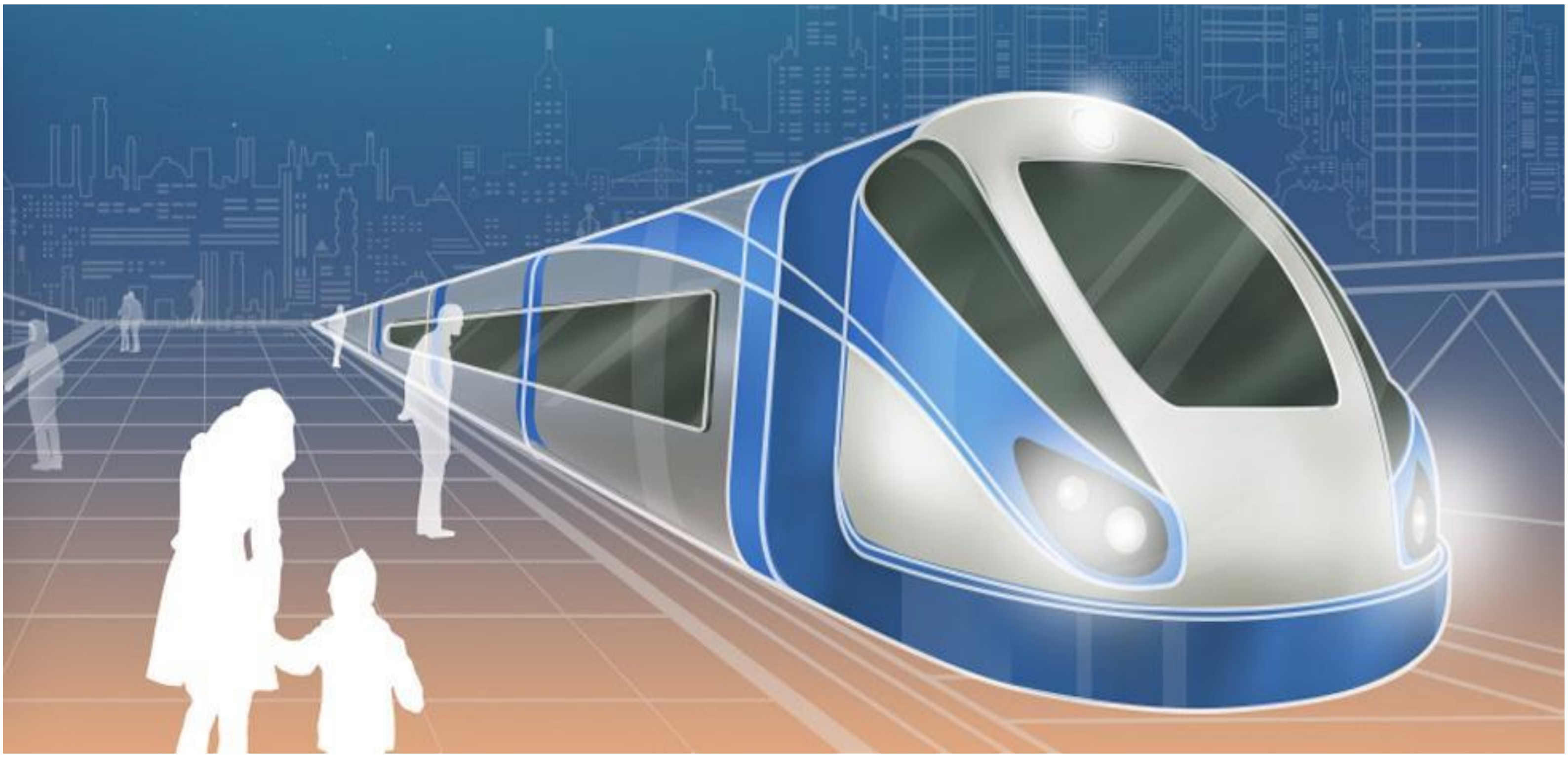
24/08/2021

UPDATED DETAILED PROJECT REPORT
(PCMC TO NIGDI –Corridor 1A)



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ABBREVIATIONS TABLE

AAC	All Aluminum Conductor
AAI	Airport Autorité of India
AAQ	Ambient Air Quality
ABD	Area Based Development
ADB	Asian Development Bank
ADB	Asian Development Bank
AFC	automatic fare collection
ALG	Advanced Launching Girder
APHA	American Public Health Association
ASR	Annual Statement of Rates
ATD	Anti-Tensioning Device
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
BAU	Business as Usual
BCD	Basic Custom Duty
BEC	Buried Earth Conductor
BHLS	Bus With a High Level of Service
BIS	Bureau of Indian Standard
BOCC	Backup Operation Control Centres
BOH	Back of House
BOT	Build Operate Transfer
BRT	Bus Rapid Transit
BS	British Standard
CBD	Central Bussiness District
CBTC	Communication based Train Control System
CENELEC	European committee for Electrotechnical standardization
CMP	Comprehensive Mobility Plan
CO	Carbon Monoxide
COI	Corridor of Impact
CPCB	Central Pollution Control Board
CPR	Community Property Resource
CTTS	Comprehensive Traffic and Transportation Study
CVRS	Central Voice Recording System
CWR	Continuous Welded Rail
DCF	Discounted Cash Flow
DG Set	Diesel Generating Set
DMC	Driving Motor Car
DMRC	Delhi Metro Rail Corporation

DP	Development Plan
EFO	Excess Fare Office
EGOM.	Empowered Group of Ministers
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
ENPV	Economic Net Present Value
EOCC	Economic Opportunity Cost of Capital
FAR	Floor Area Ratio
FC	Forest Conservation
FIRR	Financial Internal Rate of Return
FOB	Foot Over Bridge
FRP	Fire Resistance Period
FSI	Floor Space Index
GC	Generalized Cost
GOA	Grade of Operation
GOI	Government of india
GOM	Government of Maharashtra
GPR	Ground-penetrating radar
GPS	Global Positioning System
HCMTR	High Capacity Mass Transit Route
HDM	Highway Design and Maintenance Standards Mode
HMI	Human Machine Interface
IEC	International Electrotechnical Commission
IEEE	Institue of Electrical and Electronics Engineers
IMD	India Meteorological Department
IPTs	Intermediate Public Transport
IRR	Internal Rate of Return
ISM	Industrial Scientific Medical Radio Band
IT	Information Technology
ITDP	Institute for Transportation and Development Policy
ITES	Information Technology Enabled Services
ITU-T	International Telecommunication Union – Telecommunication Standardisation sector
JICA	Japan International Cooperation Agency
LAA	Land Aquisition Act
LAP	Land Acquisition Plan
LBT	Local Body Tax
LCCA	Life Cycle Cost Analysis
LoS	Levels of Service
LoS	Level of Service

LRT	Light Rail Transit
LULC	Land-use Land-Cover
LWR	Lonf Welded Rail
MIDC	Maharashtra Industrial Development Corporation
MOHUA	Ministry of Housing and Urban Affairs
MOU	Memorandum of Understanding
MoUD	Ministry of Urban Development
MSRTC	Maharashtra State Road Transport Corporation
NFPA	National Fire Protection Association
NLO	National Labour Organisation
NMT	Non-Motorised Transport
NMS	Network Management System
NMV	Non-Motorised Vehicle
Nox	Oxides of Nitrogen
NPV	Net Present Value
OCC	Operational Control Center
OD	Origin-Destination
ODA	Official development assistance
OPC	Overhead Protection Cable
OHE	Overhead Equipment
PBS	Public Bike Sharing
PCMC	Pimpri-Chinchwad Municipal Corporation
PCMT	Pimpri Chinchwad Municipal Transport
PCNTDA	Pimpri chinchwad New Town Development Authority
PCTR	Per Capita Trip Rate
PCU	Passenger Car Unit
PD	Property Development
PD	Property Development
PHPDT	Per Hour Per Direction Traffic
PM	Particulate Matter
PMPML	Pune Mahanagar Parivahan Mahamandal Limited
PMT	Pune Municipal Transport
PPE	Personal Protective Equipment’s
PRT	Personalised Rapid Transport
PSG	Platform Screen Gates
PSD	Platform Screen Doors
PST	Power Supply & Traction
PF	Platform
PT	Public Transport
RCTM	Recharge Card Terminal Machine
R&M	Repairs And Maintenance

R&R	Rehabilitation and Resettlement
RAP	Resettlement Action Plan
RAP	Rehabilitatiob Action Plan
REJ	Rail Expansion Joint
ROW	Right of Way
RH	Relative Humidity
SC	Schedule Caste
SCADA	Supervisory Control and Data Acquisition
SCR	Station Control Room
SERF	Shadow Exchange Rate Factor
SOx	Oxides of Sulphur
SPV	Special Purpose Vehicle
ST	Schedule Tribe
TAZ	Traffic Analysis Zone
TC	Trailer Car
TDM	Transportation Demand Management
TVC	Traffic Volume Count
TVM	Ticket Vending Machine
UPS	Uninterrupted Power at Stations
URDPFI	Urban and Regional Development Plan formation and Implementation
UV	Ultra Violet
VOC	Vehicle Operating Cost

I. SALIENT FEATURES

i. **GAUGE** – 1435 mm

ii. **Corridor & Route Length**

CORRIDOR	ELEVATED (KM)	UNDERGROUND (KM)	TOTAL LENGTH KM)
PCMC to Nigdi (Phase 1A) (Extension of North South corridor of Phase-1)	4.413	0	4.413

iii. **Number of Stations**

CORRIDOR	ELEVATED	UNDERGROUND	TOTAL
PCMC to Nigdi (Extension of North South corridor of Phase-1)	3	NIL	3

iv. **Traffic Forecast**

Maximum Ridership and PHPDT

Corridor	Daily Ridership			
Nigdi - Swargate Corridor	**2023**	**2033**	**2043**	**2053**
	495,000	677,000	802,000	867,000
	PHPDT			
	2023	**2033**	**2043**	**2053**
	14,450	19,480	23,690	25,600
Nigdi-PCMC Corridor	**Daily Ridership**			
	2023	**2033**	**2043**	**2053**
	29,000	43,000	64,000	72,000
	PHPDT			
	2023	**2033**	**2043**	**2053**
	1480	1700	3390	3730

v. **Station Planning**

A typical design has been suggested for all three elevated stations and will form basis for planning of the stations.

Type	Station Type	No. of stations	Size (sq. m)	Levels	Construction Type
Without PD	Elevated	2	21 x 140	3	Cantilever
With PD	Elevated	1	21 x 140	4	Cantilever

vi. Intermodal Integration

Feeder bus service, Public Bicycle sharing, Parking and Pedestrian facilities have been proposed for all the stations for intermodal connectivity.

vii. Train Operation Plan

The total number of Train car requirement to satisfy the traffic demand is given in the table below. The quantity for Line-1(NS Corridor) of Phase 1 includes existing fleet of 75-cars for section PCMC-Swargate.

Corridor	Year	Headway (Min.)	No. of rakes	Rake consist	Total coaches
Nigdi- Swargate	2025	2.9	30	3	90
	2033	2.9	30	3	90
	2043	2.5	34	3	102
	2053	2.5	36	3/6	108

viii. Speed

(A) Maximum Design speed : 90 kmph
(B) Maximum Operating Speed : 80 kmph
(C) Scheduled Speed : 33kmph

ix. Traction Power Supply

(A) Voltage: 25KV OHE
(B) Power Demand (MVA)

Corridor		Year			
		2023	2033	2043	2053
PCMC-NIGDI Route Length – 4.413 km, Number of Stations – 3 (Elevated – 3)	Traction	0.7 MVA	0.9 MVA	1.0 MVA	1.1 MVA
	Auxiliary	1.1 MVA	1.1 MVA	1.1 MVA	1.1 MVA
PCMC-SWARGATE Route Length – 17.8 km, Number of Stations – 14 (Elevated – 9, Underground - 5)	Traction	6.5 MVA	8 MVA	9.2 MVA	9.5 MVA
	Auxiliary	18.2 MVA	18.8 MVA	21.9 MVA	21.9 MVA
Total Power Demand (NIGDI-SWARGATE)	**Traction**	**7.2 MVA**	**8.9 MVA**	**10.2 MVA**	**10.6 MVA**
	Auxiliary	**19.3 MVA**	**19.9 MVA**	**23 MVA**	**23 MVA**

(C) Sources of Power Supply

Two sources of power supply are there along the corridor one is 220kV Chinchwad SS near PCMC and other is 132 kV Ganesh khind SS near agriculture college.

x. 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 GoA2 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

*the exact length of cables from GSS to RSS will be provided after the cable route survey.

xi. Depots

Stabling capacity for 25 number of 3-car trains is already provisioned in phase-1 of existing Range Hill Depot which needs to be suitably augmented.

xii. Signalling & Telecommunication

- Type of Signalling: adopting 'CATC' (Continuous Automatic Train Control System) based on "CBTC" (Communication Based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.
- Telecommunication system includes Fiber Optic System - Main Telecommunication Bearer, Telephone System, Mobile Radio Communication, Centralized Clock System, Passenger Announcement System, Centralized Clock System, Passenger Information Display System, CCTV System, Access Control System, Network Monitoring and Management, Forensic Debriefing Analysis and Cyber Security System.

xiii. Fare Collection

The AFC system for this phase shall be of contactless smart card & token type which will also allow easy accounting. The System shall be capable for open loop transactions as well to further integrate the mobility solution with the advancements in technology and to allow for seamless transition from dedicated cards to common multi-use stored value fare media that can be used for financial transactions such as making purchases at shops etc. as well as a fare media in the system.

xiv. Environment And Social Impact Assessment

- Both negative and positive impacts associated with the proposed metro corridor during various phases of project cycle have been identified. Metro will provide commuter friendly and efficient transport system, thus will bring positive impact on the environnent.
- Along with that, few negative impacts would also take place during the pre-construction (design) and construction phase eg. Approx. 342* Trees are falling within the propose Right of Way/at the station locations.
- The total estimated environmental management cost for the proposed project is about **Rs. 1.79 Crore.**
- The project will involve acquisition of 7446.35 square meter of land. Total of 49 structures will be affected.
- Estimated cost of implementation of R&R Plan, land acquisition & dismantling and Restoration of BRTS is Rs. 114.43 crore.

xv. Detailed Cost Estimate

The detaled cost estimate of the proposed extension line is given below,

S. No.	Item	Amount (INR Cr)
1	Alignment & Formation	163.28
2	Station Buildings	
a	Cost of civil structure (Including cost of one FOB)	80.68
b	E&M Cost (Including Lift and Escalator)	24.00
3	Maintenance Depot	12.88
4	P-Way for main line and depot	29.13
5	Traction and Power Supply	33.10
6	Signalling	27.92
7	Telecommunication	13.50
8	Rolling Stock	120.00
9	Multi Modal Integration	9.00
10	Cost of Security	1.11

[1] Approximatey, 342 no. of trees will be impacted due to the project. However, the no. of trees might be less. Exact no. of trees will be identified at the time of joint verification with the concerned department.

S. No.	Item	Amount (INR Cr)
11	Environment cost	1.79
12	Utility Shifting	26.48
13	**Total Cost at FY 2019 price level (Excluding Land, R&R, General Charges, Contingencies, Central & State Taxes)**	**542.86**
14	General Charges @ 5%	27.14
15	Contingencies @ 3 % on Sr. No. 13 i.e. on Basic Cost	16.29
16	**Total Cost at FY 2019 price levels incl. General Charges and Contingencies (Excluding Land, R&R, Central & State Taxes)**	**586.29**
17	Central and State Taxes @ FY 2019 Price Level	79.28
18	**Total Cost incl. General Charges, Contingencies, Central and state Taxes @ FY '19 Price Levels (Excl. Land and R&R)**	**665.57**
19	Land	72.81
20	R&R	41.62
21	**Total Cost incl. General Charges, Contingencies, Central and state Taxes @ FY '19 Price Levels (Incl. Land and R&R)**	**780.00**
22	Escalation at 5 % per annum on the above (S. No: 21)	107.66
23	**Total Completion Cost incl. Land and R&R Costs**	**887.66**
24	Interest During Construction (IDC)	11.02
25	**Total Completion cost including IDC**	**898.68**
26	PPP component (AFC)	11.50
27	**Total Completion Cost**	**910.18**

Note: FY 2019 Price Level is considered and the Prices are escalated till the completion period to arrive at the completion cost. (Ref: Page 400)

xvi. Economic Analysis

EIRR in economic term is 23.55% for proposed extension of Phase 1A i.e. PCMC to Nigdi. The evaluation has indicated that the proposed MRTS extension in Pune City with a total length of 4.413 km, considered under the investment proposals is found to be economically viable, with the calculated EIRR value exceeding the economic opportunity cost of capital. With the EIRR of 23.55%, the proposed MRTS is found to be economically viable.

Sensitivity analysis of the EIRR with Capital cost increase by 20%, O&M costs increased by 20%, Target beneficiaries reduced by 20%, Delay in accrual of benefit by 1 year and Combined adverse condition has also been carried out.

xvii. Financial Analysis

FIRR with project cost including all taxes, estimated fare and non-fare box revenue is estimated at 10.45%.

xviii. Financial Plan

Recommended Model for implementation is SPV model with loan funded at 1.2 % per annum, with completion Project cost of Rs 910.18 Cr including PPP component.

This is a continuation of an existing line being executed under SPV model. In view of the operational interconnection and in order to ensure seamless operations, we recommend the SPV model.

xix. Implementation plan

S. No	Tasks	Anticipated Timelines
1	Approval of DPR by GoM	September 2021
2	Final Approval by GoI	November 2021
3	Packaging & Invitation of Bids	January 2022
4	Commencement of Civil Works	February 2022
5	Commencement of Operation	April 2025

II. EXECUTIVE SUMMARY

0.1 Introduction

Study area for the assignment is the administrative boundary of Pimpri Chinchwad Municipal Corporation which forms part of core urban area of Pune Metropolitan Region (PMR) with an area of 170 sq. km. As per Census 2011, the population of PCMC area is 17.27 Lakh. For the last two decades, the decadal growth rate of population has been in the range of 100% while the previous two decades witnessed population growth in the range of 150%. (Source: City Development Plan, PCMC)

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 15.68 lakhs vehicles as per Maharashtra government vehicle statistics. . There has been a 700 per cent increase in the number of vehicles in Pune Urban Agglomeration in the last 20 years as per Regional Transport Office (The Indian express, 2017). The usage of private modes is increasing unabated mainly due to inadequate public transport facilities.

With a view of developing effective and efficient mass transit system towards improving the share of public transport trips, the Government of Maharashtra conceived and implemented Metro rail system covering 33.5 km in Phase 1, Corridor 1(North South corridor) of which covers 17.8 km, which is now further extended in the north. This extension of 4.413 km is corridor-IA

There is a need for extension of Phase 1 in order to meet the future traffic demand. Nationally and globally it is seen that the metro network expands progressively to serve entire City.

0.2 Existing Transportation System

City level transportation demand is catered predominantly by PMPML, Intermediate Public Transport System (IPT) in the form of shared services along major arterials and Commuter Rail System. Phase-I of Pune Metro covering 33.5 km in two corridors is being implemented–Corridor 1: PCMC to Swargate (17.8 km) and Corridor 2: Vanaz to Ramwadi (15.7 km). An extension from PCMC to Nigdi (about 4.413 km km), Swargate to Katraj (5.5 km) also has been planned in Corridor 1 (PCMC to Swargate).

0.3 Travel Demand Forecast

Revision in the original transport demand model which was developed as a part of DPR for Pune Metro Rail Project (2008) has been made and same was validated through various studies. Same basic set of assumptions including traffic zone system have been used for travel demand forecasting. Updates have been made in the public transport network including proposed metro corridors in the travel demand model.

The peak hour peak direction traffic (PHPDT) and daily ridership for horizon years up to 2053 for Phase-1A Metro corridors (PCMC to Nigdi) are presented in the following table:

Table 1 : Travel Demand Forecast For Pune Metro Phase-IA

PUNE METRO DPR - PHASE-II CORRIDORS - Scenario 1A							
Scenario 1A		**2023**	**2033**	**2041**	**2043**	**2051**	**2053**
Nigdi to Swargate	**Peak Hour**	47500	65000	75100	77000	82400	83200
	Daily	495000	677000	782000	802000	858000	867000
	PHPDT	14450	19480	23110	23690	25350	25600
PCMC to Swargate	**Peak Hour**	44700	60900	69100	70800	75600	76300
	Daily	466000	634000	720000	738000	788000	795000
	PHPDT	12970	17780	19810	20300	21670	21870
Incremental	**Peak Hour**	**2800**	**4100**	**6000**	**6200**	**6800**	**6900**
	Daily	**29000**	**43000**	**62000**	**64000**	**70000**	**72000**
	PHPDT	**1480**	**1700**	**3300**	**3390**	**3680**	**3730**

The average trip length for various horizon years is presented in table below:

Table 2 : Average Trip length (KM)

Year	Without Extension (PCMC-Swargate) (KM)	With Extension (Nigdi-Swargate) (KM)
2021	7.23	7.71
2023	7.33	7.83
2031	7.45	7.98
2033	7.51	8.05
2041	7.62	8.18
2043	7.65	8.21
2051	7.75	8.34
2053	7.76	8.36

0.4 Train Operation Plan

Train operation plan for proposed corridors is based on the following:

- Running of services for 19 hours of a day (05:00hrs to 24:00 hrs) with a maximum station dwell time of 40 seconds which may be optimized further based on ridership trend when section is opened
- Scheduled speed of 33 kmph
- Make up time of 5%-10% with 8%-12% coasting
- Adequate services to ensure comfortable journey for commuters

Provision for 6-car trains is required in year 2053 considering headway limitations and future lines which will add to demand estimated for existing length of corridor Phase 1A and may require introduction of 6-car train before the design year.

Based on the projected PHPDT demand, Train operation for Pune Metro Corridor-1A is planned with train carrying capacity calculated @6 persons per square meter of standee area in train. However, rolling stock is designed for carrying @8 persons per square meter of standee area in train. This will help to cater for excess load in peak hours.

As PHPDT in section PCMC to Nigdi is very low (PHPDT of 5440), peak headway of only 7.5 min in 2023, 5.7 min in 2033, 5 min in 2043 and 2053 is considered sufficient in this section. Accordingly, every alternate train is planned to be short looped from PCMC towards Swargate, at least during peak hours. This has minimized Rolling Stock and Train Operator requirement.

The headway and capacity provided for different sections of three corridors is given in table below:

Table 3 : Headway And Capacity Provided For Nigdi To Swargate Section

Demand (PHPDT) and capacity – line 1 Phase 1A (Nigdi- Swargate)								
Year	2025		2033		2043		2053	
Section	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate
Peak Headway (seconds)	340	174	340	174	295	150	295	150
No. of Cars per train	3	3	3	3	3	3	3	3/6
Peak Demand	2830	14450	3920	19450	5030	23690	5440	25600
Total Capacity @6p/sqm of standee area	6112	12224	8022	16044	9321	18642	9321	20262
Total Capacity @8p/sqm of standee area	7800	15600	10237	20475	11895	23790	11895	25848

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

which have been deliberately planned for optimum utilization of rolling stock. The total coach requirement for corridor 1A is given below:

Table 4 : Coach Requirement For Different Horizon Years

Year	2025	2033	2043	2053
Total Requirement	90	90	102	108

The total coach requirement includes 75 coaches already earmarked for procurement for Phase-I. Therefore, effective additional requirement will be total Requirment in corresponding year minus 75.

0.5 System Selection

The corridor 1A is a continuation of existing corridor 1 of Phase 1 (PCMC to Swargate). Considering the PHPDT for design year, it is recommended to adopt a medium capacity metro rail system which will provide seamless connectivity across the city. The medium capacity metro will be suitable to meet the PHPDT of the horizon year.It is proposed that the train run through Swargate – PCMC – Nigdi corridor. In order to ensure the same, the system of Phase 1A should be similar and compatible to that of Phase 1.

0.6 Technology Selection

0.6.1 Permanenet way

0.6.1.1 Choice Of Gauge

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

0.6.1.2 Track Structure

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

0.6.2 Traction system

Keeping in view the ultimate traffic requirements, standardisation, and other techno-economic considerations, 25 KV OHE traction system is considered to be the best trade-off and hence, proposed for adoption on Pune Metro System.

0.6.3 Signalling and Train Control

Metro carries large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability. At the same time, heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. These requirements of the metro are planned to be achieved by adopting 'CATC' (Continuous Automatic Train Control System) based on "CBTC" (Communication based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.

0.6.4 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 Announcement System, Centralized Clock System
- Passenger Information Display System
- Close Circuit Television
- Access control
- Network Monitoring and management
- Supervisory Control and Data Acquisition (SCADA) System
- Wifi system
- Forensic Debriefing Analysis and Cyber Security System

0.6.4.1 Platform Screen Doors

Platform screen doors are mainly provided at metro stations to ensure safety and comfort of the passengers. In case of Underground stations, PSDs saves considerabe amount of energy and improves climate control within the stations (heating, ventilation and air conditioning are more effective when station is physically isolated from the tunnel). In case of Phase 1A,the complete stretch is elevated and Phase 1A is an extension of the existing phase 1, thus to ensure the continuity and compatibility, PSD are not proposed at wayside stations.

For Terminal Stations due to driverless turnback, PSGs are proposed at these stations for safety purpose.

0.6.5 Automatic Fare Collection

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 System shall be capable for open loop transactions as well to further integrate the mobility solution with the advancements in technology and to allow for seamless transition from dedicated cards to common multi-use stored value fare media that can be used for financial transactions such as making purchases at shops etc. as well as a fare media in the system.

To accommodate the same the system shall conform to the following standards as a minimum:

1. EMV (Euro Mastercard Visa)
2. PCI-DSS (Payment card Industry / Data Security Standard)
3. ISO-IEC 14443

0.6.6 Rolling stock

Rolling stock proposed for the Phase IA corridors will be similar to that of Phase-I. The broad features of rolling stock are presented in table below:

Table 5 : 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 GoA2 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

0.7 Civil Engineering

0.7.1 Geometric Design Parameters

Table 6 : Design Parameters

SN	CRITERIA	DIMENSION
1	Gauge	1435 mm
2	Maximum Design Speed	90 kmph

3	Maximum Operating Speed	80 kmph
4	Maximum Axle Load	16T
5	Traction System	25 KV AC (OHE)

Table 7 : Horizontal Curve Parameters

Description	Elevated Section	
Minimum Radius in running track	Limiting = 125mm	Preferential = 110mm
Absolute minimum Radius	120 m	
Minimum curve radius at stations	1000 m	
Cant (Ca)	Limiting = 125mm	Preferential = 110mm
Cant deficiency (Cd)	Limiting = 110mm	Preferential = 85mm
* The applied cant will be decided in relation to normal operating speeds at specific locations like stations/vicinity to stations.		

0.7.2 Gradient Parameters

For running line, the desirable maximum gradient shall be 3% (Must be kept as short as possible)

Where gradient of 1% or less are used, it may be unrestricted in length

Table 8 : Gradient Parameters

Description	Desirable Minimum	Absolute Minimum
Gradient for viaducts	0.5%	0.25%
Gradient at Stations	Not steeper than 0.2%	

0.7.3 Vertical Curve Parameters

Table 9 : Vertical Curve Parameters

Parameter	Vertical Curve
Desirable Radius on Main line	2500 m
Absolute Minimum Radius on Main line	1500 m
Minimum Length of constant grade between consecutive vertical curve	Desirable Min= 50 m
	Absolute Min. = 25m

0.8 Engineering Survey

Topographical Surveys were conducted based on differential GPS.

0.9 Geotechnical Investigations

Geotechnical investigations have been carried out along the proposed corridor to determine the strata, depth of foundation and safe bearing capacity of foundations required for the above proposed metro corridors. Drilling and sampling in soil and rock was carried out using rotary drilling rig. Borehole in soil was advanced using rotary drilling method. For all viaduct locations, since heavy loads are expected, at most of the locations, driven or bored cast in-situ piles shall be provided.

0.10 Route Alignment

Corridor – 1A: PCMC to Nigdi

- Proposed alignment of Phase-1A starts from PCMC and goes up to Nigdi near Bhakti shakti Udyan. Total length of the corridor is 4.413 km which is completely elevated.
- This corridor is an extension of existing corridor 1 under Phase 1 i.e. PCMC to Swargate.
- 3 Stations have been proposed in Phase 1 A, all of which are elevated stations. Summary of the section is given below:

Table 10 : Station chainage

PCMC-Nigdi Right option		
Station	Chainage(m)	Type
Chinchwad	1789.2	Elevated
Akurdi	3459.2	Elevated
Nigdi	5489.4	Elevated

0.10.1 Station Planning

The stations have been planned based on the following parameters:

a. Station Planning has been done for the peak hour traffic load for each station in the horizon year. The planning norms have been considered for the design year. Accordingly, facilities required at any station for emergency evacuation as per NFPA 130 Guidelines has been adopted. The stations have been planned in accordance with 'Guidelines for Pedestrian Facilities, and 'National Building Code-2016', for Disabled friendly and other Indian best practices/standards.
b. The platform length is planned for 6 cars train of 140 m in length.
c. The platform width has been computed considering Peak Minute Peak Direction Boarding; Disruption time of service; Platform congregation during disrupted time of service,0.5sq m/person at Level of Service C.
d. Typical design has been suggested for all three stations and this form basis for planning of all the stations.

Table 11 : summary of type of stations Proposed

Type	Station Type	No. of stations	Size (sq. m)	Levels	Construction Type

Without PD	Elevated	2	21 x 140	3	Cantilever
With PD	Elevated	1	21 x 140	4	Cantilever

0.11 Utility Diversion

Table 12 : Utility Responsibility Departments

S.No.	ORGANIZATION	UTILITY SERVICES
1	Pimpri Chinchwad Municipal Corporation	Surface water drains, nallahs, sewerage and drainage conduits, sewerage treatment plants, pumping stations, electric poles, Road construction & maintenance of Roads etc
2	Telecommunication Department	Telecommunication cables, junction boxes, telephone posts, O.H. lines, etc.
3	Traffic Police	Traffic signal posts, junction boxes and cable connections, etc.
4	MIDC	Water supply Line
5	Electricity Board	OH & underground electric cables
6	Maharashtra Natural Gas Limited	Gas pipe line

No. of over ground utilities affected due to metro alignment, as identified during the physical survey are:

Table 13 : List of utilities affected

S.No	Location	Direction	Units
1	Light Poles	Along the alignment	31
2	Traffic Signals	Along the Alignment	27
3	Sign Boards	Along the Alignment	12
4	Hoarding Boards	Near Bhakti shakti Chowk	2
5	Electric Poles	Near Bhakti shakti chowk	2
6	Transformer	Near Bhakti shakti chowk	1
7	Overhead transmission tower	Near Bhakti Shakti Chowk	1
8	Trees	Along the Alignment	342
TOTAL			418

Only visible utilities have been listed out which will be getting affected due to the metro corridor.

0.12 Land Requirement

- Finalization of alignment, location of stations, entry / exits etc. has been done with objective of keeping land requirement to bare minimum. For this purpose, alignment & stations are planned on center of the road to the extent possible.
- Stations sizes for all three elevated stations are 140m long & 21m wide. Since the stations are elevated, land requirement for the stations has been estimated for the entry & exits only.
- No additional land is required for depot as stabling of incremental trains (15 no. of 3-car trains) is available in existing depot land only.
- The total cost of Land including R&R works out to be Rs. 114.43 Crore.

Table 14 : Total land requirement

	Type of Land	Purpose	Area (Sqm)
Station 1 (Chinchwad)	Government	Entry/exit	348.00
		FOB	147.51
	Private	Entry/exit	624.00
		FOB	1298.55
Station 2 (Akurdi)	Government	-	0.00
	Private	Entry/exit	797.00
Station 3 (Nigdi)	Government	Entry/exit	380.00
		De-tour	187.00
	Private	Entry/exit	642.00
		De-tour	3022.29

0.13 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 at corridor 1A metro stations for providing last mile connectivity.

Table 15 : Feeder Buses And Public Bicycle Requirement

Year	2023	2033	2043	2053
Feeder Buses	15	24	32	42
Public Bi-cycle	77	107	117	127

0.14 Power Supply System and Power requirement

Traction Power Supply in Metro systems is used for high acceleration and pollution-free services in urban areas. There are three standard and proven systems of electric traction for use in suburban and metro lines, viz:- 750V DC third rail, 1500V DC overhead catenary and 25kV AC overhead catenary system. All these three systems are presently in use in India.

The 25 kV AC Over Head Electrification (OHE) traction system shall be similar to existing power supply system, keeping in view the ultimate traffic requirements, standardization, and other techno-economic considerations. As 25 kV AC Over Head Electrification (OHE) traction system has already been used for traction power supply for existing corridor and also for interoperability of the system. 25kV AC traction has the economic advantages of minimal number of traction sub-stations and potential to carry large traffic upto 60,000 PHPDT.

The system requires catenary masts on surface/elevated section, thereby affecting aesthetics and skyline of the city. Since the proposed alignment of Pune Metro would traverse congested roads and built-up area of the city, 25kV AC traction system is considered a safe option. Traffic requirements of the Pune Metro have been projected in the range of 25600 PHPDT in year 2053.The alignment of proposed corridors is on elevated viaducts. Keeping in view the techno-economic considerations, 25 KV AC traction system is considered to be the best solution for Power requirements.

No extra depot is required, existing depot shall be used for the extension corridor 1A (PCMC-NIGDI) and also the existing OCC and BOCC shall be updated based on the requirements of the extension corridor 1A (PCMC-NIGDI).

The power demand calculation for the extension corridor 1A (PCMC - NIGDI) based on the operation plan is projected as below:

Table 16 : Power Demand Estimation (MVA)

Corridor		Year			
		2023	2033	2043	2053
PCMC-NIGDI Route Length – 4.413 km,	Traction	0.7 MVA	0.9 MVA	1.0 MVA	1.1 MVA

Number of Stations – 3 (Elevated – 3)	Auxiliary	1.1 MVA	1.1 MVA	1.1 MVA	1.1 MVA
PCMC-SWARGATE Route Length – 17.8 km, Number of Stations – 14 (Elevated – 9, Underground - 5)	Traction	6.5 MVA	8 MVA	9.2 MVA	9.5 MVA
	Auxiliary	18.2 MVA	18.8 MVA	21.9 MVA	21.9 MVA
Total Power Demand (NIGDI-SWARGATE)	**Traction**	**7.2 MVA**	**8.9 MVA**	**10.2 MVA**	**10.6 MVA**
	Auxiliary	**19.3 MVA**	**19.9 MVA**	**23 MVA**	**23 MVA**

0.14.1 Sources Of Power Supply

The Source of power supply system in Pune city has 220 kV and 132 kV grid substation network on the periphery of the city to cater to various types of power supply demand in vicinity of the proposed corridor.

Two sources of power supply are there along the corridor one is 132kV Chinchwad SS near PCMC and other is 132 kV Ganesh khind SS near agriculture college.

0.14.2 Auxiliary Supply Arrangements And Standby Power Supply

Auxiliary sub-stations (ASS) are envisaged to be provided at each station (1 ASS for elevated station) for stepping down 33 kV supply to 415 V for auxiliary applications and one separate ASS for Depot is already planned for the existing corridor for stepping down 33 kV supply to 415 V for auxiliary applications in depot.

However, in the unlikely events of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. The standby DG set of 500 KVA capacity is required to cater the auxiliary load of the stations.

0.14.3 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 Pune, the peak solar power generation of Pune Metro corridors is expected to be about 200 kWp for elevated stations and about 2000kWp for maintenance depot.

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

0.15 Maintenance Depot

Maintenance facilities for PCMC-Nigdi extension can be accommodated in already planned depot near Range Hill station for Phase-1, therefore, another new depot is not required. Stabling capacity for 25 number of 3-car trains is already provisioned in phase-1 of existing Range Hill Depot with suitable augmentation.

0.16 Social And Environmental Impact Assessment

0.16.1 Environmental Impact Assessment

The negative impacts due to location of proposed corridor 1A (PCMC – Nigdi) 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 and 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 Environment management plan for Compensatory Afforestation, Construction Material, Housekeeping, Air Pollution Control, Noise and vibration Control are suggested. The total estimated environmental management cost for the proposed project is about Rs. 92,90,400.00 and tree transplantation cost is Rs. 1,28,748.00. Total cost of Environment Management Plan wourks out to 1.79 Cr. including Air, Noise, Water, waste, soil management, training and capacity building activities etc.

0.16.2 Social Impact Assessment

The project will involve acquisition of 7446.35 square meter land which comprises 6383.84 square meter of private land and 1062.51 square meter of government land. Total of 49 structures will be affected.

Entitlement matrix, institutional arrangement and schedule for implementation of Resettlement Action Plan (RAP) have been recommended. Compensation for loss of private land and structure forms part of capital cost estimate. RAP has been prepared as per Right to Fair Compensation and Transparency in land acquisition, Rehabilitation and Resettlement Act, 2013 (RTFCTLARR Act), Maharashtra Notification on Resettlement and Rehabilitation, the right to fair compensation and transparency in land acquisition, rehabilitation and resettlement act, 2013 (no. 30 of 2013), and ADB's Safeguard Policy Statement (SPS), 2009 on Involuntary Resettlement. Estimated cost of implementation of R&R Plan is Rs. 114.43 crore (including land cost).

0.17 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.

0.18 Detailed Project Cost Estimates

0.18.1 Capital Cost

Table 17 : Abstract Of Cost Estimate

S. No.	Item	Amount (INR Cr)
1	Alignment & Formation	163.28
2	Station Buildings	
a	Cost of civil structure (Including cost of one FOB)	80.68
b	E&M Cost (Including Lift and Escalator)	24.00
3	Maintenance Depot	12.88
4	P-Way for main line and depot	29.13
5	Traction and Power Supply	33.10
6	Signalling	27.92
7	Telecommunication	13.50
8	Rolling Stock	120.00
9	Multi Modal Integration	9.00
10	Cost of Security	1.11
11	Environment cost	1.79
12	Utility Shifting	26.48

13	**Total Cost at FY 2019 price level (Excluding Land, R&R, General Charges, Contingencies, Central & State Taxes)**	**542.86**
14	General Charges @ 5%	27.14
15	Contingencies @ 3 % on Sr. No.13 i.e. Basic Cost	16.29
16	**Total Cost at FY 2019 price levels incl. General Charges and Contingencies (Excluding Land, R&R, Central & State Taxes)**	**586.29**
17	Central and State Taxes @ FY 2019 Price Level	79.28
18	**Total Cost incl. General Charges, Contingencies, Central and state Taxes @ FY '19 Price Levels (Excl. Land and R&R)**	**665.57**
19	Land	72.81
20	R&R	41.62
21	**Total Cost incl. General Charges, Contingencies, Central and state Taxes @ FY '19 Price Levels (Incl. Land and R&R)**	**780.00**
22	Escalation at 5 % per annum on the above (S. No: 21)	107.66
23	**Total Completion Cost incl. Land and R&R Costs**	**887.66**
24	Interest During Construction (IDC)	11.02
25	**Total Completion cost including IDC**	**898.68**
26	PPP component (AFC)	11.50
27	**Total Completion Cost**	**910.18**

Note: FY 2019 Price Level is considered and the Prices are escalated till the completion period to arrive at the completion cost. (Ref: Page 400)

0.18.2 O&M Estimate

The total O&M cost in year 2025 and 2053 is estimated at **Rs. 44 Crore** and **Rs. 419 Crore** respectively (duly escalated).

0.19 Transit Oriented Development

National Transit Oriented Development (TOD) Policy provides guidelines on development along transit 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 (500m) of transit station or along the corridor in case the station spacing is about 1km. With application of TOD policy premium shall be collected on incremental proposed FSI. For application of TOD Policy, infrastructure provisions shall be made as well. Thus, at the expense of Rs 340.78 Cr for infrastructure provision, premium Levy over the development period (30 Years) of Rs. 3082 crores shall be earned. 75% of this revenue shall be shared with Maha Metro, summary of which is given in following table:

Table 18 : Estimated Annual Revenue From TOD

Year	Revenue to Metro from Premium Levy with Max FAR 4 (Cr.)
2030-31	104
2031-32	106
2032-33	109
2033-34	112
2034-35	114
2035-36	117
2036-37	120
2037-38	123
2038-39	126
2039-40	129
2040-41	133
2041-42	136
2042-43	139
2043-44	143
2044-45	146
2045-46	150
2046-47	337
2047-48	345
2048-49	354
2049-50	363
2050-51	372
2051-52	381
2052-53	391

0.20 Sharing of cess on stamp duty

FY 19 – 1% cess collection on stamp duty in PCMC stood at 155 Crores. 25% share per year from the same is proposed to be given as revenue support to the extension from PCMC to Nigdi over a 30 year period and assumed to be escalated at 2.5% per annum.

Table 19 : Year wise share of cess on stamp duty with Maha Metro

Year	Revenue to Metro from Cess on Stamp Duty (Cr.)
2030-31	52
2031-32	53
2032-33	55
2033-34	56
2034-35	57
2035-36	59
2036-37	60
2037-38	62
2038-39	63
2039-40	65
2040-41	66
2041-42	68
2042-43	70
2043-44	72
2044-45	73
2045-46	75
2046-47	169
2047-48	173
2048-49	177
2049-50	182
2050-51	186
2051-52	191
2052-53	196

0.21 FINANCIAL ANALYSIS

The revenue has been estimated for the fare-box revenue and non-fare-box revenue. The fare structure is as per the Government Resolution No. PMR-3313/C.R.29/UD-7 dated 11 Sept. 2013. The fare is escalated by 15% every three years. Non-fare box revenue is estimated on account of advertising on stations and trains, kiosk rentals, sharing of cess on Stamp duty, Property development of government land and Premium by application of TOD Policy. The non-fare fox revenue is estimated as Rs. 138.6 Cr in year 2023, Rs. 175.1 Crore in year 2033, Rs. 232.2 Crore in year 2043 and Rs. 296.3 Cr in year 2053 respectively.

0.21.1 FIRR Analysis

The FIRR for a project operation period of 30 years is carried out with Non fare Box Revenue including TOD. Non-fare sources of revenue incorporated in financial package for the proposed Metro Projects such as advertisement, rental from kiosks inside stations, Sharing of cess on stamp duty, Property development on government land and sharing of Premium from application of TOD policy . Project IRR works out to 10.45 %

0.21.2 Sensitivity Analysis

Table 20 : Project FIRR- Sensitivity Analysis

Capital cost sensitivity			
10% increase in capital cost	20% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
9.72%	9.11%	11.11%	12.15%
O & M Cost			
9.71%		11.08%	
Property Development			
With PD		Without PD	
10.45%		9.38%	

0.22 Financial Plan

0.22.1.1 Multilateral funded loan @ 1.2% per annum

Particulars	Amount (Rs. Cr)	Percentage
Grant by GoI	67.02	10.00%
Grant by PCMC	121.97	18.20%
Grant by GoM	79.08	11.80%
Soft Loan from bilateral/multilateral funding agencies	402.11	60.000%
Project Cost Eligible for Grant	**670.18**	**100.0%**
SD for State Taxes, Central Taxes & Duties by GoM	90.63	
Contribution for Land, R&R, IDC, etc. by PCMC	137.87	
Total	**898.68**	

PPP Component	11.50	
Total Cost including PPP Component	**910.18**	

0.23 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. The EIRR in economic terms works out to 23.55 %. Sensitivity analysis of the EIRR with Capital cost increase by 20%, O&M costs increased by 20%, Target beneficiaries reduced by 20%, Delay in accrual of benefit by 1 year and Combined adverse condition has been carried out :

Table 21 : EIRR And Sensitivity Analysis

Details	EIRR (%)	ENPV @14% (Rs Crore)	MIRR (%)	SV	Benefit - Cost Ratio (2019 Price)	Benefit - Cost Ratio (Current Price)
Main Evaluation (Base Case)	23.55%	358.1	14.99%		1.60	3.57
20% Capital Cost Overrun	20.34%	275.2	14.11%	86.5%	1.40	3.34
20% O&M Cost Overrun	22.62%	321.1	14.75%	193.8%	1.51	3.16
20% Decrease in Project Benefits	18.68%	166.7	13.64%	37.4%	1.28	2.86
One Year Delay in Implementation	23.52%	309.0	14.94%		1.59	3.51
All Four Tests Combined	15.07%	37.6	12.47%		1.06	2.34

0.24 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 Maharastra has created a Special Purpose Vehicle (SPV) for implementing the Pune Metro Rail Project Phase 1. This SPV named as "NMRCL" was incorporated on 18th February , 2015 under the Companies Act and subsequently the name was changed to Maharashtra Metro Rail Corporation on 22nd January, 2017. It is a 50:50 jointly owned company of GoI and GoM responsible for implementation of all metro projects in the state of Maharashtra outside Mumbai Metropolitan region including Pune Metro Rail project phase 1 and the current extension from PCMC to Nigdi.

0.24.1 Implementation Schedule

S. No	Tasks	Anticipated Timelines
1	Approval of DPR by GoM	September 2021
2	Final Approval by GoI	November 2021
3	Packaging & Invitation of Bids	January 2022
4	Commencement of Civil Works	February 2022
5	Commencement of Operation	April 2025

1. A PROFILE OF THE CITY

Pune & Pimpri Chinchwad is the next largest urban conglomerate to Mumbai Metropolitan Region in Maharashtra. These cities are considered to be an educational hub due to the establishment of large number of educational institutes across the city.

Pune & Pimpri Chinchwad have been experiencing tremendous growth in population and employment since the last two decades. The cities have been stretching their limits to the widest extent possible, thus urban sprawl has become evident.

The growth in various industries, particularly automobile, IT and IT enabled services, in and around Pune & Pimpri Chinchwad has added further impetus to the urban sprawl and increase in population and employment.

The district also has an importance as an important military base. The urbanization of this Pune & Pimpri Chinchwad will receive a big impetus in the next 30 years due to the ambitious development plan of the 7000 sq. km Pune Metropolitan Region.

1.1 History

The city of Pune has been a city of major importance in the Indian subcontinent since the 17th century. Confined to the East bank of the Mutha river until the early 19th century, the city started to grow on the west bank as well. The city witnessed fast growth after Independence.

Subsequently, Pune became a major manufacturing as well as a higher education center.

In addition to its temples, historical attractions in and around Pune include the rock-cut Pataleshwar cave temple, Aga Khan Palace, Shaniwarwada, Lal Mahal, and Sinhagad fort.

Shinde Chhatri, located at Wanowrie, is a memorial dedicated to the Great Maratha Sardar, Mahadaji Shinde (Scindia) who was instrumental in establishing the Maratha supremacy over North India.

1.2 Geography

Pune is located in the State of Maharashtra, approximately 150km South-East of Mumbai as shown in Figure 1. Pune has a hot semi-arid climate bordering with tropical wet and dry with average temperatures ranging between 19 and 33 °C (66 and 91 °F). Pune experiences three seasons: summer, monsoon, and winter. Typical summer months are from mid-March to June often extending until 15 June, with maximum temperatures sometimes reaching 42 °C (108 °F). The warmest month in Pune is May. The city often receives heavy dusty winds in May (and humidity remains high). Even during the hottest months, the nights are usually cool due to Pune's high altitude.

The monsoon lasts from June to October, with moderate rainfall and temperatures ranging from 22 to 28 °C (72 to 82 °F). Most of the 772 mm of annual rainfall in the city falls between June and September, and July is the wettest month of the year.

The daytime temperature hovers around 26 °C (79 °F) while night temperature is below 9 °C (48 °F) for most of December and January, often dropping to 5 to 6 °C (41 to 43 °F).

Figure 1 : Pune location map
(Source: Open Street Map, 2018)

1.3 Demographic and socio economic profile

With a population of 31.2 Lakh (2011 census), Pune is the second most populated city in Maharashtra after Mumbai and the 9th most populated city in India. The total population of the Pune urban agglomeration, is 51 Lakh in 2011. The city is considered to be an educational hub due to the establishment of large number of educational institutes across the city.

In the past few years, Pune and surrounding cities including Pimpri-Chinchwad have witnessed major population growth. The population of Pimpri-Chinchwad as per 2001 Census is 1,006,417 persons. The population as per 2011 census is estimated to be in the range of 17.27 lakhs . This growth is partly fueled by the presence of multiple education institutions as well as industrial developments, notably in the manufacturing and IT sectors (source: PMC, 2008).

In addition to population growth, rapid industrialization and intense commercial developments in the past decades have resulted in steep rise in travel demand, putting Pune's transport infrastructure to stress.

1.3.1 Population growth

The population of Pimpri-Chinchwad as per 2011 Census is 17.27 lakhs. Pimpri Chinchwad provides employment to industrial workers and of late has emerged as an affordable urban destination for residential purposes. The increasing demand for industrial and residential areas led to continuous addition of areas and upgradation of the erstwhile Municipal Council to Corporation. For the last two decades, the decadal growth rate of population has been in the range of 100% while the previous two decades witnessed population growth in the range of 150%. (Source: City Development Plan, PCMC)

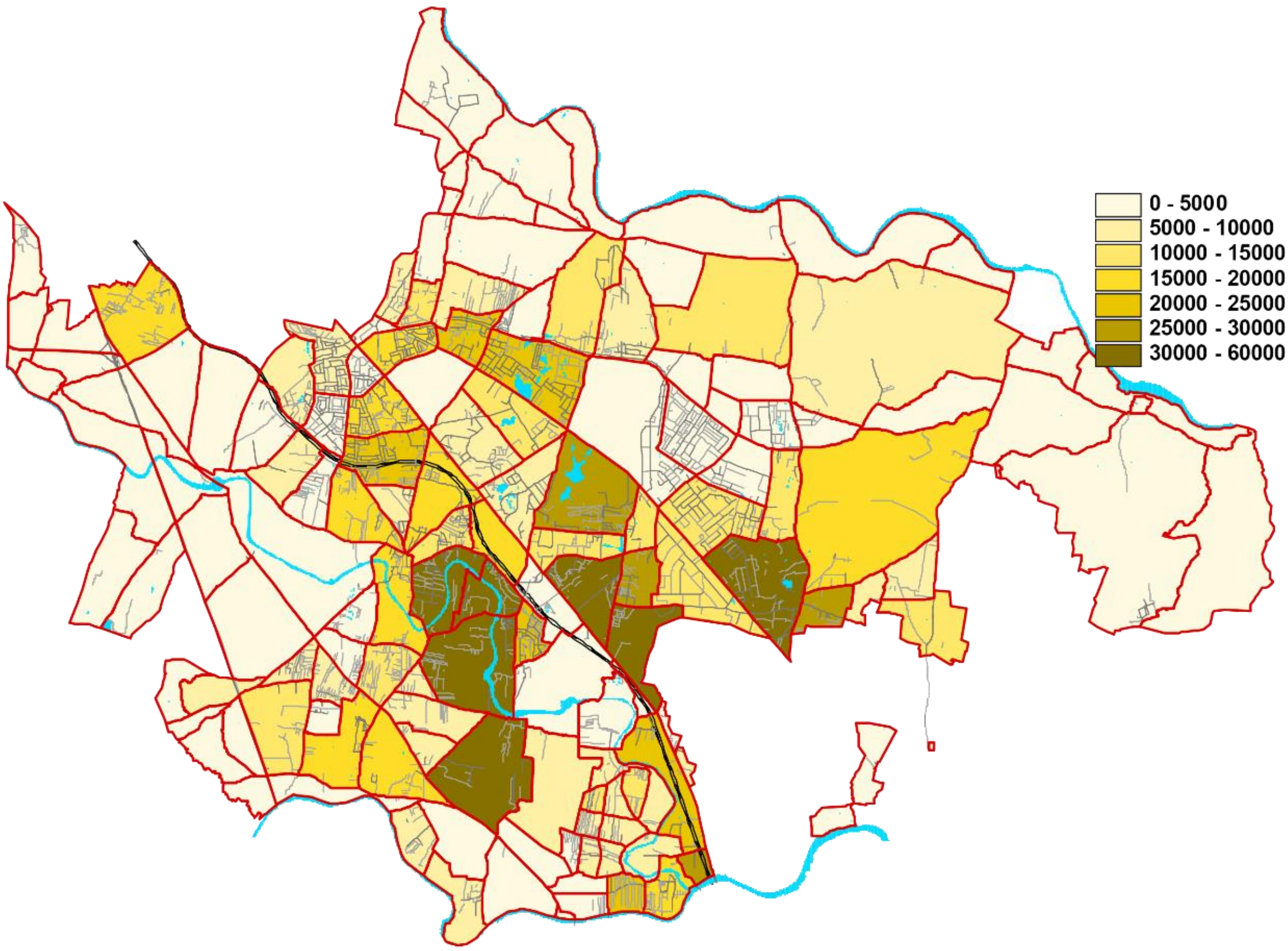


Figure 2 : spatial distribution of Population in PCMC
Source: Comprehensive Mobility Plan, PCMC

Table 22 : Population Trend in PCMC

CENSUS YEAR	POPULATION	DECADAL CHANGE	GROWTH RATE (%)
1951	26,367	-	-
1961	39,654	13,287	50.39
1971	98,572	58,918	148.58
1981	251,769	153,197	155.42
1991	520,639	268,870	106.79
2001	1,006,417	485,778	93.30
2011	1,729,320	722,903	71.83

Source: City Development Plan, PCMC

1.3.2 Population Density

Pimpri-Chinchwad has a population density of 9,353 persons per square kilometre as per the 2011 census, which is comparatively less than that of its neighbouring city, Pune. However, this is mainly due to the large extent of vacant spaces available in the peripheral, undeveloped areas of the city.

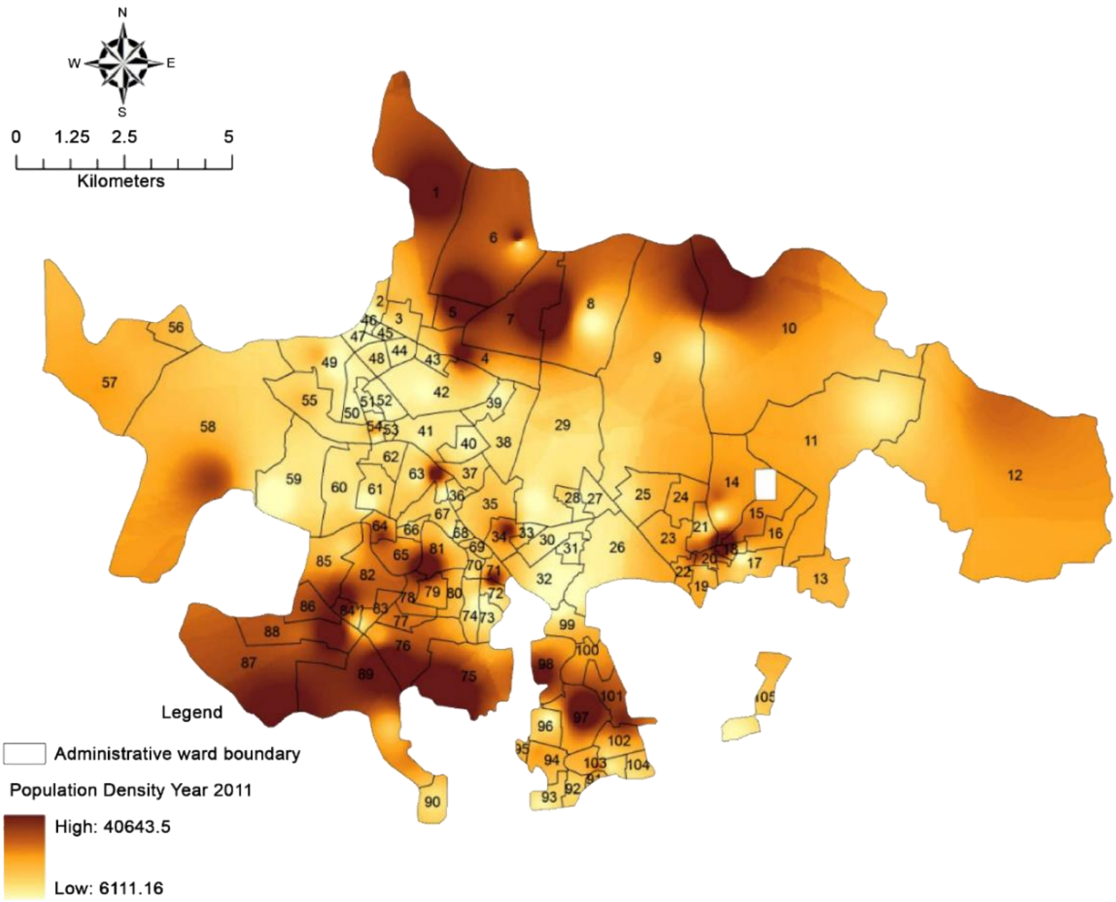


Figure 3 : Spatial distribution of Density in PCMC, 2011
Source: Comprehensive Mobility Plan, PCMC

Table 23 : Population Density in PCMC Region

YEAR	AREA SQ KM	DENSITY PER SQ KM
1971	-	-
1981	86.01	2,927
1991	86.01	6,053
2001	170.51	5,903
2011	184.72	9,353

Source: City Development Plan, PCMC

The city is tucked between the Mula, Pawana and Indrayani rivers which form the natural boundaries of the city on the northern and southern sides. The densely populated old city is located in the centre, with the Pawana River on one side and the Mumbai-Pune railway line on the other. These are also the old PCMC and PCNTDA areas. The interiors of these areas comprising Morwadi, Kharalwadi, Pimpri Waghere and Pimple Saudagar, still retain their rural character and have narrow road widths.

