1 Financing Plan with ODA Loan

The financing of project is proposed to be done through Equity contribution from Government of Tamil Nadu (GoTN) and Government of India (GoI) and loan from Bilateral / Multilateral Agency. The addition and replacement costs are assumed to be solely financed from loan. It may be noted here that financing does not have any influence on project FIRR.

The capital contribution from GoTN, GoI and Bilateral / Multilateral Agency Loan is assumed in two different Options as given below:

Option 1:

1. 100% of Cost towards Central taxes to be borne by GOI and 100% of Cost towards State taxes to be borne by GOTN.
2. 100% of Cost towards GOI land to be borne by GOI and 100% of Cost towards GoTN Land and private land to be borne by GOTN.
3. The allocation of procurement cost and IDC has been made in such a way that 20% of total project cost (including IDC and front-end fee) will be funded by GOI (15% equity and 5% Subordinate debt), 20% by GOTN (15% equity and 5% Subordinate debt) and 60% by Bilateral / Multilateral Agency.
4. Any increase in land and R & R cost over the project estimate shall be borne entirely by GOTN by way of grant

Option 2:

1. 100% of Cost towards Central taxes to be borne by GOI and 100% of Cost towards State taxes to be borne by GOTN.
2. 100% of Cost towards GOI land to be borne by GOI and 100% of Cost towards GOTN Land and Private Land to be borne by GOTN.
3. 100% of Procurement cost to be borne by Bilateral / Multilateral Agency.
4. IDC is shared between GOI and GOTN in such fashion that total contribution of GOI does not exceed 10%

Based on above, the contribution from each source under both the options is provided in **Table 19.15.**

TABLE 19.15: CONTRIBUTION FROM EACH SOURCE

Particulars	Option 1		Option 2	
	Share (in Rs. Crore)	%	Share (in Rs. Crore)	%
State Government				
State Taxes (SGST)	3838	5.43%	3838	5.43%
State Land and R&R	9672	13.68%	9672	13.68%
Construction Cost	0	0.00%	0	0.00%
IDC (@1.4%) by State Govt	592	0.84%	0	0.00%
Front End Fee by State Govt @ 0.1%	37	0.05%	0	0.00%
Sub Total (State Government)	**14138**	**20.000%**	**13510**	**19.04%**
Central Government				
Central Taxes (CGST)	4771	6.75%	4771	6.75%
Central Land and R&R	212	0.30%	212	0.30%
Construction Cost	8272	11.70%	0	0.00%
IDC (@1.4%) by Central Govt	878	1.24%	1710	2.42%
Front End Fee by Central Govt @0.1%	6	0.01%	51	0.07%
Sub Total (Central Government)	**14138**	**20.00%**	**6745**	**9.51%**
Bilateral / Multilateral Agency				
Construction Cost	42415	60.00%	50687	71.45%
Sub Total (Bilateral / Multilateral Agency)	**42415**	**60.00%**	**50687**	**71.45%**
Grand Total	**70692**	**100%**	**70941**	**100%**

The terms of Loan from bilateral/multilateral agencies (General Terms, Fixed) are given in **Table 19.16**.

TABLE 19.16: ODA LOAN TERMS

S.No.	Parameter	Value
1	Annual Interest rate for Loan	1.40%
2	Front end fee	0.1%
3	Repayment Period	30 years
4	Moratorium Period	10 years
5	Payment Schedule	Yearly

The year-wise contribution from each source is as given in **Table 19.17** and **19.18** for Option 1 and Option 2.

TABLE 19.17: YEAR-WISE CONTRIBUTION FROM EACH SOURCE-OPTION 1, ODA LOAN (RS. CRORE)

Particulars	Year-wise Contribution							Total
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
State Government								
State Taxes (SGST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	0	0	0	0	0	0	0	0
IDC (@1.4%) by State Govt	15	74	126	126	126	94	31	592
Front End Fee by State Govt @ 0.1%	37	0	0	0	0	0	0	37
Sub Total (State Government)	**5053**	**5431**	**855**	**891**	**929**	**727**	**253**	**14138**
Central Government								
Central Taxes (CGST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	62	513	1143	1624	2130	1995	804	8272
IDC (@1.4%) by Central Govt	0	0	38	112	171	247	310	878
Front End Fee by Central Govt @0.1%	6	0	0	0	0	0	0	6
Sub Total (Central Government)	**379**	**1267**	**2087**	**2687**	**3300**	**3029**	**1390**	**14138**
Bilateral/Multilateral Agency								
Construction Cost	2121	6362	8483	8483	8483	6362	2121	42415
Sub Total (Bilateral/Multilateral Agency)	2121	6362	8483	8483	8483	6362	2121	42415
Total	**7553**	**13060**	**11424**	**12062**	**12712**	**10118**	**3763**	**70692**

TABLE 19.18: YEAR-WISE CONTRIBUTION FROM EACH SOURCE-OPTION 2, ODA LOAN (RS. CRORE)

Particulars	Year-wise Contribution							Total
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	
State Government								
State Taxes (GST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	0	0	0	0	0	0	0	0

Particulars	Year-wise Contribution							Total
	2019	2020	2021	2022	2023	2024	2025	
IDC (@1.4%) by State Govt	0	0	0	0	0	0	0	0
Front End Fee by State Govt @ 0.1%	0	0	0	0	0	0	0	0
Sub Total (State Government)	**5001**	**5357**	**729**	**765**	**803**	**633**	**221**	**13510**
Central Government								
Central Taxes (Basic Customs Duty and GST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	0	0	0	0	0	0	0	0
IDC (@1.4%) by Central Govt	15	79	179	269	347	409	413	1710
Front End Fee by Central Govt @0.1%	51	0	0	0	0	0	0	51
Sub Total (Central Government)	**378**	**832**	**1085**	**1220**	**1346**	**1195**	**689**	**6745**
Bilateral/Multilateral Agency								
Construction Cost	2183	6876	9626	10107	10613	8358	2925	50687
Sub Total (Bilateral/Multilateral Agency)	**2183**	**6876**	**9626**	**10107**	**10613**	**8358**	**2925**	**50687**
TOTAL	**7562**	**13064**	**11440**	**12093**	**12762**	**10186**	**3835**	**70941**

19.6.2 Financing Plan with Step Loan

Implications of STEP Loan (i.e., tied loan) on financing plan have been analyzed in this section. The capital contribution from GoTN, GoI and Bilateral / Multilateral Agency Step Loan is assumed in two different Options – Option 1 and Option 2 is as given in **Table 19.19**.