The geographical location of the city between the rivers on one side and vast defence areas on the eastern side of the city form natural barriers to the city's growth; comprehensibly, the western side of the city facing Mumbai has the maximum potential for growth and development.

The dynamic process of population growth beyond the control of authorities is largely the function of real estate development, land prices and ease of accessibility to work place, and availability of basic services. As a result, population growth is being witnessed in the fringe areas of the city and just outside the PCMC limits, especially in the northwest direction.

1.3.3 Migration patterns

In Pimpri-Chinchwad, more than 60% of the population growth has been on account of migration largely due to the employment opportunities prevailing in the region. Migration into PCMC region is essentially from within Maharashtra. Approximately 31% of sampled population is from Pune District, 12% from other district of Maharashtra, 14% from outside Maharashtra and remaining 43% of population were original habitants of the region. The main reason for migration has been economic i.e. for employment. Location of large number of industries and service sector attracted large number of population in the area.

1.3.4 Spatial patterns of growth

The unplanned migration along with the natural growth of population led to rapid increase in the population of Pimpri-Chinchwad in the last four decades. The chronology of events in the development of the city of Pimpri Chinchwad is presented below.

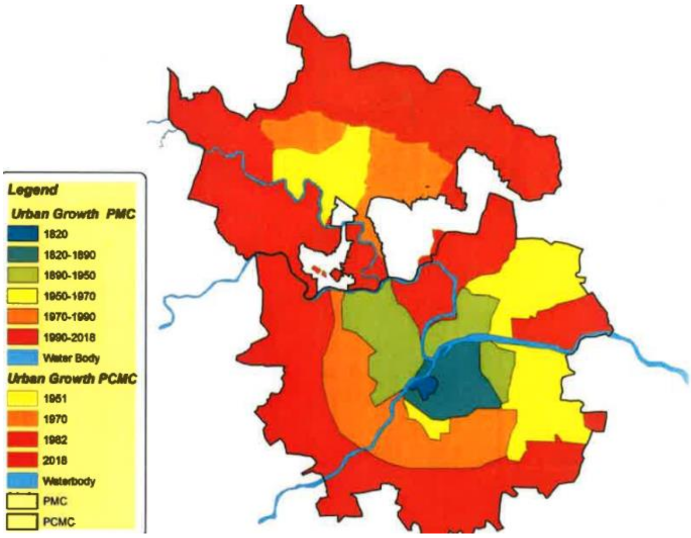


Figure 4 : Chronological expansion of Pune
Source: City Development Plan, PCMC

1970: The Pimpri Chinchwad Municipal Council with a status of 'C' class was formed on 04.03.1970 by merging four villages, namely Pimpri, Chinchwad, Bhosari and Akurdi.

1972: The Pimpri Chinchwad New Town Development Authority (PCNTDA) was established in 1972 as per the recommendations of the Pune Metropolitan Regional Planning Board. The main objective was to create a planned environment for the working population in the vicinity of their work place.

1975: Status of Municipal Council was changed from "C" Class to "A" Class from 7th January 1975.

1982: A Municipal Corporation was formed by merging seven surrounding villages in the Municipal Council, namely Sangvi, Rahatani, Thergaon, Wakad (part), Pimple Nilakh, Pimple Gurav, Pimple Saudagar and the PCNTDA area. A total area of 86 sq. km. came under PCMC's jurisdiction vide notification dated 05.10.1982.

1997: The area under the Municipal Corporation was further increased through the addition of 18 new villages in part or full, constituting an extended area of 84.51 sq.km. Thus, the total area under the jurisdiction of PCMC measured 170.51 sq.km.

These villages are located on the periphery of the erstwhile PCMC area. The villages Talwade, Chikhali, Moshi, and Dudulgaon along the Dehu-Alandi road, and Choviswadi and Wadmukhwadi along the Dighi-Alandi road are located north of the erstwhile PCMC, bounded by the Indrayani River. Charholi BK, Dighi, and Bopkhel along the Pune-Alandi road lie towards the east, bordered by the area under the Ministry of Defence. Towards the south are Dapodi, Sangavi (Aundh Chest Hospital), Bhosari, and Pimple Nilakh (Rakshak Co-operative Housing Society Private Ltd. and Bharat Electronics Ltd. Colony). To the west, the river Pavana bisects the villages Mamurdi, Kiwale, and Ravet from the villages Punawale and Wakad that lie along the westerly Mumbai-Bangalore bypass highway.

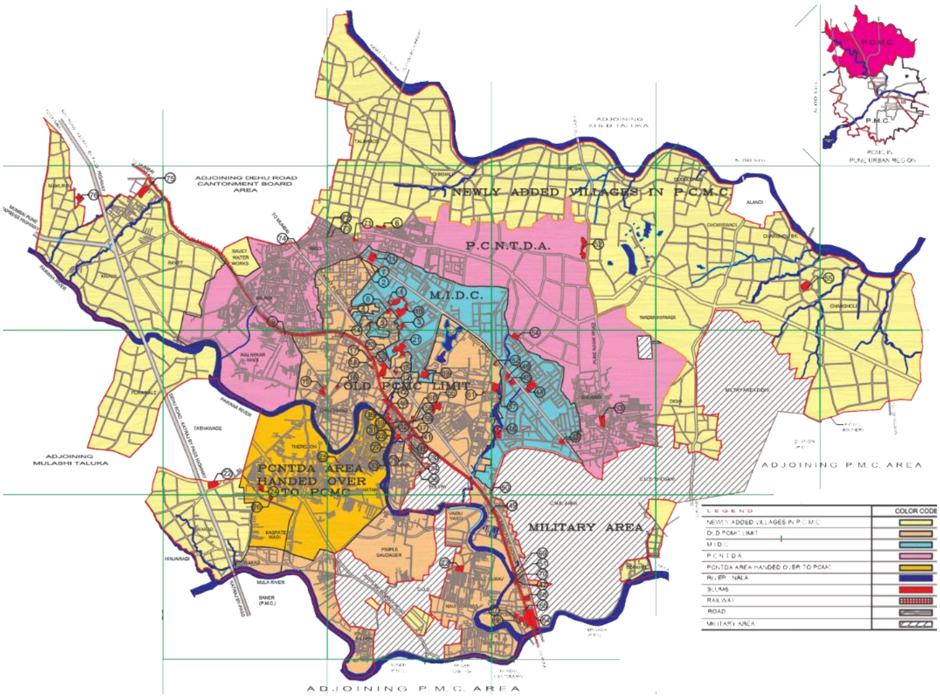


Figure 5 : Spatial pattern of growth in PCMC Region
Source: City Development Plan, PCMC

The present PCMC area borders its twin city of Pune on the north and north-west and lies on the Mumbai-Pune National Highway NH4. The Mumbai-Pune rail link also traverses through the corporation area dividing it into two halves.

1.3.5 Population Projections for next 20 years

For the last two decades, the decadal growth rate in population has been in the range of 100%; the previous two decades witnessed population growth in the range of 150%. The very high growth rates of the past decades, accounted for by migration and the addition of new areas, have started to show a downward trend; however, these would still be on the higher side for the next three decades due to the all-round economic development of the Pune region. Current population in year 2011 is 50.5 lakh in Pune Region, out of which Pune and Pimpri Chinchwad combined housed 48.52 lakh persons in year 2011. As of 2011, it is estimated that the total population of the PCMC area is about 17.27 lakhs and 20.8 Lakh in 2017. Accordingly, the population of PCMC is estimated to reach 30.9 Lakh by 2028 and 39.11 lakhs by 2038.

As in the case of Pune city, so in Pimpri-Chinchwad too, the majority of the population (over 80%) is below the age of 50; the city has a very young population with the median age being close to 24 years. Since a large chunk of the current younger generation is expected to start families within the next decade and half, the population will escalate to the projected level. The population of Pimpri-Chinchwad in the last two decades grew at an annual average rate of over 7% against the national average of 2.1% and state average of about 3.3%.

1.4 Urban Land Use Structure / Activity Distribution

1.4.1 Planning study areas and existing plans

Pimpri Chinchwad Municipal Corporation (PCMC) is situated approximately at 18° 37' north latitude and 73° 48' east longitude bordering its twin city of Pune on the north and north-west.

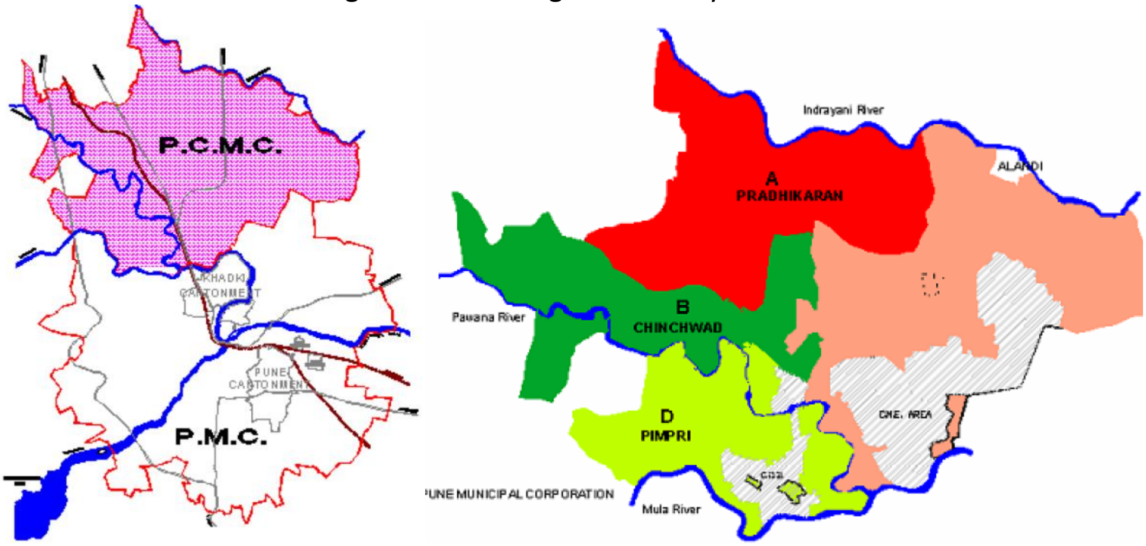


Figure 6 : Location of PCMC in Pune Region (left) and Administrative wards in PCMC (Right)
Source: City Development Plan, PCMC

The city of Pimpri-Chinchwad is predominantly an industrial area, which has developed largely during the last four decades. Pimpri Chinchwad is a relatively newly developed urban area of Pune city.

Pimpri was basically established as a centre for refugees from Pakistan. Industrialisation in Pimpri area commenced with the establishment of Hindustan Antibiotics Limited in 1956. The establishment of the Maharashtra Industrial Development Corporation (MIDC) in 1961-62 considerably facilitated industrial development in the area. The establishment of large-scale core industries has led to the growth of ancillary and small-scale industries in and around this industrial belt. With each passing year, the landscape saw significant changes, long stretches of farmland giving way to clusters of enclosed factory campuses. Pimpri-Chinchwad being an extension of Pune, enjoys the excellent connectivity that Pune has.

1.4.2 Existing Land use Distribution

Table 24 presents the land use distribution of Pimpri-Chinchwad City. Out of the total area, the residential land use constitutes about 46%. Figure 7 shows the existing land use plan of the study area. Commercial zones and mixed uses are distributed mostly along major corridors and around nodes. Commercial districts of the kind proposed in the DP have not come up primarily owing to the road structure in the city. Concentrations of residential zones are around villages and in newly developed areas. New residential construction is seen mostly between the river and the Aundh-Ravet road and in and around Wakad. Location decisions of high order institutional zones such as hospitals, colleges, etc seem to have been based on a function of market values and connectivity rather than zonation as specified in the DP. Industries have come up in the MIDC area. Some transformations from industrial to commercial are seen along major spines like the NH4.

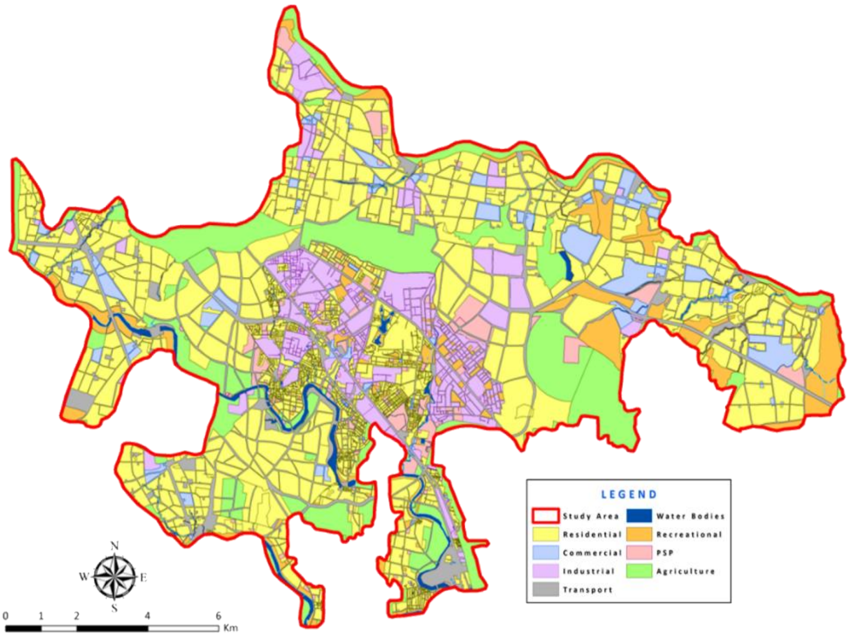


Figure 7 : Existing Land Use Map of PCMC

Table 24 : Existing Land Use analysis of PCMC

LAND USE	AREA (KM SQ)	PERCENTAGE
Residential	77.58	46.63%
Commercial	7.45	4.48%
Public Semi Public	5.95	3.58%
Industrial	15.34	9.22%
Transport	26.46	15.9%
Water Bodies	3.93	2.36%
Agricultural	15.85	9.53%
Recreational	13.75	8.26%

Source: City Development Plan, PCMC

1.4.3 Review of zoning regulations

The permissible F. A. R. shall be 1.5 for purely residential building and 2.00 for building with mixed residential and commercial user subject to maximum tenement density of 375 tenements per hectare, provided in building with mixed residential and commercial user. The commercial user will be permitted only on the ground floor and the residential user and commercial user shall not exceed F. A. R. 1.5 and 0.5 respectively. However in the case of entire building constructed on stilts, the stilt floor may be allowed for the 0.5 commercial use.

1.4.3.1 Permissibel FSI

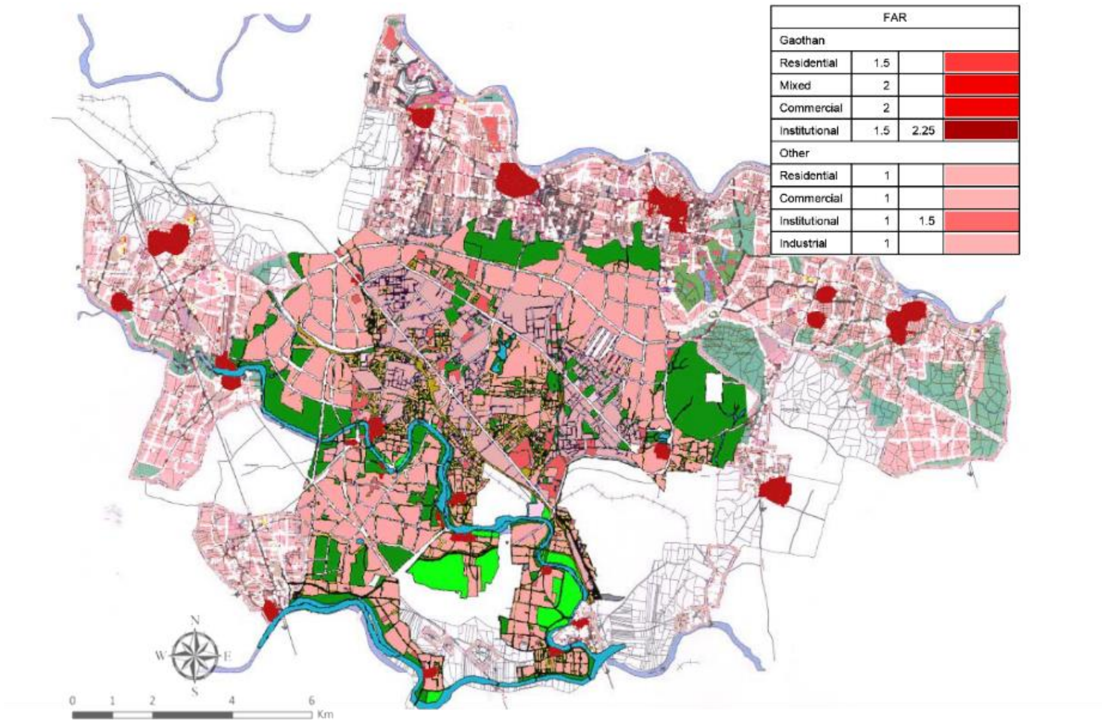


Figure 8 : Proposed FAR as per existing DCR in PCMC
Source: Comprehensive Mobility Plan, PCMC

1.4.3.2 FAR Usage/ Pattern :

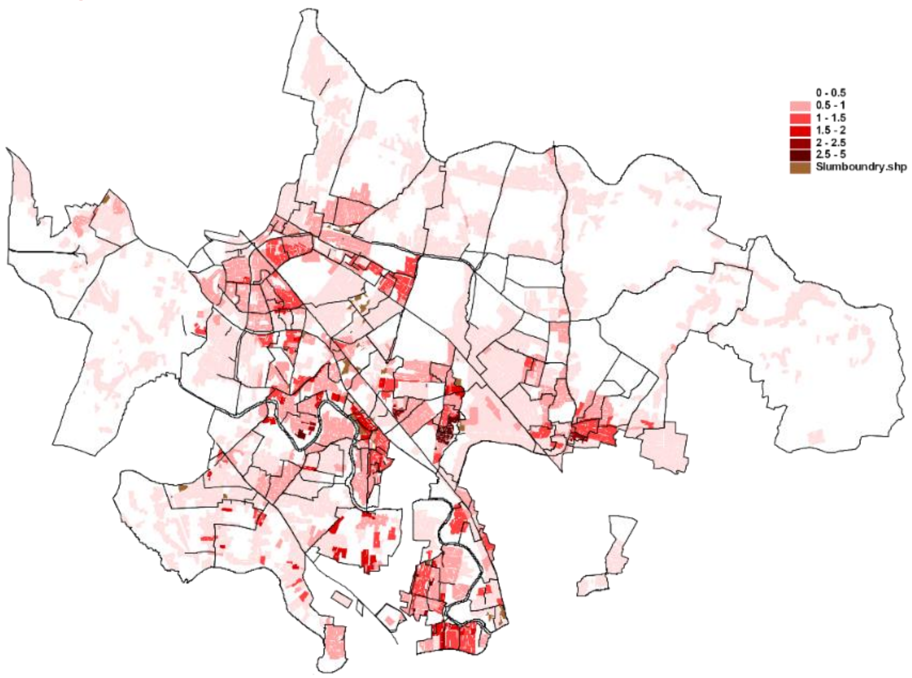


Figure 9 : Existing FSI usage in PCMC
Source: Comprehensive Mobility Plan, PCMC

Newly merged area in PCMC has not utilized the FSI of 1 as well. Small pockets in Pimpri and Chichwad has utilized higher FSI of 2.5 and above as shown in Figure 9.

1.4.4 Employment distribution by Traffic Zones

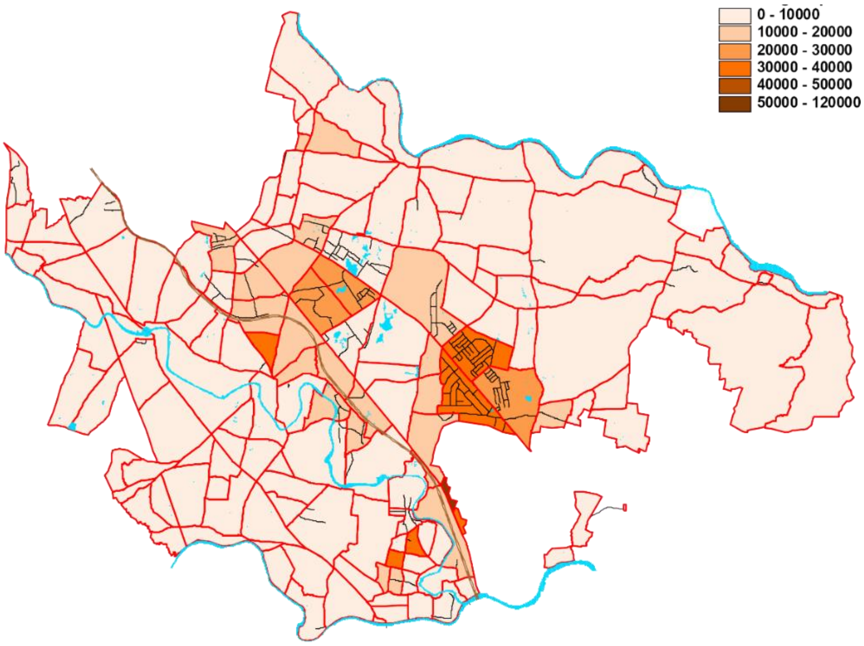


Figure 10 : Spatial distribution of jobs in PCMC
Source: Comprehensive Mobility Plan, PCMC

The highest distribution of jobs is in the MIDC area between the Old Mumbai Pune road and the Telco road. This area houses big factories such as Bajaj, Telco, Tata Motors and numerous other small and large scale manufacturing industries. However this pattern of jobs is likely to undergo a conspicuous shift in the next 5 to 10 years as the IT and ITES sector is being widely promoted. The existing distribution of jobs are shown in the Figure 10.

1.4.5 Activity locations (Business areas, University, Hospitals, Transport Terminals)

The gaonthan areas and the camp area provide for wholesale shopping in the city. New malls and large format retail development are coming up in the central city areas along the industrial belt on the old Mumbai pune highway and at the junction of NH4 & NH50. Small format commercial development is also seen spread through the neighbourhood as the development control rules allows for mixed use on roads having ROW 18 m or more (refer Figure 11). This is advantageous in reducing some of the shopping trips.

Recreational areas are few in the city despite the presence of large water bodies. Some of the neighbourhood chowks serve as recreational spaces with informal markets and eateries. Important temples like the Gnaneshwar Maharaj temple at Alandi are visited by people from the entire region and the city palace host to lakhs of people during festive occasions.

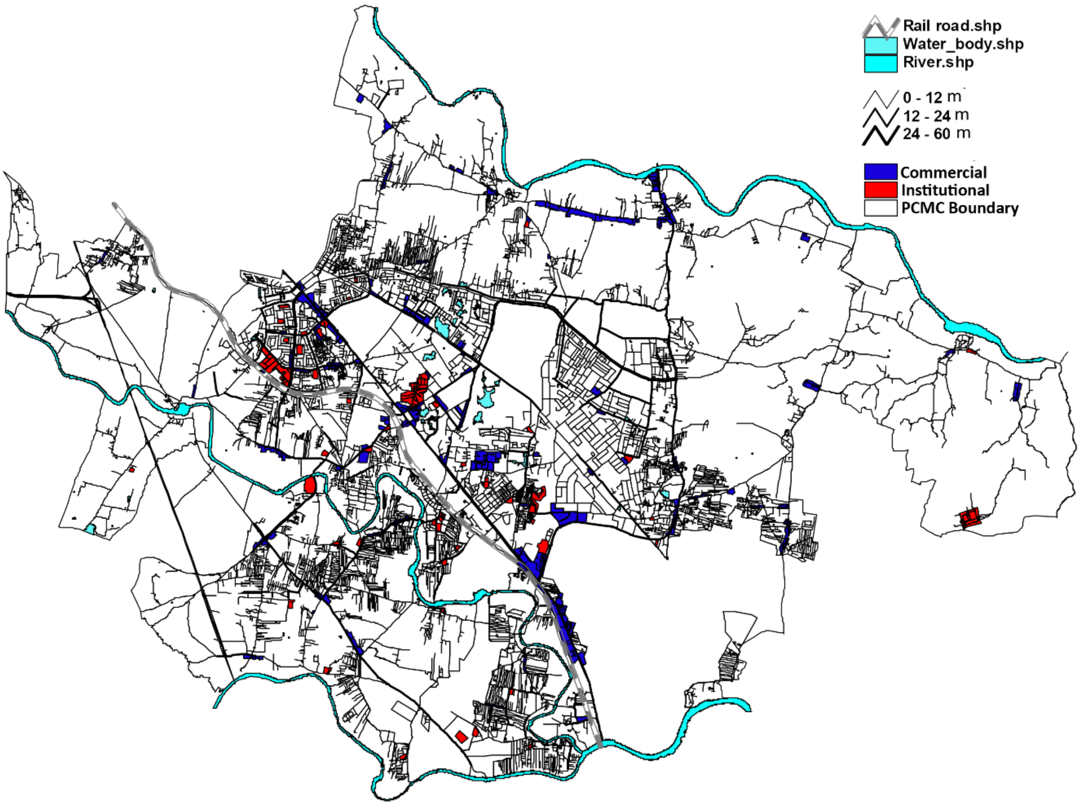


Figure 11 : Activity Location in PCMC
Source: Comprehensive Mobility Plan, PCMC

1.4.6 Land use plan proposals (Master Plan and CDP strategy)

From the Development Plan documents for PCMC old area, PCNTDA and PCMC newly added areas, the areas under different land uses has been estimated and presented in the table given below. As is evident from the map (refer Figure 12), in the respective Development Plans, the MIDC industrial estates were zoned as predominantly industrial zones while other uses were assigned to areas around them. In terms of land use zoning, status quo was maintained for village areas and the refugee camps also. Plots have been reserved both in the old DP as well as the DP for the added areas for public utilities and social infrastructure as per recommendations of the URDPFI guidelines. Commercial zones have been assigned in blocks as commercial districts, equidistantly placed around the residential areas. Buffers along the rivers and reserve forests were meant to provide the green spaces in the city.

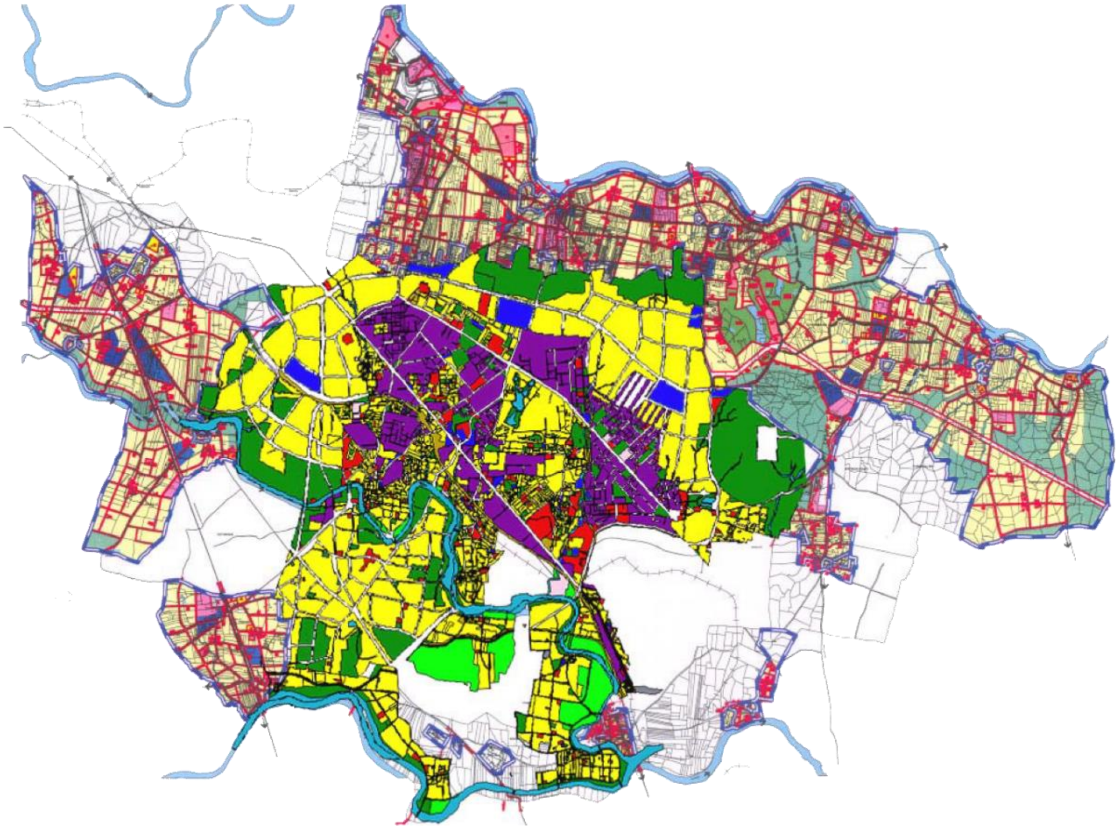


Figure 12 : Proposed Land use of PCMC as per DP
Source: Comprehensive Mobility Plan, PCMC

Table 25 : Proposed Land Use distribution of PCMC as per Development Plan

LAND USE	AREA (KM SQ)	PERCENTAGE
Residential	84.22	49.39%
Commercial	2.97	1.74%
Public Semi Public	5.79	3.40%
Public Utilities	1.74	1.02%
Industrial	18.82	11.04%
Transport	16.42	9.63%
Water Bodies	4.96	2.91%
Agricultural & Reserve	31.27	18.34%
Recreational	4.32	2.53%

Source: Comprehensive Mobility Plan, PCMC

1.4.7 Road network pattern

PCMC area is characterised by the old MIDC and the newly extended areas. Most of the developed area of PCMC has a good road network connecting the main roads and arterial roads in a planned manner. The central areas of the city comprising old PCMC areas and MIDC areas have a dense and narrow road network in comparison to the new areas to the north and west of the city where the roads are comparatively wider. The road network in the PCMC area functionally comprises arterial roads, sub-arterial roads, collector roads and local streets. Most of the arterial roads have few encroachments, which however is not the case with sub-arterial and collector roads. Proposed Road Network for PCMC is given in Figure 13:

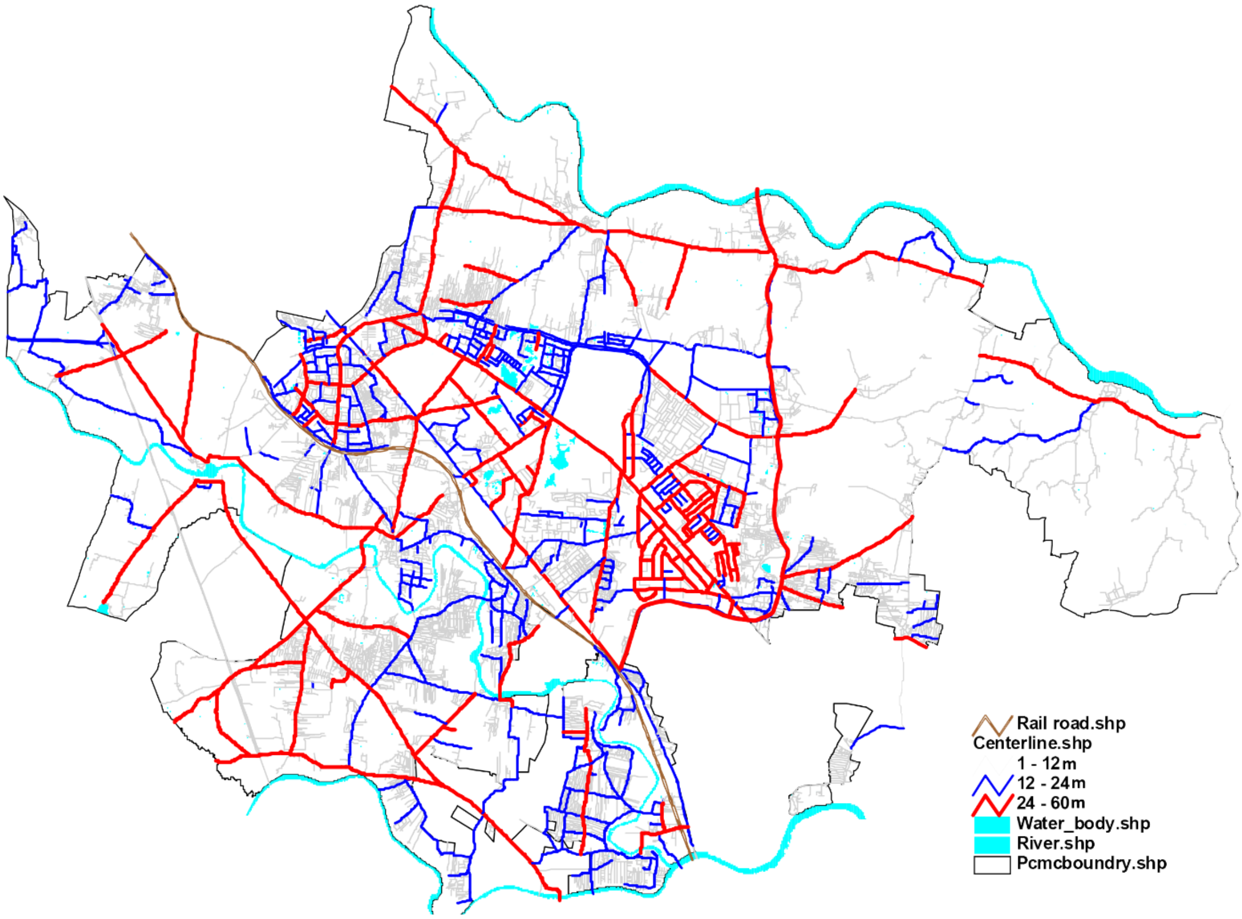


Figure 13 : Proposed Road Network in PCMC
Source: Comprehensive Mobility Plan, PCMC

1.4.8 Development of a metro network

With the projected increase in the city's population, strengthening and augmenting the existing transport infrastructure has assumed urgency.

This situation has thus called for the development of an MRT system and in 2016, Phase I of Pune Metro Project was approved by the Central Government of India. It is Maha Metro – Pune Metro that is in charge of the implementation of the Pune Metro Project.

The metro system will connect different parts of the city area with the developed and developing areas. Although the city has relatively low population compared to other metropolitan cities, a planning for a modern transportation system for Pune city shall help it to grow in terms of industrialization and commercialization.

2. EXISTING TRANSPORTATION SYSTEM IN THE CITY

2.1 Introduction

At present, the public transport system in Pune & Pimpri Chinchwad consists mainly of buses, and a few services of Bus Rapid Transit (BRT) System and suburban rail at present.

The public transport share has been completely overthrown by the tremendous growth in private vehicle transport. The vicious cycle of increase in private vehicle ownership (mostly two-wheelers and cars) has become unstoppable due to the increased transport demand and lack of convenient public transport options. In a nutshell, in the absence of augmentation of mass transit services, Pune may head towards unsustainable urban transport scenario. In order to augment public transport system to cater to the rapid increase in demand for transportation services and make urban transportation in Pune & Pimpri Chinchwad sustainable, the implementation of metro rail was envisaged, and Metro Master Plan was prepared by Delhi Metro Rail Corporation (DMRC) in 2008.

2.2 Vehicular growth and composition

2.2.1 Vehicular Growth in PCMC

The total vehicle population in PMC as on 31st March 2018 was 36.2 lakhs (under the Regional Traffic Office MH-12), and the total number of registered vehicles in PCMC is 15.68 lakhs in which 11.69 lakh two wheelers and 2.54 lakh four wheelers. Thus around 51.88 lakh vehicles are registered in PMC and PCMC. There has been a 700 per cent increase in the number of vehicles in Pune Urban Agglomeration in the last 20 years as per Regional Transport Office (The Indian express, 2017).

The analysis of vehicle registration data from the year 2012 to 2017, Compound Annual Growth Rate (CAGR) was calculated between 2012-13 to 2016-17 for various classes of vehicles. It can be noticed that two-wheelers constitute to 68.70% of the total vehicles, followed by cars with 22.70%. (Source: CMP of PCMC & PMC, 2018). It has been observed that regarding the impact of an increased vehicle population in Pune city very few studies have taken place after year 2000. According to the Srinivas Bonala, 2004 (Author), Pune city is facing problems like increased traffic congestion, reduced driving speed, increased environmental pollution and degradation of the quality of life. The capacity of many intersections has been exhausted. The central city is experiencing capacity gaps, parking problems, low-speed travel, increased congestion, and environmental pollution leading to worsening air quality. The article (India Together, 2004) reports that Pune's municipal transport system, is suffering due to an increased population, inadequate bus fleets and resources, increasing competitive private modes of transport and neglect from political and administrative officers. Pune has been labeled the 5th most polluted city in Asia. 65% of this pollution in Pune is caused by vehicular emissions.

2.3 Road network characteristics

Pune district is well connected with the state capital and surrounding headquarters through road linkages. The road network consists of Express Highways. National Highways, State Highways and Major District Roads. The district has total length of 13,642 km of roads.

Pune is connected to other major cities through Highway roads converging towards the centre of the city, 3 of which are going through the areas that are in the study perimeter (see figure below):

- Katraj (NH48 to Kolhapur);
- Pimpri-Chinchwad (NH65/48 to Mumbai);
- Chakan (NH50/60 to Nashik).

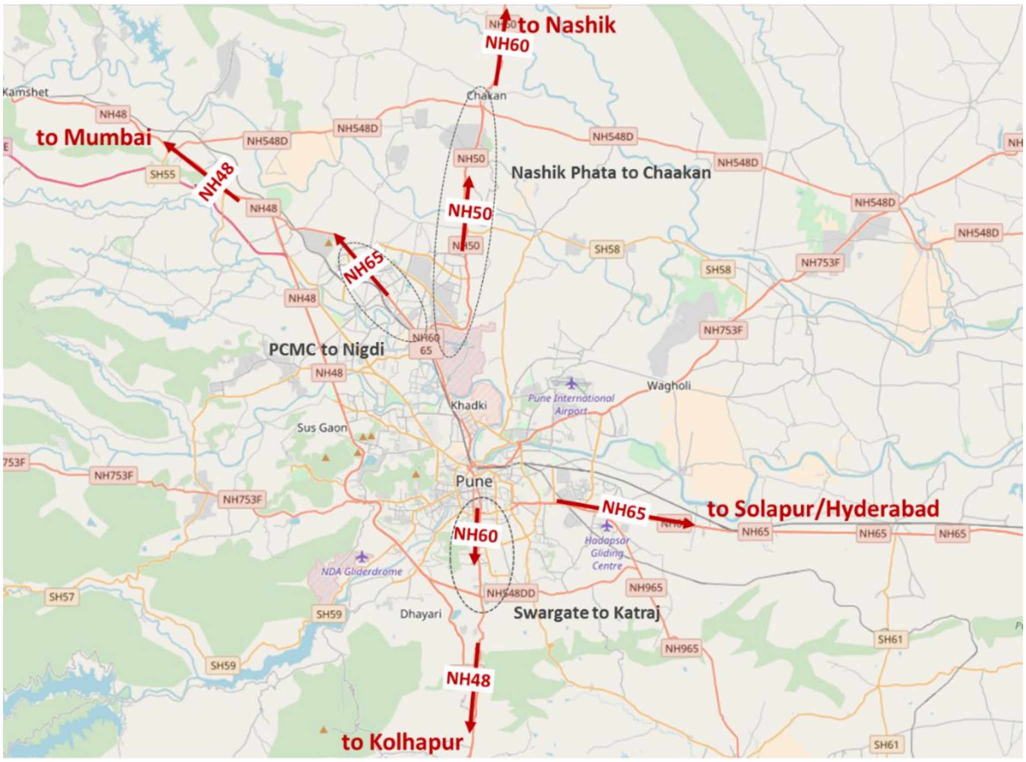


Figure 14 : Map of Main Highway Roads from Pune to other Major Cities
(Source: Open Street Map, 2018 & Systra, 2018)

2.4 Major transport nodes

2.4.1 Road Network

The Pune is located to the South East of Mumbai at a distance of 150 km. The Mumbai-Bangalore National Highway (NH-48) passes through the city and runs towards southern direction. Pune is well connected with all the major cities of India by network of National and State Highways. Some of the major highways passing through the study area are as follows:
• Mumbai - Bangalore National Highway (NH 48)

• Pune - Hyderabad National Highway (NH 65)
• Pune Nashik National Highway (NH 60)
• Mumbai Pune Expressway Major State Highways include
• Pune- Ahmednagar- Aurangabad State Highway
• Pune- Alandi State Highway
• Pune- Saswad- Pandharpur State Highway
• Pune- Paud Road State Highway
• Talegaon- Chakan State Highway The Mumbai-Pune Expressway is India's first six-lane expressway, and was built in 2002. The expressway has reduced the travel time between Pune and Mumbai to almost two hours.

2.4.2 Rail Network

The district of Pune has a total rail network of 311 km. Pune is one of the two main stations of the district (the other being Daund). Following are the three main railway routes pass through the district:

- Mumbai-Pune-Solapur;
- Pune-Miraj;
- Daund-Baramti.

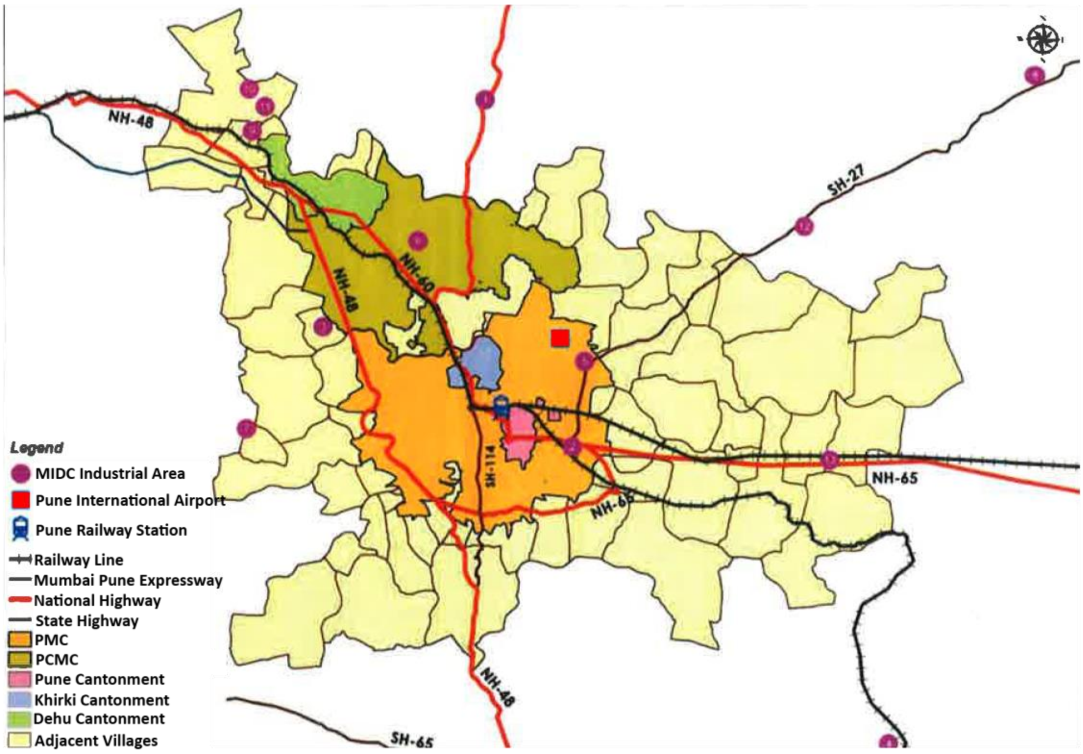


Figure 15 : Map of Major Transportation Nodes in and around Pimpri chichwad City

2.4.3 Bus

2.4.3.1 Intercity bus service

MSRTC is a state run bus service of Maharashtra. it operates buses from Pune to all major parts of the state from four bus terminals: Swargate, Shivaji Nagar, Pune Railway Station and Vallabh Nagar. Buses to Mumbai, Solapur, Nasik, Shiridi etc will be plying at regular intervals from Pune. Wide range of services is operated by MSRTC which includes Ordinary, Asiad, Hirkani, Ashwamed, Shivneri and Shivshahi.

Apart from MSRTC, state transport corporations of neighboring states such as Gujarat, Karnataka and Telangana also operates bus services to Pune.

2.4.3.2 City Bus Service

PMPML is responsible for operating bus service in the city and its suburbs. The fleet size of PMPML is about 1,500. The average life of fleet is 8 years. Average number of buses on road per day is 1,382 operating on 371 routes. On an average 17,000 trips per day and carrying around 10.65 lakhs trips passengers per day with average occupancy of 770 passengers per bus. PMPML operates various services like Regular Service, Rainbow Buses, Night Buses, Pune Darshan, Ladies Special and Airport Buses. At present PMPML have 13 bus depots and 2392 bus stops which clearly indicates need for replacing old fleet with new one. The 13 bus depots are at Swargate, Shivaji Nagar, Kothrud, Katraj, I-Iadpasar, Market Yard, Upper Depot, Pune Railway Station, Nigdi, Pimpri, Bhosari, Wagholi, Bhekrai Nagar. Apart from these the other major bus stands are Deccan Gymkhana, PMT Bus Stand, Mahatma Gandhi Bus Stand at Pulgate, Bhakti Shakti Bus Stand in Nigdi and Chinchwad Bus Stand.

2.4.4 Airport

Pune International Airport is located at Lohegaon at around 10 km from the city. It is operated by the Airports Authority of India (AAI). AAI shares its runways with the Indian Air Force base. In addition to domestic flights to all major Indian cities, the airport serves international direct flights to Dubai and Frankfurt. In 2017-18, the airport has handled about 8.16 million passengers and 41,566 tonnes of cargo. The current Airport is saturated and the new green field airport is proposed at Purandhar on southern side of Pune city near Saswad town.

2.4.5 Metro

2.4.5.1 Pune Metro Project – Phase I

The Phase I of Pune Metro project comprises two lines. The two lines with 30 stations are presented on the Figure 16.

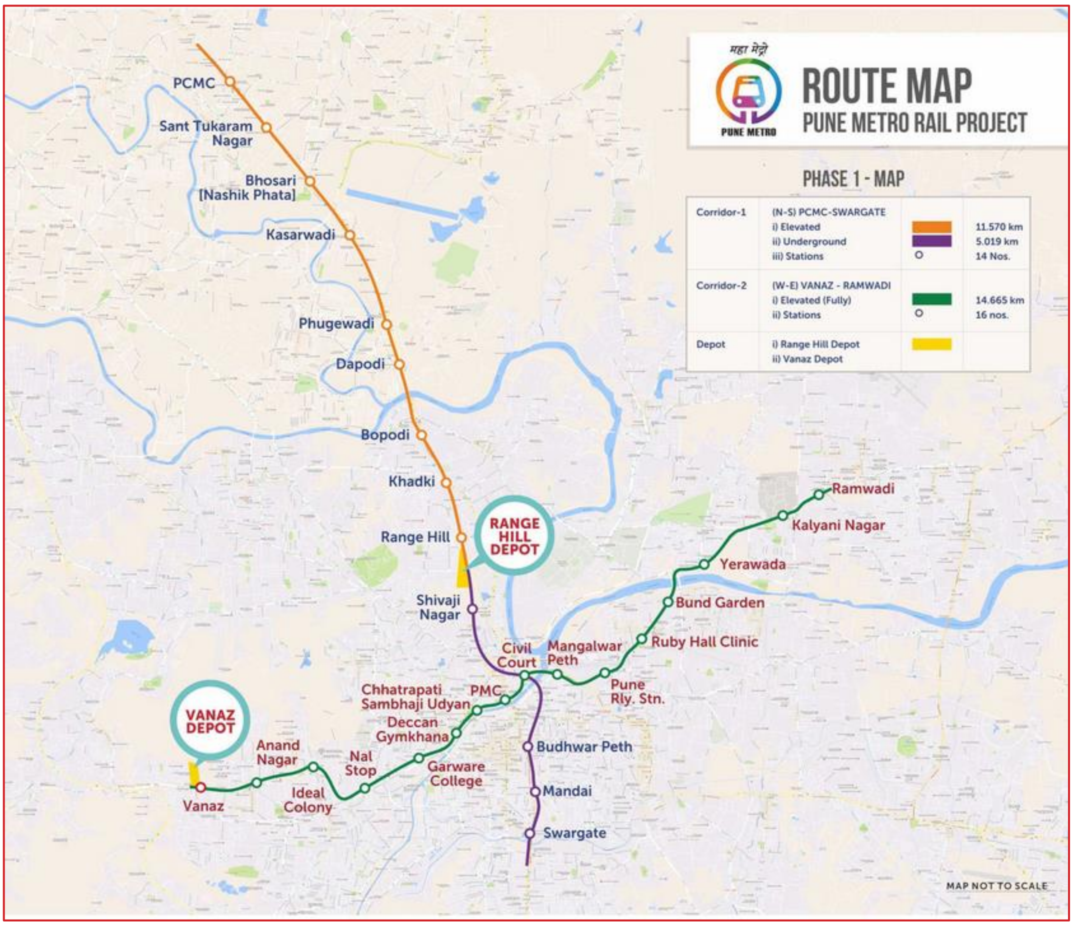


Figure 16 : Map of phase 1 Pune Metro Project

(Source: Maha Metro – Pune Metro, 2018)

- **Line 1** running from North to South from PCMC to Swargate. It is 17.8 km long and comprises 14 stations including 5 underground and 9 elevated stations;
- **Line 2** running from West to East from Vanaz to Ramwadi. It is 15.7 km long and comprises 16 elevated stations.

As mentioned above, Phase I of the Metro Project was approved in 2016 and construction is currently taking place on the two lines.

In addition, Line 3 is also planned under PPP model, which will be running between Shivajinagar and Hinjewadi. Line 3 metro is 23.33 km long and comprises of 23 stations.

2.4.5.2 Pune Metro Project – Phase II

Maha Metro – Pune Metro is planning to further develop this metro network as an extension of Phase 1 to cater to the fast development of the city.

After experiencing the rapid growth, particularly in the out-growth areas of PMC & PCMC and Chakan area, the Government of Maharashtra/ Maha Metro – Pune Metro is planning to further develop the metro network as an extension of Phase I.

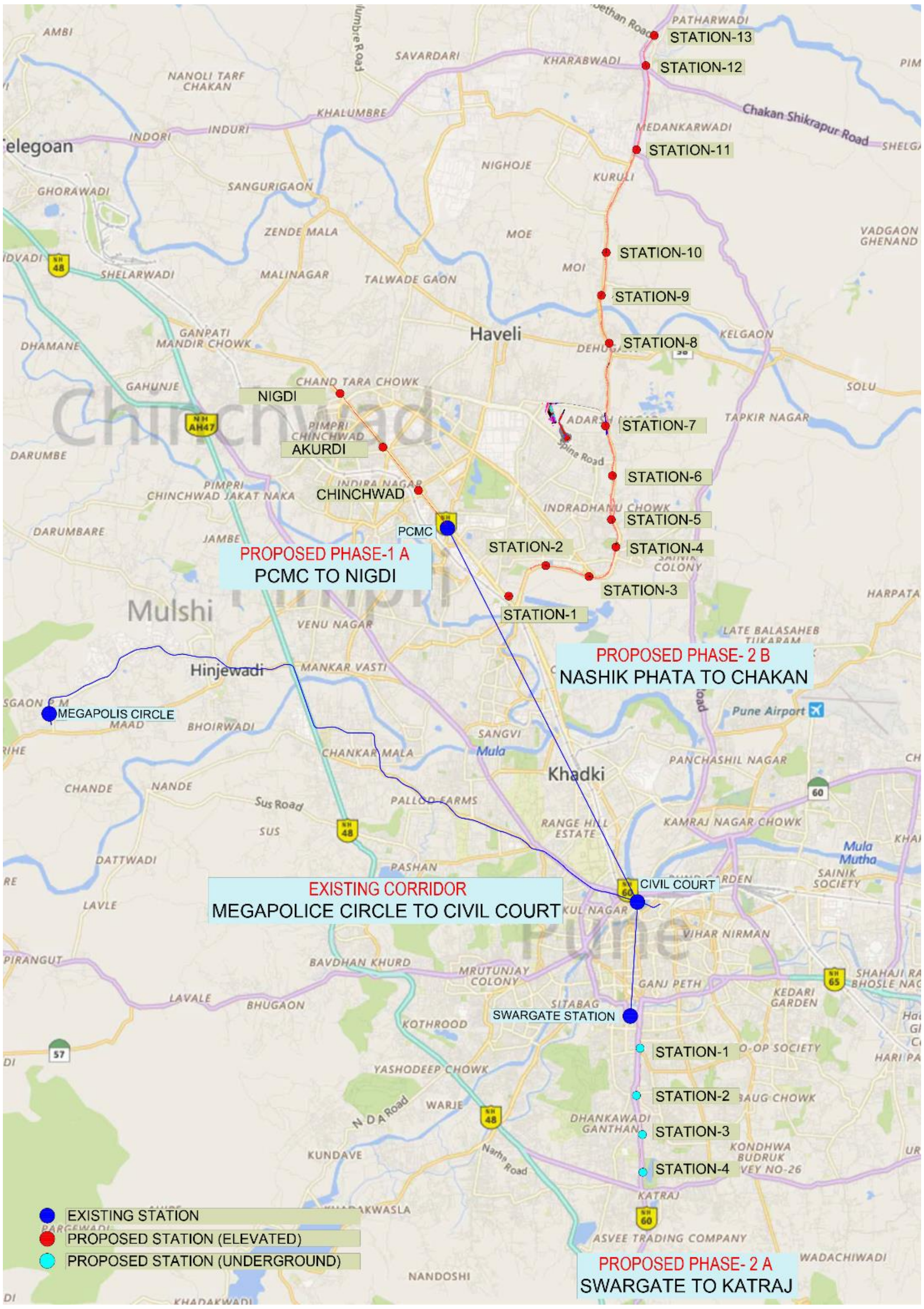


Figure 17 : Pune Metro Project Corridors

Extension of Phase 1 i.e. From PCMC to Nigdi (corridor 1A) , and Swargate to Katraj (Corridor 2A) have received the in principal approval of Government of Maharastra in October 2013. This extension corridors, as part of Pune Metro Phase II, include:

This development includes:

- **Corridor 1A**, which is an extension of line 1 from PCMC to Nigdi in the North (4.413 km);
- **Corridor 2A**, which is an extension of line 1 from Swargate to Katraj in the South (approximately 5.51 km);
- **Corridor 2B**, which is a new line running from Nashik Phata on line 1 to Chakan in the north east of the city (21.30 km). It will have interchange station with existing Bhosari Station.

These corridors are presented in Figure 17 (red lines)

2.5 Traffic Management Including parking management

Mobility Management (also called Transportation Demand Management or TDM) Is a general term for strategies that result in more efficient use of transportation resources, as opposed to increasing transportation system supply by expanding roads, parking facilities and facilities for private vehicles. Mobility Management emphasizes the movement of people and goods, not just motor vehicles, and therefore gives priority to modes (public transport, NMT and ridesharing) which optimizes available road space and causes least pollution under congested conditions. Mobility Management is particularly relevant for Indian cites, because of low costs and multiple benefits. The benefits include congestion reduction, savings on road and parking facility development, improved consumer choice, road safety, better environmental quality, community livability, efficient land-use and equity. Mobility Management can provide significant savings to commuters and society by reducing and deferring road-way capacity expansion costs. These measures can be implemented quickly, and target a particular location, time period or user group. More efficient management gives priority to modes that require less space per passenger-kilometer, and to particularly high-value trips such as emergency vehicles and walking etc., In general, Mobility Management should reflect the following priorities: Emergency vehicles/trips, Walking, Cycling, Public Transit, Service/Fright Vehicles, Taxi, Single Occupant Cars, Automobile Parking. Traffic police have a vital role to play in the success of traffic management. This may require special efforts to establish modern traffic enforcement techniques, adequately train and compensation for officers to maintain the professional force, and maintain good communication with general public. Summary of Parking Management strategies is given in the Table 26.

Table 26 : Summary of Parking Management strategies

Method	Advantages	Disadvantages
Pricing and Regulatory Strategies		
Regulate curb-side parking (loading zones, 1-hour limits, etc.) for priority	Low implementation costs	Enforcement requirements
	Flexible- can be quickly changed or apply to specific times	Generates no revenue
		Does little to reduce overall vehicle travel demand
		May shift traffic to other locations

Imposing parking prices	Generates revenue	Enforcement requirements
	Reduces travel demand	Risk of fraud
	Allows higher priority, uses more convenient spaces	May shift traffic to other locations
	Moderate implementation cost	
Require vehcile owners to have an off-street parking space	Reduces on-street parking congestion	Difficult to enforce (some residents may register their vehicles elsewhere)
	May reduce vehicle ownership	
	Low implementation costs	
Tax parking	Generates revenue	May shift traffic to other locations
	May reduce vehicle travel demand	Risk of fraud
More efficient use of parking facilities		
Share parking facilities	Cost effective	Reduces parking convenience
	Can reduce parking requirements	Requires new administrative arrangements
	Flexible	Depends upon circumstances
More acurate parking supply	Cost effective	May create future parking/ congestion problems
	Can reduce parking requirements	
Reduce parking requirements for mobility management programs	Cost saving	Limited guidance avaiable
	Can reduce parking requirements	Requires ongoing management
	Create incentives for employee trip reduction programs	
Transportation management asociations	Can reduce parking requirements	Requires new administrative arrangements
	Can provide many services to business, employees and customers	
Control complementary Parking Passes	Reduce vehicle travel demand	Requires review and enforcement
	Can increase revenue	
Cash out free parking	Can reduce vehicle travel demand and parking needs	Requires new administrative arrangements
	Gives employers a way to reduce parkng demand	Risk of fraud
Unbundle parking	Reduce vehicle travel demand	Requires new administrative arrangements
	Can reduce parking requirements	Risk fo Fraud
	Increases customer choices	
Other strategies		
Location efficient development	Supports land use objectives	Slow to achieve benefits
	Reduce vehicle travel demand	
	Can reduce parking requirements	
	Increases customer choices	

Response to spill over problems	Avoids problems	Requires new administrative arrangements
	Is equitable	
Over flow parking plans	Reduce vehicle travel demand	Requires new administrative arrangements
	Can reduce parking problems	
	Is equitable	
Parking maximums	Saves money	May lead to future parking problems
	Supports land use objectives	
	Reduce vehicle travel demand	
	Can reduce parking problems	
In Lieu fees	Saves money	Requires new administrative arrangements
	Results in more efficient use of parking facilities	May lead to future parking problems
	Reduce vehicle travel demand	
Bicycle parking	Saves money (compared with automobile parking)	Only effective where people want to bicycle
	Support bicycle travel	May lead to future parking problems
	Is equitable	
Improve parking facility design	Addresses many problems	May increase cost
		Require new design guidelines

2.6 Traffic Characteristics

2.6.1 Traffic Volume and Composition

About 10.6 Lakh PCU has been observed at various cordon points in Pune and Pimpri-Chichwad City as Per CMP, 2018. Total of 10.6 Lakh vehicles and 10.18 Lakh PCU has been observed. Satara Road is having highest number of vehicles followed by Mumbai Pune Expressway at Talegoan Toll Plaza. On Khed Shivapur Toll Plaza and Pune-Mumbai Experssway, more number of goods vehicles are observed as high as compared to other locations. Traffic volume on Velhe Bhudruk village Road, Velhe Bhagud MIDC (Mulshi Road) and Nirvi- Nhavare Road is less. Number of vehicles at Kusgaon Toll Plaza is less compared to Talegoan Toll Plaza, as the Kusgaon Toll Plaza is an entry/exit toll plaza to Lonavala.

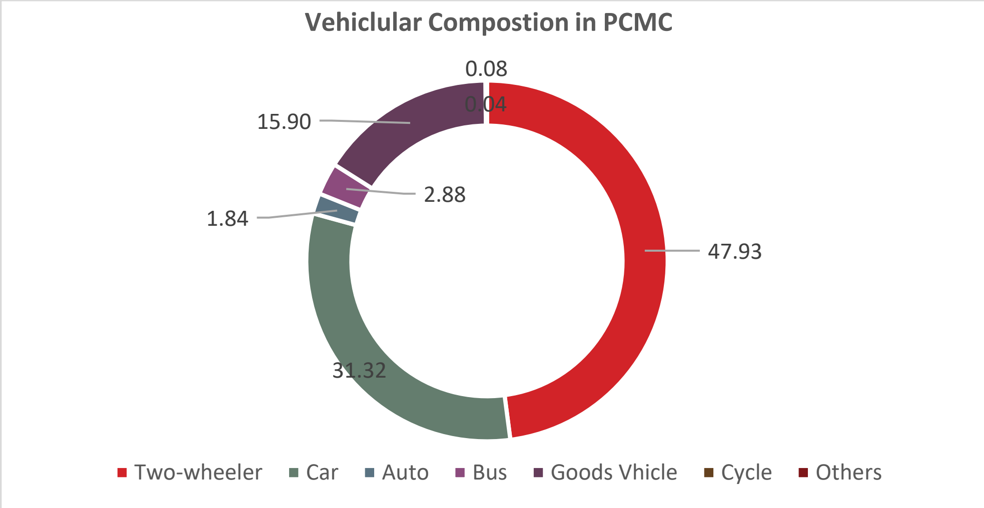


Figure 18 : Vehicluar Composition in PCMC, 2018
(Source: CMP of PCMC & PMC, 2018)

More dominant mode of transport used in PCMC is two Wheeler, followed by car. Cycle is least preferred mode which shares just 4% of traffic composition. The share of two wheelers is more on village roads as they constitute the local trips. The share of goods vehicles is considerably high on National Highways like Nasik Road, Solapur Road, Mumbai Highway and Satara Road as compared to other roads. The share of two wheelers is almost zero on Mumbai Pune Expressway as the movement of two wheelers is restricted on the expressway. Share of buses is also minimal on roads like Velhe Budruk Road, Nirvi- Nhavare Road, Saswad Supa Road and Uruli Kanchan road as these roads are not connecting any major settlements.

2.6.2 Speed and delays

Journey speed is an important parameter to measure traffic flow and Level of Service of traffic. Measurement of speed is frequently required in transport planning particularly to evaluate the road network system, to provide vital inputs to transport demand modelling process and assist in economic analysis of improvement plans.

The average journey speed varies from 10 kmph to 60 kmph in Pimpri Chichwad city. Maximum journey speed of 60 kmph is observed on bypass road. This is due to four lane divided carriageway in good condition. Some roads like Laxmi Road, NC Kelkar Road, Shivaji Road, Bajirao Road, Jawaharlal Nehru Road etc the speeds are very less as these roads are in CBD area where the speed of vehicles is being affected by various factors like pedestrian flow, narrow roads, heavy vehicular flow and roadside friction such as on-street parking, encroachments etc.

2.6.3 Pedestrian and NMV movement

As per CMP, 2018, Maximum number of pedestrians in peak hour are observed at Belbaug chowk which is around 13,000, this is because of Dagdusheth Halwai Ganapati Temple and commercial areas on Shivaji Road. On mid-block locations, maximum number of pedestrians are observed on Lal Bahadur Sastri Road near Rambaug colony road.

Less than 15% of road network is covered with NMV facilities.

2.7 Traffic safety

Various traffic safety measures are proposed in CMP pertaining to Road marking, signage and street lighting. Proper signs will be installed at appropriate locations as per guidelines provided in IRC publications 67-2001 ' Code of practice for Road signs'. The following short term alternatives may be considered for implementation:

- Speed breakers and humps be marked and signed adequately for night time visibility,
- All traffic signages be made retro reflective,
- Install minimum pavement markings such as lane lines, median lines, stop bar, fog line, etc.
- Ensure that adequate street lighting is provided on all collectors, sub-arterials, and arterial roads

Improvement in street lights are also proposed. Along with this, strategies for junction improvement and traffic calming measures are also considered.

2.8 Intermediate Public Transit (IPT) System

Auto rickshaws are the main IPT modes in Pune. The various modes of IPT in Pune are: Auto-rickshaw, Share Auto and Taxi services which include application based taxi aggregators like Ola and Uber. There are no specific route restrictions for these autos. Auto rickshaws running on the streets of Pune provide better connectivity to the city core which has a narrow road network. Many people prefer them over local bus service due to shorter wait time and point to point service. A total of 50,892 auto rickshaws, 46,511 taxies and 7759 other passenger vehicular permits are availed in Pune and Pimpri-Chinchwad.

2.9 Public Transportation System

Bus and Railway are the types of public transport available in the city. Inter city as well as city bus service is available. BRTS is also in Place. Bus is the most common public transport system used in the city. With time, usage of city bus service has been decline due to change in personal choices as shown in PMPML passenger data (Table 27).

Pune BRTS is India's first BRTS system. BRTS in Pune is named as Rainbow BRTS. BRTS serves both Pune and PCMC. At present 4 corridors of 38km is operational. Rainbow BRTS caters to 51 routes with 319 buses plying along 4 corridors.

However, it is not fully segregated system. The BRTS system has several issues i.e. lack of exclusive right of way for buses on several sections of the route, poor condition of buses, lack of safe access to BRTS stations, lack of bus priority at intersections etc. Due to the above constraints, the system is yet to attract good ridership. For success of BRTS, strict enforcement and traffic discipline is required. BRTS route from Dapodi-Nigdi on Pune-Mumbai highway will be operational soon.

Table 27 : Yearly PMPL Passenger data (2013-2017)

YEAR	TOTAL PASSENGERS	DAILY PASSENGERS
2013-14	424894432	1164094
2014-15	444357132	1217417
2015-16	411503942	1124328
2016-17	393916615	1079224

Source: CMP, PCMC, 2018

Another form of Public transportation is sub urban railways. Pune Suburban Railway is operated by Central Railway between Pune to Lonavala, runs on double line electrified broad gauge section of 63.84 km. The suburban trains are operated from Pune to Lonavala regularly to cater the suburban traffic. In a day 18 trains are being operated from Pune to Lonavala and 5 trains between Pune and Talegaon. The minimum headway of the trains is 30 minutes and generally frequency is observed to be low, which makes the system heavily crowded in peak hours. A large number of students, employees, industrial workers travel by the local trains and the poor frequency of trains leads to increased rush of passengers through the day. Mumbai Rail Vikas Corporation is planning for 3rd and 4m line between Pune and Lonavala, exclusively for suburban rail operations. Stations along Pune-Lonavala railway line are Shivajinagar Station, Khadki Station, Pimpri Station, Chinchwad Station, Akurdi Station, Dehu Road Station, Talegaon Station and Lonavala Station. It covers Lonavala to Daund and Pune to Miraj.

Metro: Metro has been approved for the Pune In December 2016. Pune Metro project has been undertaken by MAHA Metro, a SPV (Special Purpose Vehicle) of Government of India and Government of Maharashtra. Surveying and design work of Pune Metro has begun in June 2017. It will be a combination of elevated and underground sections, with initial routes being planned between PCMC - Swargate and Vanaz - Ramwadi. The estimated cost of the project is about Rs.11,522 crore. The project is expected to be completed by 2021.

2.10 Past proposals from CMP/CTTS/Transport Master Plan

2.10.1 Mass Transit system

Under CMP, 2018, the public transport network and system has been selected, considering the evaluation of public transport networks. Metro, Light Metro and BRT systems have been recommended for various corridors. The recommended Public transport network in 2028 is presented in Figure 19.

Table 28 : Recommended Public Transport Network and system, 2038 (CMP 2018)

		Length in Km (2028)	PHPDT (2028)	Length in Km (2038)	PHPDT (2038)
Metro Corridor					
1	Nigdi – Katraj	33.63	15500	33.63	19000
2	Chandani Chowk – Wagholi	25.99	13000	25.99	18000
3	Hingewadi - Hadapsar	30.35	13500	30.35	22000
4	Sinhagad Road	9.08	9500	9.08	16500
5	Hinjewadi - Chakan	30.08	14000	30.08	24000
6	Warje to Swargate			8.87	8000
7	Wagholi-chikali-Hinjewadi			35.23	95000
	Total	129.1		173.2	
BRTS Corridor					
1	Yerwada – Airport	5.05	2000	5.05	2500
2	Kalewadi phata – Chikali	12.03	2500	12.03	3400
3	HCMTR PMC	38.45	2200	38.45	2900
4	HCMTR PCMC	31.40	2000	31.40	2700
5	Chinchwad-Talewade	12.00	2800	12.00	3500
6	Total	98.93		98.93	

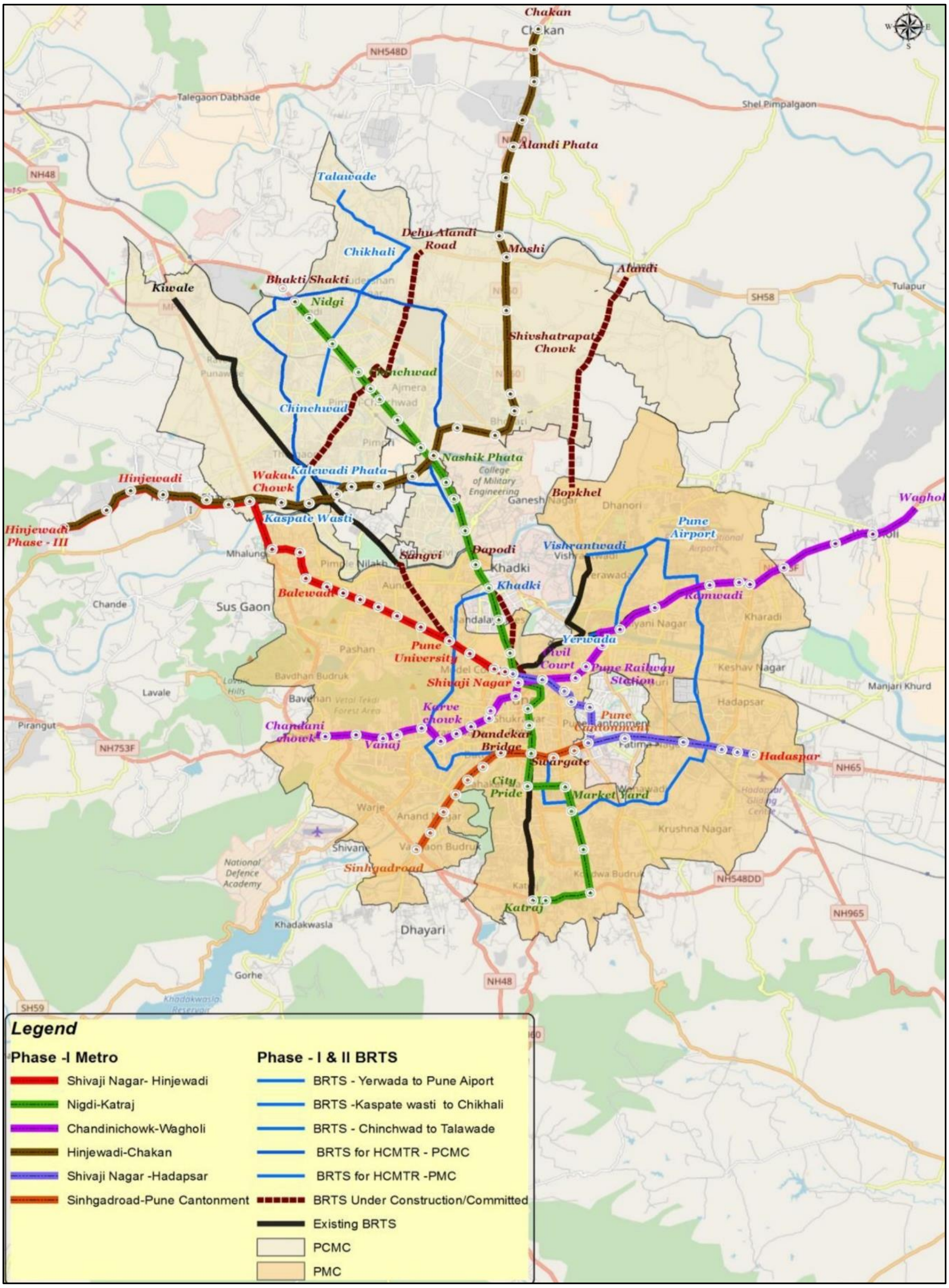


Figure 19 : Recommended Mass Transit Corridors in 2028 (CMP, 2018)

2.10.2 NMT Improvement Plan

2.10.2.1 Efforts by PMC

In view of the importance of NMT infrastructure, PMC has initiated several projects besides establishing the NMT Cell. The projects initiated by PMC are listed below:

• Bicycle Master Plan for Pune prepared in 2017. It is under implementation.

• Public Bicycle Sharing scheme (PBS) is prepared and is under implementation

• Pune Street redesign as per Urban Street Design Guidelines

• SMART City Street Development (for ABD Area)

• Pedestrian Policy A Non-Motorized Transport (NMT) Cell was set up in 2008 by PMC to look at the issues related to pedestrians and cyclists, and provision of footpath and bicycle track infrastructures.

The objective is to plan and maintain consistent, high quality pedestrian infrastructure with equitable allocation of road space. The Cell has planned to develop 75km footpath along BRT and complementary 15 km bicycle tracks on following roads:

- Sancheti-Aundh road
- Wakdewadi-Harris Bridge
- Alandi road
- Nagar road
- Nehru-Market yard road
- Upper Indiranagar road
- Satara road
- Sinhgad road
- Karve road
- Paud road

The bicycle plan for Pune has recommended formulation and implementation of following:

- City-wide Bicycle Network
- Bicycle Design Guidelines
- Public Bicycle System
- Outreach and Promotion
- Monitoring and Evaluation
- Bicycle Parking
- Integration with Transit
- Regulation and Enforcement
- Implementation Schedule

It envisaged a construction of 375 km of footpath at a cost of Rs.375 crore and Bicycle tracks for 75 km at a cost of 150 crore during 2016-2020.

2.10.2.2 Efforts by PCMC

PCMC has created bicycle tracks along several roads but most are being used to park vehicles or are encroached by hawkers. Bicycle tracks are built along the BRT routes. There is a need to ensure that the bicycle tracks are free of encroachments. PCMC is exploring to implement the PBS. The length of bicycle tracks in PCMC is around 10 km.

Proposals for footpath widening, pedestrianisation, provision of NMT Facilities , bicycle sharing scheme have been proposed in PMC and PCMC.

2.11 Issues and Prospects

- PCMC Area is transforming from a major industrial area to a mixed land use city with high residential development. This is likely to add to the already growing private vehicle population and private trips, unless major initiatives are taken to promote public transit.
- Currently, there are only few corridors which can be classified as major arterials. Most of the roads in PCMC Area have varying widths (both ROW and Pavement), which would limit the capacity and hamper traffic flow. The implementation of the DP Proposals would improve this situation considerably, but will not be sufficient to create a topology that is required for the city of the size of PCMC Area. It is anticipated that, in future, due to developments at Hinjewadi, Talawade and Chakan, the city will grow perpendicular to the current development along Old NH4. It is suggested that the proposed future network takes this aspect into account.
- While the riding quality of roads in PCMC Area is maintained to good standards, considering the likely increase in the future road network and traffic, it is essential to develop an efficient Pavement Management and Budget Allocation System for the City.
- The growth of accidents (in absolute numbers) and traffic safety is not an alarming issue. However, to derive purposeful solutions in future, it is important to develop and implement an efficient Accident Information System.
- There are very few off-street parking facilities available in PCMC Area. Multi storied parking complexes need to be developed at major transport nodes, like, local railway stations, Inter City Bus Terminus at Sant Tukaram Nagar, and at major traffic generators in PCMC Area. A combination of traditional (manual), semi automatic and fully automatic parking systems would be required for parking. No NMV facilities are available at present. As part of the road improvements projects being taken up by PCMC, separate lanes for non-motorised vehicles and pedestrians are being proposed in the RoW design.
- Public Transit services of PCMT and PMT, and IPT (particularly 6/8-seater Auto Rickshaws) presently compete with each other on major corridors in PCMC Area. While PMT and PCMT services are being clubbed together in PMPML, PT and IPT would need to be organised so that each mode complements the other.

3. TRAVEL CHARACTERISTIC AND DEMAND ESTIMATE

3.1 Preamble

Pune & Pimpri Chinchwad is the next largest urban conglomerate to Mumbai Metropolitan Region in Maharashtra. The urbanization of this region will receive a big impetus in the next 30 years due to the ambitious development plan of the 7000 sq. km Pune Metropolitan Region (PMR). These cities are considered to be an educational hub due to the establishment of large number of educational institutes across the city. Pune & Pimpri Chinchwad have been experiencing tremendous growth in population and employment since the last two decades. The cities have been stretching its limits to the widest extent possible and urban sprawl has become evident. The growth in various industries, particularly automobile, IT and IT enabled services, in and around Pune & Pimpri Chinchwad has added further impetus to the urban sprawl and increase in population and employment.

The present public transport system in Pune & Pimpri Chinchwad consists mainly of buses, and a few services of Bus Rapid Transit (BRT) System and suburban rail. The public transport share has been completely overthrown by the tremendous growth in private vehicle transport. The vicious cycle of increase in private vehicle ownership (mostly two-wheelers and cars) has become unstoppable due to the increased transport demand and lack of convenient public transport options. In a nutshell, in the absence of augmentation of mass transit services, Pune may head towards unsustainable urban transport scenario. In order to augment public transport system to cater to the rapid increase in demand for transportation services and make urban transportation in Pune & Pimpri Chinchwad sustainable, the implementation of metro rail was envisaged, and Metro master plan was prepared by Delhi Metro Rail Corporation (DMRC) in the year 2008.

The Pune metro project comprised two lines initially (Phase 1), which are being constructed;

Line 1: running from North to South from PCMC to Swargate. It is 17.8 km long and comprises 14 stations including 5 underground and 9 elevated stations.

Line 2: running from West to East from Vanaz to Ramwadi. It is 15.7 km long and comprises 16 elevated stations.

Phase I of the Metro Project was approved by the Government in the year 2016 and the construction is currently taking place on the above two lines. In addition, Line 3 is also planned under PPP model, which will be running between Shivajinagar and Hinjewadi. Line 3 metro is 23.33 km long and comprises of 23 stations. After experiencing the rapid growth, particularly in the out-growth areas of PMC & PCMC and Chakan area, the Government of Maharashtra/ Maha Metro – Pune Metro is planning to further develop this metro network as an extension of Phase I. The extension corridors, as part of Pune Metro Phase II, include:

Corridor 1A, which is an extension from PCMC to Nigdi in the North (4.413 km);

Corridor 2A, which is an extension of line 1 from Swargate to Katraj in South (approximately 5.5 km);

Corridor 2B, which is a new line running from Nashik Phata on Line 1 (Phase 1) to Chakan in north east of the city (approximately 21.308 km).

Pune Metro Project extension Corridor IA and Corridor 2A had received the in-principle approval of Government of Maharashtra in October 2013.

The transport demand model recently calibrated in the year 2017, is used as a base for the modelling process. The travel demand model uses the present and future land use patterns to assess the travel pattern. It then assigns the estimated trips to different travel routes and travel modes, including metro, based on the type and quality of the transportation network.

3.2 Objective and Scope of Traffic Study

The main objective of the traffic study is to estimate the passenger ridership on the proposed metro extension corridors; Nashik Phata - Chakan, PCMC - Nigdi and Swargate - Katraj Corridors; The scope of the traffic study includes;

- Updating the recently validated transport demand model using **CUBE Voyager** Software
- Collection and review of secondary data
- Collection of primary data including carrying out Classified Traffic Volume Counts and occupancy along the proposed metro corridors.
- Patronage forecast on all the metro corridors including the proposed PCMC - Nigdi extension. The forecast includes station wise boarding/ alighting, link loads, PHPDT, etc., for identified land use, transport and fare scenarios.

Figure 20 presents all the survey locations conducted as part of the study.

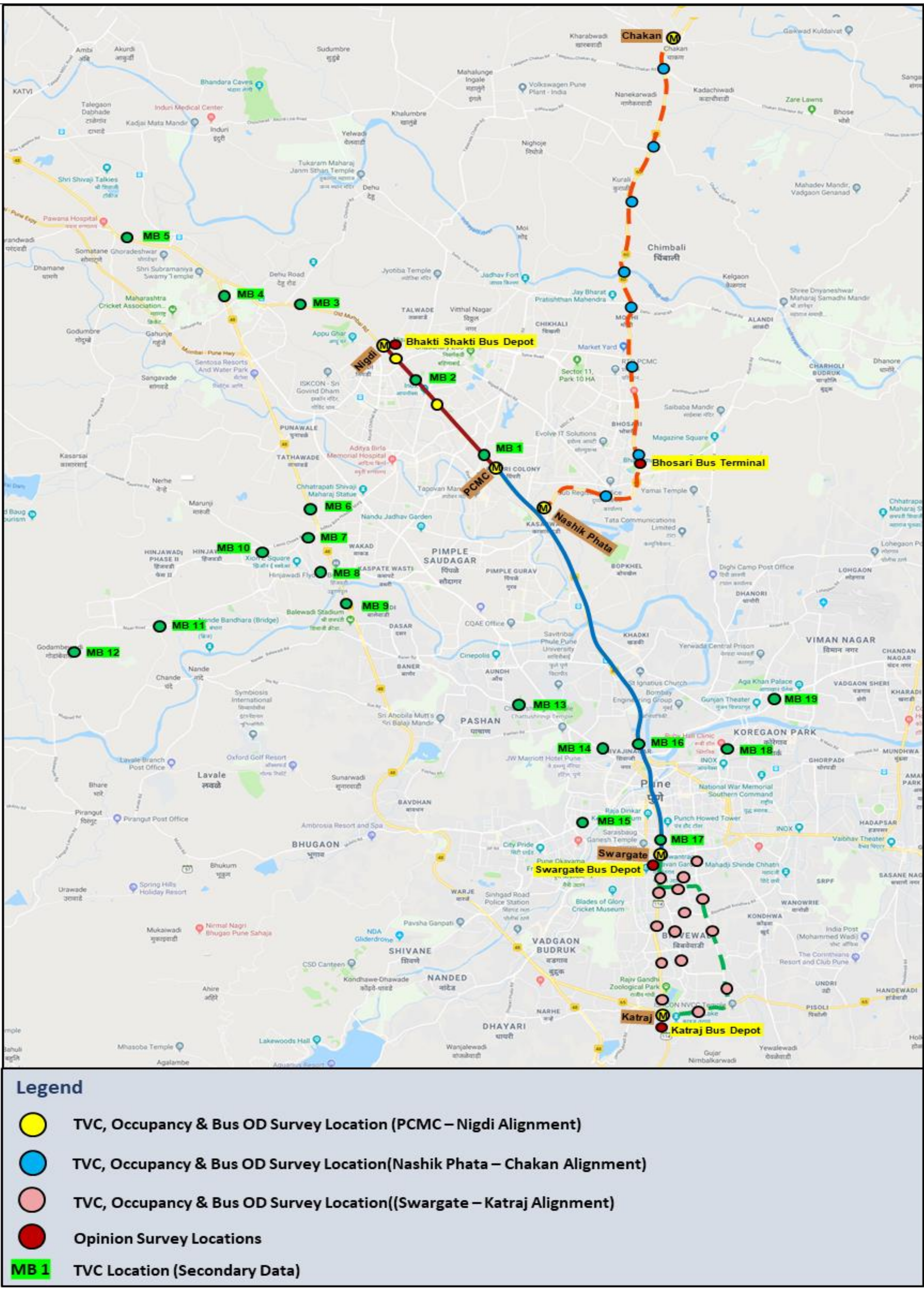


Figure 20 : Traffic survey Locations

3.3 Secondary Data

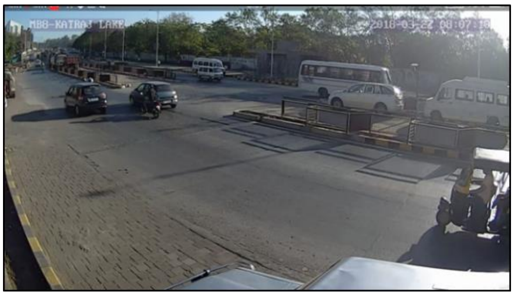
Past traffic and transportation surveys data conducted during earlier studies as well as other related secondary data were collected, and relevant data is compiled. This data is used for updating the transport demand model and its validation.

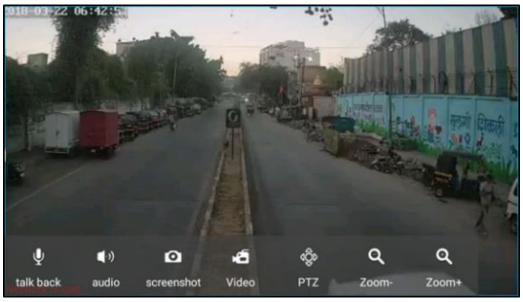
3.4 Primary Traffic Surveys

As part of the present study the following surveys were conducted. The analysis of these surveys is presented in the below sections.

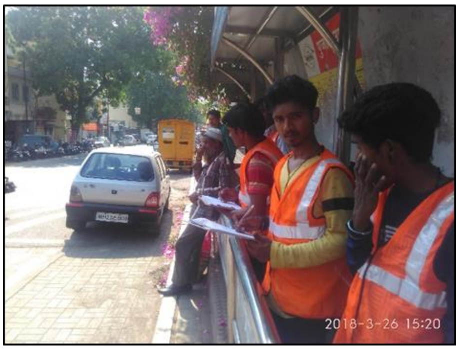
- Classified Traffic Volume Count;
- Bus Origin Destination (OD) Survey;
- Occupancy Survey;
- Opinion Survey

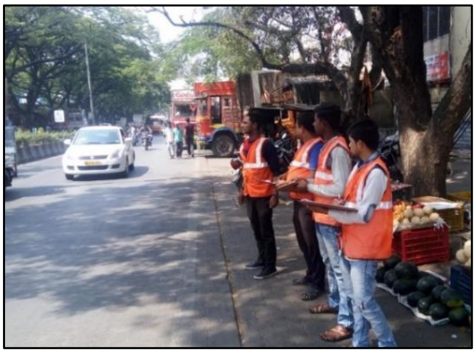
The metro patronage forecast is carried out using the transport demand model, which is calibrated and validated in the year 2017. Considering the data already available from recent past studies, survey locations for Classified Traffic Volume Count (TVC) were identified. Survey locations for Classified Traffic Volume Count and Other Surveys were included in the Weekly Progress Report 03 and 04, submitted to Client. The survey locations are identified along all the proposed metro corridors to know the existing traffic volume and traffic composition. In total, there are 25 TVC locations identified and traffic volume count surveys were conducted by video graphic technique at all the locations. The traffic data was extracted manually by playing video on computer in slow motion for better accuracy.





Bus Occupancy and other passenger modes Occupancy surveys were conducted to assess average number of passengers travelling by each mode. This is done by manual observation technique. The mode wise number of occupants were recorded at all TVC locations. These surveys were conducted simultaneously with traffic volume count surveys and provide the existing mode-wise passenger demand (person trips). Bus OD surveys were conducted at all the locations along with traffic volume counts.





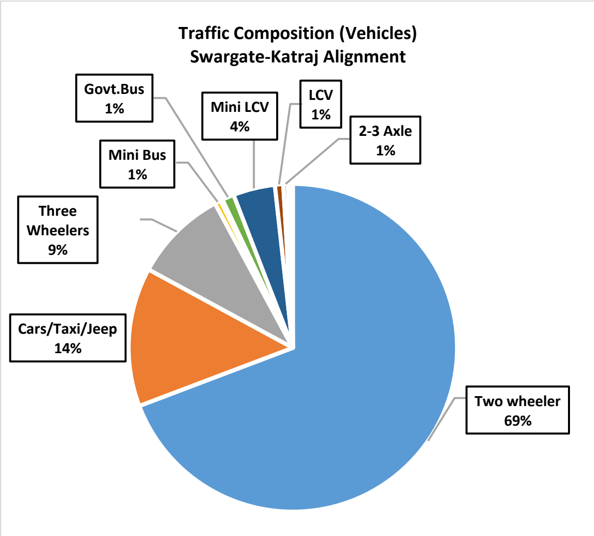
3.4.1 Classified Traffic Volume Count Survey

3.4.1.1 PCMC – Nigdi Section (Corridor 1A)

The traffic survey locations along the PCMC - Nigdi Section are presented in Table 29 and Figure 21 : Traffic Survey Locations: PCMC – Nigdi Section. The analysis of the traffic surveys is carried out and the peak hour traffic, both during morning and evening, at each of the survey locations is presented in Table 30**.**

Table 29 : Traffic survey locations : PCMC – Nigdi Section

Sr No.	Road Name	Landmark
1	MB 1 : Old Mumbai Pune Highway	St. Francis Xavier Church
2	MB 2 :Old Mumbai Pune Highway	Nigdi Private Bus Operator Stand



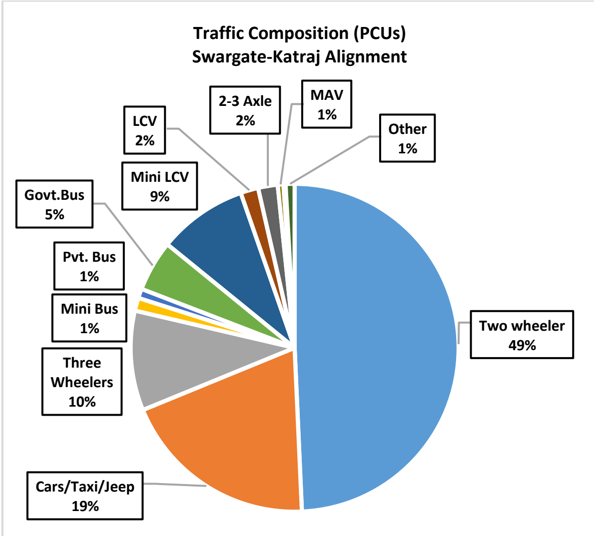


Figure 21 : Traffic Survey Locations: PCMC – Nigdi Section

Table 30 : Peak hour traffic count on PCMC to Nigdi Section

Old Mumbai Pune Highway (MB 1)	Time	Total
Morning Peak (Vehicles)	09:00 AM to 10:00 AM	10830
Morning Peak (PCUs)	09:00 AM to 10:00 AM	7465
Evening Peak (Vehicles)	06:00 PM to 07:00 PM	11148
Evening Peak (PCUs)	06:00 PM to 07:00 PM	7825
Old Mumbai Pune Highway (MB 2)	**Time**	**Total**
Morning Peak (Vehicles)	12:00 AM to 01:00 PM	7060
Morning Peak (PCUs)	12:00 AM to 01:00 PM	5369
Evening Peak (Vehicles)	06:00 PM to 07:00 PM	7756
Evening Peak (PCUs)	06:00 PM to 07:00 PM	6143

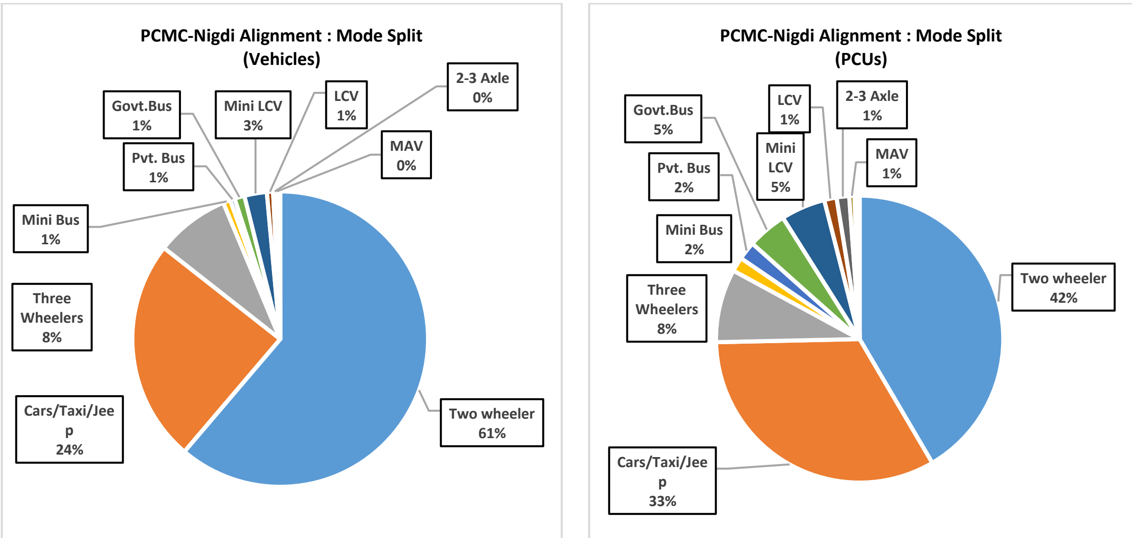


Figure 22: Traffic composition : PCMC – Nigdi section

3.4.2 Passenger Vehicle Occupancy Surveys

Passenger vehicle occupancy surveys were conducted, along with classified traffic volume counts, to assess average number of passengers travelling by each mode. This survey was done by manual observation technique. The mode wise number of occupants were recorded at the selected survey locations. These surveys provide the existing mode-wise passenger demand (person trips) at the survey locations.

Table 31 : Passenger Vehicle Occupancy

Corridor	Two Wheelers	Cars	Three Wheelers*	Bus*
Swargate-Katraj	1.32	2.31	2.67	35.70

** excluding driver*

3.4.3 Opinion Surveys

Opinion survey was conducted to understand the passengers' experience concerning current mode of transport and opinion about willingness to pay for Metro. Four locations (Bus depots) were identified along the proposed metro alignment for opinion survey. The surveys were conducted for 12 hours at each location. Questionnaire for the opinion survey was prepared and the data was collected from the bus passengers. Locations of the opinion surveys are presented in Figure 20. Outcome from the opinion survey is presented in Figure 23 to Figure 26

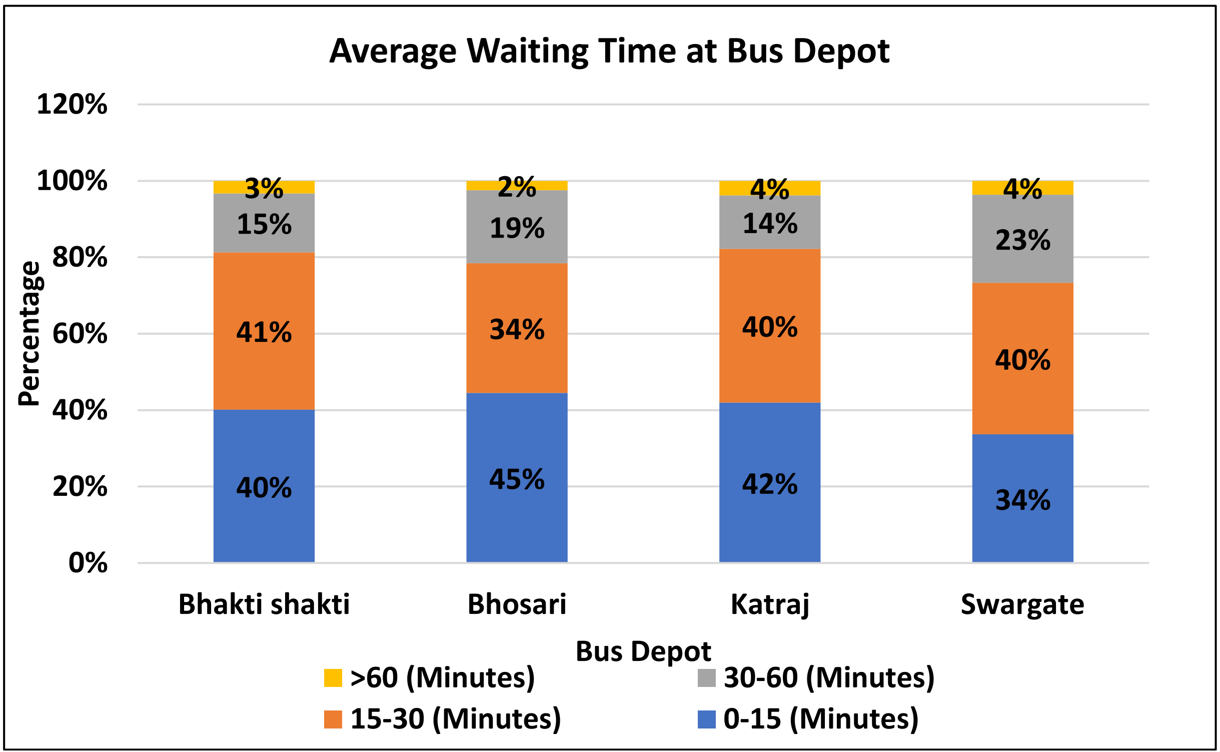


Figure 23 : Average Waiting Time at Bus Depot

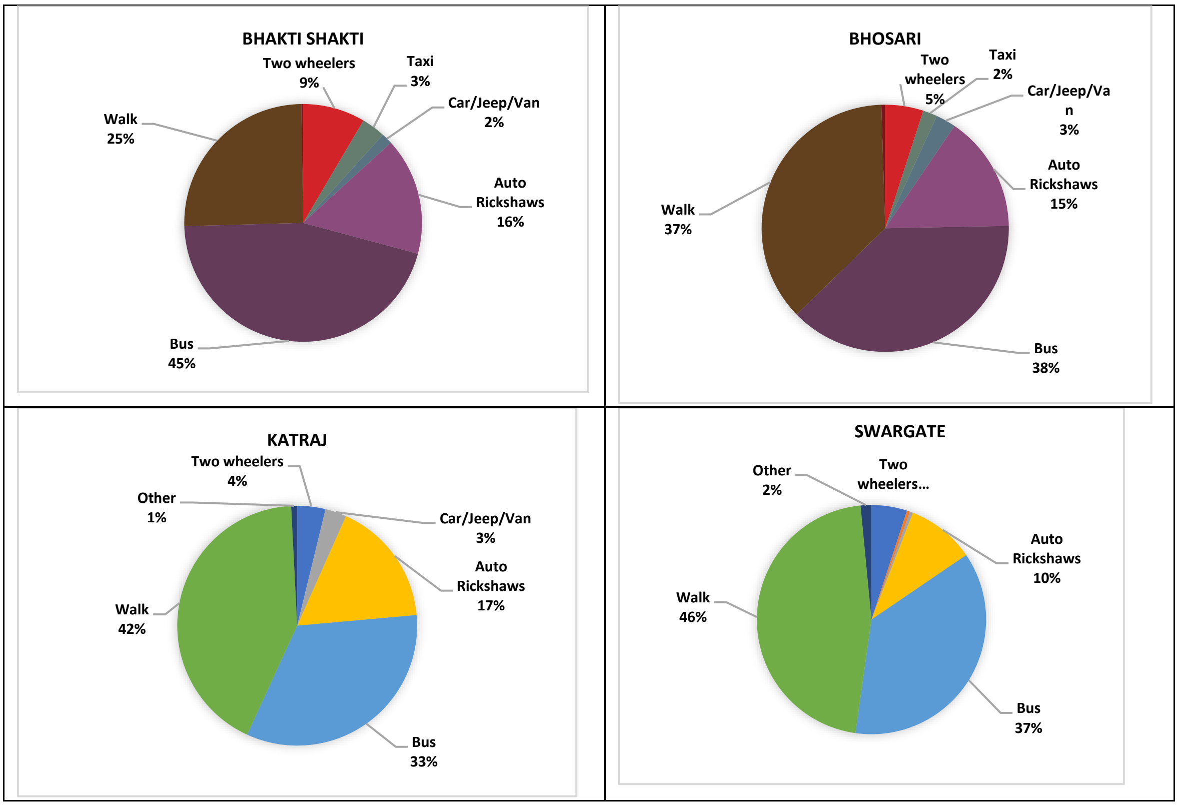


Figure 24 : Access Mode Split

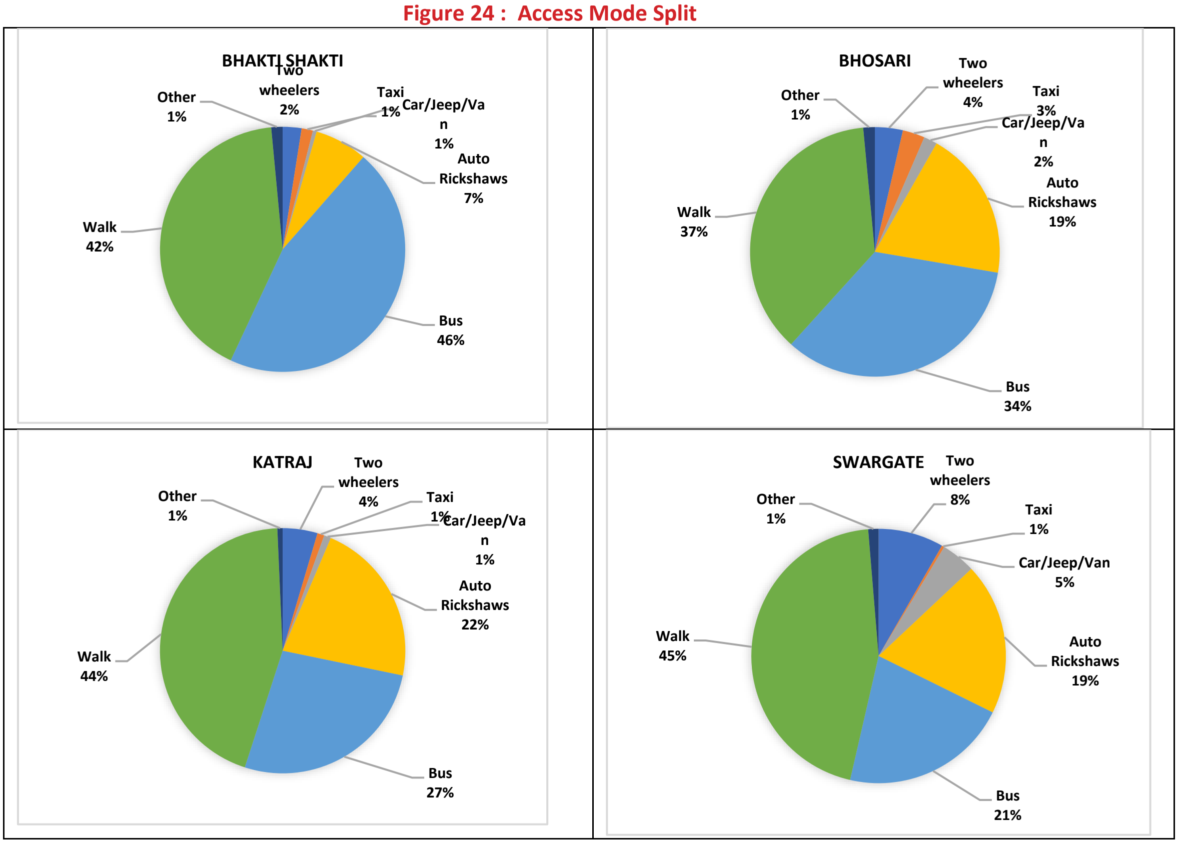


Figure 25 : Dispersal Mode Split

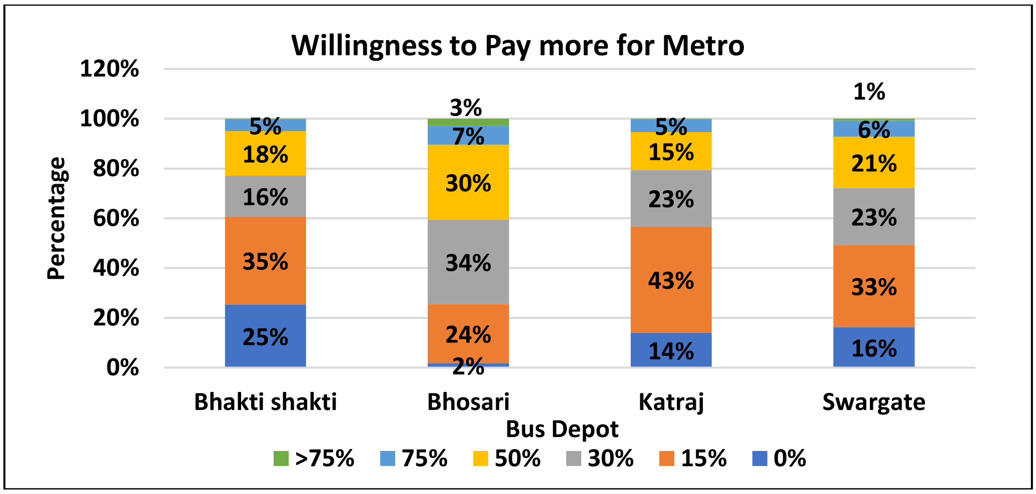


Figure 26 : Willingness to Pay *more* for Metro

3.5 Peak Hour Passenger Trips

Using the peak hour trips and the average occupancy, the existing direction-wise peak hour passenger trips on various sections of the metro extension corridors are estimated and presented in Figure 27.

Figure 27 : Existing Peak Hour Passenger Trips on PCMC- Nigdi section (Right)

3.6 Review of CMP - Traffic Surveys & Analysis

3.6.1 Traffic Surveys at Cordon Location

Table 32 presents peak hour traffic and its share in the daily traffic at cordon locations. Percentage of traffic in peak hour ranges between 5.6% and 9.9% with an average of 7.0%.

Table 32 : Daily Traffic at Cordon Lines

No.	Road/ Location ID	Total		Share
		Vehicles	PCUs	%
1	Moshi Toll Plaza, Nasik Road (L1)	85,455	88,270	8.10%
2	Near Sambhaji Chowk, Alandi Road, Alandi (L2)	63,846	58,152	6.00%
3	Nagar Road (L3)	1,38,570	1,33,484	13.10%
4	Kawadipeth Toll Plaza, Solapur Road (L4)	75,077	79,623	7.10%
5	Saswad Road (L5)	38,514	39,926	3.60%
6	Saswad-Bopdev Road (L6)	38,981	36,008	3.70%
7	Sinhgad Road (L7)	68,432	63,629	6.50%
8	NDA Academy Road (L8)	84,107	72,307	8.00%
9	Near Bhugaon, Mulshi Road (L9)	47,080	42,854	4.50%
10	Shivaji Chowk, Hinjewadi (L10)	1,15,248	1,04,056	10.90%
11	Dehu Road Toll Plaza, Mumbai- Pune Highway (L11)	61,535	65,080	5.80%
12	Talwade, Dehu Alandi Road (L12)	92,980	92,133	8.80%
13	Katraj - Satara Road (L13)	51,933	50,864	4.90%
14	Sus Road (L14)	33,449	30,563	3.20%
15	Nande-Balewadi Road (Mahalunge) (L15)	19,425	16,789	1.80%
16	Manjari Village, Manjari Road (L16)	21,115	19,814	2.00%
17	Lohegaon-Nirgudi Road (L17)	1,751	1,668	0.20%
18	Lohegaon-Wagholi Road (L18)	18,217	17,420	1.70%
Total		**10,55,715**	**10,12,640**	**100%**

Source: CMP for PMC and PCMC, 2018

3.6.2 Traffic Surveys at Screen Lines (16 Hr.)

Screen-lines in the study area are classified into North-South and East-West screen-lines. In the study area, Railway line and Mutha river are considered as North-South screen-lines and Mula and Mula Mutha rivers as the East-West screen-lines in the study area. Classified traffic volume counts are conducted at 59 screen-line locations. Table 33 presents the 16-hour traffic (06:00 a.m. to 10:00 p.m.). Based on analysis, total of about 26.48 lakh vehicles (24.60 lakhs PCU) cross the North- South screen-line locations and 14.36 lakh vehicles (13.28 lakh PCU) cross the East-West every day.

Table 33 : Daily Traffic at Screen Lines (16 Hr.)