TABLE 19.19: CONTRIBUTION FROM EACH SOURCE

Particulars	Option 1		Option 2	
	Share (in Rs. Crore)	%	Share (in Rs. Crore)	%
State Government				
State Taxes (GST)	3838	5.54%	3838	5.54%
State Land and R&R	9672	13.95%	9672	13.95%
Construction Cost	298	0.43%	0	0.00%
IDC (@0.1%) by State Govt	15	0.02%	0	0.00%
Front End Fee by State Govt @ 0.1%	42	0.06%	0	0.00%
Sub Total (State Government)	**13865**	**20.00%**	**13510**	**19.48%**
Central Government				
Central Taxes (Basic Customs Duty and GST)	4771	6.88%	4771	6.88%
Central Land and R&R	212	0.31%	212	0.31%
Construction Cost	8794	12.69%	0	0.00%
IDC (@0.1%) by Central Govt	88	0.13%	122	0.18%
Front End Fee by Central Govt @0.1%	0	0.00%	51	0.07%
Sub Total (Central Government)	**13865**	**20.00%**	**5156**	**7.43%**

Particulars	Option 1		Option 2	
	Share (in Rs. Crore)	%	Share (in Rs. Crore)	%
Bilateral/Multilateral Agency				
Construction Cost	41595	60.00%	50687	73.09%
Sub Total (Bilateral/Multilateral Agency)	**41595**	**60.00%**	**50687**	**73.09%**
TOTAL	**69325**	**100%**	**69353**	**100%**

The terms of Loan from bilateral / multilateral agencies (STEP Loan) are given in **Table 19.20**.

TABLE 19.20: STEP LOAN TERMS

S. No.	Parameter	STEP (Fixed-Standard)
1	Annual Interest rate for Loan	0.10%
2	Front end fee	0.1%
3	Repayment Period	40 years
4	Moratorium Period	10 years
5	Payment Schedule	Yearly

The year-wise Contribution from each source is as given in **Table 19.21** and **19.22** for Option 1 and Option 2 of STEP Loan.

TABLE 19.21: YEAR-WISE CONTRIBUTION FROM EACH SOURCE - OPTION 1, STEP LOAN (RS. CRORE)

PARTICULARS	Year-wise contribution							TOTAL
	2019	2020	2021	2022	2023	2024	2025	
State Government								
State Taxes (GST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	15	45	60	60	60	45	15	298
IDC (@0.1%) by State Govt	0	1	2	3	4	4	1	15
Front End Fee by State Govt @ 0.1%	42	0	0	0	0	0	0	42
Sub Total (State Government)	**5058**	**5402**	**791**	**828**	**867**	**681**	**238**	**13865**
Central Government								
Central Taxes (Basic Customs Duty and GST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	88	592	1247	1729	2234	2074	830	8794
IDC (@0.1%) by Central Govt	1	4	9	13	17	20	23	88
Front End Fee by Central Govt @0.1%	0	0	0	0	0	0	0	0
Sub Total (Central Government)	**401**	**1349**	**2163**	**2693**	**3250**	**2881**	**1129**	**13865**
Bilateral/Multilateral Agency								
Construction Cost	2080	6239	8319	8319	8319	6239	2080	41595
Sub Total (Bilateral/Multilateral Agency)	**2080**	**6239**	**8319**	**8319**	**8319**	**6239**	**2080**	**41595**
TOTAL	**7538**	**12991**	**11272**	**11841**	**12436**	**9801**	**3446**	**69325**

TABLE 19.22: YEAR-WISE CONTRIBUTION FROM EACH SOURCE - OPTION 2, STEP LOAN (RS. CRORE)

Particulars	Year-wise contribution							Total
	2019	2020	2021	2022	2023	2024	2025	
State Government								
State Taxes (GST)	165	521	729	765	803	633	221	3838
State Land and R&R	4836	4836	0	0	0	0	0	9672
Construction Cost	0	0	0	0	0	0	0	0
IDC (@0.1%) by State Govt	0	0	0	0	0	0	0	0
Front End Fee by State Govt @ 0.1%	0	0	0	0	0	0	0	0
Sub Total (State Government)	**5001**	**5357**	**729**	**765**	**803**	**633**	**221**	**13510**
Central Government								
Central Taxes (Basic Customs Duty and GST)	205	647	906	951	999	787	275	4771
Central Land and R&R	106	106	0	0	0	0	0	212
Construction Cost	0	0	0	0	0	0	0	0
IDC (@0.1%) by Central Govt	1	6	13	19	25	29	30	122
Front End Fee by Central Govt @0.1%	51	0	0	0	0	0	0	51
Sub Total (Central Government)	**363**	**759**	**919**	**971**	**1024**	**816**	**305**	**5156**
Bilateral/Multilateral Agency								
Construction Cost	2183	6876	9626	10107	10613	8358	2925	50687
Sub Total (Bilateral/Multilateral Agency)	**2183**	**6876**	**9626**	**10107**	**10613**	**8358**	**2925**	**50687**
TOTAL	**7547**	**12991**	**11274**	**11843**	**12440**	**9806**	**3451**	**69353**

19.6.3 Alternative Means of Financing - Exploring Private Participation

The basic approach to infrastructure financing is changing rapidly. The transport services have been generally considered social goods to be provided by the Government at free or at subsidized costs. The normal practice has been to provide funds through Government budgetary sources for both capital investments on projects as well to cover the short fall in their O & M costs.

However, over the past few years, the approach towards funding the infrastructure has been changing. The private sector through innovative ways is being invited to not only mobilise financial resources but also to involve in the operations and management of the system.

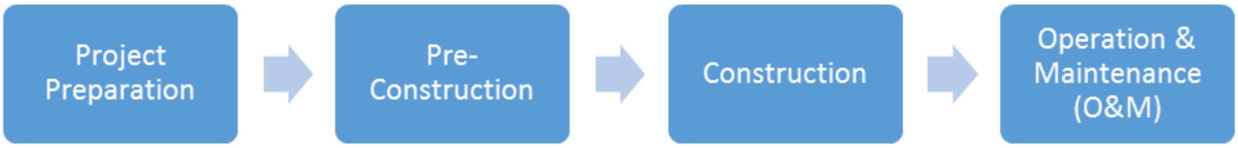
As per Metro Rail Policy 2017, it is essential to explore private participation either for complete provisioning of metro rail or for some unbundled components such as Automatic Fare Collection System of metro rail. The following paragraphs explore the various form of private participation that can be explored/ implemented at Chennai Metro Rail.