No	Road/ Location ID	Vehicles	PCUs	Share %
	North-South			
1	Talegaon Industrial Area (SL 1)	16177	22303	0.61%
2	Talegaon Chakan Road (SL2)	63,673	59,599	2.40%
3	Begdaewadi (SL3)	4,653	4,079	0.18%
4	Dehu (SL4)	50,694	47,695	1.91%
5	Bhau Patil Road (SL5)	28,126	26,883	1.06%
6	Yashwanthrao Chavan Path (SL6)	3,770	3,057	0.14%
7	Khadki Police Chowk (SL7)	58,136	52,281	2.20%
8	Dhanori Alandi Road (SL8)	28,680	25,627	1.08%
9	KB Joshi Path (SL9)	76,304	65,370	2.88%
10	HK Firodia Bridge (SL10)	1,84,933	1,77,961	6.98%
11	Juna Bazar (SL11)	99,433	93,446	3.75%
12	Connaught Road (ROB) (SL12)	42,958	46,444	1.62%
13	Bund Garden Road (SL13)	79,958	79,766	3.02%
14	Koregaon Park Road (SL14)	1,13,462	1,02,882	4.28%
15	BT Kawade Road (ROB) (SL15)	45,658	40,263	1.72%
16	Solapur Road (ROB) Kirloskar (SL16)	31,771	34,798	1.20%
17	Hadapsar Road (SL17)	76,793	74,356	2.90%
18	Western Bypass (After Warje) (SL18)	1,59,621	1,52,646	6.03%
19	Mhatre Bridge (SL19)	1,08,941	95,811	4.11%
20	SM Joshi Bridge (SL20)	62,138	55,271	2.35%
21	Shivaram Mhatre Road (Chavan Bridge) (SL21)	44,752	33,412	1.69%
22	Sambhaji Bridge (SL22)	44,615	61,991	1.68%
23	Kakasaheb Gadgil Bridge (Z Bridge) (SL23)	18,942	14,082	0.72%
24	Baba Bhide Bridge (SL24)	98,093	76,462	3.70%
25	Maha Rishi Shinde Bridge (SL25)	71,123	64,247	2.69%
26	PMC Bhavan Bridge (SL26)	59,044	51,895	2.23%
27	Shivaji Bridge-Nava Pool (SL27)	83,941	81,622	3.17%
28	Dengale Bridge Road (SL28)	75,078	75,422	2.84%
29	Sangam Bridge 1 (SL29)	1,16,910	1,12,685	4.41%
30	Sangam Bridge 2 (SL30)	53,254	49,825	2.01%
31	Ravat Nigdi Road (SL31)	63,741	56,053	2.41%
32	Akurdi Chikhali Road (SL32)	63,430	55,237	2.40%
33	Chinchwad Akurdi Link Road (SL33)	61,780	53,593	2.33%
34	Kaspate Wasti Road (SL34)	89,995	82,630	3.40%
35	Karachi Chowk (SL35)	1,02,480	97,995	3.87%
36	Jawaharlal Nehru Road (SL36)	29,086	23,188	1.10%

No	Road/ Location ID	Vehicles	PCUs	Share %
37	Power House Road (SL37)	17,564	14,671	0.66%
38	Pimple Gurav Road (SL38)	26,495	21,693	1.00%
39	Nashik Phata (SL39)	68,389	62,962	2.58%
40	From Jai Maharashtra Chowk (SL40)	17,385	14,677	0.66%
41	Dapodi Bridge (SL41)	50,160	45,341	1.89%
42	Sangam Cross Road (SL42)	7,861	6,410	0.30%
43	Ghorpadi Road (SL43)	48,023	43,673	1.81%
	Total	**26,48,020**	**24,60,302**	**100%**
	East-West			
44	Manjari Village (SL44)	21,115	19,814	1.47%
45	Theur Kesanand Road (SL45)	11,085	13,358	0.77%
46	Uruli Ashtapur Road (SL46)	3,001	2,558	0.21%
47	Western Bypass Road (SL47)	1,86,776	1,85,778	13.00%
48	Mahatma Jyotiba Phule Bridge (SL48)	44,051	37,466	3.07%
49	Mahadji Shinde Road (Aundh) (SL49)	55,618	47,847	3.87%
50	Rajiv Gandhi Bridge (Aundh Ravet Road) (SL50)	1,13,662	1,03,874	7.91%
51	Jai Ganesh Chowk (SL51)	71,265	60,450	4.96%
52	Old Sangavi Nera Petrol Pump (SL52)	66,130	62,912	4.60%
53	Harris Bridge (Old Mumbai Highway) (SL53)	1,69,809	1,58,236	11.82%
54	Yerwada Bridge (SL54)	1,33,603	1,25,251	9.30%
55	Yerwada Bridge (SL55)	1,37,401	1,29,007	9.57%
56	HH Aga Khan Bridge (SL56)	1,06,985	97,644	7.45%
57	Mundhwa Bridge (SL57)	1,00,833	95,874	7.02%
58	Alandi Road (Near Tata Communication Center) (SL58)	80,863	74,103	5.63%
59	Rajaram Bridge (SL59)	1,34,044	1,13,831	9.33%
	Total	**14,36,241**	**13,28,001**	**100%**

Source: CMP for PMC and PCMC, 2018

3.6.3 Analysis of Mid-Block Volume Count

Classified traffic volume counts are conducted at 15 mid-block locations. The location-wise traffic details are presented in Table 34.

Table 34 : Traffic on Mod-Blocks (16 Hr.)

No	Road/ Location ID	Vehicles	PCUs
1	Pashan Road	71,083	63,053
2	Jaganath Shankarsheth Road	1,35,707	1,24,679

No	Road/ Location ID	Vehicles	PCUs
3	Spine Road	51,295	47,836
4	Lal Bahadur Shastri Road	86,623	81,195
5	Senapati Bapat Road	90,081	80,850
6	Balagangadhar Tilak Road	74,449	69,767
7	RB Kumthekar Road	23,973	24,532
8	Nashik Road	86,048	76,311
9	Dehu Alandi-Akurdi Chikhali Road	59,216	55,844
10	PCMC Link Road	5,807	4,648
11	Morwadi Road	31,678	28,968
12	Timber Market Road	1,06,169	1,08,056
13	Baner Road	79,353	71,035
14	Kondhwa Road	1,30,501	1,27,483
15	Aundh Ravet Road	53,042	47,024
	Total	**7,12,648**	**6,51,063**

3.7 Socioeconomic Characteristics

The total population of Pune Municipal Corporation (PMC) and Pimpri Chinchwad Municipal Corporation (PCMC) as per Census 2011 was 31.24 lakhs and 17.27 lakhs respectively. Table 35 and Table 36 present the past trends of the study area population. The data reveals that the annual growth rate in population of PCMC is highest in the study area.

Table 35 : Past Trends of Population Growth

Year	PMC	PCMC	PC	KC	DC	Total
1961	606777	39654	65838	58496	-	770765
1971	856105	98572	77774	65497	24709	1122657
1981	1203363	251769	85986	80835	33267	1655220
1991	1566651	520639	82139	78323	40555	2288307
2001	2538473	1015598	79965	77473	46921	3758430
2011	3124458	1727692	71781	78684	48961	5051576

Source: Census of India, PC: Pune Cantonment; KC : Khadki Cantonment; DC: Dehu Cantonment

Table 36 : Compound Annual Growth Rate (CAGR) of Population

Year	PMC	PCMC	PC	KC	DC
1961-1971	3.50%	9.53%	1.68%	1.14%	-
1971-1981	3.46%	9.83%	1.01%	2.13%	3.02%
1981-1991	2.67%	7.54%	-0.46%	-0.32%	2.00%
1991-2001	4.94%	6.91%	-0.27%	-0.11%	1.47%
2001-2011	2.10%	5.46%	-1.07%	0.16%	0.43%

PC: Pune Cantonment; KC : Khadki Cantonment; DC: Dehu Cantonment

3.7.1 Age wise Population Distribution

Table 37 and Figure 28 present the distribution of population by age, as per Census 2011. From the data, it can be observed that, the population in the age group of 20-44 years has the highest contribution in the total population; 45.12% in PMC and 49.94% in PCMC.

Table 37 : Age wise Population Distribution in PMC and PCMC

Age Group (years)	PMC	PCMC
0-4	239964	160615
5-9	235616	142356
10-14	242254	131745
15-19	255256	139284
20-24	323148	225375
25-29	338321	227782
30-34	289767	173620
35-39	250558	134418
40-44	207887	101588
45-49	172972	79126
50-54	144551	63056
55-59	118278	48412
60-64	103604	39379
65-69	69702	25192
70-74	49590	15321
75-79	29557	7614
80+	32766	9159
Age not stated	20667	3650
Total	**3124458**	**1727692**

Source: Census of India, 2011

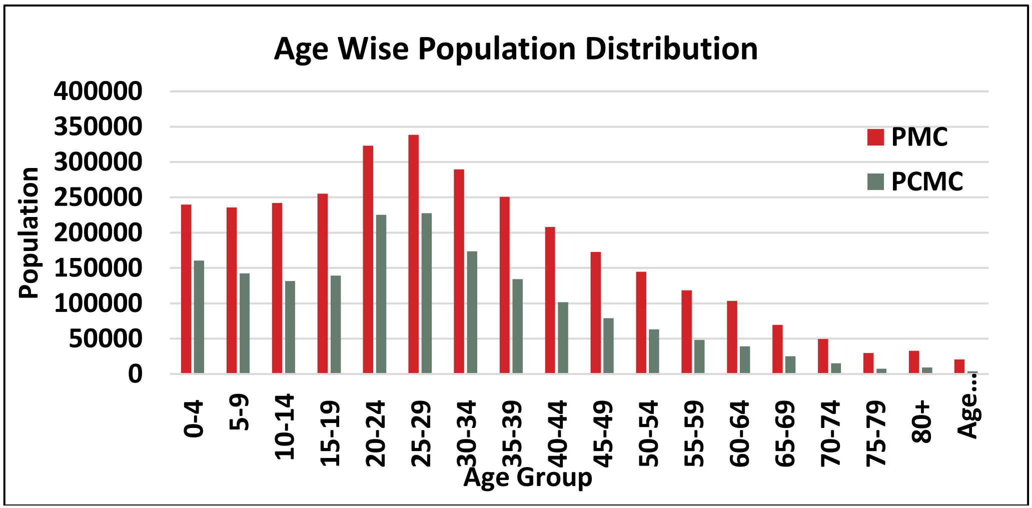


Figure 28 : Age Wise Population Distribution in PMC and PCMC

3.7.2 Literacy Rate

Literacy rate reflects the person's participation in social and economic development which contribute to the human development and poverty reduction. As per the Census 2011, Pune city has highest literacy rate (89.56%) in Pune district. The percentage of male and female literates of Pune city is 92.31% and 86.67% respectively. The literacy rate of Pimpri-Chinchwad is 89.22% and the percentage of male and female literacy of the city is 92.41% and 85.37% respectively. Table 38 presents the literacy rate in PMC and PCMC.

Table 38 : Literacy Rate in PMC and PCMC

Description	PMC		PCMC	
	Literates	Percentage	Literates	Percentage
Total Literates	2,496,324	89.56%	1,343,658	89.22%
Male Literates	1,317,345	92.31%	761,715	92.41%
Female Literates	1,178,979	86.67%	581,943	85.37%
Children (0-6 Years)	337,062	-	221,746	-

Source: Census of India, 2011

3.7.3 Work and Education Profile

In order to understand the existing traffic and transportation scenario in the study area, Household Interview Survey conducted by L&T Infra Engineering as part of Comprehensive Mobility Plan for Pune Municipal Corporation and Pimpri - Chinchwad Municipal Corporation in Pune Metropolitan Region, has been considered. Around 1% of the households were interviewed to capture the travel characteristic of residents. In total 18830 household samples were collected from different zones by L&T Infra Engineering.

Table 39 presents the distribution of population, by education level and Table 40 presents the distribution by employment in PMC and PCMC.

Table 39 : Distribution of Population by Education Level

Education Level	PMC	PCMC
Illiterate	6.30%	6.00%
Primary School (5th)	16.40%	19.60%
Secondary School (10th)	27.40%	29.00%
Higher Secondary (12th)	20.60%	19.30%
Technical Diploma	2.30%	4.30%
Graduation	21.40%	18.40%
Post- Graduation	5.50%	3.40%
Doctorate (Ph.D.)	0.30%	0.20%
Total	**100%**	**100%**

Source: CMP for PMC and PCMC, 2018

Table 40 : Distribution of Population by Employment

Employment Sector	PMC	PCMC
Argo-based/Farming	1.50%	1.00%
Construction/ Mining	8.40%	10.70%
Manufacturing (Household)	2.60%	0.90%
Manufacturing (Others)	2.60%	2.30%
Service Sector (Govt)	5.50%	5.60%
Service Sector (Private)	36.20%	58.20%
Retail/ Whole Sale Trade	10.00%	6.30%
Transport/Communication/Utilities	7.90%	3.20%
Finance/Insurance/Real Estate	2.30%	1.20%
Educational	4.70%	1.90%
Informal Employment	14.00%	7.70%
Tourism	0.40%	0.70%
Information Technology / Information Technology Enabled Service	4.00%	0.30%
Total	**100.00%**	**100.00%**

Source: CMP for PMC and PCMC, 2018

3.7.4 Average Household Size

The average household size in PMC and PCMC are 3.95 and 3.2 respectively. The distribution of household by size is presented in following table.

Table 41 : Distribution of Household by Size

Household Size	PMC	PCMC
1	2.9%	1.14%
2	14.93%	10.83%
3	23.37%	26.44%
4	33.19%	37.84%
5	15.81%	16.26%
6	6.67%	5.77%
7	1.91%	1.1%
8	0.91%	0.51%
9	0.17%	0.08%
10	0.11%	0.03%
>10	0.02%	0%

(Source: CMP, 2018)

About 20% of households are having 3 members in PMC and PCMC area. The distribution for households having 4 members is around 33% in PMC and 38% in PCMC area.

3.7.5 Income Distribution

From the Household Interview Survey data, it is observed that the income range between Rs 10000 - Rs 30,000 has highest percentage both in PMC and PCMC. This clearly indicates the domination of middle-class family in the region. The average household income in PMC and PCMC area is observed to be Rs. 26,954 and Rs. 23,610 respectively. Table 42 presents the distribution of Household by income.

Table 42 : Distribution of Households by Income

Income Range (Rs.)	PMC	PCMC
Less than 2,000	2.50%	0.80%
2,000 - 5,000	5.50%	1.00%
5,001 - 7,500	4.70%	2.20%
7,501-10,000	9.70%	10.40%
10,001-15,000	21.20%	27.90%
15,001-20,000	24.20%	27.90%
20,001-30,000	18.10%	17.10%
30,001-40,000	9.00%	9.60%
40,001-50,000	3.70%	2.50%
50,000 - 1 lakh	1.20%	0.50%
Greater than 1 lakh	0.20%	0.10%
Total	**100%**	**100%**

Source: CMP for PMC and PCMC, 2018

3.7.6 Vehicle Ownership

Vehicle ownership has a relation with household income. Since the middle-class family percentage is more in PMC and PCMC, the ownership of two-wheelers is very high. Moreover, it was also observed from the traffic data that the two-wheeler share is highest in mode split (around 60%-70%). Table 43 shows the distribution of vehicle ownership.

Table 43 : Distribution of Vehicle Ownership

Mode	PMC	PCMC
Cycle	2.80%	2.30%
Two-Wheeler	57.70%	61.50%
Car	0.90%	1.00%
Two-Wheeler & Cycle	6.60%	3.70%
Car & Two-Wheeler	12.50%	12.80%
Car, Two-Wheeler & Cycle	2.40%	1.80%
Others*	4.20%	3.40%
No Vehicle	12.90%	13.50%
Total	**100.00%**	**100.00%**

Source: CMP for PMC and PCMC, 2018

3.8 Travel Characteristics

3.8.1 Trip Rate

As per the Comprehensive Mobility Plan for Pune Municipal Corporation and Pimpri - Chinchwad Municipal Corporation, the overall Per Capita Trip Rate (PCTR) observed in PMC and PCMC area was 1.33 and 1.17 respectively, while the vehicular PCTR (excluding walk) in PMC and PCMC area was 0.88 and 0.76.

3.8.2 Trip Purpose

The CMP Household Interview Survey data revealed that, most of the trips generated from PMC and PCMC are either work trips or educational trips. The distribution of trip purpose is presented in Table 44.

Table 44 : Distribution of Trip Purpose

No.	Purpose	PMC	PCMC
1	Work	50.05%	54.18%
2	Business	5.18%	1.67%
3	Education	37.67%	41.55%
4	Shopping	3.62%	0.31%
5	Social/Religious/Recreation	0.57%	0.02%
6	Health/Hospital	0.34%	0.04%
7	Tourism	0.23%	0.01%
8	Other purpose	2.35%	2.23%
Total		**100%**	**100%**

Source: CMP for PMC and PCMC, 2018

3.8.3 Mode of Travel

The mode–wise distribution of trips in PMC and PCMC area is shown in Table 45. Trips by walk (i.e. Non-motorized) are considerably high in PMC and PCMC compared to other modes of transport. Share of two wheelers in the total trips is around 35% both in PMC and PCMC.

Table 45 : Mode wise Distribution of Trips

Mode of Travel	Total Trips		Motorized Trips	
	PMC	PCMC	PMC	PCMC
Walk	26.00%	23.10%	-	-
Cycle	3.50%	0.90%	-	-
Two-Wheeler	35.00%	35.00%	49.66%	46.06%
Car	12.50%	13.90%	17.73%	18.33%
IPT	8.50%	7.10%	12.06%	9.31%
Bus	11.00%	13.90%	15.61%	18.29%
Train	0.30%	0.60%	0.40%	0.79%

Company/ School Van	3.20%	5.50%	4.54%	7.22%
Total	**100%**	**100%**	**100%**	**100%**

Source: CMP for PMC and PCMC, 2018

3.8.4 Trip Length

Table 46 presents the mode wise average trip length in PMC and PCMC. Trip length of PMPML bus is 7.57 km in PMC and 8.14 km in PCMC. The trip length of Two-wheeler, Auto and Shared Auto varies between 6 km to 7 km. The average trip length for motorized trips is observed to be 7.13 km in PMC and 7.02 km in PCMC area.

Table 46 : Mode wise Trip Length (Km)

Mode	PMC	PCMC
Walk	1.11	0.51
Cycle	2.37	2.64
Two-Wheeler	7.13	7.18
Auto	6.7	6.5
Shared Auto	7.2	6.9
Car/ Jeep/ Van	12.87	6.17
Tempo/ others	7.83	5.56
PMPML Bus	7.57	8.14
Private Bus	9.62	6.65
State Bus	29.84	21.65
Govt/ Office Car	10.33	4
Taxi/ Ola/ Uber	11.85	7.64
Company/ School Bus	8.14	7.94
Company/ School Van	5.37	5.62
Local Train/ Train	40.85	14.7

Source: CMP for PMC and PCMC, 2018

3.8.5 Monthly Expenditure on Travel

As per the CMP, the average household expenditure on travel is Rs. 1373 and Rs. 1014 per month for PMC and PCMC, respectively. Average travel expenditure ranges about 5.1% and 4.3% of total household income for PMC and PCMC respectively.

3.9 Travel Demand analysis

3.9.1 Transport Demand Modelling Approach

Travel Demand models can be used for testing different scenarios without implementing the projects. For example, one can see the impact of adding a mass transport like a metro system. Similarly impact on transportation network due to changes in the land use patterns can be analysed.

The objective of the transport demand assessment is to provide realistic ridership on the proposed metro corridors. The transport demand model, which is recently validated in the year 2017, is used as a base for the modelling process. The original transport demand model was developed as part of DPR for Pune Metro Rail Project (2008) and later this model has been updated and validated through the following studies;

- Evaluation of Development Plans (2011)
- Feasibility of LRT/Metro within Hinjewadi (2012)
- Pune BRTS (2014)
- Pune HCMTR (2016)
- Proposed 3rd and 4th Suburban rail lines between Pune and Lonavala (2017)

The broad framework for the transport demand modelling adopted for the present study is given in Figure 29**.**

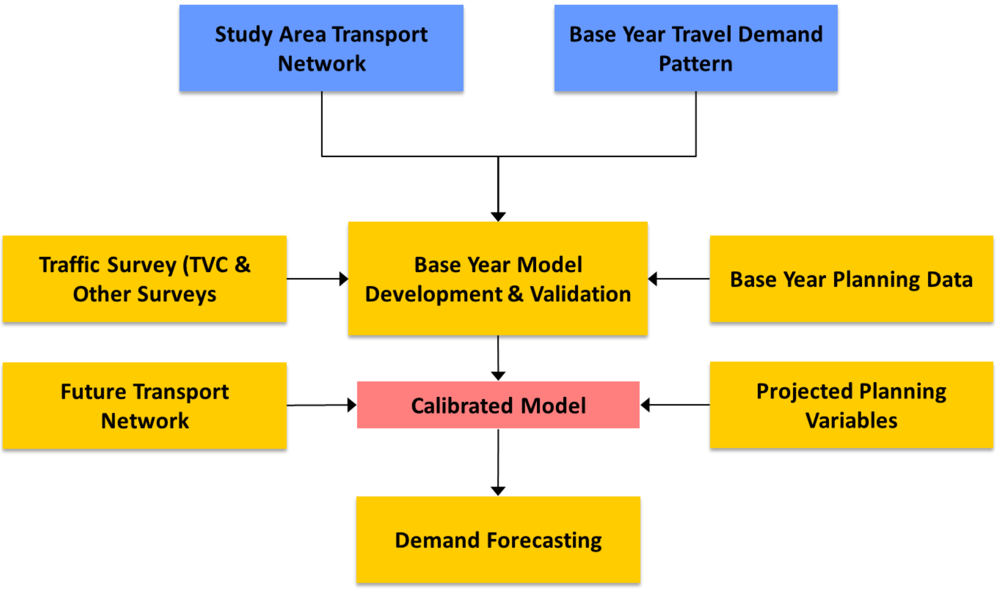


Figure 29 : Broad Framework for Transport Demand Modelling

3.9.1.1 Planning Period

Since this study is being initiated in 2018, the year 2018 is taken as the base year. Demand forecasting on the network and on any proposed transport infrastructure project/ mass transit system is required over a 30 years period. In order to analyse the travel demand in the study area and the travel demand on the proposed MRT system, it is proposed to have four horizon years, viz. 2023, 2033, 2043, and 2053 and the model forecasts are made for these four horizon years.

3.9.1.2 Modelling Software

Several software programs are available for developing travel demand models. For the present study, CUBE Voyager (a state-of-the-art Travel Demand Modelling software) for the transport demand model.

CUBE Voyager is user-friendly software for modelling a wide variety of planning policies and improvements at the urban, regional and long-distance level. The software provides interactive data input and analysis, GIS functionality via ArcGIS, model building and scenario development. Its Application Manager uses a flow-chart system for designing, coding, documenting and running the model. The structure allows the professional planner to add functions as required without the need to learn a new interface and without the need to create multiple databases. Figure 30 below illustrates the model structure in CUBE.

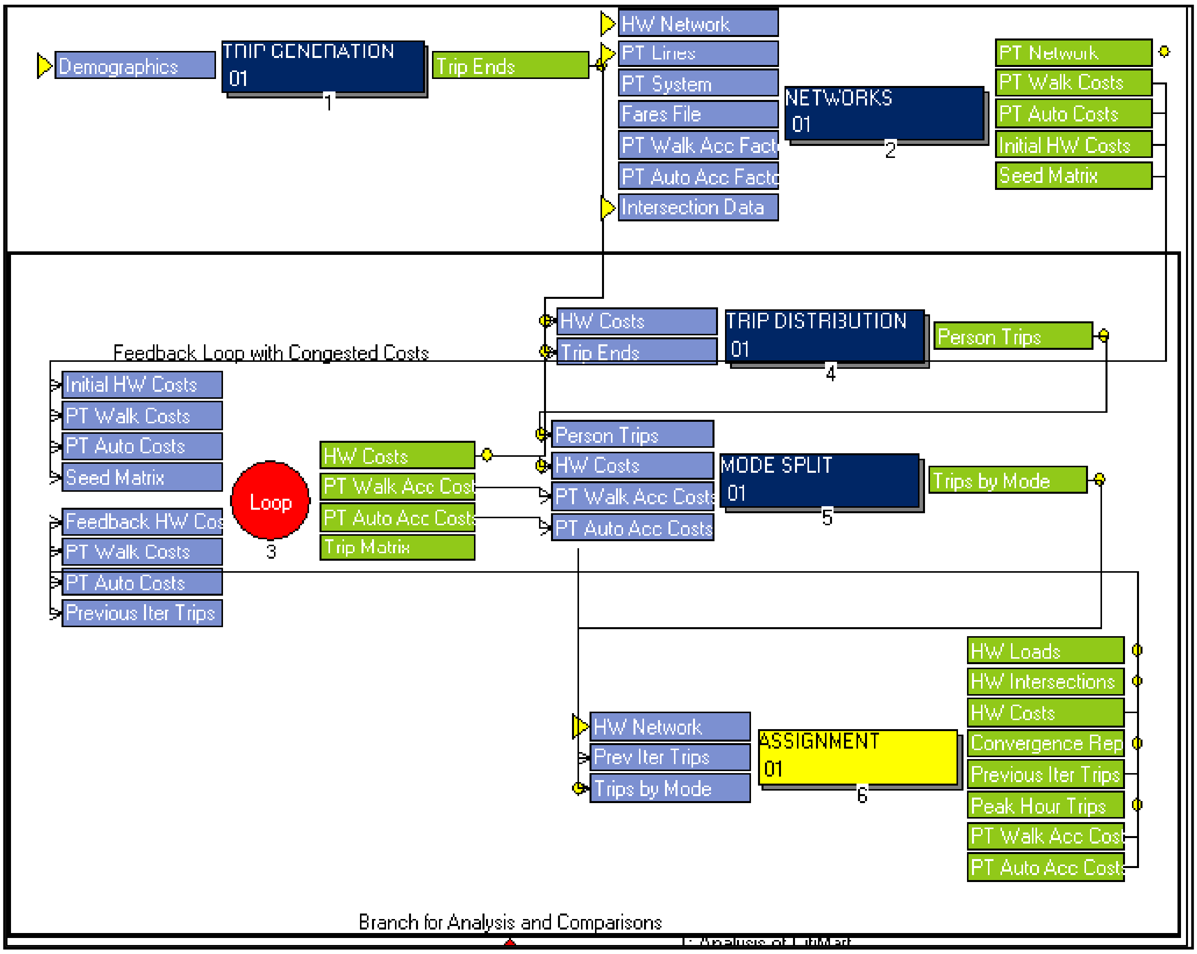


Figure 30 : Model structure as defined in CUBE

3.9.1.3 Study Area

The study area, for the transport demand modelling, comprises of Pune Municipal Corporation (PMC) area, Pimpri-Chinchwad Municipal Corporation (PMC) area, Chakan area and three cantonments, viz. Pune, Khadki and Dehu Road. The study area is shown in Figure 37.

3.9.1.4 Delineation of Traffic Analysis Zones

The zoning system considered for the previous metro study by DMRC (2008) included 91 internal zones and 13 external zones. This zoning system is further disaggregated considering the study requirement. In the updated Traffic Zoning, PMC area consists of 144 zones, PCMC 121 zones and Chakan area 12 zones. The cantonment areas are considered as separate zones. In total, there are 280 internal zones and 13 external zones. The zonal map of the study area is shown in Figure 31.

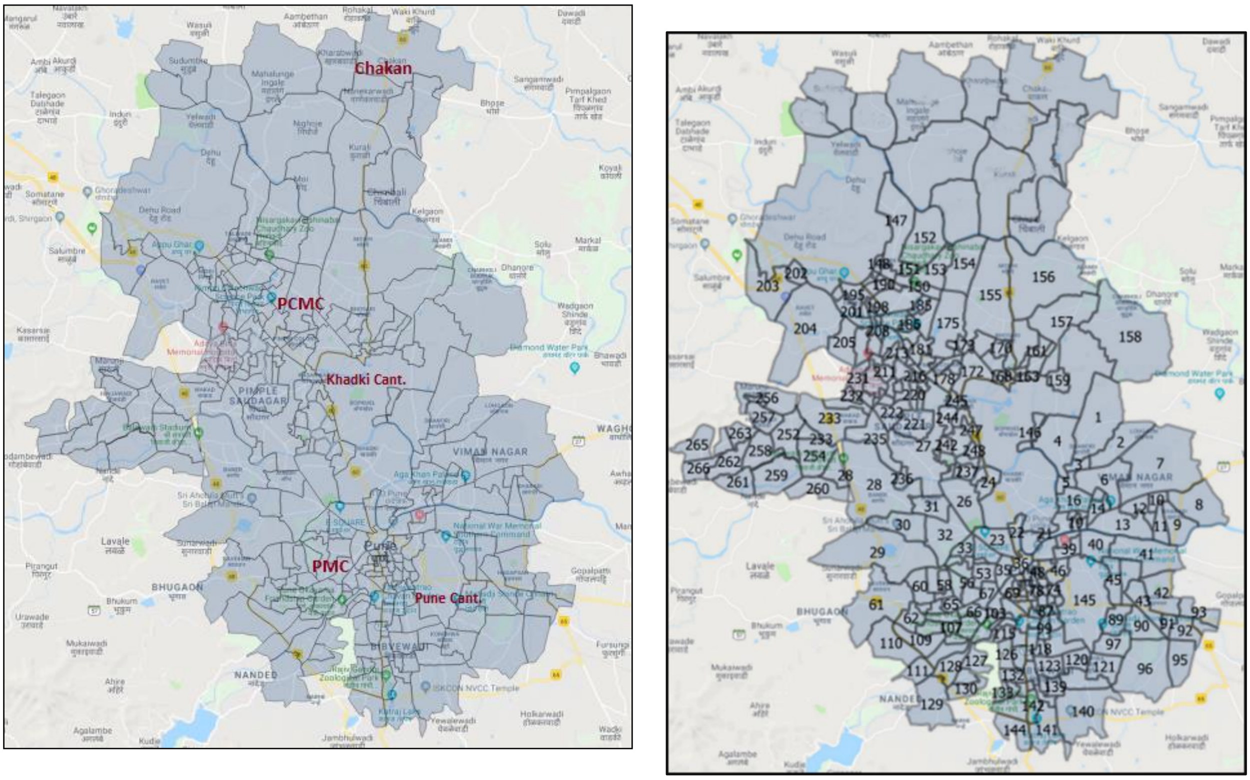


Figure 31 : Study area (Left) and Zonal Map of Study area (Right)

3.9.1.5 Population and Employment

The population and employment forecast for the study area, for the horizon years, is done considering the past trend of growth in population and employment, development plan, population density, availability of developable land, etc. The data from the latest CMP carried out by PMRDA is also considered. The projected population of study area for various horizon years is presented in Table 47.

The employment data for the study area is compiled from various authentic sources. Also, the employment forecast made as part of the recent CMP prepared by PMRDA is also taken into account.

Table 47 : Study Area Population Forecast

Study Area	2018	2021	2031	2041	2048
PMC	37,00,000	40,00,000	48,00,000	55,00,000	58,00,000
PCMC	22,00,000	24,00,000	32,00,000	40,00,000	48,00,000
Total	**5900000**	**6400000**	**8000000**	**9500000**	**10600000**

3.9.1.6 Transport Network

The transport network consists of highway and public transport network. The length of road network considered is about 5,300 km comprising of 35,720 links and 15,039 nodes. The different link types and their typical characteristics are shown in Table 48. The public transport network consists of:

- PMPML (Pune Mahanagar Parivahan Mahamandal Limited) Bus routes
- Intermediate Public Transport-IPT (Auto) routes
- Suburban rail routes
- BRTS (Bus Rapid Transit System) routes
- Shared liner routes
- Out-station bus routes
- Proposed metro routes

The highway network and public transport route network considered for the study are shown in Figure 32 and Figure 33.

Table 48 : Highway Links and Characteristics

Link Type	No. of Lanes	Divided/ Undivided	Type of Flow	Capacity Per Direction (PCU/hr)	Free Flow Speed (km/h)
1	One Lane	Undivided	One-way	1650	30
2	Two Lane	Undivided	One-way	3200	40
3	Three Lane	Undivided	One-way	4350	40
4	Four Lane	Undivided	One-way	5300	50
6	Four Lane	Divided	One-way	5500	50
7	Six Lane	Divided	One-way	7000	60
10	One Lane	Undivided	Two-way	600	25
11	Two Lane	Undivided	Two-way	1100	35
12	Three Lane	Undivided	Two-way	1500	35

Link Type	No. of Lanes	Divided/ Undivided	Type of Flow	Capacity Per Direction (PCU/hr)	Free Flow Speed (km/h)
13	Four Lane	Undivided	Two-way	2150	40
14	Six Lane	Undivided	Two-way	3600	50
16	Two Lane	Divided	Two-way	1500	40
17	Four Lane	Divided	Two-way	2600	50
18	Six Lane	Divided	Two-way	3800	60
19	Eight Lane	Divided	Two-way	4800	60
31	Four Lane (Express way)	Divided	Two-way	3000	80
41	Two Lane (Flyover)	Undivided	One-way	3840	50
42	Four Lane (Flyover)	Undivided	One-way	6360	60
43	Two Lane (Flyover)	Undivided	Two-way	1320	45
44	Six Lane (Flyover)	Undivided	Two-way	4320	60
45	Four Lane (Flyover)	Divided	Two-way	3120	60
46	Six Lane (Flyover)	Divided	Two-way	4560	70
21	Highway Node to Transit Stop				
22	Road Node to Zone Centroid Connection				
25	Suburban Rail Links				
26	BRT Links				
27	Metro Links				

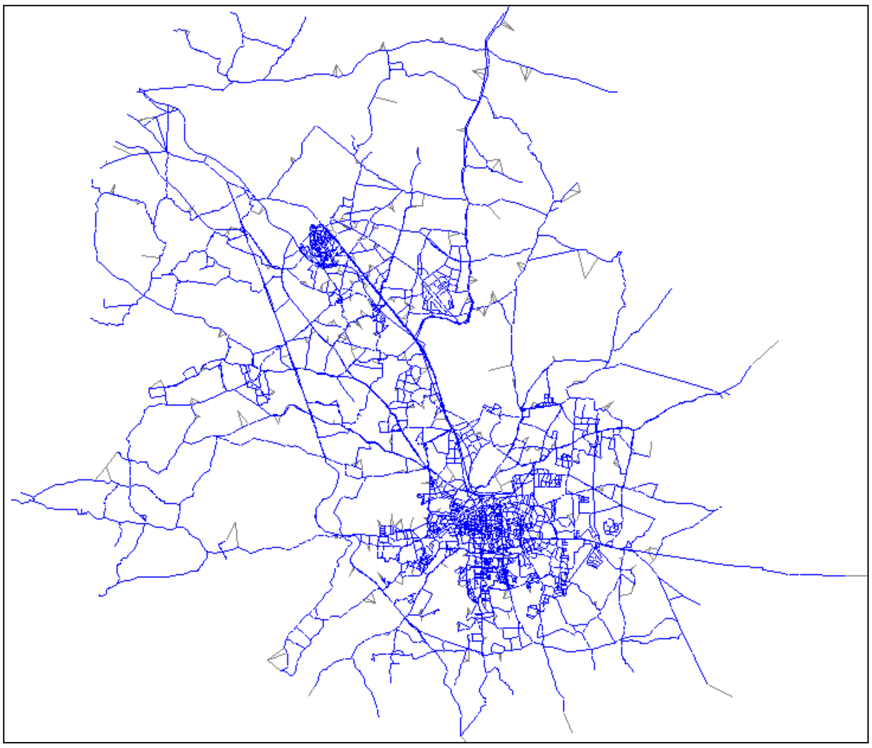


Figure 32 : Road Network of the Study Area

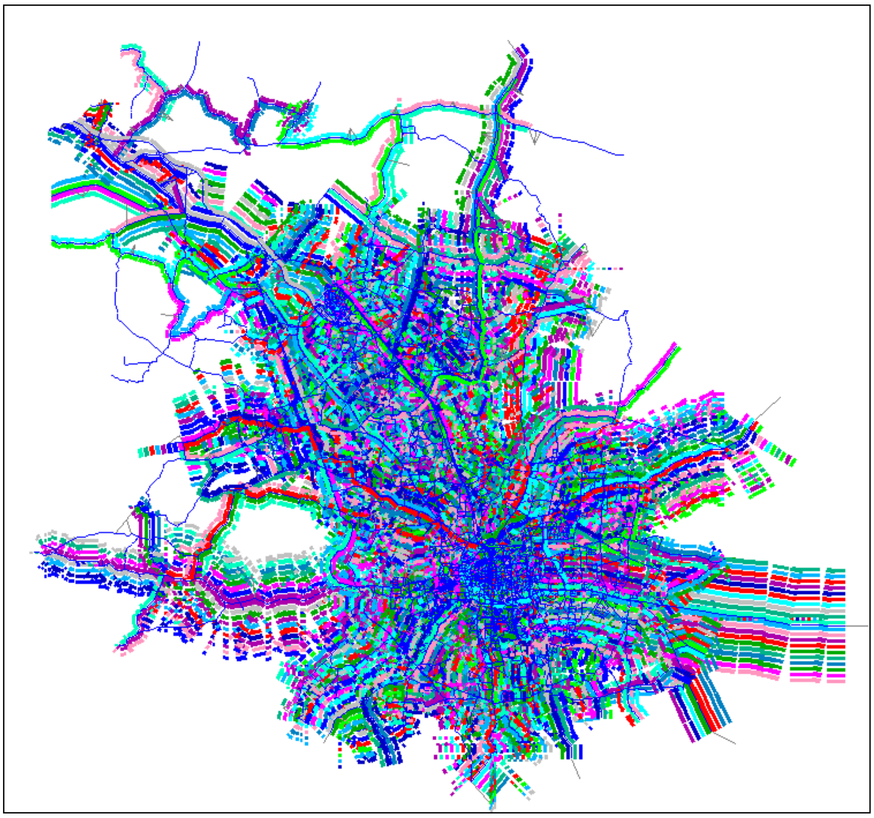


Figure 33 : Public Transport Route Network of the Study Area

3.9.1.7 Transport Network Scenarios

The year 2018 is considered as the base year for the travel demand model. The base year transport network considered all the existing routes of Bus, IPT, Shared liner, existing suburban rail routes and currently operational BRT routes. The proposed metro corridors are shown in Figure 34.

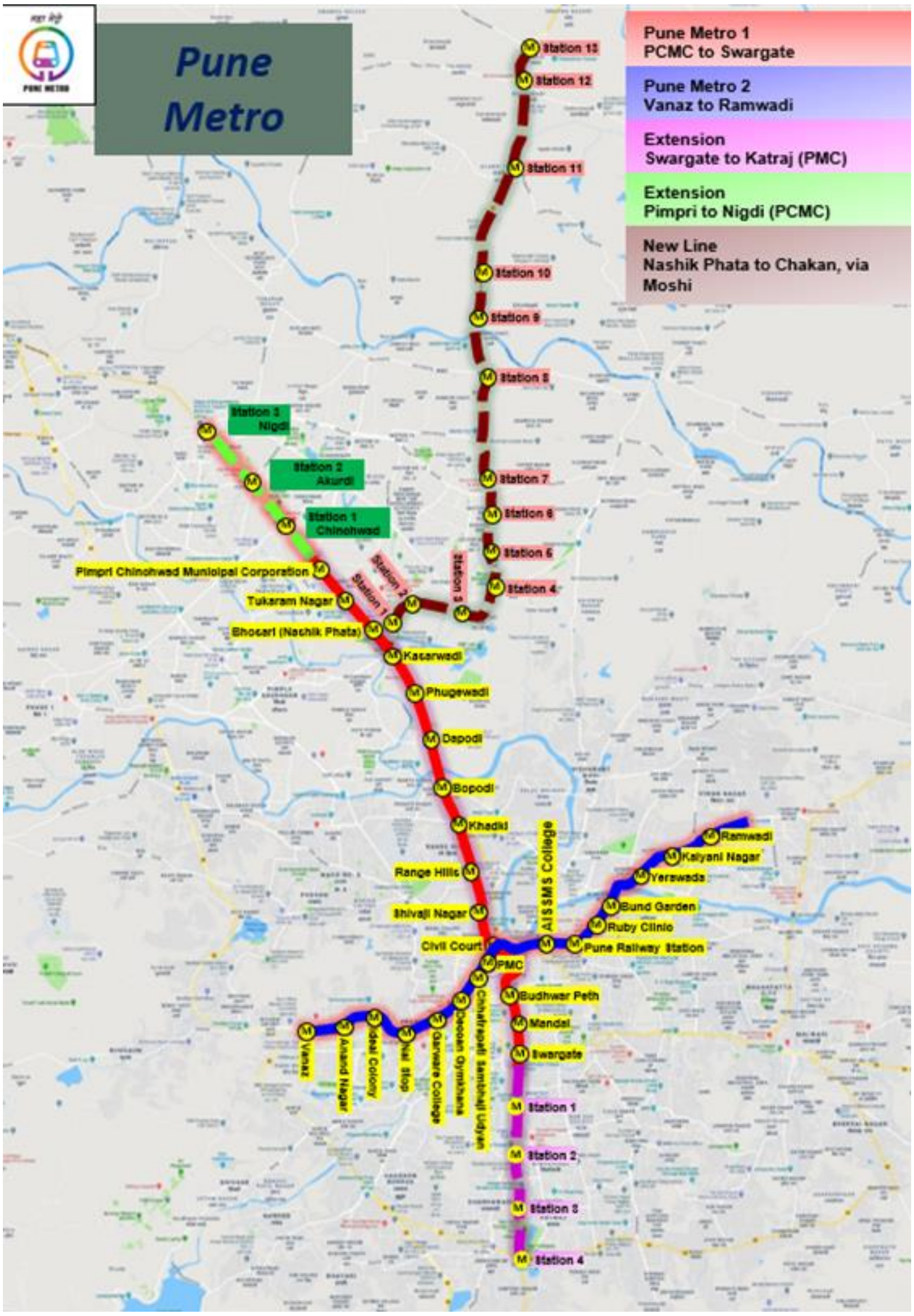


Figure 34 : Proposed Metro Corridors

For the horizon years following scenarios are considered:

1. **Scenario 1A** considers all the existing public transport services listed in base case scenario refer Table 49. Apart from the two under construction metro lines and Shivaji Nagar-Hinjewadi metro corridor, the proposed PCMC – Nigdi metro extension corridor is considered.
2. **Business as Usual (BAU) Scenario** considers all the existing public transport services as in base scenario. Only the PCMC-Nigdi extension corridor is excluded.

The network scenarios described above are briefly given in Table 49.

Table 49 : Different Transport Network Scenarios

Scenario	Year	Transport Network Systems
Base Case	2018	• Bus, IPT, Shared liner, Out-station bus routes • Existing suburban rail routes • Currently operational BRT routes
With Project	2023,2033, 2043 and 2053	• Bus, IPT, Shared liner, Out-station bus routes • Existing and proposed suburban rail route • Currently operational and proposed BRT routes • Metro Line 1 with proposed extension; PCMC-Nigdi
Without Project	2023,2033, 2043 and 2053	• Bus, IPT, Shared liner, Out-station bus routes • Existing and Proposed Suburban rail route • Currently operational and proposed BRT routes • Metro Line 1 from Swargate till PCMC only

3.9.1.8 Four Stage Transport Demand Model

The traditional four stage transportation planning model has been employed to estimate the metro ridership. For this purpose, the study area is divided into traffic analysis zones (TAZ). Study Area is divided into 280 internal TAZs as explained in the earlier sections. The model is implemented in state-of-the-art transportation planning software CUBE Voyager. The four stages of this transportation planning model are explained here:

1. **Trip Generation:** Residences produce trips for work, education, business, shopping, social and recreation purposes. Activity centres such as Industries, commercial centres, offices, educational institutions, banks, shopping centres, recreational areas, etc. attract these trips. Thus, trip productions are computed based on the resident population in zones and trip attractions are computed based on employment in zones. These trip production and attraction equations are calibrated as a first step. Separate equations are developed for the three income groups, viz., High (Car owning group), Middle (Two-wheeler owning group) and Low (No vehicle owning group) as shown in table -53

Table 50 : Trip Generation Models

Income group	Trip Generation	
	Trip Productions	Trip Attractions
Car owning group	0.72 * POP	1.45*EMP + 0.12*STEN
Two-Wheeler owning group		1.28*EMP + 0.1*STEN
No vehicle owning group		1.18*EMP

Where, POP: Population, EMP: Employment, STEN: Student Enrolment

2. Trip Distribution: The zonal trips produced/attracted are distributed to their destination/origin zones in this step to get the origin – destination matrix (zone to zone travel) after this step. The trip exchanges between zones will depend on the magnitude of their activity (population for a production zone and employment for attraction zone) and the friction due to geographical separation (represented in terms of generalized cost of travel) between them. A mathematical model is calibrated to synthesize this trip distribution process based on zonal productions, attractions and the generalized cost of travel between them. These models are calibrated separately for the three income groups. A Gravity Trip Distribution model of the following form is developed.

$$T_{ij} = A_i O_i B_j D_j F_{ij}$$

Where,

$$A_i = \frac{1}{\sum_j B_j D_j F_{ij}} \qquad B_j = \frac{1}{\sum_i A_i O_i F_{ij}} \qquad F_{ij} = (C_{ij})^{\alpha} \exp(\beta C_{ij})$$

the deterrence function

$C_{ij} =$ Generalized cost from zone *i* to zone *j*

$T_{ij} =$ Trips between zones *i* and *j*

α = Calibration parameter – power function

β = Calibration parameter – exponential function

The gravity model parameters are shown in Table 51**.**

Table 51 : Gravity Model Parameters

Income group	α	β
Car owning group	-2.09557	-0.0001819
Two-Wheeler owning group	-1.07986	-0.0236587
No vehicle owning group	-0.897392	-0.0255572

3. Modal Split: After the trip distribution stage, the trips between any pair of TAZs is known. These trips between zones are to be split as per the mode used. The behaviour of people in choosing a transport mode is modelled based on the characteristics of the mode (travel time, travel cost, waiting time, transfers, comfort, convenience, etc.), characteristics of travellers (income, employment status, etc) and journey characteristics (trip purpose, time of day of travel, etc.). A mode choice model is calibrated based on these attributes to split the trips between origin and destination into private vehicle (two-wheeler and car) and public transport trips. A multinomial logit model of the following form is developed.

$$P_j = \frac{e^{V_j}}{\sum_l e^{V_l}}$$

Where,

P_j = probability of choosing mode *j*

V_j = deterministic component of utility for mode *j*

j and *l* are indices for modes

Table 52 : Modal Split Model Parameters

Income group	Utility Equations
Car Owning Group	a) U_{car} = -0.2754*TT-0.04918*TC+0.2327 b) U_{2W} = -0.2754*TT-0.04918*TC-1.2181 c) U_{PT} = -0.2754*TT-0.04918*TC-0.1102*AT
Two-Wheeler owning group	a) U_{2W} = -0.2255*TT-0.1574*TC-3.111 b) U_{PT} = -0.2255*TT-0.1574*TC-0.0770*WT-0.1214*AT

**TT = Travel Time, TC = Travel Cost, AT = Access Time, WT = Waiting Time*

3. Trip Assignment: In this step the mode wise trips between TAZs are assigned to the transport network. Trips by private vehicle (two-wheeler and car) are assigned to road network and trips by public transport (bus, BRT, metro, auto rickshaw and taxi) are assigned to public transport network. Public transport modes like BRT and Metro have exclusive right of way and bus, auto rickshaw and taxi share the road space with private modes. The road network is represented in the form of links and nodes with each link (a road segment) characterized by its width (number of lanes), type (divided or undivided), capacity, volume-speed relation (for computing travel time at different volumes), etc. The public transport network is represented by routes (sequence of road links/exclusive links) with their characteristics such as frequency, seating capacity, crush capacity, fare, speed, etc. Highway assignment is carried out based on user equilibrium (user choses paths based on perceived generalized cost of travel) and public transport assignment is carried out based on path based stochastic user equilibrium (user choses a route again based on generalized cost, as users may not have full information stochastic aspect comes into picture). These models are calibrated for the base year (2018 for the present study). At the end of the assignment the mode wise traffic volumes on road links, and boarding/alighting and link loads on public transport routes will be obtained. As this traffic assignment is done for peak hour, all these outputs are for typical peak hour.

Generalized Cost parameters

The generalized cost (GC) between an origin and destination is computed as:

GC = (value of waiting time × waiting time) + (value of in-vehicle travel time × in-vehicle travel time) + (fare paid) + (value of one transfer × number of transfers) + (value of one unit of discomfort × number of units of discomfort)

The parameters of PT assignment and Highway assignments used in the model are shown in Table 53**.**

Table 53 : Modal Split Model Parameters

VOT (Rs/Hr)	PT Assignment	Highway Assignment	
		Two-wheeler	Car
	32	34	107

3.9.1.9 Validation of the Four Stage Travel Demand Model

The transportation planning model has been updated and revalidated particularly on the road corridors where the metro extension is proposed. For the current study traffic volume counts at all the entry points and on a few important links of catchment are collected. All the models are recalibrated and validated to reproduce the observed travel pattern (mode wise). The assigned total road-based flows during peak hour (in PCUs) and public transport passengers in peak hour in peak direction are compared with the flows observed across the screen lines. The assigned traffic flow in terms of passenger car equivalencies across all screen lines was found to match reasonably close with the observed flows.

3.9.1.10 Model Application for Forecasting

Models are applied on future land use (zonal population and employment) and transport scenarios (transport network with proposed road links and public transport routes with all their characteristics) for getting the corresponding mode wise traffic flows on road links and ridership on public transport modes on all their routes. The model application is shown in the form a flowchart in Figure 35.

Thus, it can be seen from above methodology that the model works at system level and takes care of competitive and complementary nature of all private and public transport modes. Essentially the traveller will choose that mode or route for which the perceived generalized cost is the lowest. As the perceived values of travel time gain, reduction in waiting time, number of transfers and discomfort are different for different income groups, the models are stratified accordingly to account for this variation.

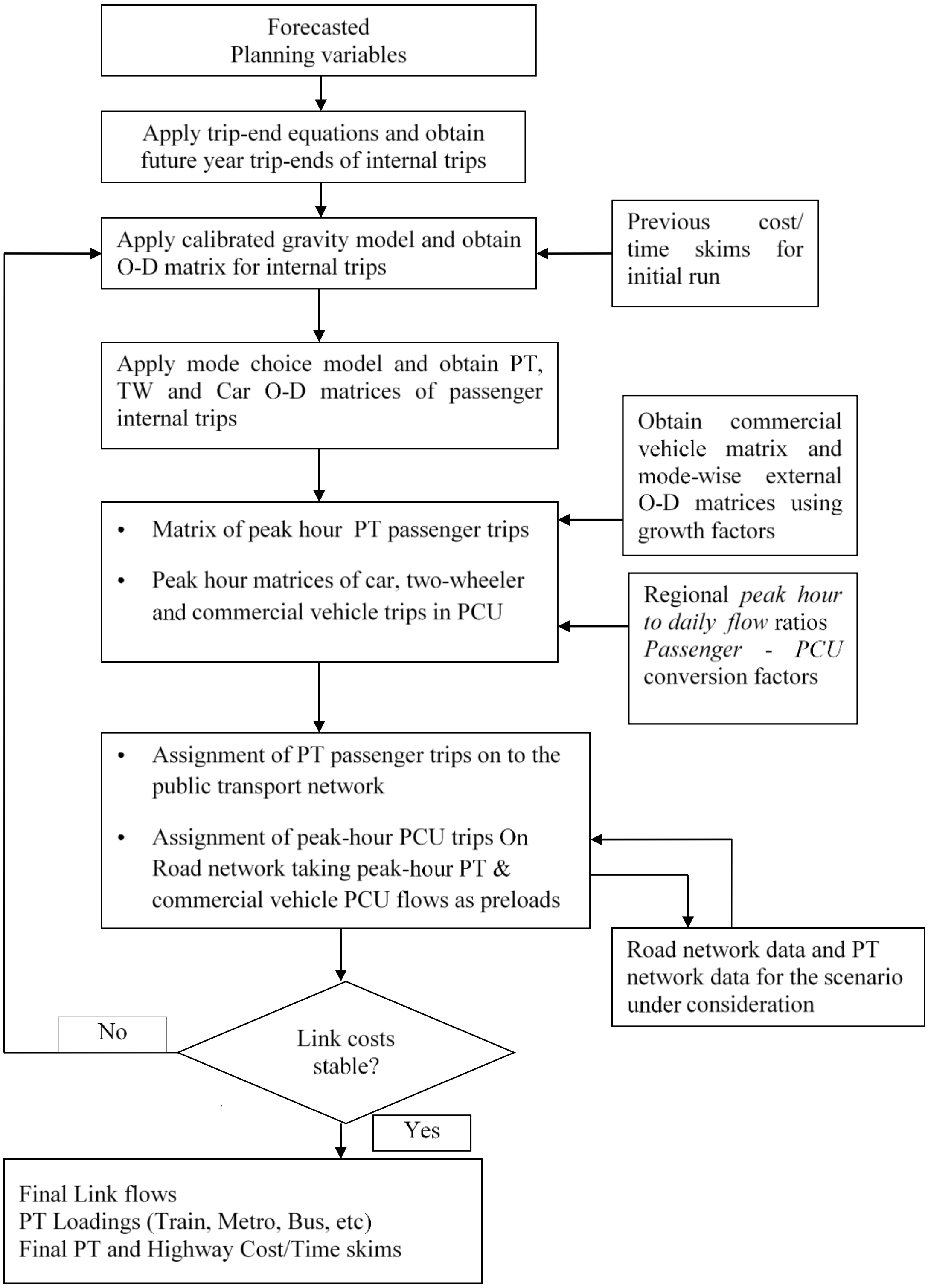


Figure 35 : Application of Four Stage Travel Demand Model

3.10 Future Travel Demand Scenarios

3.10.1 Transport Demand Forecast

As discussed in earlier sections, two scenarios are developed (*With* and *Without* project) for Metro patronage forecast. Scenario 1A includes the metro corridor between Nigdi and Swargate. Without Project Scenario do not include the proposed metro extension, viz. PCMC-Nigdi. The Nigdi – Swargate metro corridor passes through 17 stations with a total length of 22.21 km. The proposed alignment of the metro corridor with all the stations is shown in Figure 36.

Metro System Characteristics

The characteristics of the metro system considered for the travel demand modelling are given below: The adopted fare structure is shown in Table 54.