The fundamental principle underlying Public Private Partnerships (PPPs) as a development option for any infrastructure project is to combine the strengths of the private sector with those of the public sector in order to overcome challenges faced during construction & operation and to achieve superior outcomes.

The private sector can be expected to contribute to efficiency gains in the development of land, construction, operations and maintenance through the use of technology, better management and construction practices. In addition, the private sector should be expected to bring economies of scale from large projects and by involving a larger number of private partners.

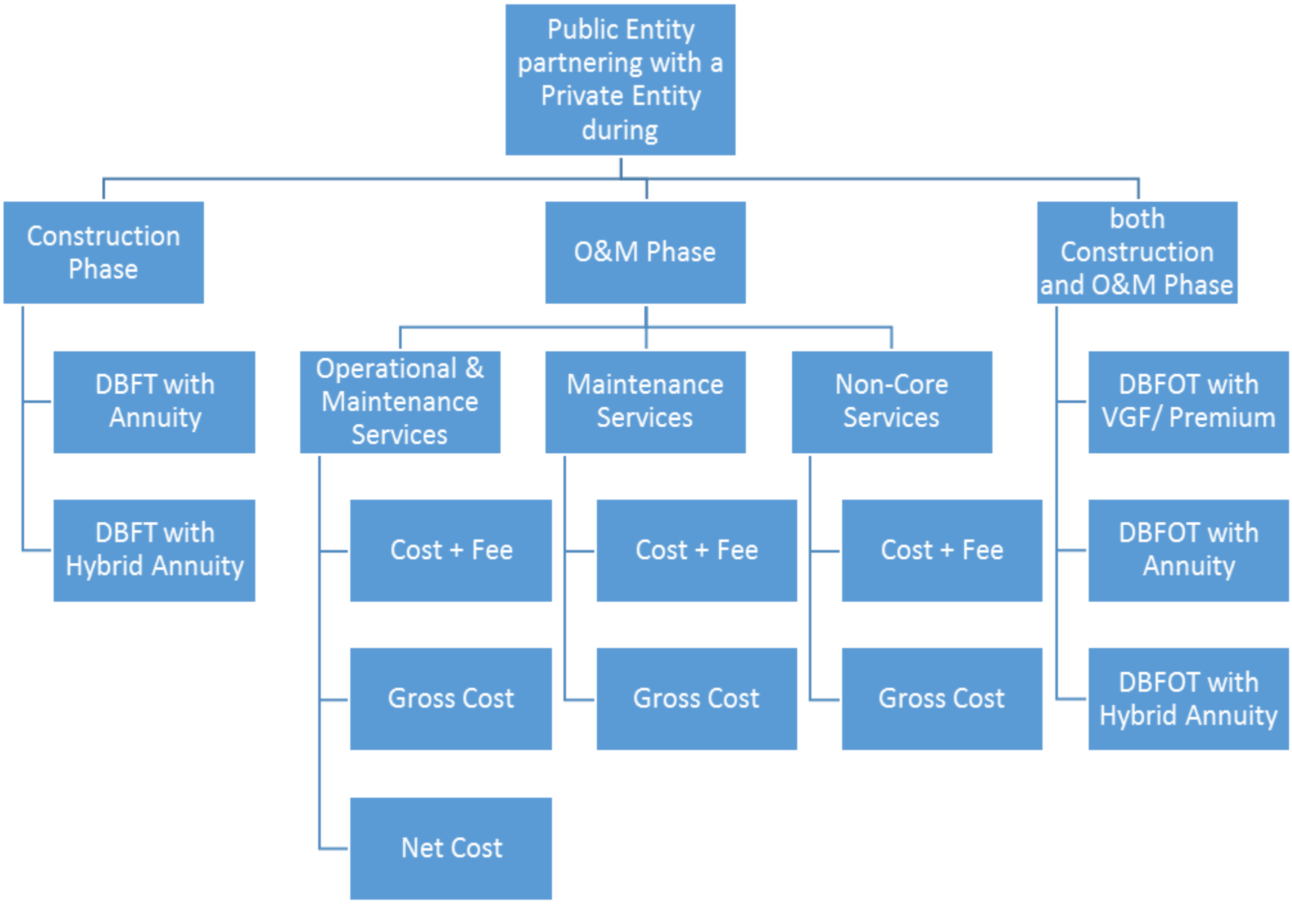
However, the success of PPP will depend critically on designing PPP structures that make an appropriate allocation of risks, responsibilities, rewards and penalties, and create the incentives for value creation. Indeed, this risk allocation is the defining feature of the PPP strategy. The golden principle is that risks should be allocated to the entity best equipped to manage each risk. The expectation is that such an allocation of risks will not only produce the best possible program and project outcomes but also optimize costs. This should lead to good quality outcomes at optimum prices.

Any infrastructure project generally goes through the following phases:



Each phase is susceptible to different types of risks. A PPP can be established in either in Construction phase/ Operation & Maintenance phase; and both Construction and O&M phase.

Based on Metro Policy 2017 and PPP models adopted in various sectors in India, the following models of PPP are explored:



19.6.4 PPP Models for Metro Rail during Construction Phase

Model 1: Development of Metro Rail System on Government Land based DBFT with Annuity.

Under this model, the public authority will provide land to the selected private developer. The private partner will develop the infrastructure with its own funds and funds raised from lenders at its risk (that is, it will provide all or the majority of the financing). The authority shall be responsible for operating (supply and running of rolling stock) and managing the infrastructure life cycle (assuming life-cycle cost risks).

The bid parameter in such projects is generally Annuity which is a fixed amount payed to the private partner post-construction and during Operation & Maintenance period. The fee is generally financed through the funds coming from users after covering O&M expenses and long-term maintenance. If these funds are insufficient to meet the Annuity pay-out, the Authority shall finance the same through State/ Central Government.

Model 2: Development of Metro Rail System on Government Land based DBFT with Hybrid Annuity.

This model is similar to DBFT with Annuity expect for one major difference – The private entity receives certain amount (% of capital cost) during construction phase while the remaining is paid out as annuity during operation & maintenance phase.

19.6.5 PPP Models for Metro Rail during O&M Phase – O&M Services

Model 1: Operation and Maintenance Services on Cost + Fee Model.

Under this model, post-construction of civil assets the private partner installs the system (signalling and electrical assets), procures rolling stock and operates and maintains all these assets. The authority collects all the revenue and pays the private entity a monthly/ annual payment for operations and maintenance of the system. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of service provided.

Model 2: Operation and Maintenance Services on Gross Cost Model

Under this model, post-construction of civil assets the private partner installs the system, procures rolling stock and operates and maintains all the assets. The authority collects all the revenue and the private entity is paid an agreed fixed sum for the duration of the contract.

Model 3: Operation and Maintenance Services on Net Cost Model.

Under this model, post-construction of civil assets the private partner installs the system, procures rolling stock and operates and maintains all the assets. The private entity collects the complete revenue generated from the services provided. In case, the revenue generated is lower than O&M cost, the Authority may agree to compensate the difference in cost to the private entity while finalizing the agreement.

19.6.6 PPP Models for Metro Rail during O&M Phase – Maintenance Services

Model 1: Maintenance Services on Cost + Fee Model

Under this model, post-construction and installation of system including provisioning of rolling stock by public authority, the private partner is awarded the contract to maintain all the assets. The authority collects all the revenue and pays the private entity a monthly/ annual payment for maintenance of the system. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of maintenance.

Model 2: Maintenance Services on Gross Fee Model

Under this model, post-construction and installation of system including provisioning of rolling stock by public authority, the private partner is awarded the contract to maintain all the assets. The authority collects all the revenue and the private entity is paid an agreed fixed sum for the duration of the contract.

19.6.7 PPP Models for Metro Rail during O&M Phase – Non-Core Services

Model 1: Non-Core Services on Cost + Fee Model

For carrying out certain non-core activities such as Automated Fare Collection system, Housekeeping, Non-Fare Revenue Collection etc., a private entity may be selected who shall be paid a monthly/ annual payment for undertaking these activities. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of service provided.

Model 2: Non-Core Services on Gross Fee Model

For carrying out certain non-core activities such as Automated Fare Collection system, Housekeeping, Non-Fare Revenue Collection etc., a private entity may be selected who shall be paid an agreed fixed sum for the duration of the contract.

19.6.8 PPP Models for Metro Rail during both Construction and O&M Phase

Model 1: Development of Metro Rail System on Government Land based DBFOT with VGF/Premium.

Under this model, the public authority will provide land to the selected private developer. The private partner will develop the infrastructure with its own funds and funds raised from lenders at its risk (that is, it will provide all or the majority of the financing). The contractor is also responsible for operating (supply and running of rolling stock) and managing the infrastructure life cycle (assuming life-cycle cost risks) for a specified number of years. To carry out these tasks, the private partner, will usually create an SPV.

The bid parameter in such projects is either Premium (as percentage of revenues) if the funds coming from users are sufficient to cover O&M expenses and long-term maintenance with a surplus that can then be used as a source to repay the financing of the construction of the asset, and where no Bidder is offering a Premium, bidding parameter is the Grant required (as per VGF scheme of Government of India).

Model 2: Development of Metro Rail System on Government Land based DBFOT with Annuity.

This model is similar to DBFOT with VGF/Premium expect for two major differences – 1) User fees/charges are collected by the public authority 2) The private entity receives a fixed amount (called as Annuity payment) for a specified number of years. The fee is generally financed through the funds coming from users and in case the revenue from users is insufficient to meet the Annuity pay-out, the Authority shall finance the same through State/ Central Government.

Model 3: Development of Metro Rail System on Government Land based DBFOT with Hybrid Annuity.

This model is similar to DBFOT with Annuity expect for one major difference – The private entity receives certain amount (% of capital cost) during construction phase while the remaining is paid out as annuity during operation & maintenance phase.

19.6.9 Risk Matrix

The transfer of risk from the public entity to the private partner in various PPP models is set out in **Table 19.25.**

TABLE 19.23: RISK BASED COMPARISON OF PPP MODELS

PPP Model	Construction Risk (including design risk and financing risk)	Operation Risk	Maintenance Risk	Non-Core activities Management Risk	Revenue Risk
DBFT with Annuity	Private	Government	Government	Government	Government
DBFT with Hybrid Annuity	Private	Government	Government	Government	Government
O&M Services – Cost + Fee	Government	Shared	Shared	Shared	Government
O&M Services – Gross Cost	Government	Private	Private	Private	Government
O&M Services – Net Cost	Government	Private	Private	Private	Private
Maintenance Services – Cost + Fee	Government	Government	Shared	Shared	Government

PPP Model	Construction Risk (including design risk and financing risk)	Operation Risk	Maintenance Risk	Non-Core activities Management Risk	Revenue Risk
Maintenance Services – Gross Cost	Government	Government	Private	Private	Government
Non-Core Services – Cost + Fee	Government	Government	Government	Shared	Government
Non-Core Services – Gross Cost	Government	Government	Government	Private	Government
DBFOT with VGF/ Premium	Private	Private	Private	Private	Private
DBFOT with Annuity	Private	Private	Private	Private	Government
DBFOT with Hybrid Annuity	Private	Private	Private	Private	Government

19.6.10 Conclusion

It is known that, compared with public entities, private firms usually have higher costs of capital as well as profitability requirements that significantly affect the cost of infrastructure initiatives. Therefore, any PPP arrangement should, in principle, enhance value for money (VfM) through a combination of factors, including financing, operational efficiencies, superior risk management, greater implementing capacity, and enhanced service quality.

The parties best suited for various types of risk are provided in **Table 19.26.**

TABLE 19.24: RISK ALLOCATION FRAMEWORK

Risk Category	Party Best Suited to Manage the Risk
Construction Risk	Private
Operation Risk	Private/ Government
Maintenance Risk	Private
Non-Core Activities Management Risk	Private
Revenue Risk	Government

From above, all risks except revenue risk can be transferred to private entity owing to private sector efficiency in these areas. In regard to revenue, government is abler to manage this risk as revenue depends on i) traffic – which depends on regional growth, connectivity, route, etc. over which government has more control and ii) tariff – which for a public transport is not flexible enough to be transferred to private entity.

Also, though a private entity is better able to manage the construction risk, the cost of financing in PPP model for a private entity is higher than the cost of financing for the government, therefore, by transferring this risk completely in a PPP mode, the government shall end up paying more to the private entity. Therefore, it will be more appropriate to enter into an EPC contract for construction in which case the construction risk excluding financing risk is transferred to the private entity.

Based on above, CMRL may explore the possibility of private participation in Operations & Maintenance phase post construction of metro rail duly ensuring cost-effectiveness of available PPP options.

20. ECONOMIC ANALYSIS

20.1 APPROACH AND METHODOLOGY FOR ECONOMIC ANALYSIS

The economic appraisal has been carried out within the broad framework of Social Cost – Benefit Analysis Technique. It is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the “with” and “without” project scenario. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices.

This has been done to iron out distortions due to externalities and anomalies arising in real world pricing systems. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost / benefit and to calculate the economic viability of the project in terms of EIRR & ENPV.