- Headway
  - Nigdi – Swargate: 2023, 2033, 2043 and 2053 – 3 minutes
- Seating Capacity – 360
- Crush Capacity – 1574 passengers

Table 54 : Adopted Fare

Distance (Km)	Fare (Rs.) @ 2018-19 prices
0-2	13
2-4	17
4-6	20
6-9	25
9-12	27
12-15	30
15-18	32
18-21	35
21-24	37
24-27	38
27-30	42
>30	45

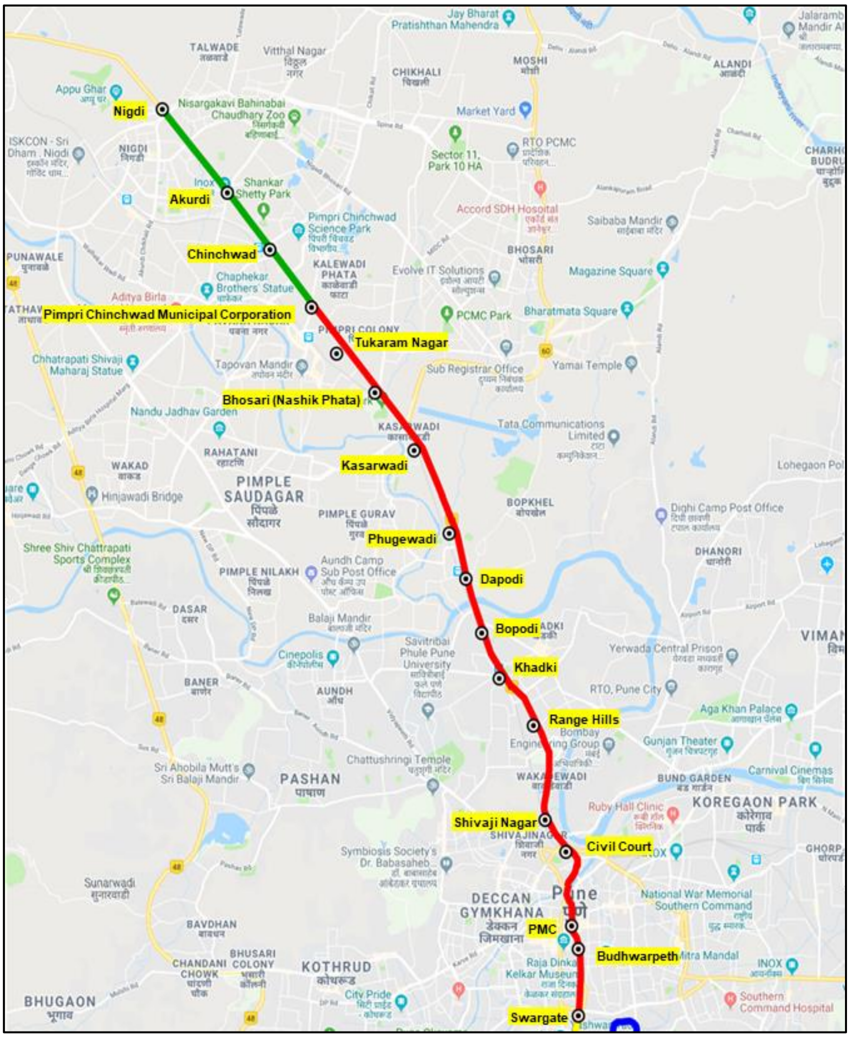


Figure 36 : Proposed Alignment: Nigdi - Swargate Metro Corridor

3.10.2 Ridership Assessment for Horizon Year

The estimated peak hour station loads (two-way boarding & alighting) at each of the metro stations on Nigdi – Swargate Corridor for the horizon years 2023, 2033, 2043 and 2053 for the Scenario 1A are presented in Table 55. The section loads between two adjacent stations for the horizon years are presented in table 59

Table 55 : Peak Hour Station Loads on Nigdi - Swargate Corridor (Scenario 1A)

SI NO	Station	Boarding				Alighting			
		2023	2033	2043	2053	2023	2033	2043	2053
1	Nigdi	780	1070	1170	1270	780	1180	1430	1540
2	Akrudi	950	1290	1360	1470	1070	1470	1940	2090
3	Chinchwad	820	1190	1380	1500	1070	1480	2000	2160
4	PCMC	3820	5220	5620	6070	2700	3730	4740	5130
5	Tukaram Nagar	2100	2790	3070	3310	2050	2830	3740	4040
6	Bhosari	2970	3970	4310	4660	2800	3930	4990	5390
7	Kasarwadi	1780	2620	2850	3080	1800	2420	3120	3370
8	Fugewadi	1700	2170	2420	2610	1430	1980	2560	2760
9	Dapodi	3430	4620	5220	5640	3120	4370	5190	5610
10	Bopodi	3550	4760	5630	6080	3450	4630	5710	6160
11	Khadki Station	1650	2360	2610	2820	1750	2530	2850	3080
12	Range Hill	2010	2820	3320	3590	2430	3260	3920	4240
13	Shivaji Nagar	4030	5510	6850	7410	4150	5660	6420	6940
14	Civil Court	6310	8640	10510	11360	6860	9280	10870	11750
15	Budhwar Peth	2810	3940	4790	5170	2180	2980	3300	3560
16	Mandai	2010	2820	3770	4080	1900	2610	2760	2980
17	Swargate	6740	9230	12110	13090	7920	10690	11480	12410
Total		**47500**	**65000**	**77000**	**83200**	**47500**	**65000**	**77000**	**83200**

Table 56 : Peak Hour Section Loads - Nigdi-Swargate Corridor

From	To	Forward				Reverse			
		2023	2033	2043	2053	2023	2033	2043	2053
Nigdi	**Akrudi**	780	1070	1170	1270	780	1180	1430	1540
Akrudi	**Chinchwad**	1730	2350	2540	2740	1850	2650	3360	3630
Chinchwad	**PCMC**	2460	3340	3590	3880	2830	3920	5030	5440
PCMC	**Tukaram Nagar**	5960	8150	8730	9430	5210	7250	9290	10040
Tukaram Nagar	**Bhosari**	7720	10510	11200	12100	6920	9650	12440	13440
Bhosari	**Kasarwadi**	9900	13400	14300	15450	8920	12490	16220	17530
Kasarwadi	**Fugewadi**	10910	14950	15870	17150	9960	13840	18060	19510
Fugewadi	**Dapodi**	12170	16480	17580	18990	10960	15170	19900	21500
Dapodi	**Bopodi**	13530	18260	19510	21080	12010	16710	21800	23550
Bopodi	**Khadki Station**	14320	19410	20680	22350	12700	17730	23060	24910
Khadki Station	**Range Hill**	14450	19480	20850	22530	12930	17960	23460	25350
Range Hill	**Shivaji Nagar**	14150	19140	20480	22120	13050	18060	23690	25600
Shivaji Nagar	**Civil Court**	12670	17200	18350	19820	11690	16270	21130	22830
Civil Court	**Budhwar Peth**	11190	15120	16190	17490	10750	14830	19330	20880
Budhwar Peth	**Mandai**	9820	13310	14240	15380	8740	12050	15890	17160
Mandai	**Swargate**	7920	10690	11480	12410	6740	9230	12110	13090
Maximum Section Load (PHPDT)		**14450**	**19480**	**20850**	**22530**	**13050**	**18060**	**23690**	**25600**

The summary of patronage forecast along with peak hour peak direction traffic (PHPDT) are presented in Table 57.

Table 57 : Summary of Patronage Forecast

Nigdi - Swargate Corridor	Daily Ridership			
	2023	2033	2043	2053
	495,000	677,000	802,000	867,000
	PHPDT			
	2023	2033	2043	2053
	14,450	19,480	23,690	25,600

3.10.3 Incremental Ridership on Nigdi – Swargate Corridor

The implementation of Nigdi – PCMC metro corridor will increase the patronage on Phase 1 corridors as well. It is necessary to duly consider the incremental patronage while doing the train operation plan, rake requirement and O&M. The incremental daily patronage due to the extension of the corridor, viz. Nigdi – PCMC have been estimated considering the difference in estimated daily trips with Nigdi – PCMC Metro Corridor in comparison to *Without this corridor* and the same is presented in Table 58.

Table 58 : Incremental Daily Patronage due to Nigdi – PCMC Corridor

Nigdi-PCMC Corridor	Daily Ridership			
	2023	2033	2043	2053
	29,000	43,000	64,000	72,000

4. SYSTEM AND TECHNOLOGY SELECTION

4.1 Technology

There are several Mass Transit Systems and Technological options available for public transport worldwide. Various options available today are described in following sections.

4.1.1 Comparison of public transport systems

Each type of mode is associated with a specific capacity range, expressed in PPHPD. The figure hereafter shows the relation between mode and capacity (as an indication, it also shows the relation between mode, capacity, commercial speed and investment costs).

For instance, it can be inferred from the figure hereafter, that heavy metros are recommended on a corridor when its busiest section has >20,000 PPHPD. On the other hand, for corridors with PPHPD of 3,000, one may recommend either bus, Bus with a High Level of Service (BHLS), Streetcar or Urban Tram.

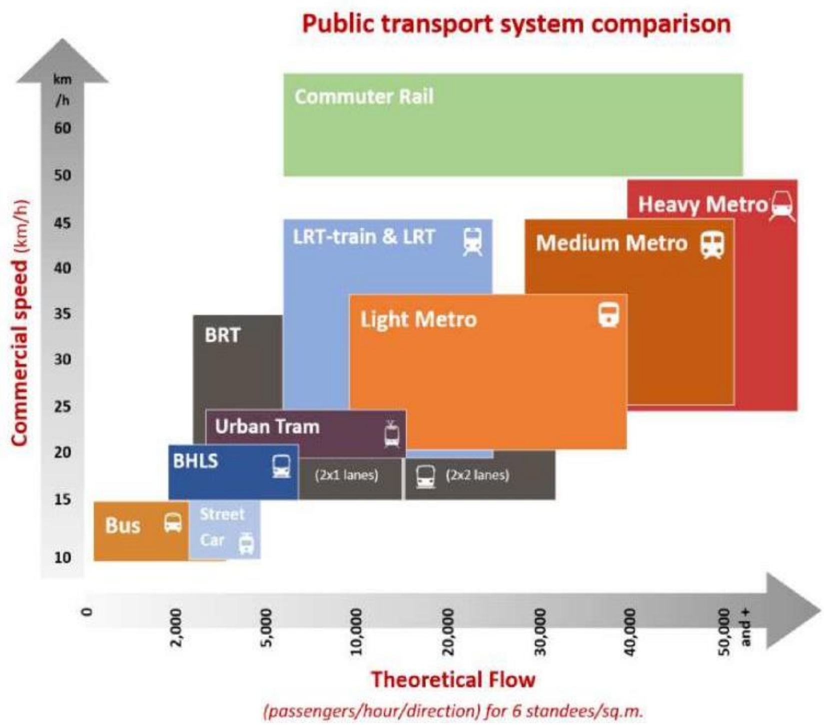


Figure 37 : Public transport system comparison graph (6 standees/sq.m.)
(Source: Systra, 2018)

The sections hereafter provide information regarding the characteristics of each mode of transport. The figures presented are indicative, the values may change a lot depending on the options taken in the MRT project.
Note: the distinction between modes is theoretical.

4.1.2 BRT systems

BRT systems can have one-lane in each direction or two-lanes in each direction. The first configuration offers capacities of up to 15,000 PHPDT for 6 standees/sq.m., 20,000 for 8 standees/sq.m. Systems with two lanes in each direction, such as the Transmilenio in Bogota (Colombia), can approximately double the capacity to 33,000 PHPDT (6 standees/sq.m.).

BRT is typically provided at grade, but there are examples of both elevated and underground BRT systems. Providing high capacity by BRT is, however, reliant on operating articulated (or even bi-articulated) vehicles.

BRT systems are distinct from other bus-based transport systems. The ITDP (Institute for Transportation & Development Policy) has established a BRT scoring system with multiple scoring items, which helps to identify the characteristics of BRT systems and their level of service. These items include notably the BRT basics which includes 5 elements, among which are the right-of-way and alignment.

According to the ITDP scoring system, in order to be considered as a BRT, a system must:

- be at least 3km long with dedicated bus lanes;
- score 4 or more points in the dedicated right-of-way element;
- score 4 or more points in the busway alignment element;
- score 20 or more points across all five BRT Basics element.

Examples of BRT corridor

Figure 39 : Transjakarta in Jakarta, Indonesia
(source : Wikipedia[†])

Figure 38 : Bogota Transmilenio
(Soure: Carlos Felipe Pardo)

[†] By Maxime Lafage - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=18631356

4.1.3 Streetcar

The streetcar system could be defined as a similar mode to the urban tram system but mixed with traffic. Indeed, the system runs at grade with no significant degree of segregation.

This mode is not the most adapted solution for Pune due to the traffic condition. Moreover the commercial speed of this system is low and thus may not be suitable for the corridors. However, it has been included in this report in order to give a complete picture of the offer/possibilities.

Example of street car systems:

Figure 40 : Berlin streetcar, Germany
(Source: Google maps 2018)

Figure 41 : Toronto streetcar
(source: Wikippedia[1)])

4.1.4 Urban Tram

Urban Tram systems typically offer capacity for 3,500 to 14,500 PPHPD (6 standees/sq.m.). They are able of operating in pedestrianized areas as well as along roads (mostly segregated).

Examples of Urban Trams

Figure 42 : . Grenoble tram, France
(Source: SYSTRA, 2005)

Figure 43 : Barcelona Tram, Spain
(Source: SYSTRA, 2005)

4.1.5 LRT systems

LRT systems typically offer capacity for 6,000 to 25,000 PPHPD (6 standees/sq.m.). They have a dedicated right of way but are usually only partially segregated.

Examples of LRT systems:

Figure 45 : Manchester Metro-Link
(Source : David Dixon[2])

Figure 44 : Stuttgart Stadt Bahn, Germany
(Source: SYSTRA,2016)

4.1.6 LRT-Train system

LRT-Train systems are systems that are designed to serve dense urban areas where distance between station is low on the one hand, and less dense areas on the other hand. They allow for speeds on less dense sections of the line that are higher than standard LRT systems, so that the offered commercial speed is higher.

Figure 46 : Line T4 in Paris (Source : Wikipedia[1])

4.1.7 Light metro

Light metro systems have a typical capacity of 10,000 to 40,000 PHPDT. They run on a segregated alignment which can be elevated, or underground.

Examples of light metros:

Figure 47 : Stuttgart Stadtbahn, Germany
(Source: SYSTRA, 2016)

Figure 48 : . Manchester Metro-Link
(Source: David Dixon[2])

4.1.8 Medium metro

A medium metro is a system half-way between light and heavy metro. Its capacity lies between 30,000 PPHPD, and 50,000 PPHPD (6 standees/sq.m.).

Examples of medium metro systems‡

Figure 50 : Nippori-Toneri Liner, Tokyo, Japan [3]

Figure 49 : Lyon Metro, France
(Source Wikipedia[2])

4.1.9 Heavy Metro

A heavy metro is a system that can move more than 40,000 PPHPD (6 standees/sq.m.) and that runs fully segregated (either elevated or underground). Theoretically some very high capacity system could reach an operating capacity of 100,000 PPHPD (6 standees/sq.m.). The PPHPD on Pune Metro Line-1 extension (PCMC-Nigdi) is projected to be 3730 in year 2053. Hence, choosing this mode will increase the cost of the system without taking advantage of the high capacity offered by this mode. It is not the most adapted solution for the present system. However, this mode is included in this report in order to give a complete picture of the metro offer/possibilities.

Examples of heavy metro systems

Figure 52 : Shanghai Metro, China
(Source: Wikipedia [4])

Figure 51 : Paris Metro line 14, France
(Source SYSTRA, 2014)

§

4.1.10 Commuter rail

Commuter rail is a system that operates between the city centre and its suburb. Unlike others, this system has a high distance between its stations and operates following a schedule.

Examples of commuter rail systems:

Figure 54 : Paris RER, France
(Source: SYSTRA, 2011)

Figure 53 : Frankfurt S-Bahn, Germany
(Source: Wikipedia)

4.1.11 Alternative Options for Lower Ridership Volumes

4.1.11.1 Personal Rapid Transit

Based on worldwide experience, Light Metro and LRT are feasible solutions for mass transit at volumes of around 5000 PHPDT or more.

Alternatives to Light Metro or LRT could be considered for the extension, for example monorail or various forms of Personal Rapid Transit (PRT).

- **A PPHPD too high for the people mover option**

Typically PRT vehicles are small in order to provide a personalised service, usually carrying between two and six passengers. As vehicles are small, infrastructure can be lighter in design.

Although larger vehicles have not so far been used for the limited examples of PRT in current operation, it might be possible to offer larger vehicles but this would increase the size and cost of infrastructure and reduce the benefits of offering a personalised service.

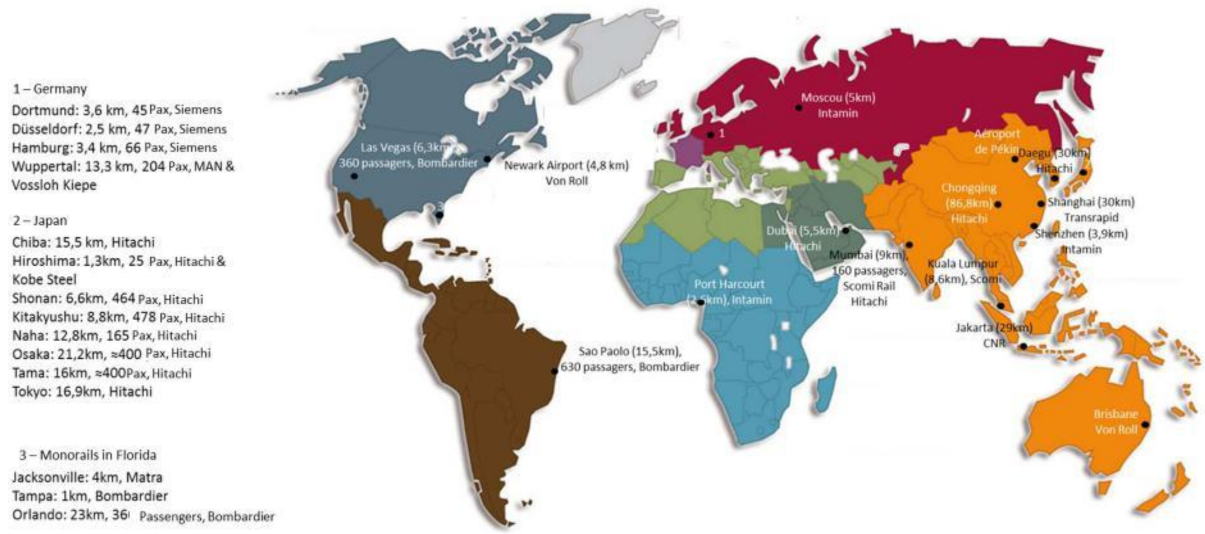
If we assume vehicles carrying as many as 20 passengers (much larger than any application so far in the world), then 250 departures would be required in the peak hour in 2043, which does not appear feasible.

4.1.11.2 Monorail

- **Monorail, a transport mode that has higher capacity than PRT but has been mainly developed for other than mass transit so far**

Monorail can accommodate larger volumes of riders than PRT, similar to Light Metro and LRT, and at similar commercial speeds.

Most Monorail systems in the world have been short-distance lines, often aimed at tourists, but there are growing applications to mass transit systems (eg the Mumbai Monorail can accommodate over 550 passengers per train).



- **Monorail, a system that has cheaper infrastructure than conventional rail-based project**

To be suitable for extension line, up to 3730 PHPDT would need to be accommodated by 2053 or beyond- even assuming trains of similar capacity to Mumbai monorail, this could require at least 9 departures per hour by 2043. Construction requires similar infrastructure to elevated Light Metro and LRT, although structures typically require less material compared to an equivalent Light Metro or LRT, with out-turn infrastructure costs per km approximately 25% lower.

- **Monorail, a system that lacks flexibility compared to more conventional modes**

One major challenge is that monorail systems are less flexible than conventional Metro and LRT systems, for example switching between tracks requires additional infrastructure than with steel rails, and ride quality is lower than on steel rails. Evacuation can be more difficult/dangerous than even elevated conventional rail systems, unless adequate additional escape routes are built into the infrastructure.

- **Lack of diversity in monorail systems suppliers implying potential higher costs and risks**

Monorail vehicles are available from only a few suppliers, have less of a successful record of operation, and are more specialist than Light Metro or LRT vehicles. Consequently monorail vehicles are likely to be more expensive than equivalent Light Metro or LRT vehicles, and the whole operating system would be provided by the vehicle supplier as it is bespoke which would increase risk and potential cost.

Different monorail systems are not compatible with each other so that for example, a Hitachi monorail system will not run with rolling stock from another supplier. If the chosen supplier decided to end its monorail business line, then the system itself would be threatened (no possibility to renew rolling stock notably).

Timelines for completing systems of similar length to that proposed for extension appear to be similar for monorail and conventional rail-based systems (e.g. Mumbai Monorail five years to opening of first section; five years for São Paulo monorail line 15).

4.2 Mode Selection

Pune is a growing city with high potential of economic activity and population growth. Commuting for day to day business and personal reasons results in to high passenger traffic and congestion on roads. Therefore, Phase-I of Pune Metro is already approved by Government and is currently under construction phase. Following this development, there is a demand for extension of Phase-I corridor from PCMC to Nigdi.

The objectibve of Mass Transportation systems should be to provide high mobility, freedom and comfort at optimum cost, keeping safety and security of passengers on high priority. Mode change over a trip should be minimized to avoid passenger discomfort. The system and technological option should be selected keeping long term demand in view.

Phase-I of Pune Metro is designed and implemented as a medium metro. Based on worldwide experience, a medium metro is a system half-way between light and heavy metro. Its capacity is around 30,000 PPHPD (6 standees/sq.m.) or more.

While projections of demand for the PCMC-Nigdi extension show PHPDT to be around 3730 in 2053 and beyond, PHPDT for corridor-1 with extension in PCMC-Swargate section, is projected around 14450 in 2033 and 25600 in 2053. PHPDT criteria indicates that Light Metro, LRT, BRT, Street-car, Urban Tram, monorail are feasible solutions for mass transit at volumes of around 5000 PHPDT or more should satisfy projected traffic demand reasonably.

Feasible alternatives (e.g. Monorail) offer limited advantages and are unlikely to be delivered any faster than Light Metro or LRT. Ensuring compatibility across the whole network should offer economies of scale (both in capital expenditure – such as sharing depots – and in operating expenditure – sharing maintenance, staff, rolling stock, etc).

Considering the above factors and systems options, it is concluded that an extension of Phase-I corriodor-1 (PCMC-Swargate) from PCM to Nigdi provides a suitable Mass Rapid Transit System (MRTS) option to public in the area of extension and beyond. It will connect public in and around the area of PCMC to Nigdi to the core area of city and can act as catalyst for further growth in this area.

4.3 System Specification to be adopted for corridor

Phase-I of Pune Metro including Line-1 is already under construction phase after due deliberation for system selection. Its extension from PCMC to Nigdi is small stretch which should be planned with system specification similar to Phase-I to ensure uniformity and compatibility. However, improvement in design may be incorporated during implementation phase based on learnings from Phase-I implementation.

The Metro system proposed for Pune Metro is recommended with system specifications described in following sub-sections. Refer relevant sub-system chapters for detailed specification.

4.3.1 Permanent Way

Choice of Gauge : Standard Gauge (1435mm) is generally adopted for metro railways world-over. During the last decade, most of the new metros, constructed in various cities of the world have gone for Standard Gauge even though the national gauge for main-lines in some of the cases was different from Standard Gauge.

Track Structure : Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus, it is imperative that the track structure selected for Metro systems should be long lasting and requires minimum maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. The track structure has been proposed keeping the above philosophy.

The proposed Track specification are further detailed in Chapter 5

4.3.2 Rolling Stock

Rolling Stock proposed for the corridor will be similar to Phase-1. The specifications of the rolling stock and its procurement may be decided on the basis of the project implementation mechanism. The important criteria for selection of rolling stock are as under:

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

The controlling criteria are reliability, low energy consumption, lightweight and high efficiency leading to lower annualized cost of service.

The proposed Rolling Stock specification are further detailed in Chapter 11

4.3.3 Traction System

Traditionally, electric traction is used in Metro systems for requirement of high acceleration and pollution-free services in urban areas. There are three standard and proven systems of electric traction for use in suburban and metro lines, viz:- 750V DC third rail, 1500V DC overhead catenary and 25kV AC overhead catenary system. All these three systems are presently in use in India (750 V DC third rail in Kolkata & Bangalore Metro, 1500V DC catenary in Mumbai suburban of Central & Western Railways and 25 kV AC catenary in Delhi, Jaipur, Chennai, Hyderabad Metro & Indian Railways). 1500 V DC system of Central and Western Railways in Mumbai suburban is currently being converted to 25 kV AC to meet increase traffic demand.

The 25kV AC overhead catenary system is being provided on the phase-I corridor of Pune Metro. Thus, to ensure consistency with the existing system, 25kV AC overhead catenary system is proposed for the extension.

The proposed Traction system specification are further detailed in Chapter 12.

4.3.4 Signalling System

Signalling & Train Control system for Pune Metro Phase-I is proposed for design headway of 90 seconds so as to meet sustained train operation at up to 2 minutes interval during peak hours. The proposed system shall be compatible with the existing Phase-I system for seamless operation & maintenance. Therefore, these requirements of the metro are planned to be achieved by adopting a State of art Communication based Train Control System. This will enable running of optimum train services meeting traffic requirements in the most efficient and cost effective way. The Signalling & Train Control system will ensure: High level of safety with trains running at close headway ensuring continuous safe train separation.

- Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.
- Provide safety and enforces speed limit on section having permanent and temporary speed restrictions.
- Improve capacity with safer and smoother operations. Driver will have continuous display of Target Speed / Distance to Go status in his cab enabling him to optimize the speed potential of the track section.
- Moving block feature shall provide enhancement of headway.
- Increase productivity of rolling stock by increasing line capacity and train speeds, and enabling train to arrive at its destination sooner. Hence more trips will be possible with the same number of rolling stock.
- Improve maintenance of Signalling and Telecommunication equipments by monitoring system status of trackside and train born equipments and enabling preventive maintenance.

The proposed Signalling system specification are further detailed in Chapter 9.

4.3.5 Telecommunication

The telecommunication system acts as the communication backbone for Signalling and other systems and provides telecommunication services to meet operational and administrative requirements of metro network. The proposed system shall be compatible with the existing Pune Metro Phase-I system for seamless operation & maintenance.

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

- Optical Fiber Cable
- Telephone Exchange
- Mobile Radio Communication
- Public Address System
- Centralized Clock System
- Passenger Information System
- Close Circuit Television
- Central Voice Recording System (CVRS)
- Access Control
- Network Monitoring and Management and
- Forensic Debriefing Analysis and Cyber Security System

The proposed Telecommunication system specification are further detailed in Chapter 9.

4.3.6 Fare Collection System

Mass Rapid Transit Systems handle a large number of passengers. Ticket issual and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate, 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.

Keeping in view Metro Railways Automatic Fare Collection System and the fact that Contactless card/ token technology proves to be cheaper than magnetic technology in life cycle cost due to reduced maintenance as it has less wear and tear and is less prone to dusty environment, computer based automatic fare collection system with contactless smart token/card type ticketing is obvious choice.

The proposed system shall be compatible with the existing Pune Metro Phase-I system for seamless operation & maintenance.

The System shall be capable for open loop transactions as well to further integrate the mobility solution with the advancements in technology and to allow for seamless transition from dedicated cards to common multi-use stored value fare media that can be used for financial transactions such as making purchases at shops etc. as well as a fare media in the system.

To accommodate the same the system shall conform to the following standards as a minimum:

1. EMV (Euro Mastercard Visa)
2. PCI-DSS (Payment card Industry / Data Security Standard)
3. ISO-IEC 14443

The system shall be of open architecture to allow for the integration of multiple fare products and shall be capable of interfacing with cards from different vendors. Additionally the system shall not be proprietary as far as possible to allow multiple types of fare media from multiple sources to be integrated into the system.

The proposed system shall offer high fare revenue protection and minimize fare revenue evasion and fare related fraudulent activities. The system shall be capable of detecting any irregularity and allow the authority to take action to correct the same.

The proposed AFC system specification are further detailed in Chapter 10.

5. CIVIL ENGINEERING AND ALIGNMENT DETAILS

5.1 Alignment Description

5.1.1 Site appreciation and reconnaissance survey

With a view to examining the alignment proposals on ground, joint inspection visits were organised from March to May, 2018. After that the detailed investigation as per TOR are being carried out as a routine manner.

Teams of experts from Signalling, Traffic, Alignment, Geo-tech, Structure, Hydrology, R & R and Environment disciplines were deployed.

With an aim of assessment and appreciation of the existing condition/characteristics of the project stretch in terms of traffic, geometry, pavement, structures, social and environmental concerns and safety issues, the key professionals of the consultants carried out the reconnaissance survey during the above said period.

This team was equipped with handheld GPS units loaded with the alignment proposals, KM-marks and other salient points so as to navigate to the correct positions on ground, measure distances between salient points and to record new points of interest. Important locations traced on ground with help of GPS were correlated with that on alignment plans. All points of interest were observed in depth and discussed with experts of various disciplines in detail at site.

During reconnaissance all the important technical site information was collected. The secondary data for some stretches were collected during the period. Photographs of important features of whole project corridor are captured. Necessary modifications/detours requested by the site conditions were also recorded for implementations in the alignment design.

Detailed Road Inventory, condition survey and investigation has been conducted. Salient features of the project road corridor are described above.

5.1.2 Route alignment option studies

Extension of line 1 towards Nigdi starts from Northern end of the under construction line 1, and follows the corridor along Pune Mumbai Highway (NH-4) in general.

The corridor runs along the BRT corridor along the right lane of the road (when travelling from PCMC towards Nigdi). Such route is chosen such as there are underpasses along the highway, and the alignment detours near Tilak Chowk towards right side to go off the road terminating at Bhakti shakti bus stop.

The terminal station i.e. Nigdi is proposed at Nigdi Bus Terminus, which is on the opposite side of Bhakti Shakti Park in Nigdi. There is a planned elevated road intersection at the Bhakti Shakti

Crossing, which is to be crossed elevated in the route. This Alignment does not pass through any prohibited, protected, restricted area of heritage structure/ Monument area'.

Figure 55 : Corridor 1A – PCM to Nigdi Analysis of corridor options
(Source: Google Earth and Systra, 2018)

The end of chainage of line 1, Phase 1 (PCMC- Swargate) is -1079.899 and the end of chainage of corridor 1A (PCMC to Nigdi) is -5601.089. Thus total length of corridor is 4.413 km, which is fully elevated. Length of viaduct beyond the end point of terminal station (Nigdi) is ~30 m . Scissor Crossover has been planned ahead of the terminal station i.e. Nigdi Station at -5100 to -5181.6 chainage, in order to prevent encroachment of defence land. This is due non-avalibility of land beyond Nigdi Station. The reduced viaduct length beyond station limits the operating speed. However, operation is still possible as proposed minimum headway is around 5 minutes. Permanent Speed restriction of 25kmph, 15kmph and 5kmph may be required to be imposed progressively for safe degraded operation. hsi is due non-avalibility of land beyond Nigdi Station. The reduced viaduct length beyond station limits the operating speed. However, operation is still possible as proposed minimum headway is around 5 minutes. Permanent Speed restriction of 25kmph, 15kmph and 5kmph may be required to be imposed progressively for safe degraded operation.

5.1.2.1 Elevated Viaduct structure

5.1.2.1.1 Superstructure Type

The superstructure of a large part of the viaduct comprises of simply supported spans. However at major crossing over or along existing bridge, special steel or continuous unit will be provided.

Following options are available elevated viaduct superstructure:

- Precast Segmental Box – Girder for standard viaduct
- Special Span – Like Steel composite girder

5.1.2.1.1.1 Precast Segmental Box – Girder

- Span range 13.0m to 34.0m;
- Track centre to centre distance 4.1m ;
- Precast segmental – maximum weight – one segment – 45T approx. – erection can be done by launching crane;
- Post-tension precast concrete – grade 50 MPa to grade 60 MPa.

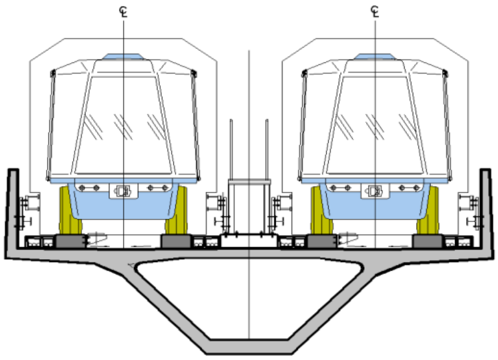


Figure 56 : Precast Segmental Box-Girder Viaduct - 2 Track Structure

Figure 57 : Precast Segmental Box-Girder Viaduct - 2 Track Structure – Delhi Metro

- **Advantages of Precast Segmental Box – Girder**

  - Simplification of all post-tensioning operations, especially installation of tendons;

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

5.1.2.1.2 Substructure & foundation type

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

At this preliminary design stage, the size of pier is found to be limited to 1.8m to 2.0 m diameter of circular shape for most of its height so that it occupies the minimum space at ground level where the alignment often follows the central verge of existing roads.

To prevent the direct collision of vehicle to pier, a Jersey Shaped crash barrier of 1.0 m height above existing road level has been provided all around the pier. A gap of 25 mm has also been provided in between the crash barrier and outer face of pier.

The shape of upper part of pier has been so dimensioned that a required clearance of 5.5 m is always available on road side beyond vertical plane drawn on outer face of crash barrier. In such a situation, the minimum height of rail above the existing road is 8.4 m. The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.4 m to 1.7m depending upon the type of superstructure. The space between the elastomeric bearings will be utilized for placing the lifting jack required for the replacement of elastomeric bearing.

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

Pile foundations or open foundation have been recommended for the foundations as per the soil stratum encountered.

Figure 58 : RC Pier cap for Segmental Box-Girder Viaduct

Figure 59 : RC Pier cap for Segmental Box-Girder Viaduct

5.1.2.2 Construction methodology

5.1.2.2.1 Superstructure

The choice of superstructure has to be made keeping in view the ease of constructability and the maximum standardization of the form-work for wide span ranges. Following types of superstructures have been considered:

- Precast Post tension segmental box girder;

5.1.2.2.1.1 Pre Cast Segmental Box Girder

This essentially consists of precast segmental construction with external prestressing and dries joints and is by far the most preferred technique in fast track projects. In such construction, the pre-stressing is placed outside the structural concrete (but inside the box) and protected with high density polyethylene tubes which are grouted with special wax or cement. The match cast joints at the interface of two segments are provided with shear keys as in traditional segmental construction. However, epoxy is dispensed with because water tight seal at the segment joints is not required in association with external tendons. The Photo and schematic arrangement is shown at Figure 60 & Figure 61.

Figure 60 : Launching Girder – Precast segmental Box Girder Construction

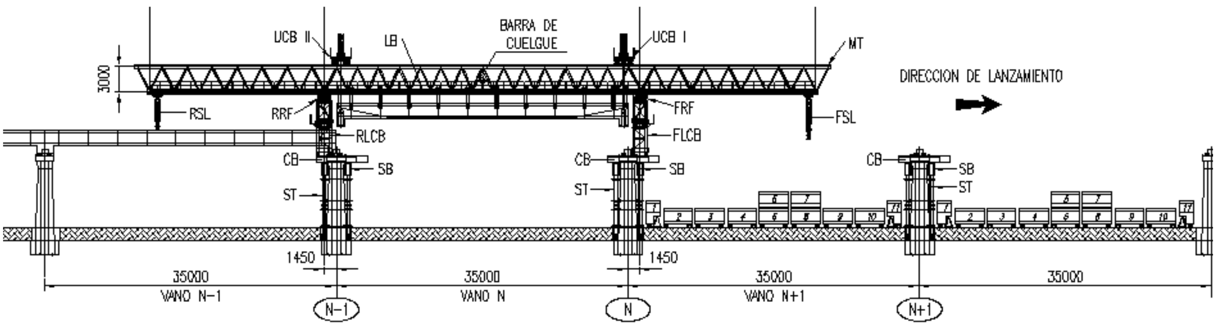


Figure 61 : Launching Girder – Precast Segmental Box Girder Construction

Constructing the typical segmental spans on an Advanced Launching Girder (ALG) with system formwork for span-by-span cast-in-situ construction:

Advanced Launching Girder with system formwork has been used in Singapore and it has demonstrated the effective use of this construction methodology in the viaduct construction to achieve quality finishes. The Advanced Launching Girder is a steel structure specially designed and fabricated for the cast-in-situ construction of the typical spans of the viaduct.

Construction steps are following for erection of segmental girder:

- Firstly, the piers and the cross heads are constructed in advance of the ALG. For the construction of every span, formwork units are adjusted, raised and suspended on the transverse trusses using Maccalloy bars (high tensile bars) in conjunction with the hollow ram jacks;
- After the formwork units are in place, fixing of reinforcement, placing of ducts and concreting will follow;
- When the structure achieves a concrete strength of 30 MPa, the stressing of the tendons will begin;
- Upon complete transfer of load to the starting elements and piers, the formwork units will be dismantled and placed on the working platform. The entire ALG will then be jacked to the next span. This cycle is then repeated.

The advantage of the span by span method of construction pertains to the prestressing steel requirement. Since the segments are supported by the form travellers, there are no cantilever stresses during construction, and pre-stress requirements are akin to those of conventional construction on false work.

5.1.2.2.2 Pre-Cast Construction

For the elevated sections: It is recommended to have pre-cast segmental construction or full span precast construction for super structure for the viaduct. For stations also, the superstructure is generally of Cast – In-situ or pre-cast members both. The pre-cast construction will have the following advantages:-

- Reduction in construction period due to concurrent working for substructure and superstructure;
- For segmental, pre-cast element (generally of 3.0m length), transportation from construction depot to site is easy and economical;
- For full Span precast element – Twin U-Girder (generally of 25.0m to 30.0m length) transportation from construction depot to site is easy and economical;
- Minimum inconvenience is caused to the public utilising the road as the superstructure launching is carried out through launching girder requiring narrow width of the road
- As the pre-cast elements are cast on production line in a construction depot, very good quality can be ensured;

- The method is environment friendly as no concreting work is carried at site for the superstructure.

Casting of segments

For viaducts' segmental pre-cast construction requires a casting yard. The construction depot will have facilities for casting beds, curing and stacking areas, batching plant with storage facilities for aggregates and cement, site testing laboratories, reinforcement steel yard, fabrication yard, etc. An area of about 20 ha to 25 ha is required for each construction depot (one per contract).

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

Figure 62 : Segments Casting in precast yard


Figure 63 : Segments Stacking in precast yard


Figure 64 : Transporting of Precast Segments from precast yard

5.1.2.2.3 Construction of stations

It is proposed to construct the elevated stations with elevated concourse over the road at most of the locations to minimize land acquisition. To keep the rail level low, it is proposed not to take viaduct through the stations. Thus a separate structural configuration is required (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.

However, there will be single viaduct column in the station area, which will be located on the median and supporting the concourse girders by a cantilever arm so as to eliminate the columns on right of way.

Super-structure will consist of precast segmental box Girders / Full Span Precast U-Girder for supporting the track structure and I Girder / Double T Girders for supporting the platform and concourse areas. A pre-cast or cast in situ pre-stressed cross girder will be required over the middle piers for supporting platform structure. Box shaped in situ pre-stressed cantilever cross girders are planned for supporting the concourse girders and escalators at mezzanine level.

Most of the members will be pre-cast in a construction depot and launched at site through cranes.

Pier arrangement drawings, viaduct & station options are represented in the drawings enclosed with the report.

5.1.2.2.4 Grade of concrete

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

- Piles - M -35
- Pile cap and open foundation - M -35
- Piers - M -40 to M-60
- All precast element for viaduct and station - M -45 to M-60
- Cantilever piers and portals - M -45 to M -60
- Other miscellaneous structure - M -35

5.1.2.2.5 Prestressing Steel

For pre-stressing work, low relaxation high tensile steel strands with the configuration 12 K 15, 19 K 15 and or 22 K 15 is recommended.

5.1.2.2.6 Reinforcement Steel

Thermo-mechanically treated reinforcement bars of grade 500D (min.) conforming to IS: 1786 will be adopted.

- Young's Modulus E= 200,000 MPa
- Yield Stress fy = 500 MPa

5.1.2.2.7 Road width required during construction

As most of the construction is to be carried out on the middle of the road, central two lanes including median will be required for construction activities. During piling and open foundation work, a width of about 9 m will be required for elevated viaduct construction and a width of about 12m will be required for at-grade construction and the same along with some clearance will be barricaded. In stretches, where the elevated alignment has to be located away from road, a strip of 15m width (with consideration of 2.5m clearance on either side to reduce land width), is proposed for acquisition, it ensures road access and working space all along the viaduct for working of emergency equipments and fire brigade. It is proposed that atleast one and maximum of two lanes are provided for traffic on either sides during construction depending upon the ROW of road, if necessary. In certain cases, one way traffic may be resorted to.

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

- Preliminary action for diversion of utility and preparation of estimates thereof;

Reservation of land along the corridor, identification and survey for acquisition.

5.1.2.3 Geotechnical investigations

5.1.2.3.1 General geology & characteristics

5.1.2.3.1.1 Location

The rail corridor which has been identified as potential MRT corridor runs through the Pune Metropolitan city & Pimpri Chinchwad Municipal Area (PCMC).

The proposed corridors 1A, covers the distance of 4.413 km and run along the road. The proposed sections are completely elevated.

Geotechnical investigations have been carried out along the proposed corridor including to determine the strata, depth of foundation and safe bearing capacity of foundations required for the above proposed metro corridors.

5.1.2.3.1.2 Physiography & climate

Pune District is in the western part of Maharashtra. It is bounded by Thane District to the northwest, Raigad District to the west, Satara District to the south, Solapur District to the southeast, and Ahmednagar District to the north and northeast.

Pune district lies in the Western Ghats or Sahyadri mountain range and it extends on to the Deccan Plateau on the east. Pune stands on the leeward side of the Western Ghats. Pune is at an altitude of 559m.(1863 ft.).

Pune city has assessed in seismic Zone 3. The temperature ranges from 5°C to 40°C. The city gets an average yearly rainfall of 772mm.

5.1.2.3.2 Field work

The entire site lies within built up area as the natural topography must have been altered during construction activities. But the terrain generally is of a rolling terrain of fairly level to a gentle slope, with some cases of a fairly sloppy terrain.

Subsurface explorations were carried out along the length of the proposed corridors. Boreholes were done at every 1000m at the proposed corridors.

5.1.2.3.2.1 Geotechnical Characteristics

A total of 20 boreholes were drilled for the corridor Phase 1A from PCMC to Nigdi section. Boreholes were drilled from depth 8.0m to 19.0m below ground level. The details of boreholes along the section is given below:

Table 59 Details of boreholes along the section

Borehole No.	Borehole Location	Water Table below ground level (m)
BH-1	Km 6.0	Nil
BH-2	Km 7.0	Nil
BH-3	Km 8.0	9.20
BH-4	Km 9.0	Nil
BH-5	Km 10.0	Nil
BH-6	Km 11.0	Nil
BH-7	Km 12.0	9.10
BH-8	Km 13.0	Nil
BH-9	Km 14.0	Nil
BH-10	Km 15.0	Nil
BH-11	Km 16.0	Nil
BH-12	Km 17.0	Nil
BH-13	Km 18.0	Nil
BH-14	Km 19.0	Nil
BH-15	Km 20.0	Nil
BH-16	Km 11.8	Nil
BH-17	Depot	Nil
BH-18	Gokul Nagar	Nil
BH-19	Gokul Nagar	Nil
BH-20	Gokul Nagar	Nil

The geological stratum for this site is majorly categorized in 2 stratums as shown Table 60:

Table 60 Summary of geological units

Soil Type	Stratum	Description
SOIL	Stratum – 1	Filled up soil & Silty Clay (CI & CH)
ROCK	Stratum – 2	Highly weathered to Fresh basalt rock

Stratum-1 SOIL: This layer is majorly encountered at top of the ground and underlain by Highly weathered basalt rock. Filled up soil is majorly encountered at top layer varying from 0.5m to 4.0m thickness. Silty clay layer of medium to high plasticity is observed from boreholes BH-5, BH-7, BH-14, BH-15 & BH-16. Thickness of this stratum is varying from 0.5m to 4.0m below ground level.

Stratum-2 ROCK: Highly weathered to fresh basalt rock is presented below soil stratum. This layer is encountered at the surface from boreholes BH-3, BH-8, BH-11, BH-17 & BH-18.

The summary of field work conducted is presented in the Geotechnical Report given as annexure at the end of the report..

Detailed Geotechnical – Soil Testing Report were also enclosed with Feasibility Report for all two sections and GIS report for third section shall be provided separately.

5.2 Design Norms

5.2.1 Alignment definition

This chapter deals with geometrical standards adopted for horizontal and vertical alignments, route description, etc. The proposed corridors under Pune MRTS network will consist of Standard Gauge (SG) lines.

The geometrical design norms are based on international practices adopted for similar systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 80 kmph. Planning for any higher speed is not desirable as the shorter inter station distance will not lead to significant difference in running time.

The elevated tracks will be carried on elevated deck supported by piers, generally spaced at varying centre to centre distance as per site requirement. 13m to 34m span length (pier centre to centre) is followed as much as possible with most of the piers located along the BRT and rest on footpath followed by private property to terminate at Bhakti – Shakti bus depot. The horizontal alignment and vertical alignment are, therefore, dictated to a large extent by the geometry of the road and ground levels followed by the alignment.

5.2.2 Rolling stock assumptions for alignment study

The conditions of implementation of the MRT system, partly at-grade & partly elevated without impacting the space given to road vehicle circulations command the choice of a rail based MRT system rather than a BRT. Therefore, assumptions of MRT rolling stock had been used for the alignment studies and are detailed in Chapter 11 Rolling stock.

5.2.3 Geometric design parameters

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

5.2.4 Horizontal alignment

As far as possible, the alignment follows the existing roads. This leads to introduction of horizontal curves. The criteria for designing horizontal curves are detailed next.

5.2.4.1 Transition Curves

It is necessary to provide transition curves at both ends of the circular curves for smooth riding on the curves and to counter act centrifugal force. Due to change in gradients at various locations in the corridor, it is necessary to provide frequent vertical curves along the alignment. It is desirable that the vertical curves and transition curves of horizontal curves do not overlap. These constraints may lead to reduced lengths of transition curves at certain locations. The transition curves have certain minimum parameters.

- Length of Transitions of Horizontal curves (m)
  - Minimum: 0.44 times actual cant or cant deficiency (in mm) whichever is higher;
  - Desirable: 0.72 times actual cant or cant deficiency, (in mm), whichever is higher.

- Overlap between transition curves and vertical curves not allowed;
- Minimum straight between two transition curves: either 25m or nil;
- Minimum curve length between two transition curves: 25 m.

5.2.4.2 Assumptions

Track gauge (between interior rails)	1435mm
Spacing of rail lines (between axes of rails)	1507mm
Distance between centre lines in straight alignment	4100mm in Line 1 & Line 2, 4600mm in Line 3
Maximum design speed*	90 km/h
Maximum operating speed*	80 km/h

Note*: *This maximum design speed is applicable for the straight and the flatter curved alignment, which covers most of the alignment. However, in curves sharper than 1000m radius, suitable speed restriction shall be applicable, which may be optimized for higher speed based on final survey details available.*

For any consecutive circular curves with opposite direction of curvature the length of straight track between the ends of the curves or of the transitions where these are required shall be not less than 25m. When it is not possible to provide a straight portion of 25m, no straight portion shall be provided and the transitions extended accordingly. The rate of change of cant and versine over both transitions shall be kept the same in such cases.

Transition curves will not normally be required between different radii of a compound curve where the change of radius of curvature does not exceed 15% of the smaller radius and provided that the cant deficiency and/or cant excess criteria are not exceeded for either curve.

Where a compound curve is employed with a change of radius greater than 15% of the smaller radius, or where the cant deficiency or cant excess criteria necessitates a change in cant between the circular curves, a suitable transition curve shall be interposed between the two parts of the curve. The length of such a transition shall be equal to the difference between the required transition lengths at each end of the curve.

When the actual shift of any calculated transition curve would be less than 10mm the actual transition curve may be omitted. In this case, the required change of cant shall take place over the calculated length of the transition, or 25 m whichever is the greater, and in the same location as if the transition had been provided.

In general for all running and depot lines transition curves shall be provided wherever possible between a circular curve and adjoining straight, between the different radii of a compound curve and at the adjoining ends of circular curves forming reverse curves. Transition curves are not required in sidings.

Applied cant shall be specified to the nearest millimetre for concrete track and to the nearest 5 mm for ballasted track.

Track at terminus stations shall continue past the end of the platforms by 25 metres where stabling or refuge tracks are not required. Minimum radius in station must not be less than 1000m.

Whenever possible the track shall be straight throughout the length of the stations. The presence of external restrains may necessitate limited encroachment of transition curves at station ends but this shall be avoided whenever possible. Where encroachment is unavoidable this shall be limited such that the vehicle throw does not affect the platform nosing clearance.

5.2.4.3 Design value

Table 61: Design Values Summary

PARAMETERS	THEORITICAL FORMULAE	REQUIREMENTS TO COMPLY WITH	
		LIMITING	PROJECT'S PREFERENTIAL
Theoretical equilibrium cant	$11.8V^2/R$	225 mm	195mm
Cant		125 mm	110mm
Cant deficiency		100 mm	85mm
Cant Gradient (geometrical variation of the cant)		≤ 1 in 500	≤ 1 in 750
Rate of change of cant		55 mm / s	35 mm / s
Rate of change of cant deficiency		55 mm / s	35 mm / s
Minimum radius in Running Track		120 m	225 m
Minimum radius in Depot		100 m	190 m
Length of pure circular arc between transitions		25 m	50 m
Length of Transition or Tangent Length		15 m	25 m
Minimum length of straight between reverse direction curves		25m or 0m	25m

5.2.5 Vertical alignment

Vertical curves shall wherever possible be positioned such that coincidence with horizontal transitions is avoided. Where such coincidence is unavoidable the largest practicable vertical curve radius shall be employed.

Vertical curves shall, for each location, be selected on the basis of the largest practicable vertical curve radius subject to the following limit:

- Minimum desirable radius 2500 m
- Absolute Minimum Radius 1500 m

The length of constant grade between consecutive vertical curves shall be as follows:

- Desirable minimum 50 m
- Absolute minimum 25 m

At point and crossing work vertical curves shall not coincide with any part of the overall length of switches or of cast crossings. At other point and crossing work vertical curves shall be avoided whenever possible. Where they cannot be avoided the vertical curve radius shall be 3000 m or more.

At station ends the tangent point of the vertical curve shall be permitted to encroach within the length of the platform to a limited extent. This length of encroachment shall be such that the vertical offset of the curve from the station gradient at the platform end shall not exceed 15mm.

5.2.6 Gradient

For running lines the desirable maximum gradient shall be 3% and where unavoidable shall be 4%. Where gradients of 1% or less are used they may be unrestricted in length. Gradients above 3.0% shall be kept as short as possible.

At stations the track shall be level or of constant gradient not steeper than 0.2% throughout the platform length except for the limited lengths of vertical curves as specified in relevant clause under Vertical Alignment.

A drainage gradient shall be provided for all viaducts, other than at stations, as follows :

- Desirable minimum 0.5%
- Absolute minimum 0.25%

Sidings shall be level or shall fall away from the main line switch at a gradient not exceeding 0.25%. Train berths shall be level or shall fall towards the buffer stops at a gradient not exceeding 0.25%.

5.2.7 Levels

All levels shall be quoted in metres correct to three decimal places and shall be above mean sea level (MSL).

Rail level on canted track will refer to the level of the running edge of the lower rail.

5.2.8 Points and crossings

Whenever possible, points and crossing work shall not coincide with vertically or horizontally curved track.

Where it is not possible to avoid coincidence with vertical curves the switches and stock rails shall not be laid on vertical curves.

Points and crossing work shall not coincide with horizontal transitions.

No part of the switches, switch operating gear or crossing nose shall be over a structural movement joint.

In case of unavoidable circumstances, if the coincidence with horizontal curve cannot be avoided, the same may be laid in curve having radius greater than 1000m with cant applied made zero.

Generally 1 in 9 turnout with 300m Radius (1 in 9 R300) is to be adopted in Main Line and 1 in 7 turnout with 190m Radius (1 in 7 R190) is to be adopted in depot tracks.

5.2.8.1 Scissors crossovers

Scissors crossovers shall be based on a transitioned crossover with vertical rails.

The switch points and turnout radius shall be standard UIC or approved equivalent, designed to accommodate a minimum operational speed of 40 km/hr.

5.2.8.2 Turnouts

Turnouts shall be based on a transitioned turnout with vertical rails.

- The speed through the turnout shall be 50 km/hr.
- Operational speed in the depot shall be 25 km/hr.

5.2.9 Stations locations

Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport. However effort has also been made to propose station locations such that the locations where maximum commuter travel. Further detail on stations locations is provided in the Station Planning chapter - 6 of this report.

5.2.10 Track structure

Track on MRT systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus it is imperative that the track structure selected for MRT systems should be long lasting and should require minimum maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. The track structure has been proposed keeping the above philosophy in view.

Two types of track structures are proposed for the corridors under Pune MRT network. The normal ballasted track in depot (except inside the workshops, inspection lines and washing plant lines). The ballastless track is recommended on viaducts as the regular cleaning and replacement of ballast at such locations will not be possible. For the depots, ballasted track is recommended as ballastless track on formation is not suitable due to settlement of formations. Ballastless track in depot is required inside the workshop, on inspection lines and washing plant lines.

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

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

5.2.11 Rail section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1080 Head Hardened. For the depot lines, the rails of grade 880 are recommended.

5.2.12 Ballastless track on main lines

On the viaducts, it is proposed to adopt plinth type ballastless track structure with RCC derailment guards integrated with the plinths, with a base-plate spacing of 60 cm.

5.2.13 Ballastless/ballasted track in depot

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

- Supported on steel pedestal for inspection lines;
- Embedded rail type inside the workshop;
- Plinth type for washing line;
- Track is to be laid on PSC sleepers with sleeper spacing of 65 cm;
- All the rails are to be converted into rail panels by doing flash butt/alumino thermic welding.

5.2.14 Buffer stops

On main lines and depot lines, friction buffer stops with mechanical impact absorption (non-hydraulic type) will be provided.

In elevated portion, the spans on which friction buffer stops are to be installed will be designed for an additional longitudinal force, which is likely to be transmitted in case of Rolling Stock hits, the friction Buffer Stops.

5.2.15 Rail structure interaction

For continuing LWR (Long Welded Rail)/CWR (Continuous Welded Rail) on viaducts, the elevated structures will be adequately designed for the additional longitudinal forces likely to be transmitted as a result of Rail-Structure interaction. Rail structure interaction study will determine the need and locations of Rail Expansion Joints (REJ) required to be provided.

5.3 Geometric Design of Corridor including plan/profile

Enclosed

5.4 Identification of existing services/utilities

5.4.1 Introduction

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

- Existing utilities and planning for their diversion during construction, if necessary;
- Land acquisition necessary for the project both on permanent basis as well as temporary, including its break up between Government and private ownership.

5.4.2 Utilities and services

Large number of sub-surfaces, surface and overhead utility services viz. sewers, water mains, storm water drains, telephone cables, O.H electrical transmission lines, electric poles, traffic signals, etc. exists along the proposed alignment. These utility services are essential and must be maintained in working order during different stages of construction, by temporary/permanent diversions 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. Also, these may affect construction and project implementation time schedule/costs, necessary planning/action needs to be initiated in advance. Organizations/Departments with concerned utility services in Pune are mentioned in the following table.

Table 62 : Organisations/Departments with concerned utility services in Pune

S.No.	ORGANIZATION/ DEPARTMENT	UTILITY SERVICES
1	Pimpri Chinchwad Municipal Corporation	Surface water drains, nallahs, sewerage and drainage conduits, sewerage treatment plants, pumping stations, electric poles, Road construction & maintenance of Roads etc
2	Telecommunication Department	Telecommunication cables, junction boxes, telephone posts, O.H. lines, etc.
3	Traffic Police	Traffic signal posts, junction boxes and cable connections, etc.
4	MIDC	Water supply Line
5	Electricity Board	OH & underground electric cables
6	Maharashtra Natural Gas Limited	Gas pipe line

5.4.3 Guidelines for Diversion

5.4.3.1 Above Ground Utilities

Above ground utilities namely street light, poles, traffic signal posts, telecommunication posts, junction boxes, trees etc., also needs to be shifted and relocated suitably during construction of elevated viaduct. Since these will be interfering with the proposed alignment.
Such 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.

Such overground utilities identified during physical survey are listed below :

Table 63 : Number of Overground affeted due to metro alignment

S.No	Location	Direction	Units
1	Light Poles	Along the alignment	31
2	Traffic Signals	Along the Alignment	27
3	Sign Boards	Along the Alignment	12
4	Hoarding Boards	Near Bhakti shakti Chowk	2
5	Electric Poles	Near Bhakti shakti chowk	2
6	Transformer	Near Bhakti shakti chowk	1
7	Overhead transmission tower	Near Bhakti Shakti Chowk	1
8	Trees	Along the Alignment	342
TOTAL			418

5.4.3.2 Underground utilities

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

- 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.

5.4.3.2.1 Sewer Lines, Storm Water Drains and Water Lines

The sewer/drainage/Water lines etc. generally exist in the service lanes and footpaths i.e. away from main carriageway. However, at certain points these utilities are crossing the main carriageway.

The major sewer/drainage/Water lines etc. running across the alignment and likely to be affected at certain location due to metro column foundations and are proposed to be taken care of by relocating on column supports of viaduct by change in span or by suitably adjusting the layout of pile foundations. Where, this is not feasible, lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines. which works out to 26.48 Cr. for the alignment length.