20.1.1 Evaluation Assumptions

Project horizon comprises of the construction and operation period of the rail-based transit project. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost / benefit and to calculate the economic viability of the project in terms of EIRR. The key assumptions used in the evaluation are listed in **Table 20.1**.

TABLE 20.1: KEY EVALUATION ASSUMPTIONS

Parameter	Assumption
Price Level	December’2018
Construction period	2019-2025
First year of operation	2025
Daily to annual factor	340

20.1.2 Development of Alternative Scenarios

The development of the two scenario starts with estimating the traffic and modal share in these scenarios for the system. **Table 20.2** gives the estimated traffic and modal share in different horizon years. It can be seen that the total estimated demand in the year 2025 is about 153 Lakh which is expected to rise to about 274 Lakh in the year 2055. In the year 2025, Metro system is expected to cater to about 25 Lakh trips per day which is expected to rise to about 52 Lakh in the year 2055.

TABLE 20.2: ESTIMATED MODAL SHARE IN 'WITH' AND 'WITHOUT' SCENARIO

Mode	Trips With Phase I & Phase II Metro Corridors (in Lakh)				Trips With Phase I Metro Corridors only (in Lakh)			
	2025	2035	2045	2055	2025	2035	2045	2055
Bus	56.65	59.52	87.04	127.29	65.67	77.91	108.00	151.03
Car	19.85	25.14	25.39	25.64	21.36	27.38	28.63	29.95
2 Wheelers	31.25	22.04	18.80	16.03	33.62	26.25	23.62	21.25
Auto	4.76	7.86	11.65	17.25	5.71	9.69	13.59	19.27
Sub/Mono/MRTS	15.56	27.18	31.38	36.24	19.44	30.25	34.55	39.47
Metro	24.62	41.98	46.81	51.64	6.90	12.24	12.68	13.13
Total	**152.69**	**183.73**	**221.07**	**274.09**	**152.69**	**183.73**	**221.07**	**274.09**

20.2 ESTIMATION OF ECONOMIC COST OF PHASE II METRO CORRIDORS

The economic costs of the capital works and annual operation and maintenance costs have been calculated from the financial cost estimates by excluding:

- Price contingencies/price escalations
- Import duties and taxes
- Sunk costs
- Interest payment, principal payment and interest during construction period

The economic costs (**Table 20.3**) have been derived from financial costs using following shadow price factor for each component to take care of the distortions brought by above factors.

TABLE 20.3: FACTORS USED FOR ECONOMIC COSTS

S. No	Item	Factor
1	Capital Cost	0.83
2	Operations & Maintenance Cost	0.87

Table 20.4 and **Table 20.5** give the capital and O& M costs of the system at December 2018 price level in financial and economic terms respectively.

TABLE 20.4: FINANCIAL COSTS OF PHASE II METRO CORRIDORS - CAPITAL AND O&M

Cost Component	Metro (Rs. in Crore)
Capital Cost Including Land and R&R	53010.47
Taxes & Duties	7324.74
O&M Costs	
• 2025	1304
• 2035	3023
• 2045	6302

TABLE 20.5: ECONOMIC COSTS OF PHASE II METRO CORRIDORS - CAPITAL AND O&M

Cost Component	Metro (Rs. in Crore)
Capital Cost Including Private land and R&R	49767.8
O&M Costs	
• 2025	715.2
• 2035	875.4
• 2045	932.9

20.3 ECONOMIC BENEFITS OF PHASE II METRO CORRIDORS

Chennai Metro Phase II will yield tangible and non-tangible savings due to equivalent reduction in road traffic and certain socio-economic benefits. The introduction of Phase II Corridors will result in reduction in number of Buses, IPT, usage of private vehicles, air pollution and increase in the speed of road-based vehicles. This, in turn, will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers. Reduction in accidents, pollution and road maintenance costs are the other benefits to the society in general. The benefit stream includes:

- Savings in Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing modes in case this Metro project is not taken up.
- Savings in operating costs of different modes due to de-congestion including those that would continue to use the existing transport network even after this Metro is introduced.
- Savings in time of commuters using this Metro over the existing transport modes because of faster speed of Metro.
- Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of accidents and pollution with introduction of this Metro corridors.

- Savings in road infrastructure and development costs that would be required to cater to increase in traffic, in case this Metro corridors is not introduced.

The Quantification of some of the social benefits has not been attempted because universally acceptable norms do not exist to facilitate such an exercise. However, it has been considered appropriate to highlight the same, as given below:

- Reduced road stress
- Better accessibility to facilities in the influence area
- Economic stimulation in the micro region of the infrastructure
- Increased business opportunities
- Overall increased mobility
- Facilitating better planning and up-gradation of influence area
- Improving the image of the city

Following factors have been used for converting project benefits to economic costs (**Table 20.6**).

TABLE 20.6: FACTORS USED FOR CONVERTING PROJECT BENEFITS IN TERMS OF ECONOMIC COSTS

S. No	Item	Factor
1	Savings in Capital & Operating Cost of Buses	0.83
2	Savings in Capital & Operating cost of Private Vehicles	0.83
3	Savings in Passenger Time	1.0
4	Savings in VOC	0.9
5	Savings in Accident Costs	0.9
6	Savings in Pollution Costs	1.0

20.3.1 Input Parameters

Inputs used for Economic analysis have been collected from primary and secondary data sources. Vehicle Operating cost (VOC) and Value of Travel Time (VOT) are the two important parameters of Economic Analysis.

Various assumptions have been made, while assessing the economic benefits to the society on account of various factors after introduction of project. Following are the assumptions made for each of the factors as shown in **Table 20.7.**

TABLE 20.7: ASSUMPTIONS FOR VEHICLE OPERATING COST & VALUE OF TIME

S.No	Mode	VOC/Km.*(Rs.)	Value of Time** Passenger/Hour (Rs.)
1	Metro	-	55.3
2	Bus	27.8	32
3	Car	6.7	101.1
4	2 Wheeler	2.0	49.3
5	3 Wheeler	3.3	38.7

*Source :*Figures updated to 2018 price level on the basis of Manual on Economic Evaluation of Highway Projects in India ,IRC:SP:30-2009*

***Preparation of Metro Rail Master Plan of Chennai Metropolitan Area by CDM Smith 2015*

Other operational parameters required to assess the savings in VOC and VOT, accidents, pollution for the system are presented in **Table 20.8**.

TABLE 20.8: MODE WISE OPERATIONAL PARAMETERS – WITH PHASE II CORRIDORS

Mode	Average Lead KM	Veh-KM/ Day*	Average Speed (Km/Hr)		Occupancy
			Without MRTS	With MRTS	
Bus	12.89	200	13	16	55
Car	14.43	30	18	22	2.2
2wh	7.35	20	18	22	1.2
Auto	8.14	150	16	22	3.0

Other benefits that will accrue to the society include reduction in emission, savings due to reduction in accidents. The input for the benefit estimation from these parameters includes the emission factors by vehicle category as given by CPCB (**Table 20.9**), vehicle and accident statistics and cost of accidents (**Table 20.10**) in Chennai.

TABLE 20.9: MODE WISE EMISSION FACTORS (Gram/Km)

Vehicle Type/ Pollutant	CO	HC	NOX	PM	CO2
2-wheeler	1.4	0.7	0.3	0.05	28.58
Auto	2.45	0.75	0.12	0.08	77.89
Cars (incl. cabs)	1.39	0.15	0.12	0.02	139.52
Bus (incl. BRT)	3.72	0.16	6.53	0.24	787.72
Treatment Cost (Rs. /ton)	1,00,000	1,00,000	1,00,000	1,00,000	500

Source: Appraisal guidelines for Metro Rail Project Proposals MoHUA, GOI 2017

TABLE 20.10: COST OF ACCIDENTS

Type of Accident	Accident Cost (Rs.)	
	(2004 prices)*	(2018prices)**
Cost of fatal accident	437342	865907
Cost of major accident	64256	127222
Cost of damage to Two wheelers	2286	4526
Cost of damage to Car	9763	19330
Cost of damage to buses in road accidents	32818	64977

*Source: *Appraisal guidelines for Metro Rail Project Proposals MoHUA, GOI 2017*
***derived using escalation factor of 5%*

20.3.2 Estimation of Project Benefits

Quantifiable benefits accrued to the society owing to implementation of the Metro project include:

- Travel Time Savings
  - Travel Time Savings due to higher speed of this Metro project as compared to 'Without' project scenario.
  - Congestion reduction due to modal shift leads to fewer vehicles on roads. This also contributes to time savings of passengers travelling on other modes.
- Savings in Vehicle Operating Cost
  - Absence of vehicles on road due to modal shift passengers on this Metro
  - Smoother operations of passenger trips of other mode vehicles owing to reduced congestion on roads.
- Savings from Accident Reduction
  - Reduction in fatal and injury accidents due less no of vehicles on roads
  - Savings in damage cost to vehicles involved in accidents.
- Savings from Pollution Reduction
  - Absence of vehicles on road due to modal shift passengers on this Metro
  - Less pollution due to reduced congestion on roads.
- Savings in Road Infrastructure Maintenance
  - With less no of vehicles on roads, expenditure on road maintenance is expected to go down. In the absence of data, a lump-sum expenditure of Rs. 214 Cr/ year has been assumed.

Above socio-economic benefits have been converted in money cost. With input from above tables, the accrued project benefits for Chennai Metro during the frame work period of 30 years have been summarized in **Table 20.11.**

TABLE 20.11: COMPARISONS OF SAVINGS IN HORIZON YEAR – 2045

S.NO	BENEFITS	Ph II Metro	
		Amount (Rs. in Crore)	% Share
1	Travel Time Savings	5952	61.3
2	Savings in Vehicle Operating Cost	3108	32.0
3	Savings from Accident, Pollution & Road maintenance Reduction	653	6.7
	Total	**9713**	**100.0**

It is clear from the table that benefits irrespective of the system benefits are mainly come from saving of travel time by Metro from road passengers (61%), VOC savings (32%), and Environmental benefit from emission reduction, accident reduction and road maintenance cost (together 7%).

20.4 EIRR FOR 30 YEARS

For deriving the values of economic indicators (EIRR, ENPV), cost and benefit stream has been constructed in terms of money value. The 'Toolkit on Finance and Financial Analysis 2013' by MoHUA, suggests that ENPV to be calculated on social cost of capital or government security rate. Accordingly, ENPV have been calculated on both the rates.

Metro Rail Policy, 2017 prescribes 14% as acceptable EIRR rate for metro project, same has been considered as the social cost of capital. The government security rate in December'2017 is 8%. Accordingly, ENPV has been calculated based on these rates. The summary of the ENPV and EIRR is presented in **Table 20.12**. The cost and benefit streams for Metro system is presented in **Table 20.14**.

TABLE 20.12: ECONOMIC RETURN PARAMETERS FOR PHASE II CORRIDORS

S.NO	PARAMETER	Metro
1	EIRR	17.78%
2	ENPV - Social cost of capital @14% - Government Security Rate@ 8%	 Rs.8086 Crore Rs.38730 Crore

20.5 OUTCOME ON ECONOMIC VIABILITY

The project has EIRR more than 14%, indicating that the benefits to the society are more than the social cost of capital of 14%. It also meets the acceptable norm of MOUD. Thus, the project is economically viable and should be implemented.

20.5.1 Sensitivity Analysis

The sensitivity analysis has been carried out to see the impact of change in critical parameters in the range of 5% to 15% on EIRR and is presented in **Table 20.13**.

TABLE 20.13: SENSITIVITY ANALYSIS

S. No.	Factor	Range		
		5%	**10%**	**15%**
1	Cost overruns due to delay or other factors	17.10%	16.47%	15.88%
2	Increase in Maintenance Cost	17.70%	17.63%	17.55%
3	Reduction in Ridership	17.34%	16.90%	16.46%
4	Reduction in benefits	16.99%	16.19%	15.37%
5	Combination of reduction in benefits and increase in cost	16.33%	14.97%	13.66%

TABLE 20.14: COST AND BENEFIT STREAM FOR OF PHASE-2 METRO CORRIDORS (IN CRORE)