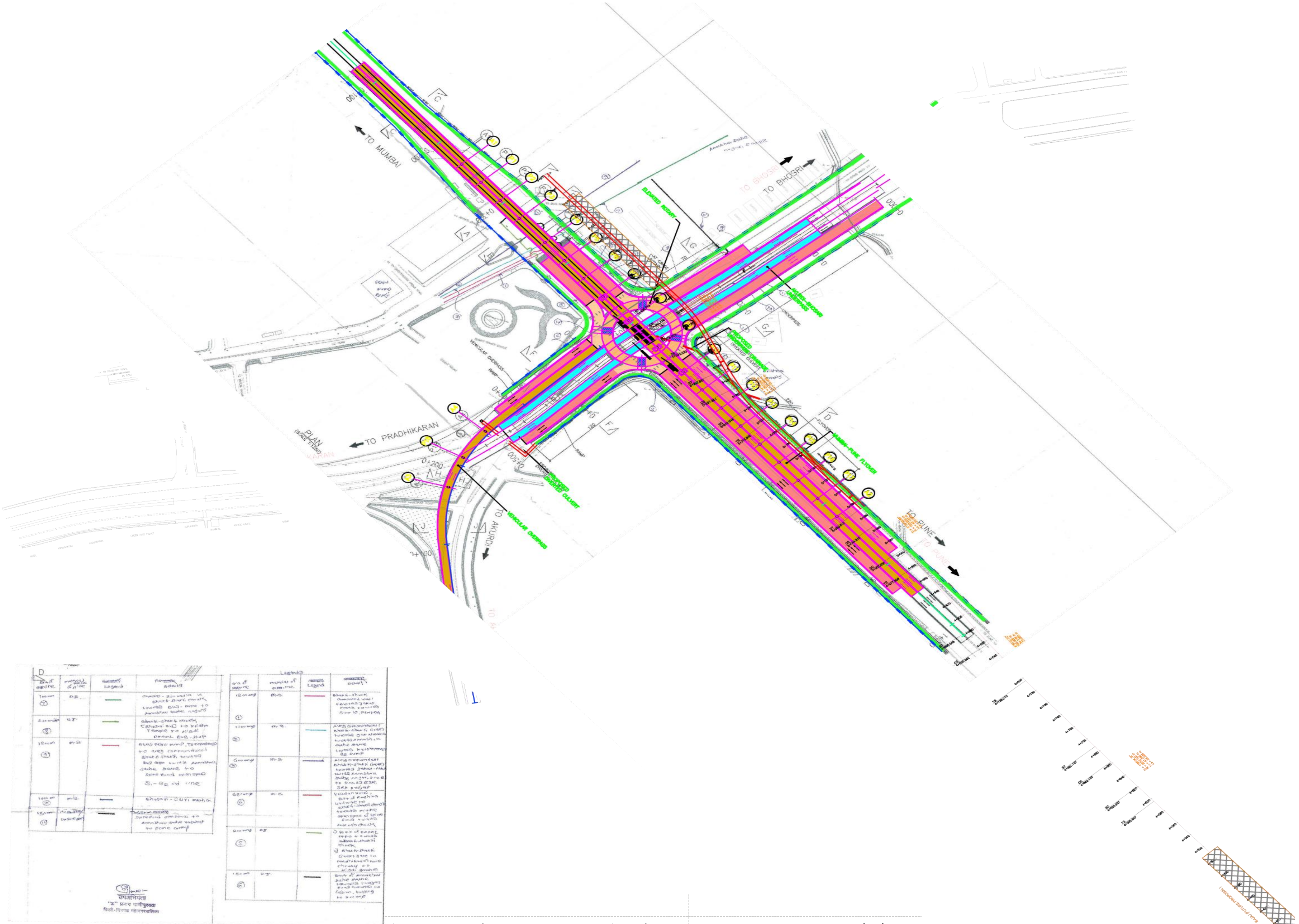
Water utility around Bhakti shakti chowk and nearby area is shown in Figure 65 by super imposing metro alignment over it, with final station over bhakti-shakti bus depot. Details of affected utility is documented Table 64.

Table 64 : Details of utility affected at Bhakti shakti chowk due to Metro alignment

S.No.	Type	Location	Diameter
1	Ductile Iron Pipes	Bhakti Shakti chowk – Bus Depot toward anna bhau sathe	100mm
2	Ductile Iron Pipes	Bhakti Shakti chowk – Krishna Temple – PMPML Bus stop	200mm
3	Ductile Iron Pipes	Front of PMPML Bus stop – Bhakti-Shakti Chowk	200mm
4	Mild Steel Pipes	Petrol Pump – Bhakti Shakti Depot-Spine road	1200mm
5	Cast Iron pipes	Spine Road – Anna Bhau Sathe	150mm
6	Cast Iron pipes	Anna Bhau sathe statue – Talegaon Road	150mm
7	Cast Iron Pipes	Anna Bahu sathe statue – Talegaon	
8	Mild steel pipe	Bhakti-Shakti - Anna Bhau Sathe –	1100mm

		Krishna Nagar	
9	Mild steel pipe	Radhika Hotel – Bhakti-Shakti chowk – Open space on spine road	450mm
10	Mild steel pipe	Bhakti-shakti Garden – Anna Bhau sathe	400mm

Figure 65 : Location of affected Land Required For Corridors



5.5 Land Required for Corridor

Availability of land is one of the major prerequisites for a project in cities like Pune. As the Metro alignment has to be planned on set standards and parameters, it becomes difficult to follow the road alignment. Apart from alignment the various structures like stations, parking facilities, traction sub stations, communication towers, etc. require large plots of land. The land being scare, costly and acquisition being complex process; the alignment is so planned that barest minimum land acquisition is involved. Land is mainly required for;

- Metro Structure (including Route Alignment), station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities, etc.

5.5.1 Land Required for Elevated Stretches

For elevated section, single pier supporting the viaduct will be located in the BRT alignment on the middle of road so that the existing roads remain in use as usual. Accordingly, necessary permission for using such right-of-way will have to be obtained from the concerned authorities. Elevated stations are generally proposed with elevated concourse so that land is required only for locating the entry/exit structures. Traffic integration facilities are provided wherever the same are required but no land is proposed for acquisition.

The normal viaduct structure of elevated Metro is about 10 m (edge to edge) wide. Ideally the required right of way is 9-10m and it is available hence no LA is proposed. In stretches, where the elevated alignment has to be located away from road, a strip of 15m width (with consideration of 2.5m clearance on either side to reduce land width), is proposed for acquisition, it ensures road access and working space all along the viaduct for working of emergency equipments and fire brigade.

5.5.2 Land for Stations

Provision of land for Traffic integration has been made on those stations only, where space is available. It is proposed to provide traffic integration facilities at all the following Metro stations. Land for these facilities has been identified and is given in the Table 65.

Table 65 : Lands For Stations & Traffic Integration

<table>
<tr><th>S.NO.</th><th>Station.</th><th colspan="2">Area (sqm)</th><th>Type of property</th><th>Ownership</th><th>Remarks</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">(Chinchwad)</td><td rowspan="2">972</td><td>624</td><td>Open</td><td>Pvt</td><td rowspan="2">Park/Market</td></tr>
<tr><td>348</td><td>Open</td><td>Govt</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">(Akurdi)</td><td rowspan="2" colspan="2">797</td><td rowspan="2">Commercial</td><td rowspan="2">Pvt</td><td>Madarsa+Bajaj</td></tr>
<tr><td>Auto Company</td></tr>
</table>

<table>
<tr><td rowspan="2">3</td><td rowspan="2">(Nigdi)</td><td rowspan="2">1022</td><td>642</td><td>Commercial</td><td>Pvt</td><td></td></tr>
<tr><td>380</td><td>Bus Depot Land</td><td>Govt</td><td></td></tr>
<tr><td colspan="2">Total Area</td><td colspan="5">2791 m2</td></tr>
</table>

5.5.3 Land Requirement for Running Section

As indicated earlier, the ROW of the roads along which the alignment is planned is sufficiently wide hence no land is required for acquisition as long as the alignment is straight and at the center of the road. However, at curved portions, the alignment could not be kept at the center of the road and acquisition of certain land is inevitable in spite of introduction of sharper radius curves in elevated sections. The land required for alignment planning is given in Table 66.

Table 66 : Land Requirement Running Section

<table>
<tr><th>S.NO.</th><th>PLOT NO.</th><th>LOCATION</th><th>DETAILS</th><th>AREA(m2)</th><th>OWNERSHIP</th></tr>
<tr><td colspan="6">Corridor – IA (PCMC – Nigdi)</td></tr>
<tr><td>1</td><td>1RS 1</td><td>Ford Showroom</td><td>Commercial</td><td>1619</td><td>Pvt.</td></tr>
<tr><td>2</td><td>1RS 2</td><td>Open Land</td><td>Open Land</td><td>187</td><td>Govt.</td></tr>
<tr><td>3</td><td>1RS 3</td><td>Temple Area</td><td>Open Land</td><td>623</td><td>Pvt.</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">1RS 4</td><td rowspan="2">Open land with temporary structure</td><td rowspan="2">Open Land</td><td>451</td><td>Pvt.</td></tr>
<tr><td>329</td><td>Pvt.</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">1RS 5</td><td rowspan="2">Land for Foot Over Bridge</td><td rowspan="2">Market</td><td>1299</td><td>Pvt.</td></tr>
<tr><td>148</td><td>Govt.</td></tr>
<tr><td colspan="4">Total Area</td><td>4655</td><td></td></tr>
</table>

5.5.4 Land Required For Property Development

5.5.4.1 Identification of Sites for Property Development:

To ensure fast implementation of the proposals and optimisation of earnings, the following criteria have been kept in view:

- Land plots to be close to the proposed MRTS corridor.
- Land plots should be vacant and owned preferably by a Government agency.
- Proposed usage to be in conformity with provisions of Development Plans of the city.
- Availability of adequate infrastructural support and optimum potential for commercial utilization and early high returns.

5.5.4.2 Methodology of Property Development:

Process of property development requires land, labour, capital, entrepreneurship and management as major inputs. Following steps are involved in the process:

- To obtain land free from all encumbrances with a clear title.

- To obtain clearances of the concerned government and local authorities for proposed usage, ground coverage, FAR, height and other basic controls and availability of essential services like water supply, sewers, electric supply, approach roads, etc.
- To assess demand and optimum usage and expected returns.
- To prepare architectural plans/models and obtain sanctions of concerned authorities.
- To prepare construction plans, structural designs, etc. for implementation.
- To appoint executing agency and create supervising organization.
- To sell the developed property and realize the proceeds thereof.
- To allow the property on long-term lease.

Property development and its transfer can be under taken by MRTS either by themselves or in collaboration with a builder/developer. Since it involves not only heavy financial investment but also real estate expertise and risk, it is considered better to undertake this activity in collaboration with some established builder/developer of repute on pre-agreed terms regarding individual responsibilities and various related financial aspects. Thus in our case, 2 parcel of government owned land has been identified, which was proposed to be given on a 50 year capital lease to a private builder, after the commencement of the project in order to maximize the benefit.

The details of land identified for property development are shown in Table 67.

Table 67 : Land identified for Property Development

S. No	Location	Land Area (Sqm)	Ownership
1.	Govt land under PCNTDA (Near Bhakti Shakti Chowk)	30000	Government
2.	Open land at the back of City one mall	24000	Government
TOTAL		**54000**	

5.6 Summary of land requirements

Abstract of land requirements for project is given in Table 68 : Summary of Permanent Land Requirement (sqm)

Table 68 : Summary of Permanent Land Requirement (sqm)

Sr.No.	Description	Type of Land	
		Govt.	PVt.
1	Stations	728	2063
2	Running Section	335	4321

Total Land required for aquisition for the project is : **0.7446 Ha**.

5.6.1 Relocation / Resettlement

The project involves relocation of few shops, commercial cum residential buildings and hutments along the alignment. Compensation for relocation of these affected structures shall be paid and it has been considered in the project cost estimate. The alignment has been so chosen, that it remains mostly within the government land. However, at certain locations while negotiating the curves, the land acquisition became inevitable.

5.7 Principles of Traffic Diversion Plan

The primary objective of the Traffic Diversion Plan is to identify alternate actions to alleviate congested roadway conditions, during the construction of MRT, which would be efficient, convenient, economical and safe for both pedestrians and vehicular movements.

It is suggested to create a balance between safety needs of the road users and the site operatives and to minimize the delay to road users. Recognized and uniform procedures have to be applied to ensure that:

- Road users are accommodated through and around the construction zones safely with minimum delay;
- Bicyclists and pedestrians, including those with disabilities, should be provided with access and safe passage through the work zones;
- Traffic control and construction activities are coordinated to provide for safe and efficient flow of traffic together with efficient, safe and rapid progress of construction activity;
- If construction activities are taking place at multiple sites along same or parallel routes, construction activity and road traffic management should be coordinated so as to minimize the total delay;
- In urban environment, works requiring partial road closures on alternative routes should be phased, where possible, so that they are not undertaken at the same time.

The diversion plan will be prepared based on detailed reconnaissance survey and duly considering the Classified Traffic Volume Counts conducted during morning / evening peak periods, along the Pune MRT corridor and around the surrounding areas and also taking the following factors into account:

- It is assumed that half of the carriageway width shall be available for the traffic movement;
- For easy movement of pedestrians, the footpath width shall be kept available for pedestrians at diversion locations;
- Access to the property along MRT stations shall be provided.

The Traffic Diversion Plan suggested should take into consideration the road widths of the surrounding road network.

The Traffic Diversion Plan shall be suggested based on the understanding that on-street parking will be removed/relocated and the carriageway would be free of encroachments along the MRT corridor and alternative roads during construction period for efficient vehicular and pedestrian movement.

Appropriate traffic management measures should be adopted like relocation of bus stops, junction improvement measures, road geometric improvements, installation of traffic signage, barricading the construction area and road carriageway, etc. A broad methodology for preparing the traffic diversion plans is shown in following figure:

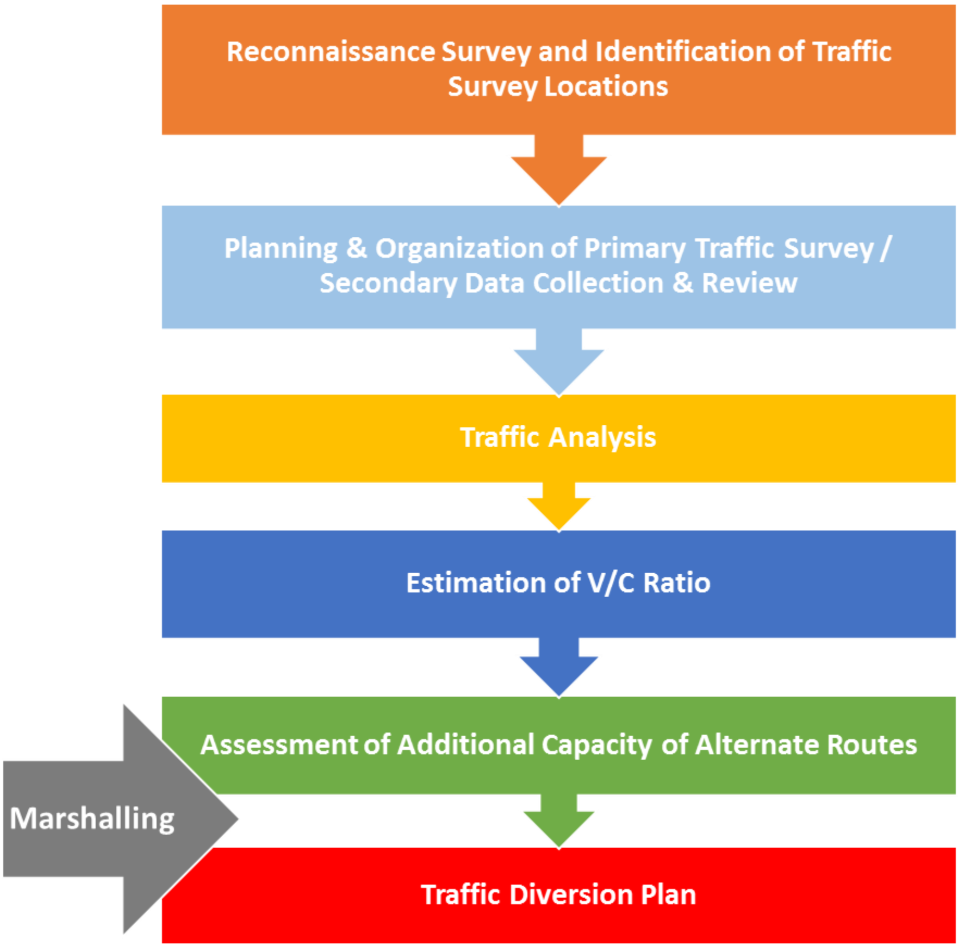


Figure 66 : Broad methodology for preparing the traffic diversion plans

6. STATION PLANNING

6.1 Introduction

Pune is well known as the 'Queen of Deccan' due to its scenic beauty and rich natural resources. Besides, it is famous for its religious and historical places. Pune city is known in the world map because of its educational, research and development institutions. The district also has an importance as an important military base. Pune is the most industrialized district in western Maharashtra and a famous IT hub in the country. Pune exemplifies an indigenous Marathi culture and ethos, in which education, arts & crafts and theatres are given due prominence. Pune is the cultural capital of Maharashtra. It is the birth place of the poet-saint Tukaram. It is the home of great freedom fighters like Bal Gangadhar Tilak, Agarkar and Gopal Krishna Gokhale. Jayant Narlikar, the famous contemporary scientist is from Pune.

6.1.1 History and architectural characteristics of Pune

6.1.1.1 History of the city

The city of Pune has been a city of major importance in the India subcontinent since the 17th century. Confined to the East bank of the Mutha river until the early 19th century, the city started to grow on the west bank as well. The city witnessed fast growth after Independence.

In addition to its temples, historical attractions in and around Pune include the rock-cut Pataleshwar cave temple, Aga Khan Palace, Shaniwarwada, Lal Mahal, and Sinhagad fort. The city is also known for its British Raj "bungalow architecture" and the Garden Cities Movement layout of the Cantonment in the early Twentieth Century.

- **Kasba-Peth – heart of the city**

Kasba Peth or Kasba is the oldest residential part, "Peth " (locality), in Pune, India. It is adjacent to the historic Shaniwar Wada palace-fort. Kasba Peth was the first Peth to be established sometime during the 5th century and is the oldest area in Pune. It is called the "Heart of Pune City". In the history of Pune, the city was once known as "Kasbe Pune".

A wide variety of shops surround Kasba Peth (Tambat Ali, Shimpi Ali, Vyavahar Ali, Bhoi Ali, etc.). It is well known for the Kumbhar Wada (area of earthen potmakers) and the Tambat Ali (area of brass/copper utensil manufacturers).

Lal Mahal

The Lal Mahal (Red Palace) of Pune is one of the most famous monuments located in Pune, India. In the year 1630 AD, Shivaji Maharaj's Father Shahaji Bhosale, established the Lal Mahal for his wife Jijabai and son. Shivaji Maharaj stayed here for several years until he captured his first fort.

Kumbhar Wada

In Kumbhar Wada the past of old Pune lives on. Kumbhar Wada is the ancient potterymakers' quarter in Kasba Peth, a district in the city's historic core. Kumbhar means potter and wada a place or area. The kumbhars have kept their traditional craftsmanship alive in Pune since the era of Shivaji Maharaj (1630--1680), founder of the Maratha Empire.

Tambat Ali

On invitation of the Peshwas the Tambats came some 400 years ago, when Pune was being established as their administrative headquarters. The Tambats came from regions like Thane, Colaba, Ratnagiri, etc. Tambats are part of an age old social system known as 'Bara Balutedars'. These are craftsmen working and dealing in utensils of copper, bronze, brass, etc. Copper is known as 'tamba' in Marathi from which the name 'Tambat Ali' has evolved.

Shaniwar Wada

Peshwa Baji Rao I, prime minister to Chattrapati Shahu, laid the ceremonial foundation of his own residence on Saturday, January 10, 1730. It was named Shaniwarwada from the Marathi words Shaniwar (Saturday) and Wada (a general term for any residence complex). Teak was imported from the jungles of Junnar, stone was brought from the nearby quarries of Chinchwad, and Lime (mineral) was brought from the lime-belts of Jejuri. Shaniwarwada was completed in 1732, at a total cost of Rs. 16,110, a very large sum at the time. Later the Peshwas made several additions, including the fortification walls, with bastions and gates; court halls and other buildings; fountains and reservoirs.

Sinhagad Fort

Sinhagad (also known as Sinhgad) is a hill fortress located at around 25 km southwest of the city of Pune, India. Some of the information available at this fort suggests that the fort could have been built 2000 years ago. The caves and the carvings in the Kaundinyeshwar temple stand as proofs for the same. The Sinhagad (Lion's Fort) was strategically built to provide natural protection due to its very steep slopes.

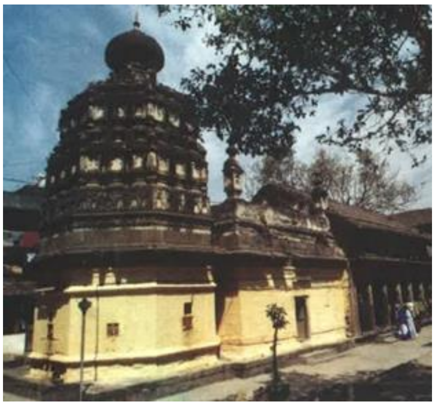
Aga Khan Palace

The Aga Khan Palace was built by Sultan Muhammed Shah Aga Khan III in Pune, India. Built in 1892, it is one of important landmarks in Indian history. Aga Khan palace has Italian arches and spacious lawns. The building comprises five halls. It covers an area of 19 acres (77,000 sq m), out of which 7 acres (28,000 sq m) is the built-up area. The area of the ground floor is 1756 sq m, that of the first floor is 1080 sq m, whereas the second floor has a construction of 445 sq m. The specialty of this structure is its corridor of 2.5 meters around the entire building.

Dagadusheth Halwai Ganpati Temple

It is dedicated to the Hindu God Ganesh. The temple is popular in Maharashtra and is visited by thousands of pilgrims every year.The temple is situated in the center of city, local shopping market is also the nearby temple. The temple is a beautiful construction and boasts a rich history of over 100 years. Jay and Vijay, the two sentinels made of marble catch the eye of all at the outset. The construction is so simple that all the proceedings in the temple along with the beautiful Ganesh idol can be seen even from outside. The Ganesh idol is 2.2 meters tall and 1 meter wide.

Nageshwar Temple



Nageshwar Temple is one of the oldest temples of Pune, Maharashtra. It's a small but graceful temple. The main shrine or Garbhagriha, where the deity is kept, is certainly very old, probably dating back to the 14th century.The main shrine is an octagonal stone structure on square plinth. Over it rises an octagonal tower or shikhara, with an intricately carved band of creepers around its base. The Shikhara is ornamented with a tiered series of miniature temples and is surmounted by a small onion-shaped dome on a narrow base.

Hari Mandir – an example of colonial architecture

A solid stone structure with an arched front and a porch, it is an example of colonial architecture could be adopted for Indian needs. The large hall inside has a gallery and a lectern from which the prayers were led. The size of the hall is an indication of popularity in Samaj at one time. The compound also has a small stone stupa, the samadhi of sir R. G. Bhandarkar whose ashes it contains. This interesting building binds Pune to the Indian Renaissance of the 19th century.

Vernacular colonial style at Dastur Meher Road

When the poona cantonment was set up (1818-1820), an area called Sa dar Bazar was set aside for Indian traders, which was felt necessary for providing the army with its daily needs. It constitutes a very cosmopolitan urban settlement, comprising people from all provinces & communities. The streets & lanes here developed a remarkable character reflecting a mixture of European architecture with that of the regional styles of the owner's original home.

Key

Laxmi Road environs
7. Paars
17. Tulshibaug
18. Nagar Vachan Mandir
23. Belbaug
24. Vishrambaug Wada
26. Nivadungya Vithoba
31. Lakdi Pul
49. Ghode Pir

Kasaba Peth environs
1. Tambat Ali
2. Shimpi Ali
3. Nageshwar Temple
5. Trishund Ganpati
6. Mujumdar Wada
8. Kumbharwada
9. Hari Mandir
12. Hauds
19. Beauty of Bricks
30.Nava pul

City
10. Talims
13.Deepmala
14. Bohri Ali
16. Irani Restaurant
20. Pune University
25. Khunya Murlidhar
27. Handicrafts
28. Poona Toys
29. Bund Garden Bridge
32. Mandai-Mahatma Phule Market
33. Bharat Itihas Samshodhan Mandal
34. Deccan College
40. BEG Mess, Khadki
41. Sangam
43. Pune's Gates
44. Fergusson College
50. Burud Ali
51. Dagadusheth Halwai Ganpati Temple
52. Pataleshwar Temple
53. Aaga khan palace

Cantonment
4. Dastur Meher Road
11. St. Mary's Church
15. Synagogue
21. St. Paul's Church
22. Camp Education Society
35. Camp Library
36. Arsenal Tower
37. Ghashiram Kotwal Mansion.
38. Kolsa Galli
39. Club of Western India
42. Zero Stone
45. Mahadaji shinde Chhatri
46. St. Xavier's Church
47. Shivaji Market
48. West End & Victory Theatres

Figure 67 : Heritage map of Pune
(Source: "Glimpses of Pune's Heritage - A Mosaic " by Samita Gupta)

6.1.1.2 Architecture and heritage of the city

6.1.2 Overview of corridor and proposed stations

This study comprises Corridor 1A, for which 3 number of stations have been proposed:

S.No	Corridor	Approx. Length of corridor	Number of proposed stations
Corridor 1A	PCMC to Nigdi	4.413 km	3 (elevated)

6.2 Station locations

This section is aimed at presenting the stations locations, showing their sequencing and analyzing their local catchment areas.

6.2.1 General

Stations have been located to serve major passenger catchment areas/destinations and to enable convenient integration with other modes of transport. The sequence of stations and types of proposed stations for corridor 1A is presented in the section hereafter.

6.2.2 Sequence of stations and types of proposed stations

The Table 67 present the sequence of stations and type for proposed corridor 1A .

Table 69 : Sequence of stations in Phase 1A (PCMC to Nigdi)

SN	Station Name	Inter-station Distance (Km)	Cumulative Distance (Km)	Elevated/ Underground	Chainage
	Phase 1A: PCMC To Nigdi				
1	Station 1 (Chinchwad)	0.89	0.89	Elevated	1789.2
2	Station 2 (Akurdi)	1.67	2.56	Elevated	3459.2
3	Station 3 (Nidgi)	2.03	4.59	Elevated	5601.089

6.2.3 Stations areas characteristics

This section provides a general overview of the corridor and the proposed stations : locations, existing and future local urban fabric, landmarks, access etc.; For each station, an analysis has been conducted regarding:

- The station location;
- The main roads to access the station;
- The land use around the station;
- The issues and concerns identified;
- The potential for improvements.

The corridor 1A PCMC to Nigdi is a 4.413 km long extension of phase I line, which runs from PCMC to Swargate. It is proposed on Old Mumbai Road. 3 elevated stations are proposed on this corridor (see following figure):

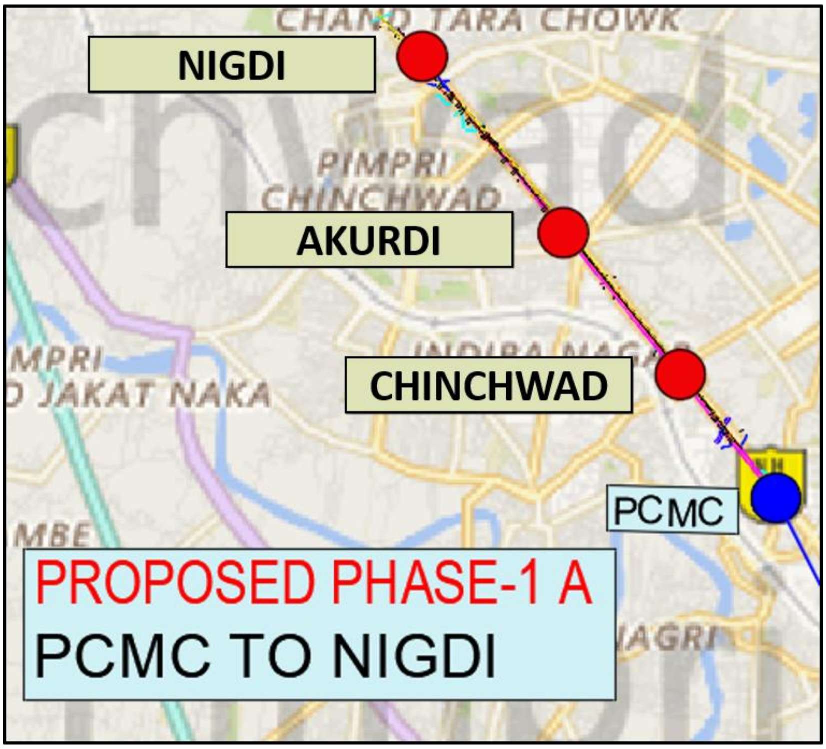


Figure 68 : PCMC to Nigdi corridor
(Source: Google Maps and Systra, 2018)

Local area along corridor:

- This corridor is excessively crowded (both in terms of population density and road congestion) at present;
- Road contains many flyovers, underpasses and less pedestrians.

Areas covered by stations:

- Stations at the proposed locations cover existing famous Temples (Khandoba, Bhakti Shakti);
- Stations at the proposed locations cover existing residential, educational, office and commercial area of corridor areas as well as future developments proposed by respective local authorities.

Access to stations:

- Access to & egress from stations will be guaranteed by the implementation of:
  - pick-up and drop-off areas for different modes (bus stops when relevant, IPT modes and car)
  - pedestrians facilities (footpath, pedestrian crossing, over bridge etc.)
  - cyclists (cycle stands etc.)

  General recommendations for access/egress to/from stations will also be made;
- For optimal access to stations:

- four entries are proposed for On Road Stations
- for Off Road Stations two entries along with one entry across the road is proposed with a Foot Over Bridge (FOB).

- Entries/exits are mostly proposed between service roads and highways;
- Entries shall be covered;
- FOB will be also used for crossing the road for safety purpose;
- Narrow entries proposed due to lack of land availability (at some stations);
- The proposed stations shall be disable friendly.

Stations with specific characteristics:

- Station 3 (Nigdi):
    - Station 3 is proposed with Property Development area above;
    - Station 3 also caters bus terminals, proposed future connection road near it as well as local residential area.
- Station 1 (Chinchwad):
    - Station 1 also caters Chinchwad Railway Station through FOB;

Station 1 (Chinchwad)

STATION INTRODUCTION: it is the first station on the PCMC to Nigdi corridor. It is an elevated station proposed on the Old Mumbai Road near Chinchwad Station Chowk. The major roads connecting the station are Chinchwad Station Road and Chinchwad - Bhosari Road. The station caters the public, semi-public, commercial and the residential areas of Pimpri and Chinchwad and the Railway Station of Chinchwad through proposed FOB. It also caters the Sony complex building , Pimpri Police station and Mayur Tread Centre.	
ISSUES & CONCERN	**POTENTIAL FOR IMPROVEMENT**
• Lack of pedestrian facilities like footpath, pedestrian for crossing road along the road results in pedestrian spill over on road; • Chaotic operations of Tempo services	• Dedicated non-motorized modes friendly facilities like footpath and cycle stands, and FOB is used for crossing roads; • Planning of dispersal activities through feeder modes will cater to a larger catchment.

 1. Roadside encroachment and on-street parking.	 2. PCMC empty land (may be used for entry structure in the future)
 3. Commercial area along the road.	 4. Road side encroachment and on-street parking.

Station 1 (Chinchwad) Entry

Figure 69 : Entry/Exit of Station 1 (Chinchwad)

Figure 70 : Proposed FOB from Metro Station to Railway Station

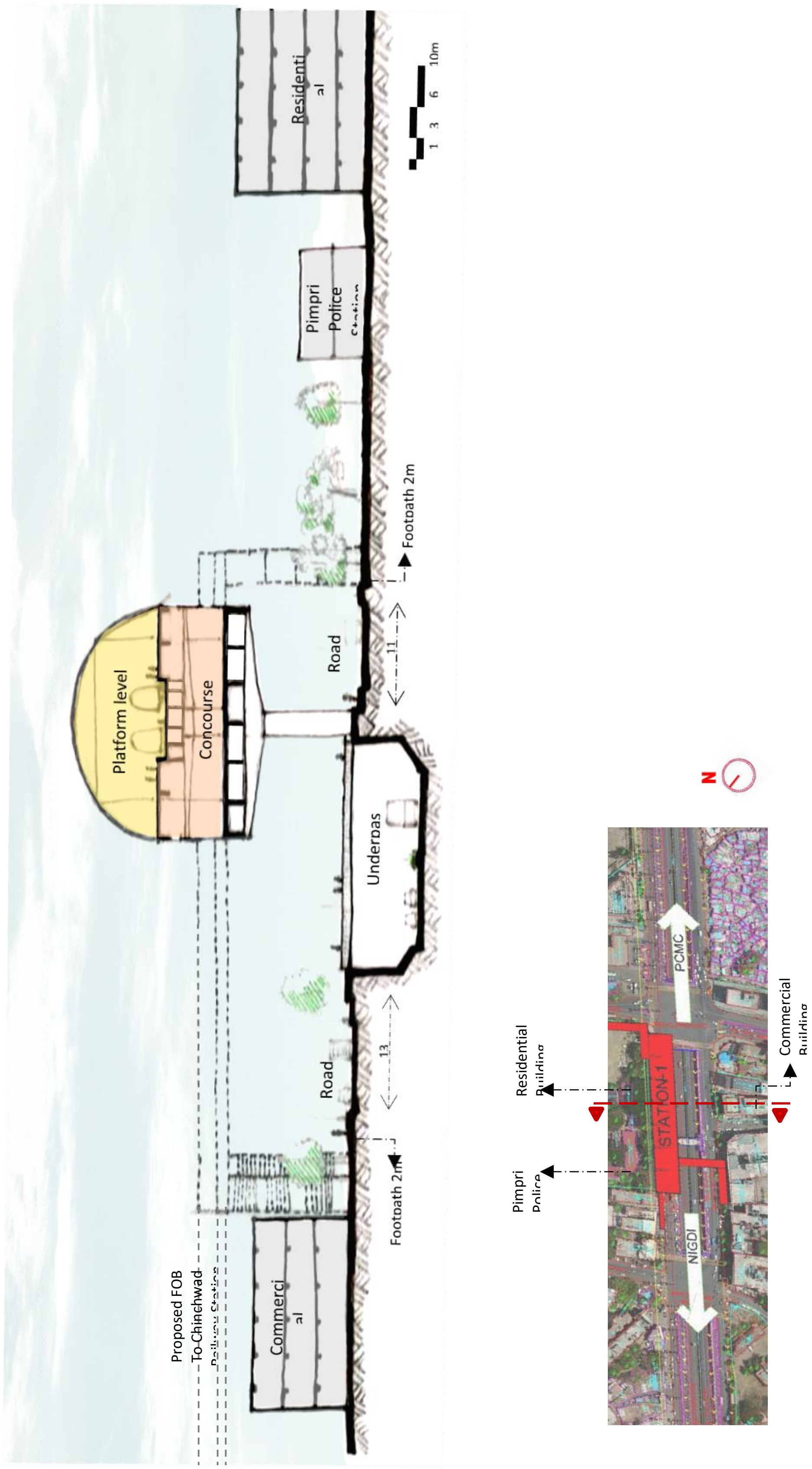
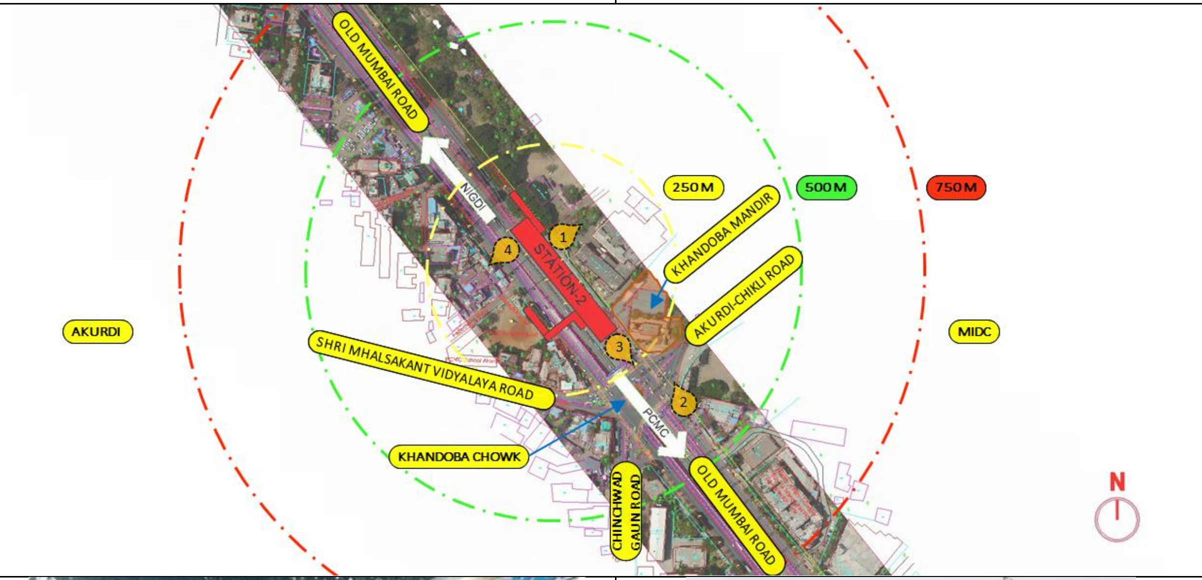


Figure 71: Cross-section at Chinchwad Station

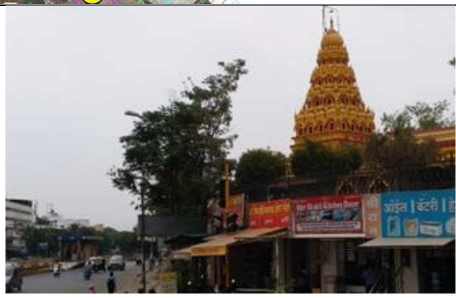
Station 2 (Akurdi)

STATION INTRODUCTION: it is an elevated station proposed on the Old Mumbai Road near Khandoba Chowk. The major roads connecting the station are Akurdi – Chikhli Road, Chinchwad Gaon Road, Shri Mhalsakant Vidyalaya Road. The station provides dispersal connectivity to public, semi-public and the residential areas of Akurdi and MIDC.

ISSUES & CONCERN	POTENTIAL FOR IMPROVEMENT
• Lack of pedestrian facilities like footpath, • Chaotic operations of Tempo services; • Huge encroachments of the road space.	• Dedicated non-motorized modes friendly facilities like footpath and cycle stands. • Planning of dispersal activities through feeder modes will cater to a larger catchment. • Removal of encroachments and optimal usage of ROW.



1. Entry gate of Force factory.



2. Khandoba temple.

3. Vulnerable Pedestrians – No pedestrian facilities existent.

4. Commercial area along the road.

Station 2 (Akurdi) Entry

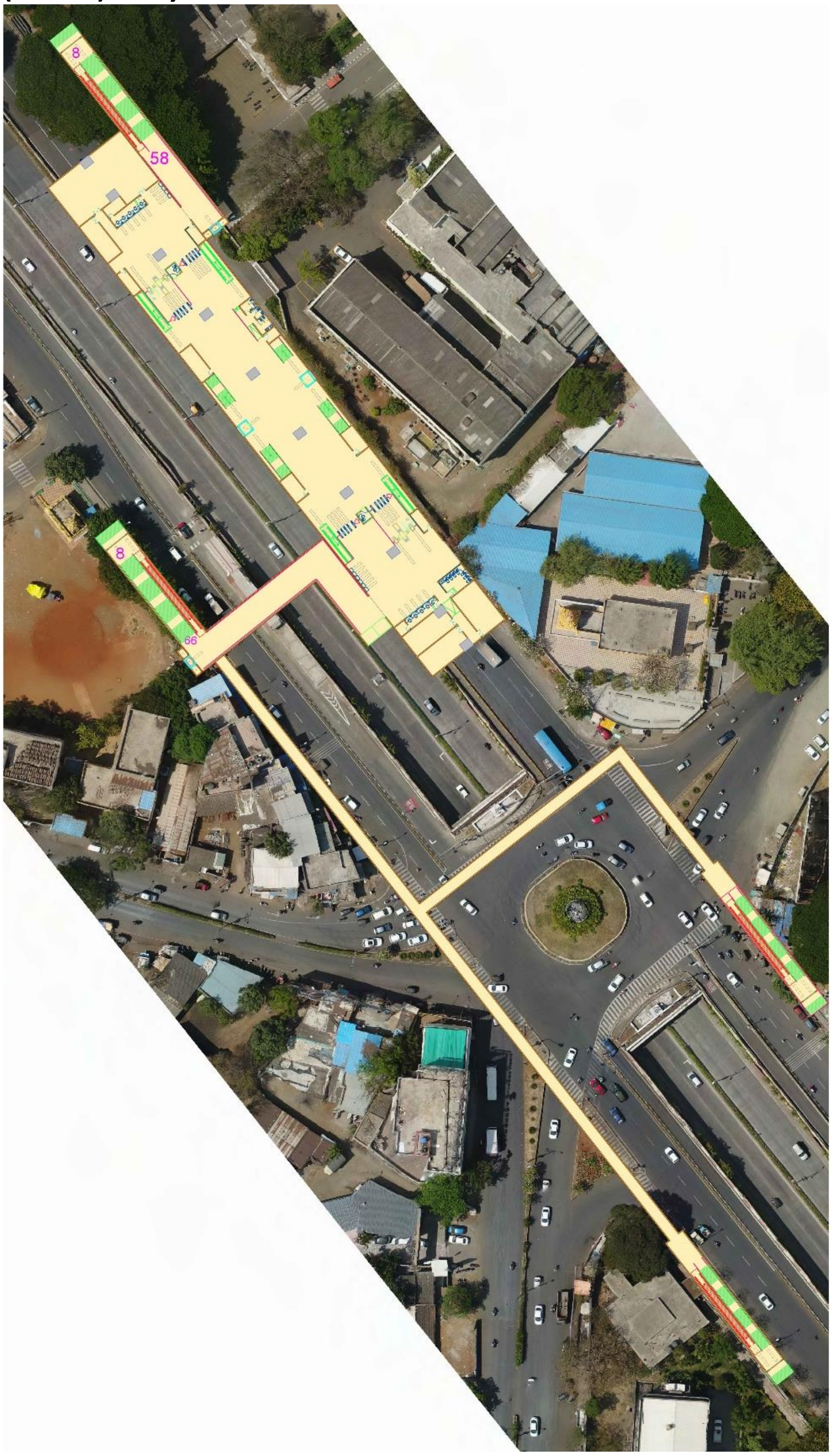


Figure 72: Entry/Exit at Akurdi Station

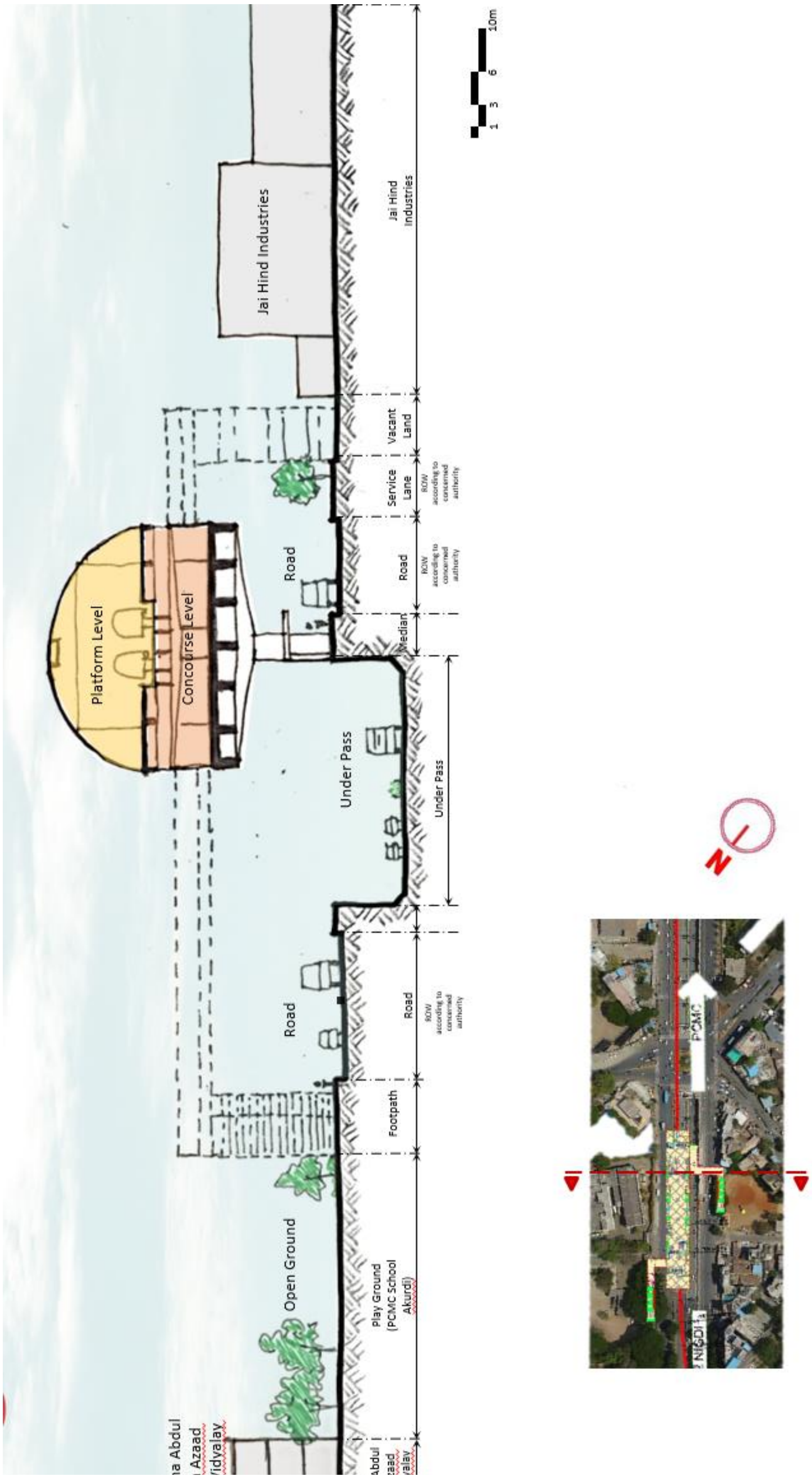
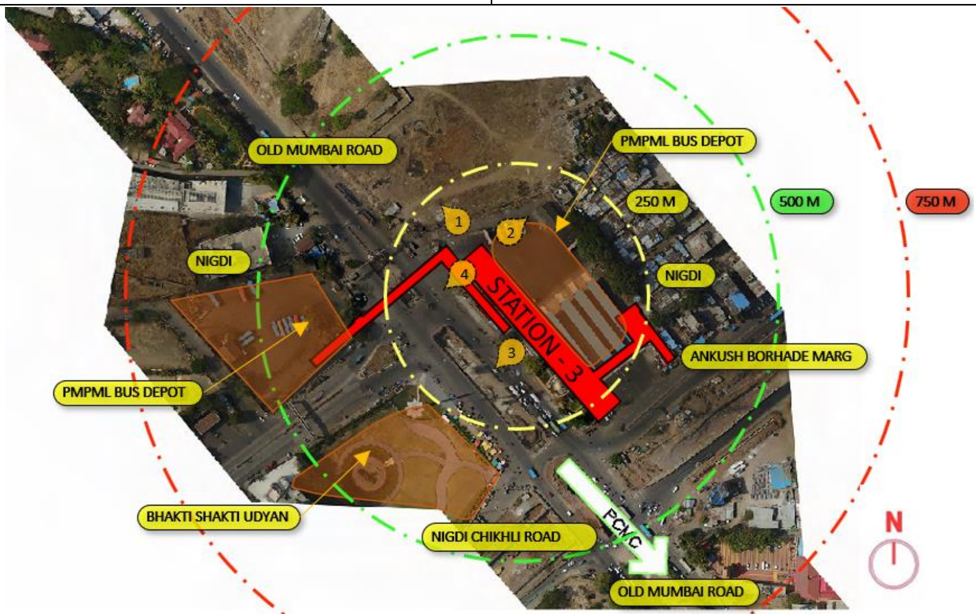


Figure 73: Road Cross-section at Akurdi station

Station 3 (Nigdi)

STATION INTRODUCTION: it is an elevated station proposed on the Old Mumbai Road near Bhakti Shakti Udyan. Public Development area is also proposed above this station. The major roads connecting the station are Nigdi – Chikhli Road, Ankush Borhade Marg. The station provides dispersal connectivity to the residential areas of Nigdi, Appu Ghar, Bhakti Shakti Udyan and PMPML Bus Depot.

ISSUES & CONCERN	POTENTIAL FOR IMPROVEMENT
• Lack of pedestrian facilities like footpath • Chaotic operations of Tempo services • Huge encroachments of the road space	• Dedicated non-motorized modes pedestrian friendly facilities like footpath and cycle stands. • Planning of dispersal activities through feeder modes will cater to a larger catchment. • Removal of encroachments and optimal usage of ROW



1. Depot wall and defense land beyond.

2. PMPML Bus Depot.

3. Bhakti Shakti Udhyan.

4. Chaotic traffic movement.

Station 3 (Nigdi):

Figure 74: Entry/Exit at Nigdi station

Proposed Skywalk

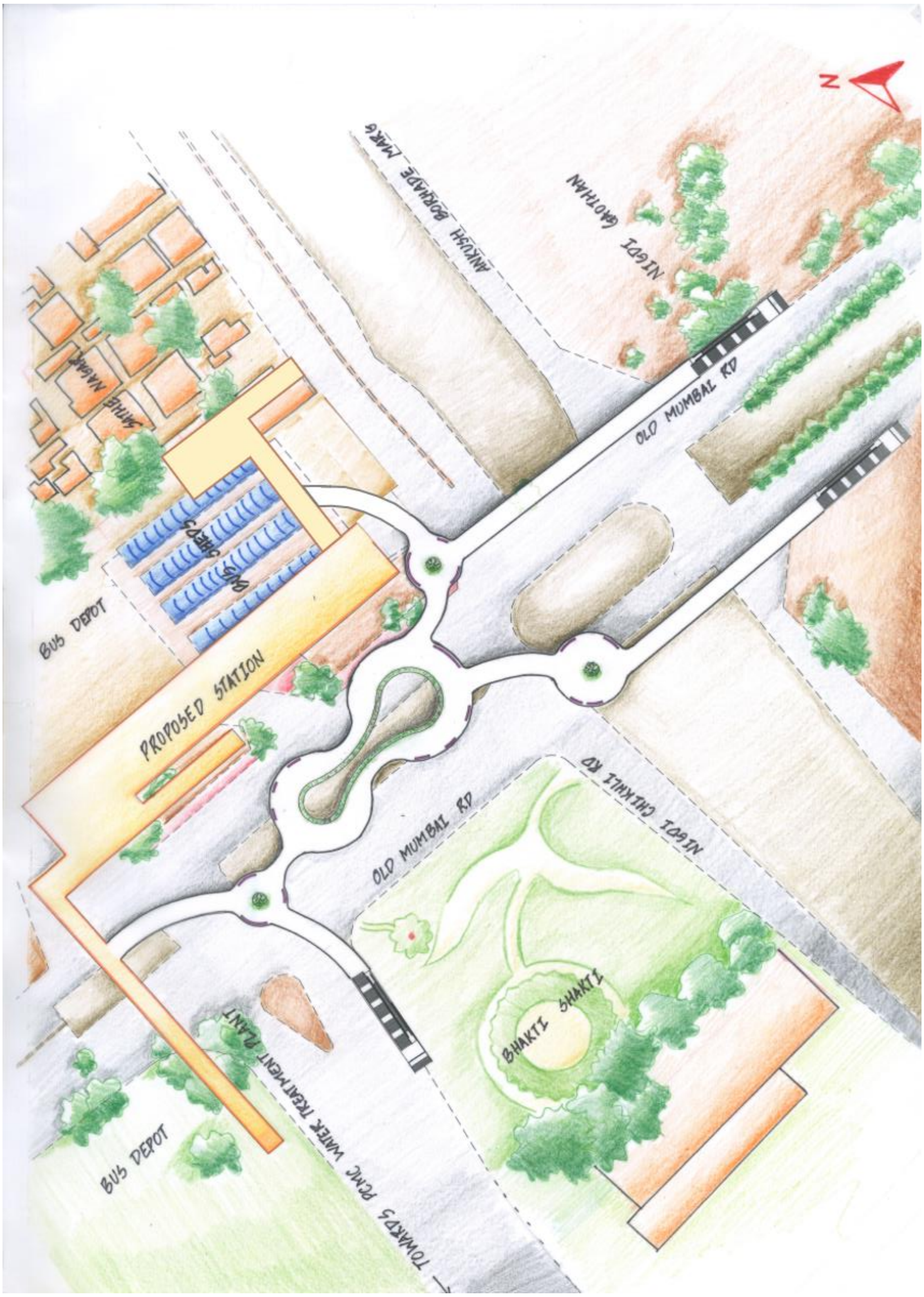


Figure 75: Proposed skywalk at Nigdi station

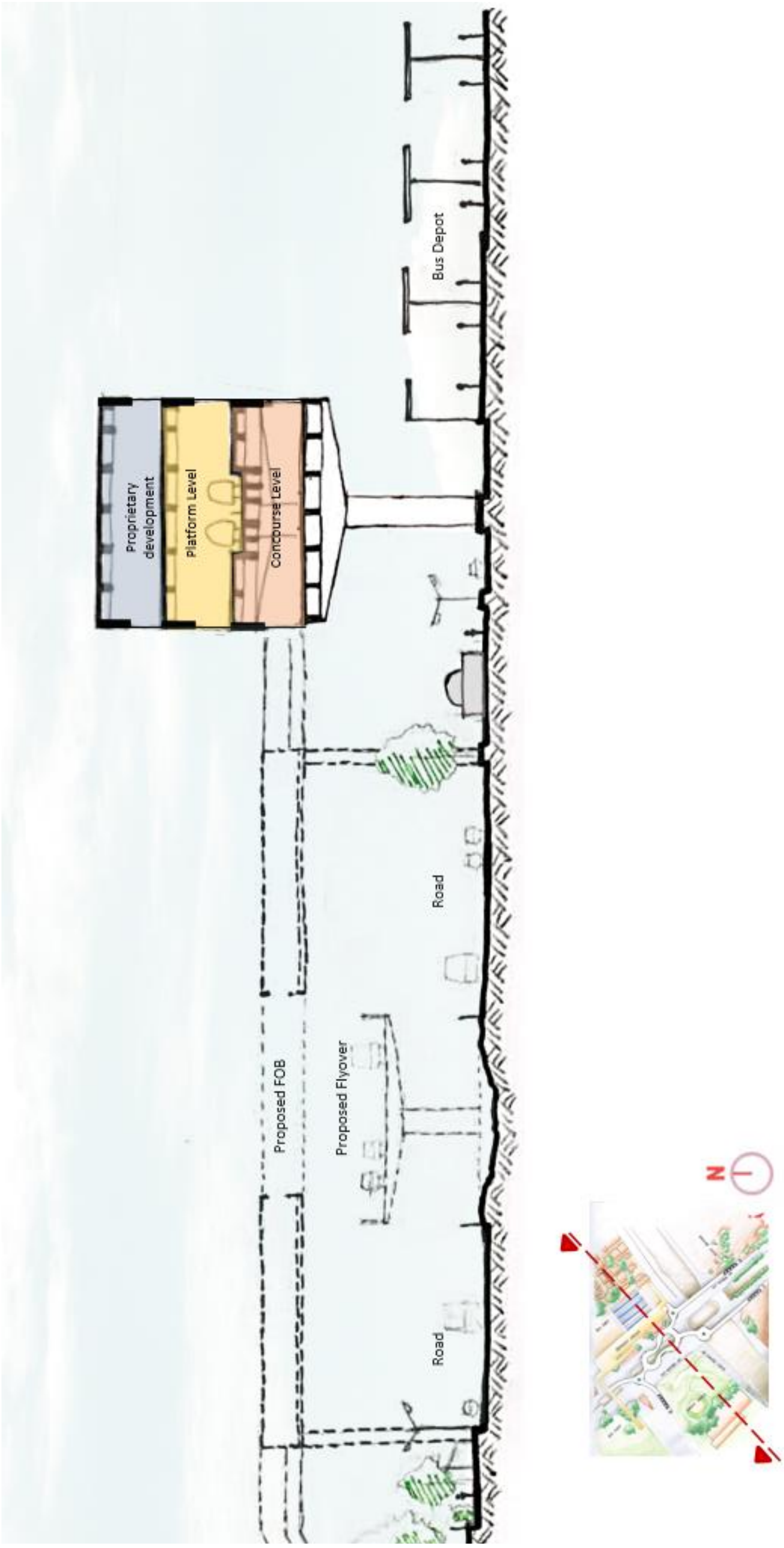


Figure 76: Road Cross-section at Nigdi station

6.2.3.1 Passengers Amenties and Vertical Circulation:

S.NO.	PASSENGERS AMENITIES	NO's in Station 1	NO's in Station 2	NO's in Station 3
1	TICKETING GATES	9	9	9
2	TICKET OFFICES	2	2	2
3	TVM	6	6	6
4	EFO	1	1	1
5	FIRST AID ROOM	1	1	1
6	TOILET (MALE)	1	1	1
7	TOILET (FEMALE)	1	1	1
8	TOILET (HANDICAP)	1	1	1
9	STAIRS (GROUND TO CONCOURSE)	3	2	3
10	STAIRS (CONCOURSE TO PLATFORM)	4	4	4
11	ESCALATORS (GROUND TO CONCOURSE)	2	2	3
12	ESCALATORS (CONCOURSE TO PLATFORM)	4	4	4
13	LIFTS (GROUND TO CONCOURSE)	2	2	2
14	LIFTS (CONCOURSE TO PLATFORM)	2	2	2

6.3 Station planning and design

This section is aimed at presenting station planning and design as proposed for Pune metro, providing details on planning and design criteria, platform sizing and egress, station layout, miscellaneous functions (commercial, advertising and branding)

6.3.1 General

Stations vary in complexity and the proposed station designs are influenced by station spacing, alignment, utilities, road clearances and pedestrian requirements.