PRICE LEVEL: DECEMBER 2018

Period	Capital Cost	O&M Cost	Addition Cost + Replacement Cost	Total Cost	Saving in Capital Cost of Reduced Buses	Saving in Capital Cost of Reduced of other vehicles	VOC Saving of all vehicles	Savings due to Decongestion Effect	Savings in Passenger time	Savings due to Less pollution	Savings due to Less number of accidents	Savings in Infrastructure Maintenance	Total Savings	Net Cash Flow (Rs. in Crore)
2019-20	2065.36													
2020-21	6196.09			6196.1										
2021-22	8261.46			8261.5									0.0	-8261.5
2022-23	8261.46			8261.5									0.0	-8261.5
2023-24	8261.46			8261.5									0.0	-8261.5
2024-25	6196.09			6196.1									0.0	-6196.1
2025-26	2065.36	715.2		2780.6	757.2	4016.2	1302.4	835.4	3723.62	348.0	19.7	214.2	11216.7	8436.1
2026-27		719.8		719.8	47.1	131.0	1343.5	843.2	3841.8	350.0	20.0	214.2	6790.7	6070.9
2027-28		724.3		724.3	47.1	131.0	1386.0	851.0	3963.7	351.9	20.3	214.2	6965.1	6240.8
2028-29		785.3		785.3	47.1	131.0	1429.8	858.8	4089.5	353.9	20.6	214.2	7144.8	6359.5
2029-30		789.9		789.9	47.1	131.0	1475.0	866.8	4219.2	355.9	20.9	214.2	7330.0	6540.1
2030-31		852.6		852.6	47.1	131.0	1521.6	874.8	4353.1	357.9	21.2	214.2	7520.9	6668.2
2031-32		857.2		857.2	47.1	131.0	1569.6	882.9	4491.3	360.0	21.5	214.2	7717.5	6860.3
2032-33		861.8		861.8	47.1	131.0	1619.2	891.0	4633.8	362.0	21.9	214.2	7920.2	7058.4
2033-34		866.3		866.3	47.1	131.0	1670.4	899.3	4780.8	364.1	22.2	214.2	8129.0	7262.7
2034-35		870.9		870.9	47.1	131.0	1723.1	907.6	4932.5	366.1	22.5	214.2	8344.2	7473.3
2035-36		875.4	1232.7	2108.1	1181.0	5194.9	1777.6	916.0	5089.0	368.2	22.9	214.2	14763.7	12655.6
2036-37		881.2		881.2	32.1	87.3	1806.6	925.7	5169.4	372.5	23.1	214.2	8630.8	7749.6
2037-38		886.9		886.9	32.1	87.3	1836.0	935.5	5251.0	376.9	23.2	214.2	8756.2	7869.3
2038-39		892.7		892.7	32.1	87.3	1866.0	945.5	5333.8	381.3	23.4	214.2	8883.6	7990.9
2039-40		898.4		898.4	32.1	87.3	1896.4	955.5	5418.0	385.8	23.6	214.2	9012.8	8114.4
2040-41		904.2		904.2	32.1	87.3	1927.3	965.6	5503.5	390.3	23.8	214.2	9144.1	8239.9
2041-42		909.9		909.9	32.1	87.3	1958.7	975.9	5590.4	394.9	23.9	214.2	9277.4	8367.5
2042-43		915.7		915.7	32.1	87.3	1990.6	986.2	5678.6	399.5	24.1	214.2	9412.7	8497.0

Period	Capital Cost	O&M Cost	Addition Cost + Replacement Cost	Total Cost	Saving in Capital Cost of Reduced Buses	Saving in Capital Cost of Reduced of other vehicles	VOC Saving of all vehicles	Savings due to Decongestion Effect	Savings in Passenger time	Savings due to Less pollution	Savings due to Less number of accidents	Savings in Infrastructure Maintenance	Total Savings	Net Cash Flow (Rs. in Crore)
2043-44		921.4		921.4	32.1	87.3	2023.1	996.7	5768.3	404.2	24.3	214.2	9550.1	8628.7
2044-45		927.2		927.2	32.1	87.3	2056.1	1007.2	5859.3	408.9	24.5	214.2	9689.6	8762.5
2045-46		932.9	4320.3	5253.2	1470.2	5980.4	2089.6	1017.9	5951.8	413.7	24.7	214.2	17162.5	11909.3
2046-47		938.8		938.8	42.3	90.7	2123.7	1032.8	6051.4	420.2	24.9	214.2	10000.3	9061.5
2047-48		944.6		944.6	42.3	90.7	2158.4	1047.9	6152.7	426.8	25.2	214.2	10158.2	9213.6
2048-49		950.4		950.4	42.3	90.7	2193.6	1063.2	6255.6	433.5	25.4	214.2	10318.7	9368.2
2049-50		956.3		956.3	42.3	90.7	2229.4	1078.7	6360.3	440.4	25.7	214.2	10481.8	9525.5
2050-51		962.1		962.1	42.3	90.7	2265.8	1094.5	6466.8	447.3	26.0	214.2	10647.6	9685.5
2051-52		968.0		968.0	42.3	90.7	2302.8	1110.5	6575.0	454.3	26.2	214.2	10816.1	9848.1
2052-53		973.8		973.8	42.3	90.7	2340.4	1126.7	6685.0	461.5	26.5	214.2	10987.4	10013.6
2053-54		979.7		979.7	42.3	90.7	2378.6	1143.2	6796.9	468.7	26.7	214.2	11161.4	10181.8
2054-55		985.5		985.5	42.3	90.7	2417.5	1159.9	6910.7	476.1	27.0	214.2	11338.4	10352.9
													EIRR	**17.78%**
													ENPV@14%	**8086**

21. IMPLEMENTATION PLAN

21.1 PROJECT IMPLEMENTATION PLAN

The appointment of Detailed Design Consultants and General Consultants may be initiated for the preparation of tender documents as well as project management – as soon as DPR is approved by GoTN. The possible dates for important milestones are given in **Table 21.1** and **Figure 21.1**.

TABLE 21.1: PROJECT IMPLEMENTATION SCHEDULE

S.N.	Tasks	Timelines
1	Final DPR	November, 2018
2	State Government Approval of DPR	December, 2018
3	Appointment of DDC for Civil Works	March, 2019
4	Approval by Central Government	April, 2019
5	Appointment of General Consultants	June, 2019
6	Packaging and Invitation of Bids	September, 2019
7	Commencement of Civil Works	January, 2020
8	Commencement of Operation	April, 2025

The commercial operation on Phase 2 corridors may start from April 2025 after about 6 years of construction including land acquisition & approval and 3 months for safety audit and certification.

21.2 IMPLEMENTATION STRUCTURE

Chennai has a successful example of metro operation in Phase-I on SPV model by Chennai Metro Rail Limited (CMRL). Phase-II metro corridors may also be implemented under same SPV. However, some sub-components of operations & maintenance may be taken up with private sector participation (PPP) model.

The PPP model to be adopted and implementation structure shall be decided at the time of implementation.