The typical length of elevated stations would be 140 meters and width would vary from 21 m depending upon the integration of the station box and its entry structure within it immediate urban environment.

6.3.2 Planning and design criteria for stations

The design objectives that will be considered as the planning and design criteria are presented in the following sections:

6.3.2.1 Passengers' experience

One of the main objectives of station planning and design is to maximize passengers' experience. This is done by insuring stations.

- **Attractiveness**: the station experience will be positive;
- **Integration with urban realm**: the station will be well integrated with the existing street and its surroundings;
- **Intermodal integration**: design will integrate the station entries with other modes of transport;
- **Passengers-oriented**: patrons shall experience a system simple, easy to use and accessible;
- **Comfort**: the station atmosphere will be comfortable;
- **Safe and secure**: the station will be provided with sufficient safety features like well-lit areas, cctv etc;
- **Environmental considerations**.

6.3.2.2 Mass Rapid Transit operator requirement

Pune metro stations shall be designed to accommodate different operating, hence be tailored for normal, peak, off-peak, congested (delayed) and emergency conditions. Station design shall ensure for the operating body:

- Ease of use for operating staff;
- Manage and maintain / monitor and control;
- Flexibility in operations keeping in mind peak and off peak hours;
- Revenue models: fare box and possible non-fare box sources like commercial advertising;
- Provisions, small kiosks or large retail spaces wherever possible;

These design objectives will respond to the following design factors :

- Operational requirements in the use of center and side platforms, elevated stations are proposed to have side platforms;
- Station boarding/alighting and the resulting entry/exit location requirements;
- Utilities such as firefighting systems, ventilation, water requirements;
- Structural requirements;
- Flexibility in design to allow stations to respond to site specific requirements;
- Platform design criteria;
- Concourse design criteria;
- Passenger forecasts and resulting entrance locations;
- Traffic, roads and pedestrian requirements;
- Future expansion provisions;
- Flexibility in design to meet site-specific requirements, if any.

6.3.2.3 Level of Service (LoS)

The level of service assessment is based on the concept of Fruin's Levels of Service (LoS) which was first derived by J.J. Fruin ('Pedestrian Planning and Design', 1971).

LoS scale

There are six LoS categories, as shown in the figure below, ranging from A representing free-flow conditions to F representing very congested densities with restricted movements conditions.

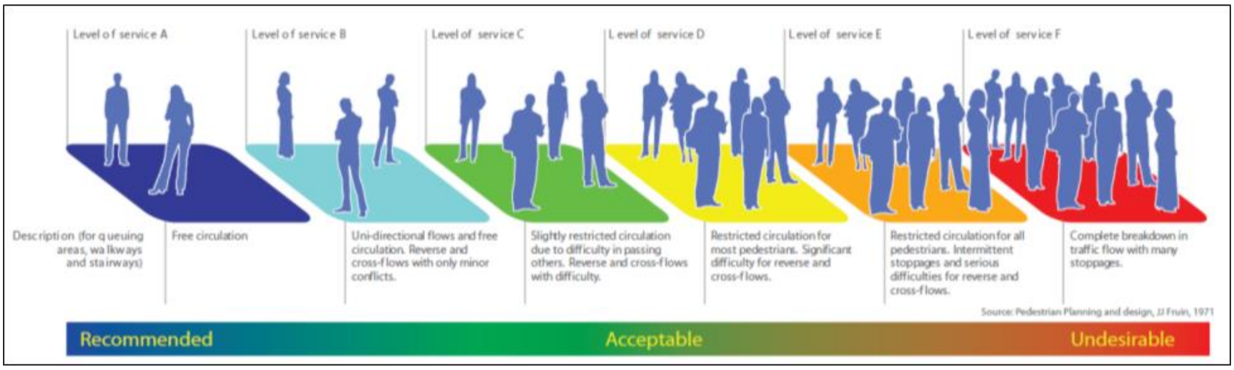


Figure 77 : Levels of Service categories (Source: Pedestrian Planning and Design, 1971)

LoS types

There are **three different types of Level of Service**: walkways, stairs and queuing; which consider the different characteristics of pedestrian activities (i.e. walking on flat ground, walking up/down stairs and waiting).

Fruin's Levels of Service for Walkways

	Person per square metre	Square metre per person (Fruin, 1987)
LOS A	0-0.31	>3.3
LOS B	0.32-0.43	2.3-3.3
LOS C	0.44-0.72	1.4-2.3
LOS D	0.73-1.08	0.9-1.4
LOS E	1.09-2.17	0.5-0.9
LOS F	2.18-10	<0.5

Fruin's Levels of Service for Stairs (Escalators)

	Square metre per person	Person per metre width per minute
LOS A	>1.87	0-16
LOS B	1.39-1.87	16-23
LOS C	0.93-1.39	23-33
LOS D	0.65-0.93	33-43
LOS E	0.37-0.65	43-56
LOS F	<0.37	>56

Fruin's Levels of Service for Queuing

	Person per square metre	Square metre per person (Fruin, 1987)
LOS A	0-0.83	>1.208
LOS B	0.84-1.08	1.208 - 0.929
LOS C	1.09-1.54	0.929 - 0.650
LOS D	1.55-3.59	0.650 - 0.279
LOS E	3.60-5.38	0.279 - 0.186
LOS F	5.39-10	<0.186

Figure 78 : Levels of Service by type (Source: Pedestrian Planning and Design, 1971)

In general:

- LoS walkways are used for areas of circulation such as passageways, underpass and over bridges;
- LoS queuing are used for platform areas, ticket halls and lift waiting areas;
- LoS stairs are used for staircases and escalators.

It is generally accepted – subject to the functional use of space within a station – that a LoS C/D is acceptable. Any area with a LoS E or F for a long period of time indicates levels of congestion exceeding the normal planning standard, which could warrant further investigation and design improvements.

6.3.2.4 Salient features of typical station

These features will be used as the basis for the design of Pune's station, ensuring standardization across stations. They are presented below

- Station entrances provide the link between the station concourse and the surrounding streets. Their location must reflect the separate constraints of both;
- Station entrances are located with reference to passengers catchment points and cater for intermodal interchange which includes buses, pick-up/drop-off by private modes etc;
- Important criterias which have 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.

6.3.2.5 Station boarding and alighting forecasts

Each station's planning and design is notably based on the number of passengers boarding/alighting. The tables below show the passengers boarding/alighting forecasts for 2023, 2043 and 2053. These figures will be used for station sizing (platforms, staircases, entries etc) and egress calculations.

6.3.2.5.1 Boarding - Phase 1A PCMC to Nigdi

Table 70: Station boarding in design year on Phase 1A (Source: Systra, 2018)

SN	Stations	Peak Hour Boarding			
		2023	2033	2043	2053
1	Chinchwad Station	820	1190	1380	1500
2	Akurdi Station	950	1290	1360	1470
3	Nigdi Station	780	1070	1170	1270

6.3.2.5.2 Alighting - Phase 1A PCMC to Nigdi

Table 71: Station alighting in design year on Phase 1A

SN	Stations	Peak Hour Alighting			
		2023	2033	2043	2053
1	Chinchwad Station	1070	1480	2000	2160
2	Akurdi Station	1070	1470	1940	2090
3	Nigdi Station	780	1180	1430	1540

6.4 Platform sizing and egress calculations

Platform areas should be designed in such a manner that it will comfortably cater normal operations as well as delayed operations. The total evacuation time for the movement of all passengers in an emergency from platform level to the landing at the next level should not exceed **5.5 minutes** in elevated stations considering that these stations are open, and risk is much less and time limit to evacuate platform load from most remote point to a point of safety is **8 minutes** as per **NBC 2016 edition annx – J (J-5.1, b & c)**. Station sizing and egress calculations for all three stations are given in following tables.

Table 72 : Standards for egress calculation

TL - 6 -Train Crush Load for 6 coach rolling stock (Crush Load capacity taken from rolling stock specs)	1574	persons	Refer section 11.1.2
PL - Platform length (For 6 car train)	140	meters	Pune DPR, Phase 1
SF - Surge Factor	1.2	times	Assumed
ET - Time limit to evacuate platform as per NBC 2016	5.5	minutes	NBC, 2016 Edition ,annx - J (J-5.1, b)
ERT - Time limit to evacuate platform load from most remote point to a point of safety as per NBC 2016	8	minutes	NBC, 2016 Edition ,annx - J (J-5.1,c)
STRC - Capacity of Stairs as per NFPA 130	0.0555	persons per mili meter per minutes	NFPA130, 2017 Edition ,section 5.3.5.3
ECN - Capacity of Escalators in stopped condition as per NFPA 130	0.0555	persons per mili meter per minutes	NFPA130, 2017 Edition ,section 5.3.5.3
ECE - Capacity of Escalators in moving condtion in direction of egress (it is to be ensured that such elevators will be of reversible type, emergency powered with ability to be restared again from stopped position in line with NFPA 130)	0.12	persons per mili meter per minutes	NBC, 2016 Edition ,annx - J(J-5.4.5, h)
SD - Service Disruption Period (Two missed headway)	3	period	NBC, 2016 Edition ,annx - J (J-4.1, g)
SI-Service Interval	3 & 6	minutes	Pune DPR
Maximum mean of egress travel speed along platform, corridors and ramp	37.7	meter/minute	NFPA130, 2017 Edition ,section 5.3.4.4
Time taken in afc gate	50	persons per minutes	
Vertical travel speed	14.6	meter/minute	NFPA130, 2017 Edition ,section 5.3.5.3

Table 73 : Platform occupant load

Station Name	Peak Hour Boarding	Peak Hour Alighting	Normal Load (Boarding /50)	F1 (Boarding /50 X 1.2)	Train Crush Load(T.L.)	Platform Occupant Laod POL({F1(3XS1)}+TL)
CORRIDOR I A (PCMC TO NIGDI)						
CHINCHWAD	1500	2160	30	36	1574	1898
AKURDI	1470	2090	29	35	1574	1892
NIGDI	1270	1540	25	30	1574	1848

NFPA 130 (2017) Station Egress Analysis

Station name : **CHINCHWAD**
Station occupant load : 1898

Egress Element	units	mm	p/mm-min		p/min
Platform to Concourse					
Stairs	2	2850	0.0555		316.35
Moving Escalators	1	1000	0.12		120.00
				Total	436.35
Through Fare Barriers					
Fare Gates	9		50		450.00
Service Gates	0	1000	81.9		0.00
Emergency Gates	0	1000	81.9		0.00
				Total	450.00
Fare Barriers to Safe Area					
Stairs	3	7800	0.0555		1298.70
Moving Escalators	1	1000	0.12		120.00
				Total	1418.70

Walking Time for Longest Exit Route			m	m/min	Minutes
Central Platform					
On Platform	T1	horizontal	40.00	37.7	1.06
Platform to Concourse	T2	vertical	6.00	14.6	0.41
On Concourse(Till AFC)	T3	horizontal	30.00	37.7	0.80
On Concourse(AFC to Stairs)	T4	horizontal	35.00	37.7	0.93
Concourse to grade	T5	vertical	9.69	14.6	0.66
On grade to safe area	T6	horizontal	3.00	37.7	0.08
T (total walking time) = T1+T2+T3+T4+T5+T6				**Total**	3.94

*one escalator discounted

Test No. 1 : Evacuate platform occupant load(s) from platform(s) in 4 minutes or less

Fp (time to clear platform) = $\frac{\text{Platform occupant load}}{\text{Platform exit capacity}}$ Fp= $\frac{1898}{436.35}$ = **4.35** min

Test Fp <= 5.5

Test No. 2 : Evacuate platform occupant load from most remote point on platform to a point of safety in 6 minutes or less

Wp (waiting time at platform exits) = Fp-T1
Wp = 3.29 min
Concourse occupant load - (Fp - emergency stair capacity)
Concourse occupant load = 1898
Wf (waiting time at fare barriers) = Ffb - Fp

Ffb (fare barrier flow time) = $\frac{\text{Concourse occupant load}}{\text{Fare barrier exit capacity}}$ Ffb = $\frac{1898}{450}$ = 4.22 min

Wf = Ffb - Fp
Wf = 0.00 min
Wc (waiting time at concourse exits) = [Fc-max(Ffb or Fp)]

Fc(concourse exit flow time) = $\frac{\text{Concourse occupant load}}{\text{Concourse exit capacity}}$ Fc = $\frac{1898}{1418.70}$ = 1.34 min

Wc = Fc - max(Ffb or Fp) (if Wc<0 ----- Wc=0)
Wc = 0.00 min
Total exit time = T + Wp + Wf + Wc Total = **7.23** min

Test <= 8

NFPA 130 (2017) Station Egress Analysis

Station name : **AKURDI**

Station occupant load : 1892

Egress Element	units	mm	p/mm-min		p/min
Platform to Concourse					
Stairs	2	2850	0.0555		316.35
Moving Escalators	1	1000	0.12		120.00
				Total	436.35
Through Fare Barriers					
Fare Gates	9		50		450.00
Service Gates	0	1000	81.9		0.00
Emergency Gates	0	1000	81.9		0.00
				Total	450.00
Fare Barriers to Safe Area					
Stairs	2	7800	0.0555		865.80
Moving Escalators	1	1000	0.12		120.00
				Total	985.80

Walking Time for Longest Exit Route			m	m/min	Minutes
Central Platform					
On Platform	T1	horizontal	40.00	37.7	1.06
Platform to Concourse	T2	vertical	6.00	14.6	0.41
On Concourse(Till AFC)	T3	horizontal	27.00	37.7	0.72
On Concourse(AFC to Stairs)	T4	horizontal	40.00	37.7	1.06
Concourse to grade	T5	vertical	9.87	14.6	0.68
On grade to safe area	T6	horizontal	3.00	37.7	0.08
T (total walking time) = T1+T2+T3+T4+T5+T6				**Total**	4.00

*one escalator discounted

Test No. 1 : Evacuate platform occupant load(s) from platform(s) in 4 minutes or less

Fp (time to clear platform) = $\frac{\text{Platform occupant load}}{\text{Platform exit capacity}}$ Fp= $\frac{1892}{436.35}$ = **4.33** min

Test Fp <= 5.5

Test No. 2 : Evacuate platform occupant load from most remote point on platform to a point of safety in 6 minutes or less

Wp (waiting time at platform exits) = Fp-T1
Wp = 3.27 min
Concourse occupant load - (Fp - emergency stair capacity)
Concourse occupant load = 1892
Wf (waiting time at fare barriers) = Ffb - Fp

Ffb (fare barrier flow time) = $\frac{\text{Concourse occupant load}}{\text{Fare barrier exit capacity}}$ Ffb = $\frac{1892}{450}$ = 4.20 min

Wf = Ffb - Fp
Wf = 0.00 min
Wc (waiting time at concourse exits) = [Fc-max(Ffb or Fp)]

Fc(concourse exit flow time) = $\frac{\text{Concourse occupant load}}{\text{Concourse exit capacity}}$ Fc = $\frac{1891.52}{985.80}$ = 1.92 min

Wc = Fc - max(Ffb or Fp) (if Wc<0 ---- Wc=0)
Wc = 0.00 min
Total exit time = T + Wp + Wf + Wc Total = **7.28** min

Test <= 8

NFPA 130 (2017) Station Egress Analysis

Station name : **NIGDI**
Station occupant load : 1848

Egress Element	units	mm	p/mm-min		p/min
Platform to Concourse					
Stairs	2	2850	0.0555		316.35
Moving Escalators	1	1000	0.12		120.00
				Total	436.35
Through Fare Barriers					
Fare Gates	9		50		450.00
Service Gates	0	1000	81.9		0.00
Emergency Gates	0	1000	81.9		0.00
				Total	450.00
Fare Barriers to Safe Area					
Stairs	3	7800	0.0555		1298.70
Moving Escalators	2	1000	0.12		240.00
				Total	1538.70

Walking Time for Longest Exit Route			m	m/min		Minutes
Central Platform						
On Platform	T1	horizontal	40.00	37.7		1.06
Platform to Concourse	T2	vertical	6.00	14.6		0.41
On Concourse(Till AFC)	T3	horizontal	30.00	37.7		0.80
On Concourse(AFC to Stairs)	T4	horizontal	35.00	37.7		0.93
Concourse to grade	T4	vertical	11.75	14.6		0.80
On grade to safe area	T5	horizontal	3.00	37.7		0.08
T (total walking time) = T1+T2+T3+T4+T5					**Total**	4.08

*one escalator discounted

Test No. 1 : Evacuate platform occupant load(s) from platform(s) in 4 minutes or less

Fp (time to clear platform) = $\frac{\text{Platform occupant load}}{\text{Platform exit capacity}}$ Fp= $\frac{1848}{436.35}$ = **4.24** min

Test Fp <= 5.5

Test No. 2 : Evacuate platform occupant load from most remote point on platform to a point of safety in 6 minutes or less

Wp (waiting time at platform exits) = Fp-T1
Wp = 3.17 min
Concourse occupant load - (Fp - emergency stair capacity)
Concourse occupant load = 1848
Wf (waiting time at fare barriers) = Ffb - Fp

Ffb (fare barrier flow time) = $\frac{\text{Concourse occupant load}}{\text{Fare barrier exit capacity}}$ Ffb = $\frac{1848.32}{450}$ = 4.11 min

Wf = Ffb - Fp
Wf = 0.00 min
Wc (waiting time at concourse exits) = [Fc-max(Ffb or Fp)]

Fc(concourse exit flow time) = $\frac{\text{Concourse occupant load}}{\text{Concourse exit capacity}}$ Fc = $\frac{1848.32}{1538.70}$ = 1.20 min

Wc = Fc - max(Ffb or Fp) (if Wc<0 ---- Wc=0)
Wc = 0.00 min
Total exit time = T + Wp + Wf + Wc Total = **7.26** min

Test <= 8

6.4.1 Signage and way - finding

Passenger information signs located at stations will be many and varied ranging from station entrance to train indicator panel and information panels. Signs are to be provided in a Tri-lingual format. Signage provided information essential to passengers use and navigation of the system, engendering a of reassurance, security, and orientation when entering, existing, or transferring, which contributes to a positive, user-friendly customer experience. In brief, signage:

- Guides passengers to and from the various station areas
- Accommodates the myriad information requirements of the stations and the service
- Informs passengers of service information
- Accelerate their way finding process

General principles for signage placement in new stations shall include:

- Keeping signs to the minimum necessary to properly communicate the required information, while considering that certain signs need to be repeated to reassure passengers that they are on the correct path.
- Placing signs exactly at decision points in lateral and vertical circulation paths.
- Placing signs perpendicular to the line of travel or sight.
- Glow signs for publicity should be placed parallel to the passenger movement in the station. Placement of commercial signs should not obstruct passenger's movement.
- To reduce sign cutter, utilizing both sided of signs for information display wherever applicable.
- Integrating signage with other station elements wherever possible.
- Placing signs in areas that have clear sights lines and are free of visual obstructions.
- Use the international symbol of accessibility (ISA) to identify accessible entries and paths.
- To encourage left-hand circulation, placing signage or sign information on the left-hand sides of corridors and VCE's.
- All signage shall have alternate pictorial signage of the same size as the letters and should be in at least Tri- Lingual (English, Hindi and Marathi Language).
- Every access point to the metro shall have a variable sign that provides information on station conditions and operations through an electronic display screen.

The sign hardware system is defined as the physical sign units (their sizes, material and attachment methods) that display the sign graphics.

Public clocks in metro stations shall be digital and located at the fare areas and on the platforms clearly visible to all passengers in the direction of movement.

6.4.2 Station function and layout

A number of functions are associated to each station that structure the way stations are planned. These functions and their typical location in the station structure are presented below:

6.4.2.1 Station's functions

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

6.4.2.2 Planning norms and standards

- **General**
    - The platform length is planned for 6 cars train;
    - The total evacuation time for the movement of all passengers in an emergency from platform level to the landing at the next level should not exceed 5.5 minutes in elevated stations considering that these stations are open, and risk is much less;
    - The station planning is also in 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;
    - The egress requirement (Platform to Concourse) & platform width calculations, evacuation time calculations and passenger related facilities for the design year will be provided at next stage.

- **Entry/Exit**
    - Entrances to stations shall be of adequate capacity to satisfy predicted passenger flows and emergency evacuation requirement;
    - The position of entrances shall be determined by the juxtaposition of building location, of roadway footpath width, space availability and flow directions of passenger traffic;
    - The width of entrances shall consider the predicted passenger flow and available space;
    - All entrances extending to street level are proposed to be protected against flooding. This protection is done by the provision of a minimum staircase to be added in next stage.

- **Walkways / Ramps**
  - Walkways / ramps shall be 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 shall be minimized or eliminated;
  - Minimum Corridor width:
    - Unidirectional movement: 1.8 m
    - Bi-directional movement: 2.0 m
    - Where length of the corridor is more than 30 m: 3.0 m
    - For staff: 1.2 m
  - Ramps
    - Preferred gradient: 1:20
    - Maximum gradient: 1 :12
    - Minimum width:
      - Unidirectional movement: 1.2 m
      - Bi-directional movement: 1.5 m
    - For ramp exceeding 10 m, rest platform: 1.8m

6.4.2.3 Functional layout

The station box is divided into public area and non-public area (where access is restricted to operating staff and not accessible to passengers).

Public area design : stations will be designed to the crush load capacity (having 0.5 per sq. meter) of 6-car train. The station shall be designed for an eventual operating headway of 2.0 minutes.

6.4.2.4 Platform level

- The **length of platform** will be 140m. This allows for the length of 6 car train and a stopping tolerance;
- **Minimum platform widths**:
  - The nominal platform width measured from platform edge to any continuous (longer than 2000mm) fixed structure shall be a minimum of 3000 mm.
  - The minimum distance from platform edge to any isolated obstruction e.g. columns, shall be 2500mm (an isolated obstruction shall not be longer than 2000 mm).
  - This clearance shall be maintained for safety reasons, irrespective of passenger flow. The platform width greater than the minimum may be required at stations with large passenger flow.

- **Platform widths** shall be determined to cater to the following scenarios:

    - Normal service: the platform width shall be determined by multiplying the peak minute flow by 0.5 sqm/person and headway, then dividing by the platform length;
    - Delayed / Emergency service: the platform width shall be determined by the peak minute flow, allowing for two missed headways. The crush load is assumed as sectional load between two stations. For an island platform, the area between the boundaries of the two platforms can be included in the calculation.

- The **platform edge** shall have a safety margin of 600 mm width with a non-slip surface and a yellow warning strip of 100 mm wide of contrasting texture.
- The **platform ends** shall be provided with 1200 mm wide security gate and be installed with a Pressure Mat Alarm system.
- Platform shall be laid to a fall at 1:100 from the inner face of platform screen doors for 3000mm towards the back of the platform. Where platform screen doors are not provided then platform shall be laid to a fall of 1:100 from the platform edge for 350mm towards the back of the platform;
- **Markings on the platform** to assist and control the flow of passengers for boarding and alighting the trains shall be provided;
- Space occupied by stairs, escalators, structure, seating, platform supervisor's accommodation etc. is not to be included as part of the platform area.

6.4.2.5 Concourse level

- The **arrangement of concourse** is assessed on station-by-station basis and is determined by site constraints and passengers access requirements. However, it shall be 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 shall be positioned to minimize cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow shall be allowed in front of the AFC gates;
- **Concourse consists of** "Non-Public Areas" and "Public Areas":
    - The "**Non-Public Areas**" comprise of the Back of House (BOH) areas. The BOH areas consists of Power Supply & Traction (PST), System Rooms, Operations, Staff Facilities, Water Supply and Drainage System and Miscellaneous requirements. A list of BOH areas is given below in Table 4. The description of such areas is also detailed in the subsequent paragraphs.
    - The "**Public Area**" is further subdivided into "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.

- **Passengers 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 shall be 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 shall be provided for system wide uniformity, although the requirement of the facilities varies from station to station based on the peak hour passenger load.
- The accommodation of station facilities are presented in the table below:

Table 74: Station Facilities accommodation

(Source: Systra, 2018)

PST (POWER SUPPLY & TRACTION) • Auxiliary substation • Track disconnection switch DG set • Fuel tank	**STAFF FACILITIES** • Staff toilets/ locker (male) Staff toilets/ locker (female) First aid • Staff mess room • Train crew room
SYSTEM ROOMS **SIGNALLING** • Signalling Equipment Room (SER) UPS room (signalling)	**OPERATIONS** • Station Control Room (SCR) Station Manager • Ticket Office/Ticketing Ticket Office Supervisor Audit and Cash Storage TVM/ BOMS • Security/ Police Room Excess Fare Office (EFO)
TELECOMMUNICATION • TER • Mobile phone equipment room UPS Room (telecom)	**MISCELLANEOUS** • Emergency Equipment Room • Cleaners Room-1 • Cleaners Room-2 • Refuse Store • Permanent Way Store

6.4.2.6 Operational rooms (back house areas)

- **Operation Rooms for Public Use**

- **Ticketing gates**: the gate design will depend upon:
  - Check-in and check-out: implying bi-directional gates;
  - Fare media: smart card, magnetic or paper ticket;
  - Special gates are designed for:
    - Disabled persons access;
    - Customers with luggage;

- Customers with strollers.

- **Ticket Counters and Ticket Vending Machines (TVMs):** it is proposed to deploy manual ticket issuing counters in the beginning of the operation of the line. t a later stage, automatic TVMs would be used, for which space provision will be made at the concourse Figure 80


MTR wall mounted TVM with maintenance corridor in the back – Paris (left) Shinjuku station Tokyo (right)

Figure 79 : Ticket vending machines at stations

- **Ticket offices:**

- The number of ticket offices is determined by the passenger traffic and the operation policy;
- A minimum of 2 ticket offices per station in the stations with high traffic, and 1 ticket office per station in the stations with low traffic shall be planned.


Figure 80 : Ticket offices at stations

- **First aid room:**
- First aid room is not a specific operation room but is proposed to be located in every station in accordance with the technical provisions of the project. This room could also be used as a detention room if it is needed;

- **Passenger Amenities :**
- Toilets for disabled are not specific operation rooms are proposed to be provided at all stations in accordance with the technical provisions of the project.

6.4.2.7 Passengers handling facilities

Escalators requirements

The escalators will be heavy duty "public" service escalators capable of operating safely and smoothly. The planning of escalators which may act as emergency stairways should meet all the criteria requirements in NFPA 130 Standards. The planning of 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.

Stairs requirements

- Stair widths:
  - Minimum stair width for public use: 2400mm;
  - Minimum stair width for emergency evacuation: 1120mm.(as per NFPA 2017 5.3.5.2)

- A central handrail is provided where stair width is 4.5 m or more;
- Risers per flight: 3 minimums, 15 maximums;
- 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;

Lifts requirements

A minimum three to four lifts will be used of having 13 passengers capacities. Lifts are also used for betterment of differently abled people.

6.4.2.8 Emergency evacuation standards

- The requirement is to evacuate people from a station platform to another location, initially the next level below or above and then on to street level without hindrance;
- The principles to be followed are:
  - The maximum distance to an exit route on the platform shall be 50 meters;
  - The time required to walk from the farthest point on a platform to the escalator or stair landing must be considered. Walking speed is assumed to be 1 meter/sec;
  - A 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.

- The emergency is assumed to be occurring in one direction of travel only at any given point of time;

- 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 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 at the station in case of an emergency;
- The train will not move from the platform until passengers have begun clearing the platform and hence the 500mm unoccupied zone adjacent to the platform edge for platform without platform screen doors is included in the calculations.

6.4.3 Station accommodation

Each station is provided with adequate public areas for passenger movement.

Space is also provided for station systems. The ancillary equipment housing including generators, pump rooms, water tanks and sumps shall be located at one area of station site preferably at street level provided for each station. Any change will be discussed with the Client.

6.4.3.1 Queuing Length

Sr. No	Location	Minimum queing space
1	Add value Machines, from face	2400 mm
2	Card readers, from face	2400 mm
3	Customer service center, from counter edge	2400 mm
4	Escalation, from working point	2400 mm
5	Lifts, from threshold	2400 mm
6	Stairs, from working point	4000 mm
7	Ticket Gates and smart card gates from face	6000 mm
8	Ticket sales window, from counter edge	2400 mm
9	Ticket Vending Machines, from face	2400 mm

6.4.3.2 Doors

- Sizes of doors will be depending upon type and function of the room;
- Fire resistance door will be depending on fire resistance of room as per NFPA.

6.4.3.3 Fire protection

- The design of stations shall be in accordance with NFPA 130;
- The design of station shall include the following:
  - Fire preventions measures;
  - Fire control measures;
  - Fire detection systems ;
  - Means of escape;
  - Access for firemen;
  - Means of firefighting.

- All aspects of fire preventions and control will be subject to the approval of the employer having jurisdiction.
- All offices and plant room shall be separated from the public circulation spaces by FRP (Fire Resistance Period) separation.
- The station is required to meet NFPA 130 standards for fire protection and emergency egress. Preliminary assumptions shall be made regarding the minimum required widths of circulation elements for emergency egress within the stations. A full analysis of the design is necessary to confirm that all NFPA 130 requirement and other emergency code requirements are met.

6.4.4 Advertising areas

- A high level of passenger traffic using the stations presents a great potential for high commercial value for advertising;
- 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 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.

- 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 escalator;
    - On the walls of the first level of the stations;
    - Inside the Rolling Stock (specific dedicated areas).

The provision of advertisements at stations is presented the figure hereafter.

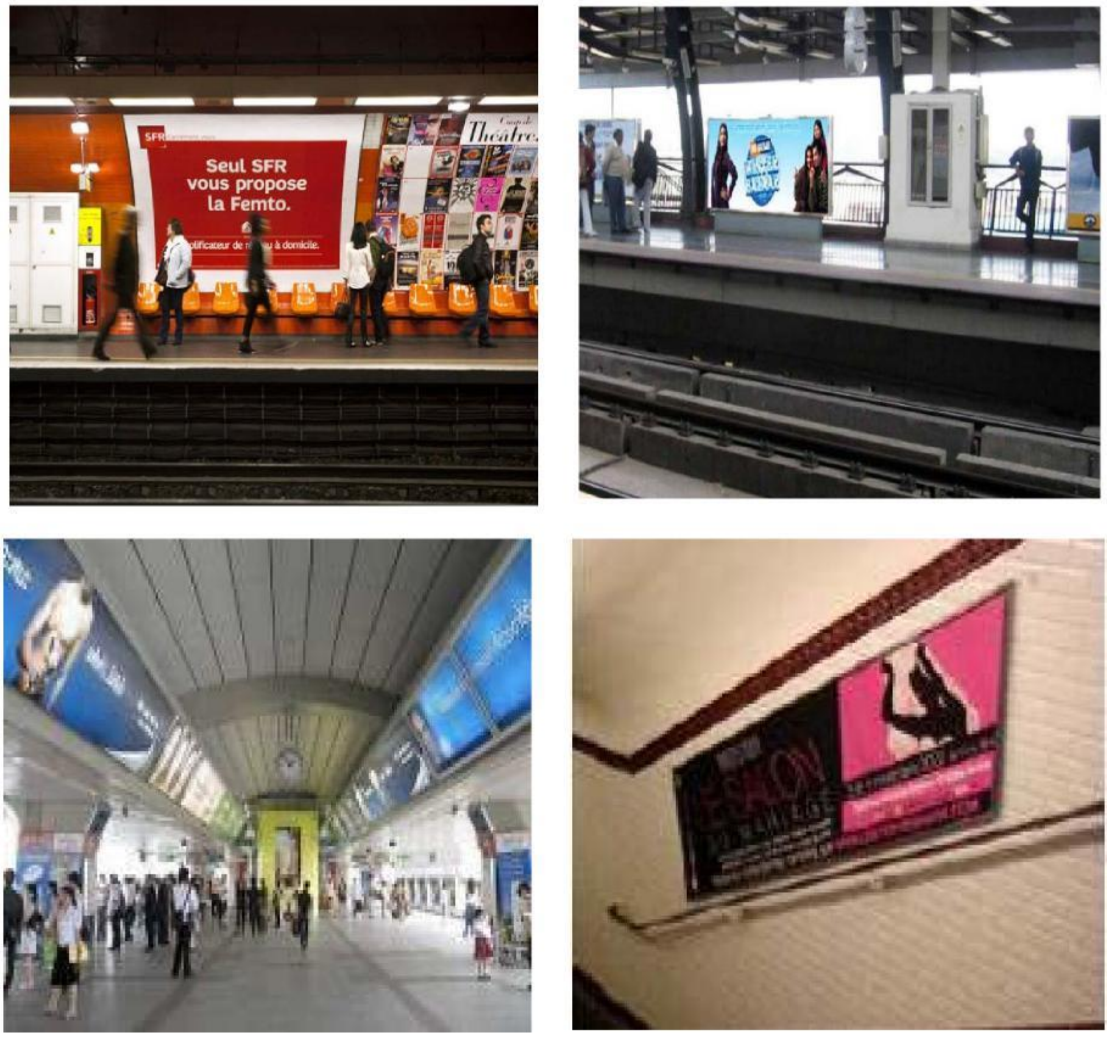


Figure 81 : Advertisements at stations

General principles about the advertising on platforms: advertising spaces must be seen by the customers on the platforms and on the platforms. On the Rolling Stock: train wearing advertisement campaign (train is used as an advertising medium for one campaign). Advertisement on Rolling Stock is presented in the figure hereafter.

Figure 82 : Advertisements at stations

- The entire station can be used as an advertising medium for one campaign;
- New technologies can be used especially on the platforms: LCD screens (about 8 sq m) with projection. It implies cables must 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.

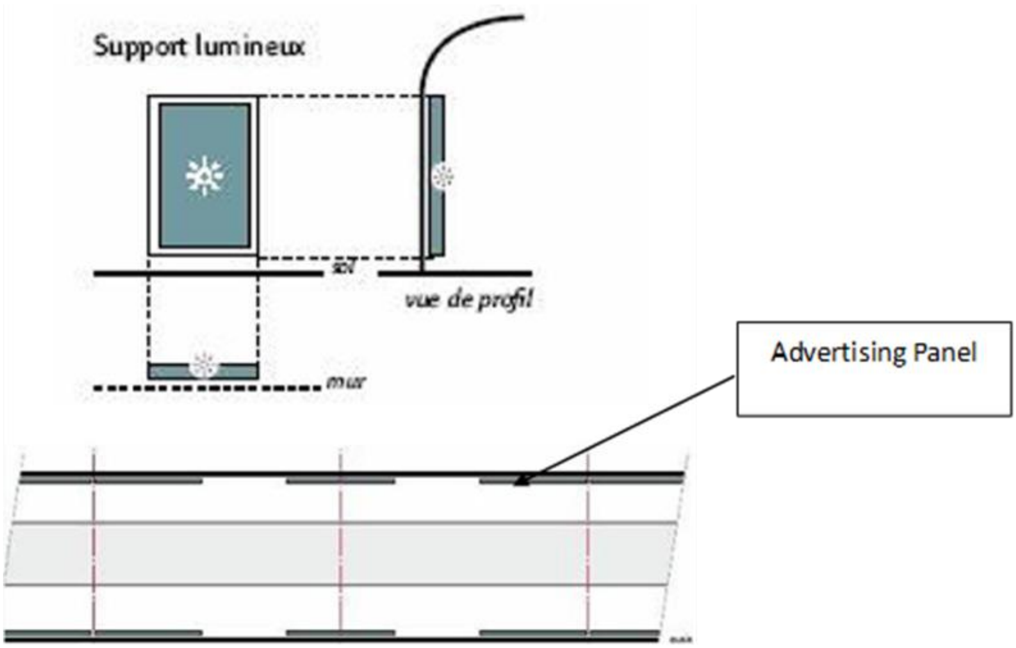


Figure 83 : Advertisements on station platforms

Figure 84 : Advertisements on station platforms

Commercial areas for retail shops

- 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 preferably be appointed for management of these retail shops at all stations on the proposed corridor.

- The different area possibilities for location of retail shops are:
  - **Inside the stations** (paid as well as unpaid areas):
    - **On the platforms**: space to be provided on platform for automatic vending machines (for drinks, eatables, etc.) or small convenience stores;
    - **Inside the stations** (before the BOH 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.
  - **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 habit

6.4.5 Station Branding

Architectural Branding is about to identify the station through Architectural components. Branding a transit service creates an identifiable, marketable and common theme that extends across the service and provides to the customer an opportunity to interact with the service.

Branding a MRTS service gives it a distinct identity, which results in clear and positive public recognition and improved acceptance of the service. In addition to creating or enhancing positive public acceptance of the service, creating a relevant and compelling brand for a BRT system can deliver the following benefits:

• **Clearly differentiated transit service**: Branding can create a premium, higher-quality rapid transit feels for a MRTS service, distinguishing it from standard or more conventional services.

• **Enhanced outreach efforts**: A common brand proposition among the various components of a MRTS system will simplify marketing efforts and will allow a transit agency to more effectively reach its target customers.

• **Improved employee satisfaction and retention**: A consistent and compelling brand creates pride and a sense of contribution for employees.

• **Increased brand value**, as measured by added revenue and increased market share.

Colour schemes, graphics and logos can be used in branding the station as they can carry the brand from the vehicle to the stations, to the signage and to the printed materials, unifying the elements under one brand identity. It also can serve as a unifying element among the larger family of services and can aid passengers in wayfinding, boarding and transferring among interconnected services.

6.4.5.1 Elements Covered Under Branding

6.4.5.1.1 Transit Station

Station is highly identifiable and major component of brand identity. It must be considered if station styling is distinct or appealing. It must be ensured that the station is easily distinct. The distinctive branding can come from a unique paint or graphics package, easily identifiable as different from other transit stop/ station.

Few examples of station branding are given in Figure 85:

Figure 85: Station branding at companypady station of Kochi Metro (Right) and ITO Metro Station of DMRC (Left)

To promote art and culture through artworks, display panels and exhibits, some of its stations have been turned into canvases. Having tied up with various government bodies/organizations like National Book Trust, Delhi Tourism, Sahitya Akademi, India Habitat Centre and the textile ministry, DMRC is enhancing the overall commuting experience. As part of a beautification drive for its stations, DMRC commissioned artworks at several of stations, many of them in south Delhi.

6.4.5.1.2 Mass Transit Vehicle

The vehicles themselves, which in many cases are highly identifiable, are often a major component of the brand identity. Some issues to be considered:
• Is the styling distinct and appealing?
• Do the paint and the graphics package support the brand?
• Do the interior features such as seating support the brand identity?

6.4.5.2 Station Branding In Pune Metro (Maha Metro)

Like the metro system in Naples (Italy) is known for its 'art stations', Stockholm's Tunnelbana as the longest art exhibition in the world and Moscow's subway for the dreamy murals, Pune Metro shall also offers artistic excursions of sorts to its commuters. The Metro stations in the city are not merely overcrowded intersections but also culture hubs. History is no more confined to books and libraries but is on a proud display in the form of photographs, metallic installations, graphs and paintings.

6.4.5.2.1 Approach For Pune Metro Architectural Branding

Major component considered is identity of line. In few stations, station identity is also considered. Thus, the identity of the stations as well as the identity of the line are both to be considered in unison during the development of the Architectural Branding Programme.

To brand the station, few themes are identified along the line, which are: Heritage, Contemporary and Handicrafts.

6.4.5.2.1.1 Contemporary Theme

Under this theme, modern day station, will give the glimpse of tomorrow's technology. Impressive and futuristic shapes combined with sustainable materials and enhanced passenger and transportation flow concepts will make revolutionary architectural and public transport models.

Figure 86: Reference image for contemporary brand identity of a metro station (Exterior)

For Exterior of the station, Glass façade will give modern look. For interior, the choice of colours will be inspired by the Pune Metro logo. Maha metro used multiple colours in its logo. Multiple colours would represent diversity and culture, which Pune uphold. Thus a multi-colour façade shall be created in the concourse are with dominant colours used being Green, Blue, Violet and Orange.

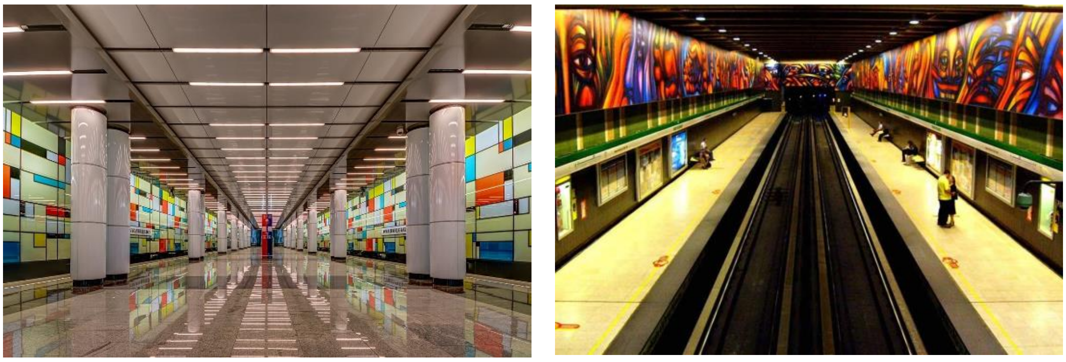


Figure 87: Reference image for contemporary brand identity of a metro station (right and Middle) & Logo of Pune Maha Metro (Left)

6.4.5.2.1.2 Heritage Theme

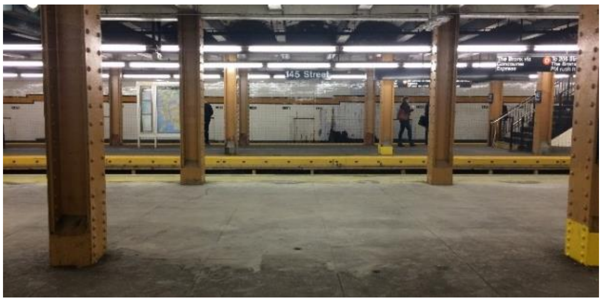
Famous heritage sites in Pune are Deccan college, Pataleshwar Cave temple, Mahadaji Shinde Chhatri, Aga Khan Palace, Lal Mahal, Sight Mahal etc. No dominanat style of architecture is seen in Pune. Though different types of arches are present in most of the heritage structures. Thus, arches forms a very integral part of Pune's Heritage. Arches can be used at the entrances of the station. Another very important component of Pune's Heritage is columns. Artistically carved columns and column capital can use used while designing the station. Few examples are given below:

Figure 88: Reference image for use of column in defining the brand identity of a metro station

6.4.5.2.1.3 Handicrafts Theme

Craftsmen in Pune are known to work and deal in utensils and other handicraft item made of copper, bronze or what is popularly called as ‘tamba’. In the early period the system was based on barter where people would exchange goods for goods or goods for services. If someone wants to get a copper vessel then he would go to the Kasar or coppersmith and provide the old material. Thus, bronze forms an integral part of heritage of Pune. Therefore, Bronze theme can be used in the station to give them an identity.

External sheds, furniture etc shall be given bronze theme. Few examples are given below:



6.4.5.2.1.4 Stations with special character

There are few stations which have special features in the vicinity, which can define the station. An illustration or a paining shall be used to give the station a sense of identity.


Stations with special feature are:

Corridor 1A: PCMC to Nigdi	
Station 2 (Akurdi)	Khandoba Mandir
Station 3 (Nigdi)	Bhakti shakti Udyan

6.4.6 Typical stations and adaptations

6.4.6.1 Typical station layout

This section presents typical metro station of type I (elevated). The objective of conceiving typical metro stations is to show how the different functions of the metro stations are organised space-wise. The principles on which the layout is based are presented below:

- The stations are generally **located on the road median**. Total length of the station is 140 m;
- All the stations are **three-level** stations; (Ground Level, Concourse Level, Platform Level), except Nigdi station, which has an additional level for Property Development.
- The passenger areas on concourse level shall be concentrated in a length of about 140 m in the middle of the station, with 2-4 **staircases, escalators & elevators** leading from either side of the road;
- Typically, the **concourse** is divided into public and non-public zones:
    - The **non-public zone** or the restricted zone contains station operational areas such as Station Control Room, Station Master's Office, Waiting Room, Meeting Room, UPS & Battery Room, Signalling Room, Train Crew Room & Supervisor's Office, Security Room, Station Store Room, Staff Toilets, etc.
    - The **public zone** is further divided into paid and unpaid areas.

- **Passenger facilities** like ticketing, information, etc as well as operational areas are provided at the concourse level;
- **Accommodation for staff and plant rooms** shall be 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 level at each end. The S&T equipment rooms are provided;
- The internal arrangement for the stations shall be 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;
- The 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;

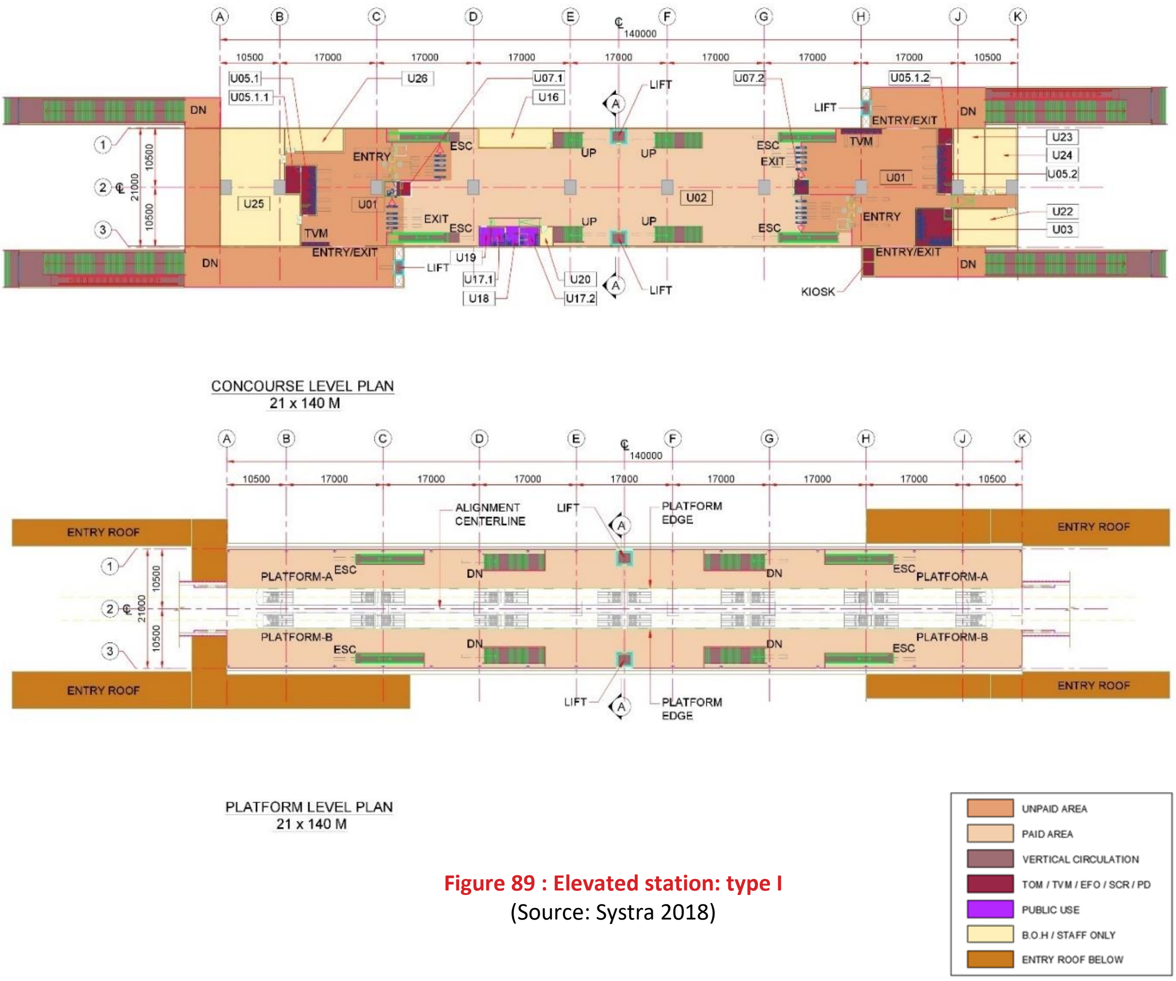


Figure 89 : Elevated station: type I
(Source: Systra 2018)

Typical surfaces for different rooms are provided in the table below:

ROOM NO.	ROOM NAME	AREA PROVIDED (SQ. M)
U01	STATION ENTRANCE UNPAID AREA	660.00
U02	CONCOURSE PAID AREA	1400.00
U03	STATION CONTROL ROOM	40.00
U05.1	TICKET OFFICE MACHINE	25.00
U05.2	TICKET OFFICE MACHINE	25.00
U07.1	EFO	9.00
U07.2	EFO	9.00
U16	CREW ROOM MALE/FEMALE	40.00
U17.1	TOILET MALE	12.00
U17.2	TOILET FEMALE	12.00
U18	HANDICAP TOILET	6.00
U20	CLEANERS ROOM	6.00
U19	CHILD CARE	6.00
U22	SIGNALING EQUIPMENT ROOM (SER)	60.00
U23	TELECOM EQUIPMENT ROOM (TER)	60.00
U24	UPS ROOM FOR S & T	60.00
U25	AUXILIARY SUB STATION	250.00
U26	UPS ROOM FOR ELECTRICAL	40.00

Figure 90 : Room schedule for station
(Source : Systra 2018)

6.4.6.2 Typical cross section

Since the station is generally in the middle of the road, minimum vertical clearance of 5.5-m has been provided under the concourse.

Concourse floor level is about 7.2-m above the road.

Consequently, platforms are at a level of about 13.5-m from the road. To reduce physical and visual impact of the elevated station, stations have been made narrow towards the ends.

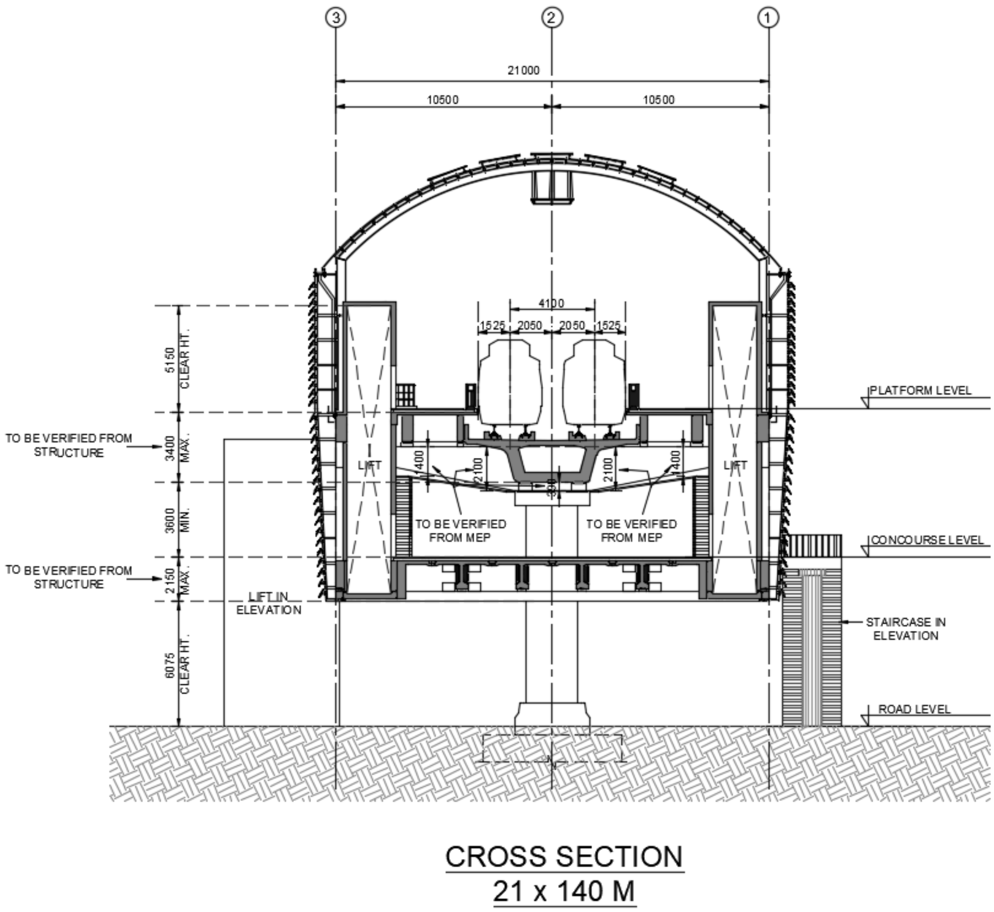


Figure 91 : Cross section of elevated typical elevated station (Source : Systra 2018)

6.4.6.3 Typical design

With respect to its spatial quality, an elevated metro 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 track. Structures that afford maximum transparency and are light looking have been envisaged. A slim and ultra-modern concrete form is proposed, as they would look both compatible and modern high-rise environment as well as the lesser-built, low-rise developments along some parts of the corridor.