FIGURE 21.1: IMPLEMENTATION SCHEDULE FOR MONITORING OF PROJECT

	2018-2019	2019-2020				2020-2021				2021-2022				2022-2023				2023-2024				2024-25				2025-26	
MAIN ACTIVITIES	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun	July - Sep	Oct - Dec	Jan - Mar	Apr - Jun
APPROVAL OF DPR BY STATE GOVERNMENT																											
APPROVAL OF DPR BY CENTRAL GOVERNMENT																											
APPOINTMENT OF DDC																											
ARRANGEMENT OF FINANCE INCLUDING POSSIBLE PPP																											
APPOINTMENT OF GENERAL CONSULTANT																											
PACKAGING & INVITATION OF BIDS																											
LAND ACQUISITION																											
SHIFTING OF UTILITIES																											
DEPOT CONSTRUCTION																											
VIADUCT CONSTRUCTION																											
ELEVATED STATIONS																											
GT SURVEY, BUILDING CONDITION SURVEY																											
UG STATIONS																											
TUNNELLING																											
CONSTRUCTION OF CROSS PASSAGES																											
BASE SLAB LAYING																											
TRACK LINKING																											
OHE FIXING TESTING																											
S&T WORKS																											
TRIAL RUN TESTING																											
CRS INSPECTION AND COMMISSIONING																											

21.3 LEGAL AND INSTITUTIONAL FRAMEWORK FOR IMPLEMENTING THE PROJECT

21.3.1 Institutional Arrangements

The Government of Tamil Nadu created a Special Purpose Vehicle (SPV) for implementing the Chennai Metro Rail Project. The SPV, "Chennai Metro Rail Limited" was incorporated on 03.12.2007 under the Companies Act. It has now been converted into a Joint Venture of Government of India and Government of Tamil Nadu with equal equity holding.

Chennai Metro Rail Limited (CMRL) shall be responsible for implementation of the proposed Phase-II Metro corridors.

Metro construction is a very specialized and multi-disciplinary job. It is therefore, impossible to have a single organizational set up which can be responsible for all aspects of metro implementation, namely investigation, planning, design, drawing up of specifications, preparation of tender documents, fixing of contractors, supervising the contractors' works, ensuring interface fusion between different contractors, ensuring quality and safety during constructions, planning and supervising integration system trials and getting the project commissioned in time.

It is suggested to have a two tier organization with well defined responsibilities for implementation of this project. At the apex will be the CMRL with full mandate and total power with accountability. The second level will be project management team called the 'General Consultant', who will be engaged by the CMRL on contract basis. They will be fully responsible for planning, designing and project management. In fact, they will be 'Engineers' for the CMRL, who will be the 'Client'. The Detailed Design Consultants as required may be engaged by the General Consultants as their sub-consultants within their own contractual responsibilities.

Since most of the alignment length is elevated, it is recommended that the contracts may be made on 'design and build' basis, based on broad technical specifications and performance requirements drawn up by the general consultants.

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, Tamil Nadu may be set up. Other members of this Committee may be the Secretaries of concerned Departments of State Government and Heads of civic bodies who are connected in one way or the other with the implementation of the project.

21.4 ROLE, RESPONSIBILITY AND INVOLVEMENT OF CITY GOVERNMENT

21.4.1 Unified Metropolitan Transport Authority (UMTA)

The National Urban Transport Policy 2014 has recommended setting up of Unified Metropolitan Transport Authorities (UMTA's) in million plus cities. The policy document stipulates following on UMTA.

"The current structure of governance for the transport sector is not equipped to deal with the problems of urban transport. These structures were put in place well before the problems of urban transport began to surface in India and hence do not provide for the right coordination mechanisms to deal with urban transport. The central government will, therefore, recommend the setting up of Unified Metropolitan Transport Authorities (UMTA's) in all million cities to facilitate more coordinated planning and implementation of urban transport programs & projects and integrated management of urban transport systems. Such Metropolitan Transport Authorities would need statutory backing in order to be meaningful."

The Metro Rail Policy - 2017 makes it mandatory for the cities which are planning to have MRTS to address their mass transport requirements to have city level UMTA.

For integrated approach in planning and management of urban transport in the city, State Government shall constitute Unified Metropolitan Transport Authority (UMTA) as a statutory body. This Authority would implement various proposals as per CMP for the city, organize investments in urban transport infrastructure, establish effective coordination among various urban transport agencies, manage the Urban Transport Fund (UTF) etc. UMTA will have to play active role in the implementation of Chennai Metro Phase-II, being a city government authority.

21.4.2 Steering Committee

Apart from a High Power Committee under the chairmanship of Chief Secretary, Tamil Nadu, a 'Steering Committee' may be set up under the chairmanship of Commissioner, Chennai zone. Other members of this Committee may be District Magistrate, Municipal Commissioner, and other heads of civic bodies who will be connected in one way or the other with the implementation of the project.

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. The steering committee will work for expeditious resolution of these problems at local level. This Committee may meet regularly to sort out all problems brought before it by CMRL.

21.4.3 Performance Monitoring During Construction and Implementation

The efficiency in standards during construction and implementation will be monitored in following manner:

1. Constant monitoring in the meeting of the Board of Directors of the company.
2. Monitoring by High Powered Committee (HPC) of the State Government: During implementation of the project, a High Powered Committee under the chairmanship of the Chief Secretary of the State Government will be set up by the State Government to take expeditious decisions on land acquisition matters, diversion of utilities, shifting of structures in the project alignment, rehabilitation of Project Affected Persons, multimodal integration and such other matters where the State Government has to facilitate quick action including various conditions of sanction of this project.
3. Audit of the projects accounts to be monitored in the Audit Committee of BoD.

21.4.4 Way Forward

On acceptance of the Comprehensive Detailed Project Report for Phase-II Metro, following actions may be initiated for implementing the project:

- Approval of State Government to the Detailed Project Report.
- Issue of notifications for the project, alignment and setting up of UMTA.
- DPR to be forwarded to the Ministry of Housing and Urban Affairs, Niti Aayog and Finance Ministry with request for approving the Metro project and for financial participation through equity contribution to the SPV.

- Approval from Government of India.
- Appointment of Detailed Design Consultants (DDC).
- Appointment of General Consultants (GC).
- Packaging and invitation of bids for various contracts.
- Land acquisition related issues.
- Examination and appraisal of DPR by bilateral/multilateral funding agencies for possible funding.
- Stakeholder consultation on environmental and social impact of the project.
- Signing of an MOU between Tamil Nadu State Government and Government of India giving all details of the Joint Venture bringing out the financial involvement of each party, liability for the loans raised, the administrative control in the SPV, policy in regard to fare structure etc.
- Agreement between the State and Central Government for financing the debt portion of the project along with the setting up of time frame for completing the Project.
- Loan approval.
- Providing legal cover for construction as well as O&M stages of the Project.
- Memorandum of Understanding between various service providers to provide seamless integration between various transport modes.