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

6.4.6.4 Adaptation of typical station

The typical station is used to set a standard across the metro line. It shall then adapted for each station depending station-specific factors. These include:

- **Land availability**: since land is at a premium throughout the corridor, the process of reconciling the land that is required for the station development has a major influence upon the design process and important elements of the stations such as entry/exits, concourse, platforms, ancillary buildings etc. shall been designed and marked for each station to overcome land acquisition problems. But, wherever the vacant land parcels are not found available, land acquisition shall be proposed for placing the necessary utilities/facilities;

- **Passenger flows**: The most important design consideration is to provide a safe and comfortable environment to passengers during both normal and emergency operation. In order to provide such an environment, space planning requirement for each of the stations depends on passenger flows as they influence the number of AFC gates, ticket windows, stair widths, number of escalators, platform width etc. These calculations not only accommodate the normal and delayed operation but also satisfy NFPA 130 guidelines.

6.4.6.5 Conceptual views of elevated station

This section provides illustrations of concepts associated with elevated stations. These are meant to provide ideas of how these concepts can be applied.

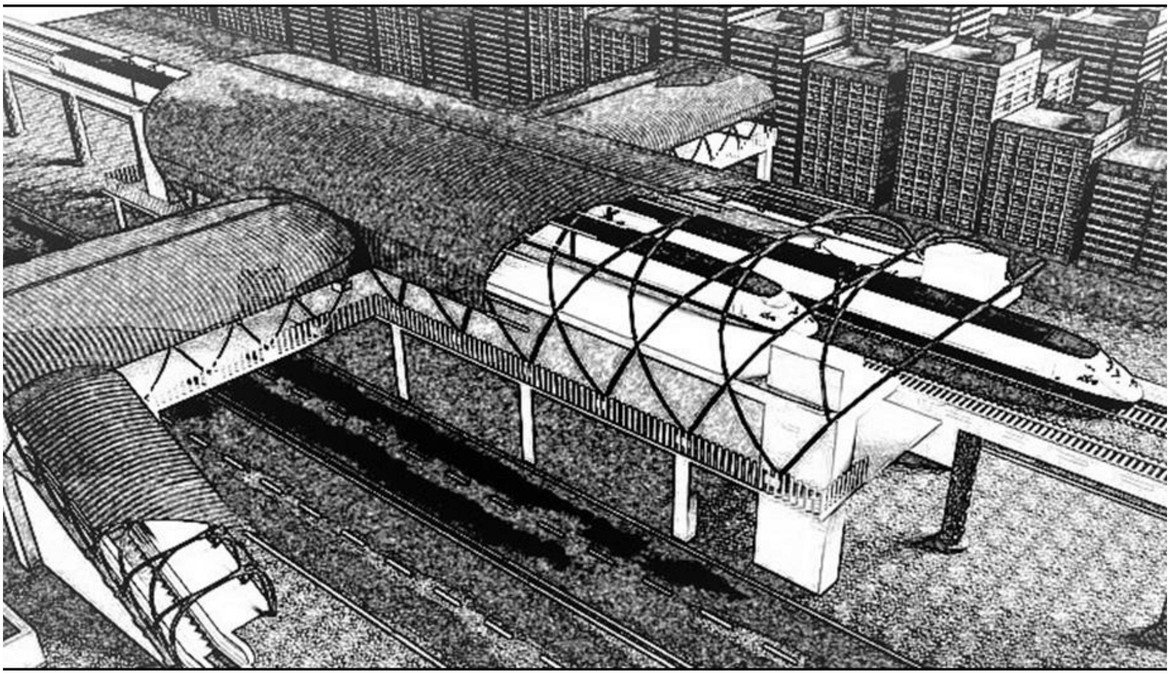


Figure 92 : Station entries to be covered in the rain prone area

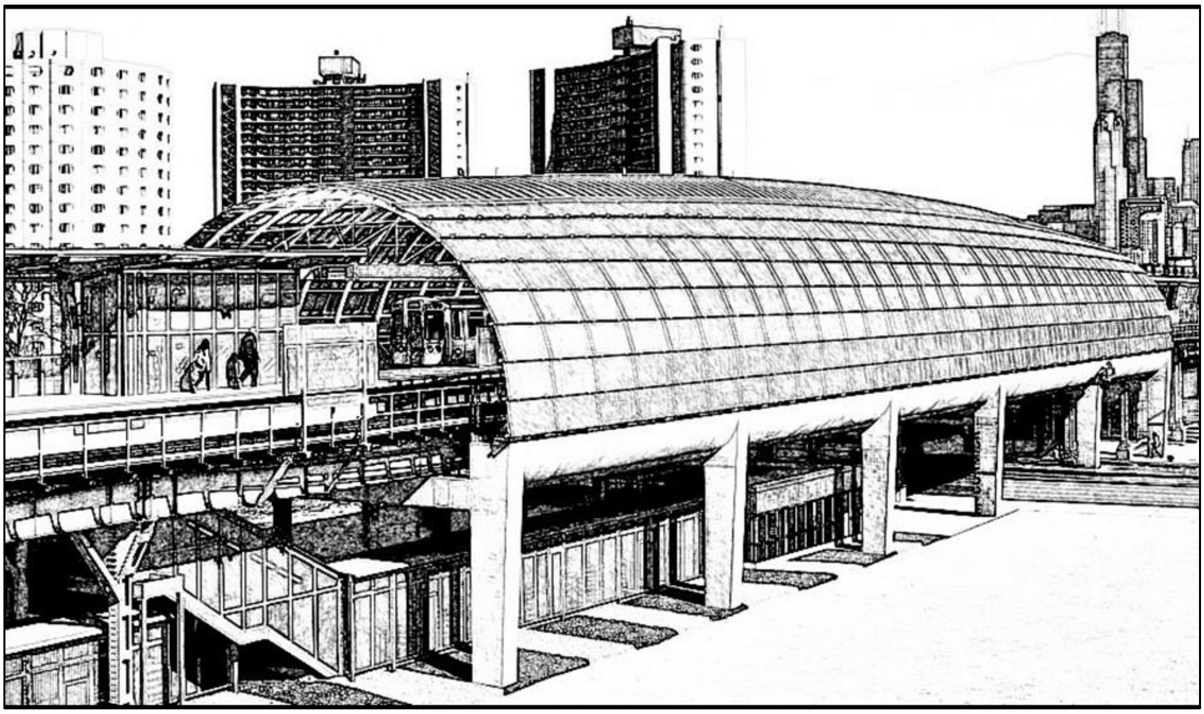


Figure 93 : Station can be designed Semi-Open for Lighting, Ventilation and keeping the station mass lighter

Figure 94 : Glasses used for natural light from sides and Skylight from roof

Figure 95 : Structural Glazing used for natural lighting

Figure 96 : Stations can be designed to create a landmark in the fast-developing city

6.4.6.6 Types of metro stations on Phase 1A

Corridor- 1A stations with their types are presented in the table below:

Table 75: Details of station types

Corridor 1A PCMC TO NIGDI		
1	Station 1 (Chinchwad)	Elevated
2	Station 2 (Akurdi)	Elevated
3	Station 3 (Nigdi)	Elevated

6.5 Disabled friendly features

6.5.1 Introduction

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

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

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

6.5.2 Rail transport

- **General**

- Whether over-ground or grade or underground, rail travels is a highly effective mode of transport.
- Every train should contain fully accessible carriages.
- Staff should be trained in methods of assistance and be at hand on request.
- Stations for all rail travel should be fully accessible with extra wide turnstiles where possible alongside wheelchair accessible doorways.
- Staff should be on hand to assist persons with disabilities and elderly to enter or exit through convenient gates.
- All new metro stations should be designed to be fully accessible.
- For persons with hearing impairments, an electronic sign board (digital display) should be displayed on each platform at conspicuous location for all announcements made by the railways.

- For persons with visual impairments audio system announcing the station names and door location should be available.

Accessible railway cars

The metro cars should have the following features:

- Railway car doors should be at least **900 mm** wide;
- The gap between the car doors and the platform should preferably be less than **12 mm;**
- Identification signage should be provided on the doors of wheelchair accessible coach
- If the car door and the platform cannot be at the same level, then at least one car doors should have apparatus such as a hydraulic lift or pull-out ramp installed in the doorway for wheelchair users.

Wheel Chair Space

- Space for a wheel chair should be available at the side of the door;
- The space should be indicated inside and outside the car by using the international symbol of access
- Wheel stopper and ring-strap or other appropriate safety grip should be provided for wheelchair users.
- Emergency communication is accessible to person in wheel chair.

Seats

- An appropriate number of designated seats for passengers with disabilities and elderly people should be provided near the doors

Aisles

- Aisles should be at least 900 mm wide.

6.5.3 Metro railway station

6.5.3.1 Information signs and announcements

A map of train routes should be installed. This should be in Braille/raised numbers as well. In each car, there should be an announcement and provision of a visual display of the names of stations route. This display should be in raised numbers with sharp contrast from the background.

6.5.3.2 Level approach

- Approach route should not have level differences. If the station is not on the same level as the walkway or pathway, it should a ramp.

- Walkway surfaces should be non-slip.
- Approach walkway should have tactile pavements for persons with visual impairments.

6.5.3.3 Station entrances and exits

- These should have a minimum width of 1800mm and is level or ramped.

6.5.3.4 Reservation and information counters

- Should have clear floor space of at least 900 mm x 1200 mm in front of the counters; There should be at least one low counter at a height of 750 mm to 800 mm from the floor with clear knee space of 750 mm high by 900 mm wide by 480 mm deep.
- At least one of the counters should have an induction loop unit to aid people with hearing impairments.
- The counters should have pictographic maps indicating all the services offered at the counter and at least one of the counter staff should be sign language literate.

6.5.3.5 Toilet facilities

- There should be at least one unisex accessible toilet
- Ticket Gates

At least one of the ticket gates should:

- Be minimum 900 mm wide to allow a wheelchair user through and
- Have a continuous line of guiding paver for people with visual impairments.

6.5.3.6 Platforms

The Platforms should have the Following characteristics:

- Have non-slip and level flooring;
- Have a row of warning paver installed 600mm before the track edge
- Have seating areas for people with ambulatory disabilities
- Be well illuminated lux level of 200 lux
- There should be no gap or difference in level between the train entry door and the Platform.
- All platforms should inter-connect by means of an accessible routes or lifts and provide accessible level entrance to the train coach.

6.5.3.7 Way finding

- Way finding references should be available at decision points.
- Color can be used to identify routes and aid in locating doors, walls and hazards. Proper color contrast between different elements greatly improves visibility for all users and is critical for persons with low vision. For example, color contrasting

of door frames can assist in locating doors, and likewise floors should be contrasted with walls. In addition, furniture should contrast with walls and floors so as not to create an obstacle.

- Structural elements such as columns should be color contrasted or brightly marked so as to be visible to those who may have a visual disability.
- Generally, patterns on flooring should be avoided or else should be minimal and small to avoid visual confusion.
- In addition to identifying hazards or warnings, tactile floor surfaces can also be used to inform that there is a change in area (e.g. leaving a corridor and entering a boarding area).
- Tactile systems should be consistent throughout the building. For example, terminals should not have carpeting in some boarding areas and tile in others as this may create confusion for those who rely on tactile surfaces to guide them to their destination.
- Good lighting assists those with a visual disability to see better and allows people who have a hearing impairment to lip read easier. However, care should be taken to properly direct lighting and to use matte finishes on floors, walls and signage, so as not to create glare which may create difficulties for all travelers.
- Blinds can be used to adjust lighting levels in areas where the natural lighting changes significantly throughout the day.

6.5.3.8 Signage

Signs must be clear, concise, and consistent. All travelers need clear information about the purpose and layout of terminals to maintain a sense of direction and independent use of all facilities. Using internationally and nationally established symbols and pictograms with clear lettering and Braille ensures universal accessibility cutting across regional/cultural and language barriers. A cohesive information and signage system can provide visual (e.g. signs, notice boards), audible (e.g. public address and security systems, induction loops, telephones, and infrared devices), and/ or tactile information (e.g. signs with embossed lettering or Braille).

6.5.3.9 Sign design specifications

- The sign should be in a prominent position.
- The face of the sign should be well-illuminated by natural or artificial light.
- Letters should be simple such as Arial, Helvetica medium, and san serif or similar and numbers should be Arabic.
- The color of the text should be in a color that contrasts with the sign board.
- The sign board should also contrast with the wall on which it is mounted.
- Some signs such as those adjacent to or on a toilet door may be embossed so that they can be read by touch.
- Illuminated signs should not use red text on a dark background.
- Signs should be supplemented by Braille where possible.
- The surface of the sign should not be reflective.

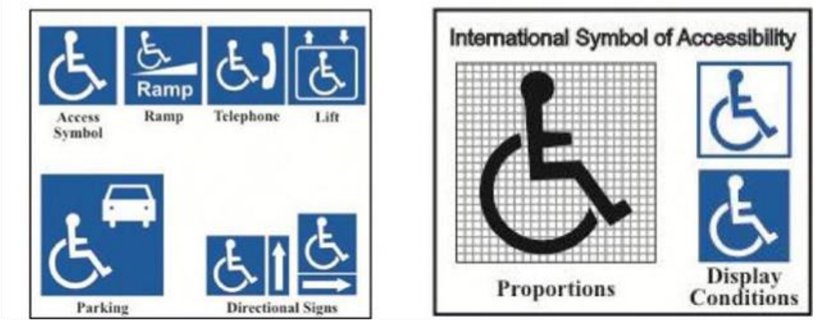


Figure 97 : Way finding signage and International Symbol of accessibility

6.5.3.10 Automated kiosks

- Automated kiosks should be accessible for wheelchair users.
- Should be clearly marked with international symbol of accessibility.
- Should have Braille buttons and audio announcement system for persons with vision impairments.
- Operations should be easy to understand and operate for persons with learning disabilities, intellectual disabilities, and elderly persons.

6.5.3.11 Public dealing counters

- Ticketing, Information, Check-in, help desk, Restaurants, Shops, etc. should have Information or help desks should be close to the terminal entrance, and highly visible upon entering the terminal. In addition, they should be clearly identified and accessible to both those who use wheelchairs and those who stand.
- It should provide information in accessible formats, viz. Braille leaflets for persons with vision impairments.
- Ideally, these desks should have a map of the facility that desk attendants can view with
  passengers, when providing directions.
- Staff manning the counters should know sign language.
- Information desk acoustics should be carefully planned and controlled as a high level of background noise is confusing and disorienting to persons with hearing impairment.
- Lighting should be positioned to illuminate the receptionist/person manning the counter
  and the desk top without creating glare.
- Lighting should not create shadows over the receptionist staff, obscuring facial detail and
  making lip reading difficult.
- There should be a hearing enhancement system such as a loop induction unit, the availability of which is clearly indicated with a symbol.

- One of the counters should not be more than 800mm from the floor, with a minimum
  clear knee space of 650mm high and 280mm- 300mm deep.

6.5.3.12 Audio-visual displays

- Terminal maps should be placed so that they are readily visible to persons who are standing and persons who use wheelchairs. They should also be accessible to persons with a visual disability (i.e. tactile maps). Other alternatives include electronic navigation systems or audio maps.
- Enable captioning always on all televisions and other audiovisual displays that are capable of displaying captions and that are in any portion of the terminal.
- The captioning must be in high contrast for all information concerning travel safety, ticketing, check-in, delays or cancellations, schedule changes, boarding information, connections, checking baggage, individuals being paged by bus railway or airlines, vehicle changes that affect the travel of persons with disabilities, and emergencies (*e.g.*, fire, bomb threat).

6.5.3.13 Rest areas/seating

- Seating area / benches should be provided along the circulation path at regular intervals so that passengers do not need to walk more than 50 to 60 meters before being able to sit and rest.
- Where seating is provided, designated seating for passengers with disabilities is to be
  provided at boarding gates and departure areas within viewing distance of communication boards and/or personnel and identified by the symbol of access.
- Public transit operators should provide seating in passenger service areas where there may be long waiting lines or times, including at ticket sales counters, check-in counters, secured screening and during inter-country travel in customs areas and baggage retrieval areas.
- Designated seating should be provided for at boarding gates and departure areas within viewing distance of communication boards, and within hearing range of audio announcements as well. Such seating areas should be identified by the symbol of accessibility and shelter should be provided where this seating is outdoors.
    - In outdoor settings, seating should be provided along with the planned hawker spaces.
    - At waiting lounges for persons with disabilities chairs should have armrests and backrest.

6.5.3.14 Tactile paving – guiding & warning

Tactile Guiding Paver (Line-Type)

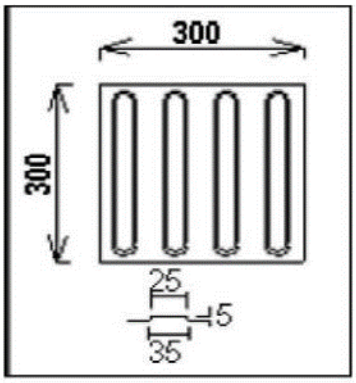
It is recommended to install a row of tactile guidance paver along the entire length of the proposed accessible route for visual impaired persons. Care must be taken to ensure that there are no obstacles, such as wall, pillar, uneven surfaces, Soffit (underside /open area under the stairs, along the route traversed by the guidance paver. Also, there should be clear headroom of at least 2.1 meters height above the tactile guidance paver, free of protruding objects such as overhanging advertisement panel and signage, along the entire length of the walk.

Tactile Warning Paver (Dot-Type)

Indicate an approaching potential hazard or a change in direction of the walkway, and serve as a warning of the approaching danger to persons with visual impairments, preparing them to tread cautiously and expect obstacles along the travel path, traffic intersections, doorways, stairs, etc. They are used to screen off obstacles, drop-offs or other hazards, to discourage movement in an incorrect direction, and to warn of a corner or junction. Two rows of tactile warning paver should be installed across the entire width of the designated accessible passenger pathway at appropriate places such as before intersections, terminal entrances, obstacles such as signage, and each time the walkway changes direction.

Places to install warning paver

- In front of an area where traffic is present.
- In front of an entrance/exit to and from a staircase or multi-level crossing facility.
- Entrances/exits at public transport terminals or boarding areas.



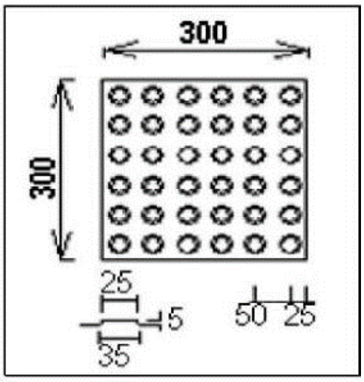


Figure 98 : Guiding paver and warning paver

6.5.3.15 Doors

- Whatever the type of entrance door, it must be wide enough to accommodate passenger traffic comfortably.

- The recommended minimum clear opening width of an internal door is 900mm minimum.
- Where doors comprise two leaves (i.e. double doors), each leaf should be 900mm min. wide, so that persons carrying large items and people using wheelchairs do not have to open both leaves.
- Manual doors should incorporate kick plates 300-400mm high to withstand impact of wheelchair footrest (this is especially important where doors are glazed).
    - Also, be fitted with vision panels at least between 900mm and 1500mm from floor level.
    - Be color contrasted with the surrounding wall and should not be heavier than 22N to open.
    - Lever handles and push type mechanisms are recommended. When a sliding door is fully open, handles should be usable from both sides.
    - Where revolving doors or turnstiles are used, an alternative wheelchair-accessible entrance must also be provided.
- 400mm should be provided beyond the leading edge of door to enable a wheelchair user to maneuver and to reach the handle.
- To ensure maximum clarity for persons with visual impairments, the entrance should be easily distinguishable from its surroundings by the effective use of landscaping, signage, color (preferably yellow/orange), tonal contrast and tactile surfacing.
- Door hardware should be positioned between 900-1000mm above floor.
- Operable devices such as handles, pulls, latches and locks should:
    - Be operable by one hand
    - Not require fine finger control, tight grasping, pinching or twisting to operate
- Glazed doors and fixed glazed areas should be made visible by use of a clear, color and
  tone contrasted warning or decorative feature that is effective from both inside and outside and under any lighting conditions, e.g. a logo, of minimum dimensions 150mm by 150mm (though not necessarily square), set at eye level.

6.5.3.16 Steps and stairs

- Steps should be uniform with the tread not less than 300mm and the risers 150mm.
- The risers should not be open.
- The steps should have an unobstructed width of 1200mm minimum.
- All steps should be fitted with a permanent color and tone contrasting at the step edge, extending the full width of the step, reaching a minimum depth of 50mm on both tread and riser.

- Have continuous handrails on both sides including the wall (if any) at two levels
- Warning paver to be placed 300mm at the beginning and at the end of all stairs.
- Nosing to be avoided.
- The staircase should be adequately and uniformly illuminated during day and night (when in use). The level of illumination should preferably fall between 100-150 lux.
- The rise of a flight between landings must be no more than 1200mm.
- There should be no more than 14 risers in one flight run.
- The stair covering, and nosing should be slip-resistant, non-reflective, firmly-fixed and easy to maintain.
- Soffit (underside /open area under the stairs) of the stairs should be enclosed or protected.

6.5.3.17 Handrails

- Handrails should be circular in section with a diameter of 38-45mm and formed from materials which provide good grip such as timber, nylon or powder coating, matt finish metal finishes.
- The handrail should contrast in color (preferably yellow/orange) with surrounding surfaces.
- At least 50mm clear of the surface to which they are attached and should be supported on brackets which do not obstruct continuous hand contact with the handrail.
- The handrail should be positioned at two levels- 760mm and 900mm above the pitch-line of a flight of stairs.
- Handrail at foot of the flight of stairs should extend 300mm beyond the stairs in the line of travel and returning to the wall or floor or rounded off, with a positive end that does not project into the route of travel.

6.5.3.18 Ramps

- Ramps gradient should ideally be 1 in 20 and no greater than 1 in 12.
- Width of the ramp should not be less than 1200mm and preferred width is 1800mm.
- The steeper the gradient, the shorter the length of ramp between landings.
- On long ramps, a horizontal resting space should be provided every 6 meters.
- Surface materials should be slip-resistant, non-reflective, firmly-fixed and easily maintained
- The edge of the ramp should have an edge protection with a minimum height of 100mm.
- Landings every 750mm of vertical rise.

- A tapping or lower rail should be positioned so that its bottom edge is no higher than 200mm above ground level.
- Handrails on the ramps should be on both sides at two levels: upper at 900mm and lower at 760mm; both end to be rounded and grouted; extend 300 mm beyond top and bottom of ramp.
- A row of tactile warning paver should be placed 300mm beginning and end of each run.
- Landings should be provided at regular intervals as indicated in the table.

6.5.3.19 Lifts

A carefully designed lift makes a huge contribution to the accessibility of a station for persons with disabilities.

- Lift locations should be clearly signposted from the main pedestrian route and recognizable through design and location.
- The color and tone of the lift doors should contrast with the surrounding wall finish to assist in their location. Lift doors with metallic finishes such as steel grey and silver should be avoided as they are difficult to identify by persons with low vision.
- The lift lobby shall be of an inside measurement of 1800mm X 2000mm or more. A clear landing area in front of the lift doors of minimum dimensions 1500mm x 1500mm should be provided.
- By making the landing area distinguishable by floor surface and contrast, it will aid location and recognition of core areas. This could comprise a change in floor finish from thin carpet to vinyl/PVC, or cement/mosaic floor to carpet.
- Changes in floor finish must be flushed. There should be no level difference between lift
  door and the floor surface at each level; the gap if unavoidable should not be more than 12mm.
- The floor level/location should be indicated on the wall adjacent to or just above the call buttons, and opposite the lift doors where possible.

- **Lift dimensions**

Provisions of at least one lift shall be made for people using wheelchairs with the following car dimensions:

- Clear internal depth - 1500 mm minimum
- Clear internal width - 1500 mm minimum
- Entrance door width - 900mm minimum

Lift controls

- The lift call button should be wall-mounted adjacent to the lift and should contrast with
  wall finish, either by using a contrasting panel, or a contrasting border around the button panel.
- The call buttons should be located within the range 800-1000mm above floor finish.
- Buttons should not be touch sensitive, but should require a light positive pressure and
  should ideally be large enough to be operable by the palm of the hand if required.
- The control buttons inside the lift should be positioned on the side wall rather than front
  wall to allow access from the back and front of the lift car, by mobility aid users like wheelchair users.
- The control buttons should contrast with their surroundings and illuminate when pressed
  and should incorporate highly visible tactile embossed (NOT engraved) characters and in Braille.
- Time of closing of an automatic door should be more than 5 seconds and the closing speed should not exceed 25 meters per second. There should be a provision of censor enabled closing.
- In larger lifts, controls should be positioned on both side walls, at least 400mm from front wall and between 800-1000mm above floor level.

Car design

- Internal walls should have a non-reflective, matt finish in a color and tone contrasting with the floor, which should also have a matt, non-slip finish.
- Use of reflective materials such as metal (stainless steel for example) can be problematic
  in creating sufficient contrast with control buttons, emergency telephone cabinet, etc. for persons with low vision and the use of such materials should be avoided wherever possible.
- A mirror (750mm above floor level) on the rear wall can be useful to persons using wheelchairs and other mobility aids should they need to reverse safely out of the lift car or view the floor numbers.
- Internal lighting should provide a level of illumination of minimum 100 lux (approximately 50-75 lux at floor level), uniformly distributed, avoiding the use of spotlights or down lighters.
- A grab bar should be provided along both sides and the back wall, 900mm above floor level.
- Handrails should be of tubular or oval cross section, to be easily gripped and capable of providing support.

- Handrails should be positioned so that there is a clear space behind the handrail to allow it to be grasped i.e. knuckle space should be 50mm.

Information systems

- Lifts should have both visual and audible floor level indicators
- Audible systems are also usually capable of incorporating additional messages, such as door closing, or, in the case of an emergency, reassurance (with manual over-ride allowing communication with lift occupants).
- Announcement system should be of 50 decibels.
- The display could be digital or segmented LED, or an appropriate alternative. A yellow or light green on black display is preferred to a red on black display as it is easier to read.

6.5.3.20 General and accessible toilets

Signages

- All signage of general toilets should be in bold and contrasting colors.
- For persons with low vision and vision impairments: male pictogram in triangle and female pictogram in circle, marked on plates along with Braille & raised alphabets, to be mounted on wall next to door near the latch side, at a height between 1400mm-1600mm.
- Warning strip/ thin rubber door mat to be provided 300mm before and after the toilet entrance.
- Tactile paver to be provided for urinals, WC and washbasins for persons with vision impairments.

Accessible Toilets

- Should have the international symbol of accessibility displayed outside for wheelchair access.
- The toilet door should be an outward opening door or two ways opening or a sliding type and should provide a clear opening width of at least 900mm.
- It should have a horizontal pull-bar, at least 600mm long, on the inside of the door, located so that it is 130mm from the hinged side of the door and at a height of 1000mm.

WC (WC) Compartment Dimensions

- The dimensions of a unisex toilet are critical in ensuring access. The compartment should be at least 2200mm and 2000mm. This will allow use by both manual and motorized wheelchair users.
- Layout of the fixtures in the toilet should be such that a clearing maneuvering space of 1500mm x 1500mm in front of the WC and washbasin.

Water Closet (WC) Fittings

- Top of the WC seat should be 450-480mm above finished floor level, preferably be of wall hung or corbel type as it provides additional space at the toe level.
- An unobstructed space 900mm wide should be provided to one side of the WC for transfer, together with a clear space 1200mm deep in front of the WC.
- WC should be centered 500mm away from the side wall, with the front edge of the pan 750mm away from the back wall. Have a back support. The WC with a back support should not incorporate a lid, since this can hinder transfer.
- L-shape grab bar at the adjacent wall and on the transfer side (open side) swing up grab bar shall be provided.
- The cistern should have a lever flush mechanism, located on the transfer side and not on
  the wall side and not more than 1000mm from the floor.

Grab Bars

- Grab bars should be manufactured from a material which contrasts with the wall finish (or use dark tiles behind light colored rails), be warm to touch and provide good grip. - It is essential that all grab rails are adequately fixed, since considerable pressure will be placed on the rail during maneuvering. Grab bars should sustain weight of 200kgs minimum.
- A hinged type moveable grab bar should be installed adjacent to the WC on the transfer side. This rail can incorporate a toilet tissue holder. 320mm from the center line of the WC between heights of 200-250mm from the top of the WC seat. It should extend 100-150mm beyond the front of the WC.
- A fixed wall-mounted L- shape grab bar (600mm long horizontal and 700mm long vertical)
  on the wall side should be provided. It should be placed at a height of 200-250mm above the WC seat level.

Washbasins

- The basin should be fixed no higher than 750mm above the finished floor level.
- Be of dimensions 520mm and 410mm, mounted such that the top edge is between 800 - 900mm from the floor; have a knee space of at least 760mm wide by 200mm deep by 650-680mm high.
- The position of the basin should not restrict access to the WC i.e. it should be located 900mm away from the WC.
- A lever operated mixer tap fitted on the side of the basin closest to the WC is useful as it allows hot and cold water to be used from a seated position on the WC.
- The hand drying facilities should be located close to the hand washbasin between 1000-1200mm.
- Hand washbasins should be fitted on cantilevered brackets fixed to the wall.

- Lever type handles for taps are recommended.
- Mirror's bottom edge to be 1000mm from the floor and may be inclined at an angle.

Fixtures and Fittings

- Contrast between fittings and fixtures and wall or floor finishes will assist in their location. For example, using contrasting fittings, or dark tiles behind white hand washbasins and urinals, contrasting soap dispensers and toilet roll holders. Contrast between critical surfaces, e.g. floors, walls and ceilings help to define the dimensions of the room.
- Towel rails, rings and handrails should be securely fixed to the walls and positioned at 800-1000mm from the floor.
- The mirror should be tilted at an angle of 300 for better visibility by wheelchair users.
- It should have lower edge at 1000mm above floor finish and top edge around 1800mm above floor finish.
- Hooks should be available at both lower-1200mm and standard heights- 1400mm, projecting not more than 40mm from the wall.
- Where possible, be equipped with a shelf of dimensions 400mm x 200mm fixed at a height
  of between 900mm and 1000mm from the floor.
- Light fittings should illuminate the user's face without being visible in the mirror. For this reason, most units which have an integral light are unsatisfactory.
- Large, easy to operate switches are recommended, contrasting with background to assist
  location, at a maximum height of 1000mm above floor finish.
- All toilet facilities should incorporate visual fire alarms.
- Alarms must be located so that assistance can be summoned both when on the toilet pan i.e. at 900mm height and lying on the floor i.e. at 300mm, from floor surface. Alarms should be located close to the side wall nearest the toilet pan, 750mm away from rear wall and at 900mm and 200mm above floor finish.

1. Signage of Accessible Toilets

- All unisex accessible toilets to have access symbol in contrast colors. A distinct audio sound (beeper/clapper) may be installed above the entrance door for identification of the toilets.

Figure 99 : Signage for accessible washroom

6.5.3.21 Accessible urinal

- At least one of the urinals should have grab bars to support ambulant persons with disabilities (for example, people using mobility aids like crutches).
- A stall-type urinal is recommended.
- Urinals shall be stall-type or wall-hung, with an elongated rim at a maximum of 430mm
  above the finish floor. This is usable by children, short stature persons and wheelchair users.
- Urinal shields (that do not extend beyond the front edge of the urinal rim) should be provided with 735mm clearance between them.
- Grab bars to be installed on each side, and in the front, of the urinal.
- The front bar is to provide chest support; the sidebars are for the user to hold on to while standing.

6.5.3.22 Drinking water units

- Drinking water fountains or water coolers shall have up front spouts and control.
- Drinking water fountains or water coolers shall be hand-operated or hand and foot-operated.
- Conventional floor mounted water coolers may be convenient to individuals in wheelchairs if a small fountain is mounted on the side of the cooler 800mm above the floor.
- Fully recessed drinking water fountains are not recommended.
- Leg and knee space to be provided with basin to avoid spilling of water. This allows both front and parallel access to taps for persons using mobility aids like wheel chair, crutches etc.

6.5.3.23 Visual contrasts

- Visual contrasts mean adequate contrast created by difference of at least 30 LRV (Light Reflectance Value) of the two surfaces/ objects and it helps everyone especially persons with vision impairments.
- Visual contrast should be provided between:
    - Critical Surfaces (walls, ceiling and floor),
    - Signage and background sign frame/ wall,
    - Step edges and risers/ treads on steps,
    - Handrails and background walls,
    - Doors and surrounding walls,
    - Switches/ sockets and background wall,
    - Toilet fixtures and critical surfaces in toilet.

- Barriers and hazards should be highlighted by incorporating colors and luminance contrast.

6.5.3.24 Emergency egress/evacuation

- Placement (accessibility) and visibility of such devices is very important. The following is to be considered for the installation of such alarm devices; fire alarm boxes, emergency call buttons and lit panels should be installed between heights of 800mm and 1000mm from the furnished floor surface. These should be adequately contrasted from the background wall and should be labelled with raised letters and should also be in Braille.
- A pre-recorded message, alerting an emergency to the control room or reception should be installed in the telephone and this should be accessible by a 'hotkey' on the phone keypad. This 'hotkey' should be distinct from the rest of the keypad.

6.5.3.25 Alert systems

- In emergency situations, it is critical that people are quickly alerted to the situation at hand, for persons with disability the following needs to be considered.
- Consider having audible alarms with 'voice instructions' that can help guide them to the nearest emergency exit. As an alternative to the pre-recorded messages, these alarms may be connected to the central control room for on-the-spot broadcasts.
- Non-auditory alarms (visual or sensory) to alert persons with hearing impairments should be installed at visible locations in all areas that the passengers may use (including toilet areas, etc.).

6.5.3.26 Written evacuation procedure

A written evacuation procedure that details the egress plan for people with disability should be installed behind the entrance door in the accessible rest rooms. The evacuation procedure should be detailed in large print letters that contrast strongly against the background. Where possible, it should also incorporate raised letters and Braille. The evacuation route should be displayed on a high contrast tactile map for benefit of persons with vision impairments.

6.5.3.27 Emergency evacuation route

- Designate routes that are at least 1200mm wide, to ensure that a person using a wheelchair and a non-disabled person can pass each other along the route. The route should be free of any steps or sudden changes in level and should be kept free from obstacles such as furniture, coolers, AC units and flower pots.
- Use Exit signage along the route. Orientation and direction signs should be installed frequently along the evacuation route and these should preferably be internally illuminated. The exit door signage should also be internally illuminated.

- A 'way guidance lighting system' consisting of low mounted LED strips to outline the exit route (with frequent illuminated direction indicators along the route) should be installed along the entire length of the evacuation route. Way guidance systems allow persons with vision impairments to walk significantly faster than traditional overhead emergency lighting. Moreover, emergency exit lights in green color and directional signals mounted near the floor have been found to be useful for all people in cases where a lot of smoke is present.

6.5.3.28 Way guidance system

- Luminance on the floor should be 1lux minimum provided on along the center line of the route and on stairs.
- Install clear illuminated sign above exit and directional signage along the route.
- The directional exit signs with arrows indicating the way to the escape route should be provided at a height of 500mm from the floor level on the wall and should be internally illuminated by electric light connected to corridor circuits.

6.5.3.29 Fire resistant doors

Fire resistant doors and doors used along the emergency evacuation route are generally heavy and the force required to open these is much higher than 25 Newtons, making it difficult for people with disability to negotiate these doors independently. There are, however, magnetic and other types of door holders available that can be connected to fire alarms so that they will hold the doors open normally but will release the doors when the fire alarm is activated.

6.5.3.30 Street design

- **Footpath (Sidewalk)**

Footpaths should be regarded as a transportation system which is connected and continuous, just like roadways and railways. They should not be sporadically placed where ever convenient, but instead should be provided consistently between all major attractions, trip generators, and other locations where people walk.

Footpath should have the following characteristics:

- Have height of a standard public step riser i.e. 150 mm maximum;
- Be at least 1800 mm wide.
- Have non-slip surface;
- Be along the entire length of the road;
- Have tactile guiding paver for persons with visual impairments.
- Preferably have well defined edges of paths and routes by use of different colors and textures
- Have no obstacles or projections along the pathway. If this is unavoidable, there should be clear headroom of at least 2200 mm from the floor level

- The minimum 1.8m (width) x 2.2m (Height) Walking Zone should be clear of all obstructions– both horizontally and vertically.
- Have kerb ramps where ever a person is expected to walk into or off the pathway.
- Have tactile warning paver installed next to all entry and exit points from the footpath.

Kerb Ramp

- Kerb should be dropped, to be flush with walk way, at a gradient no greater than 1:10 on both sides of necessary and convenient crossing points. Width should not be less than 1200mm. If width (X) is less than 1200mm, then slope of the flared side shall not exceed 1:12.
- Floor tactile paving- Guiding & Warning paver shall be provided to guide persons with vision impairment so that a person with vision impairment does not accidentally walk onto the road.
- Finishes shall have non-slip surface with a texture traversable by a wheel chair.

Road Intersections

- Pedestrian crossings should be equipped with traffic control signal.
- Traffic islands to reduce the length of the crossing are recommended for the safety of all road users.
- Warning pavers should be provided to indicate the position of pedestrian crossings for the benefit of people with visual impairments.
- Table tops (raised road level to the sidewalk height) are helpful in reducing the speed of traffic approaching the intersection.

Median/Pedestrian Refuge

Raised islands in crossings should:

- Cut through and level with the street; or Have kerb ramps on both the sides and have a level area of not less than 1500 mm long in the middle; and
- A colored tactile marking strip at least 600 mm wide should mark the beginning and end of a median/ pedestrian refuge to guide pedestrian with visual impairments to its location.

6.5.3.31 Traffic signals

- Pedestrian traffic lights should be provided with clearly audible signals for the benefit of pedestrians with visual impairments;
- Acoustic devices should be installed on a pole at the point of origin of crossing and not at the point of destination;
- The installation of two adjacent acoustic devices such as beepers is not recommended to avoid disorientation;

- The time interval allowed for crossing should be programmed according to the slowest crossing persons; and
- Acoustical signals encourage safer crossing behavior among children as well.

6.5.3.32 Subway and Foot Over Bridge

Subways and foot over bridges should be accessible for people with disabilities. This may be achieved by:

- Provision of signage at strategic location;
- Provision of slope ramps or lifts at both the ends to enable wheelchair accessibility;
- Ensuring that the walkway is at least 1500 mm wide;
- Provision of tactile guiding and warning paver along the length of the walkway;
- Keeping the walkway; free from any obstructions and projections; and
- Providing for seats for people with ambulatory disabilities at regular intervals along the walkway and at landings.

6.5.3.33 Alighting and boarding areas

All areas and services provided in the station that are open to the public should be accessible.

6.5.3.34 Approach

- Passenger walkways, including crossings to the bus stops, taxi stands, terminal / station building, etc. should be accessible to persons with disabilities.
- Uneven surfaces should be repaired and anything that encroaches on corridors or paths of travel should be removed to avoid creating new barriers. Any obstructions or areas requiring maintenance should be white cane detectable.
- Access path from plot entry and surface parking to terminal entrance shall have even surface without any steps.
- Slope, if any, shall not have gradient greater than 5%. The walkway should not have a gradient exceeding 1 :20. It also refers to cross slope.
- Texture change in walk ways adjacent to seating by means of tactile warning paver should be provided for persons with vision impairment.
- Avoid gratings in walks.

6.5.3.35 Car park

- **Signage**

- International symbol of accessibility (wheelchair sign) should be displayed at approaches and entrances to car parks to indicate the provision of accessible parking lot for persons with disabilities within the vicinity.
- Directional signs shall be displayed at points where there is a change of direction to direct persons with disabilities to the accessible parking lot.

- Where the location of the accessible parking lot is not obvious or is distant from the approach viewpoints, the directional signs shall be placed along the route leading to the accessible parking lot.
- Accessible parking lot should be identifiable by the International Symbol of Accessibility. The signs should not be obscured by a vehicle parked in the designated lot.
- Vertical signs shall be provided, to make it easily visible, the sign should be at a minimum height of 2100 mm.

Symbol

International Symbol of Accessibility should be clearly marked on the accessible parking lot for drivers/riders with disabilities only.

- A square with dimensions of at least 1000 mm but not exceeding 1500 mm in length;
- Be located at the center of the lot; and
- The color of the symbol should be white on a blue background.

Car Park Entrance

- The car park entrance should have a height clearance of at least 2400 mm. Location;
- Accessible parking lots that serve a building should be located nearest to an accessible entrance and / or lift lobby within 30 meters. In case the access is through lift, the parking shall be located within 30 meters.
- The accessible route of 1200 mm width is required for wheelchair users to pass behind vehicle that may be backing out.

Accessible Car Parking Lot

The accessible car parking lot should:

- Have minimum dimensions 5000 mm × 3600 mm
- Have a firm, level surface without aeration slabs
- Wherever possible, be sheltered and there are two accessible parking bays adjoining each other, then the 1200 mm side transfer bay may be shared by the two parking bays. The transfer zones, both on the side and the rear should have yellow and while cross-hatch road markings
- Two accessible parking lots shall be provided for every 50 no of car spaces.

Drop-off and pick-up areas

- Designated drop-off and pick-up spaces, to be clearly marked with international symbol of accessibility. Kerbs wherever provided, should have kerb ramps.

7. INTERMODAL INTEGRATION

The Multi-modal Integration Plan shall include requirements in respect of integrated transport and how the System must integrate into the existing transport modes in Pune Metropolitan Area, including non-motorized trips, viz. walking and cycling. All the physical elements necessary to ensure seamless connectivity between the metro and the broader transport network shall be accommodated.

While Pune Metro provides a high capacity transport system to carry the passengers, the need for integration with other transport modes is essential to ensure a seamless transfer. This concept is to provide first mile and last mile connectivity to the commuters within their places of residence/ business. At present the various modes of commute in Pune region comprise of State Transport buses, Mini buses, Auto Rickshaws, Private cars, Two Wheelers and Bi-Cycles.

The new Metro Rail Policy (2017) also highlights provision of infrastructure for integration of various modes of transport, last mile connectivity, seamless transfer between various modes through common payment instrument and universally accessible infrastructure.

A world-class public transport system, incorporating best practice interchange hubs, will also help to meet the social, economic and environmental needs of a thriving and growing city, including;

- Improve public transportation provision, mobility, reliability, connectivity and accessibility in Pune region;
- Easing congestion and tackling climate change by promoting more sustainable modes of transport;
- Encourages a mode shift from private to public transportation use;
- Meeting the increasing demand for travel by public transport;
- Attracts existing public transport users to the Metro system;
- Improving access to facilities and services in urban centres;
- Takes into consideration the needs of the various stakeholders and the environment, and is socially and environmentally sensitive and sustainable;
- Improving quality of life by improving air quality and by reducing noise and other environmental impacts;
- Providing links between neighborhoods and employment, education and other opportunities;
- Provides commercial opportunities that reap positive benefits for Maha Metro and Pune;
- Effectively and efficiently interfaced and integrated into the existing public transport services, community infrastructure, buildings and activity centres at an economical cost;
- Easily customizable, modifiable and upgradable for the whole of its life to accommodate and support future expansion, demand and growth for the Metro system at an economical cost;
- Improves the overall image of Pune.

Multi Modal Integration refers to transportation and land use planning that considers diverse transportation options, typically including walking, cycling, public transit and private transport modes, and accounts for land use factors that affect accessibility. Multi Modal transportation accounts for the integration of different capabilities of different modes, including their availability, speed, costs, limitations, and therefore their most appropriate uses. To be efficient and fair, a transportation system must serve diverse demands. For example, would be inefficient, if inadequate sidewalks force parents to chauffeur children to local destinations to which they would rather walk or bicycle, or if inadequate mobility options force urban commuters to drive although they would prefer to rideshare or use transit. Physically, economically and socially challenged people in particular need diverse mobility options; walking and cycling for local travel, public transit for longer trips, and automobiles (ridesharing, chauffeuring and taxi travel) when necessary. As a result, to be efficient and fair, transportation must be Multi Modal.

Before about 1980, walking and bicycling were recognized as important travel modes, but for most of the last century transport planning was automobile-oriented. As a result, most communities now have well developed road systems that allow motorists to drive to most destinations with relative convenience and safety; at worst they may be delayed by peak period congestion and pay tolls and parking fees at some destinations. From the past case experience, it is evident that integration plays a very vital role in emphasizing the commuters to shift from private mode of transportation to public transportation. The main tools of any public transportation system must be Multi Modal. As there is constant change in the requirement / advancement of infrastructure, other essential tools of integration are promoting active mobility (cycling and walking) users, providing safe and reliable infrastructure to reach primary mode of public transportation system, through feeder services, park & ride system, education and public outreach to commuters (marketing strategy), etc.

Transport Integration Plan shall enable maximum number of passengers with ease of accessibility which ensures, safe, quick, convenient and seamless connectivity among the various modes of transport. Making streets safe, clean and walkable reduce impact on the natural environment, making less harm and to retain the natural resources. Access modes to transit stations is presented in Figure 100.

Figure 100 : Access Modes to the Transit Station

Integration of modes should be planned in such a way that the people using various modes are integrated well by providing footpath for pedestrians, bicycle racks/parking for cyclists, bus bays for buses, taxi ranks and stands for Taxi and auto rickshaw, kiss & ride for Car users. Approach for safe access is presented in Figure 101.

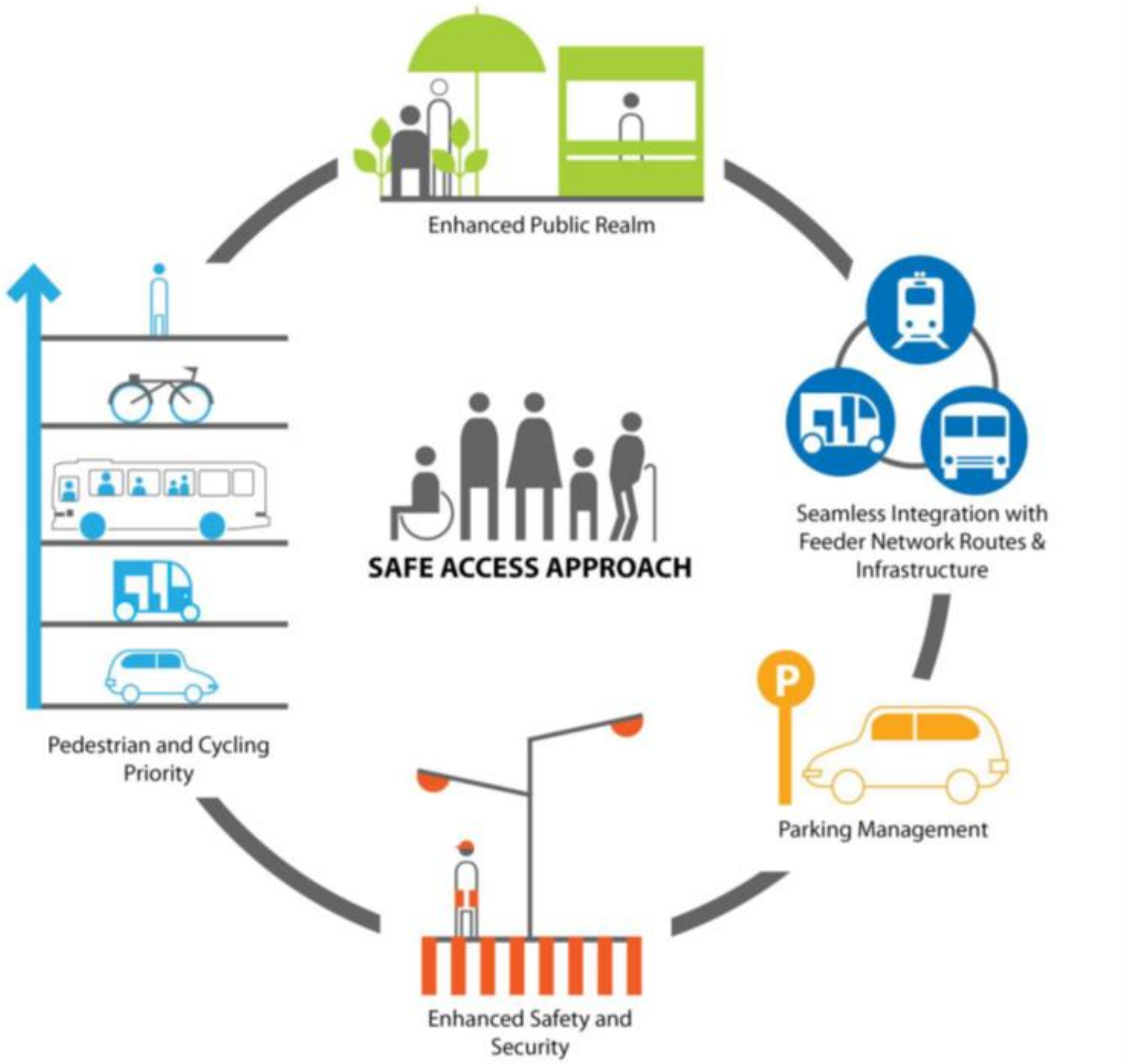


Figure 101 : Approach of Safe Access

7.1 Intermodal Integration with Existing Modes

Maha Metro a Special Purpose Vehicle (SPV), a 50:50 jointly owned company of Government of India and Government of Maharashtra for implementing Pune Mass Rapid Transit system for selected corridors. Figure 102 shows the proposed extension layout of North-South Corridor which consists of three stations with a total length of 4.413 km along the Old Mumbai Pune

Highway. The key feature along this corridor is Bhakti Shakti Bus Depot, which is very near to the proposed Metro Stations.

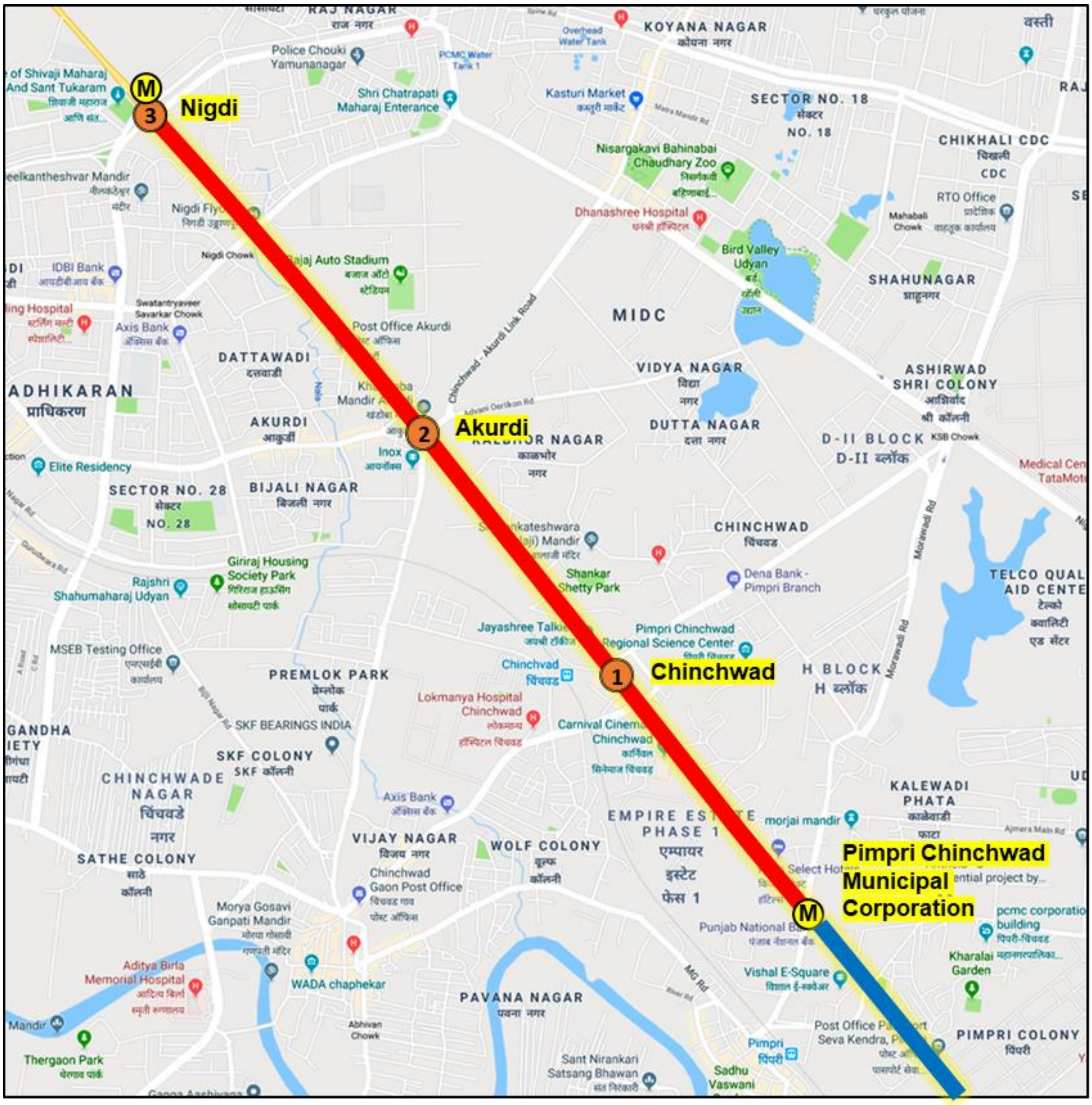


Figure 102 : Proposed Stations along PCMC-Nigdi

Table 76: Connectivity with Other Public Transport Systems

Station Name	Connectivity with City Bus System and Other Features in the Year 2053
Station 3/Nigdi	• Nigdi/ Station 3 is the terminal point of PCMC-Swargate north extension. It is proposed to be elevated above Bhakti Shakti bus depot. • At Nigdi Metro station, the estimated number of boarding and alighting passengers during peak hour are 1270 and 1540 respectively in the year 2053. • This station is surrounded by public area (Bhakti Shakti bus depot, Police Station, Banks, Post Office, Temples), residential buildings, commercial area (Hotels, Jio digital stores, etc.). • Roads near Metro station are Old Mumbai Pune Road, Bhakti Shakti Chikhli road and Roopi Nagar Road. • The transport integration plan for Nigdi Metro station would facilitate a seamless connectivity for passengers by providing proper facilities like, footpath, bus stop, parking, pick up /drop off area. As Nigdi station is proposed above the Bhakti Shakti bus depot. Staircase, ramps & escalators are proposed for seamless transfer of passengers.
Station 2/Akurdi	• Akurdi is proposed as an elevated metro station along Corridor 1A near Khandoba Chowk. • The surrounding land use around the station are commercial (Acro Roadways Private Limited, Star Bazaar, etc.), public (National institute of Aeronautical Engineering, bank etc.), and residential (Subhashree Residential Phase 2, etc.). • At Akurdi Metro station, the estimated number of boarding and alighting passengers during peak hour are 1470 and 2090 respectively in the year 2053. • Akurdi station is proposed above Khandoba chowk intersection, which has 5 arms. Roads near station are Chikhali Akurdi Road, Advani Oerlikon Road, Old Mumbai Pune Highway, Shri Mhalsakant Vidyalaya Road, Chinchwad Gaon Road. • The proposed transport integration plan of Akurdi Metro Station facilitates smooth and safe interchange of passengers by providing proper facilities

Station Name	Connectivity with City Bus System and Other Features in the Year 2053
	like pedestrian pathway, cycle track, bus stop, parking, pick up & drop off area, etc. Akurdi Chowk bus stop shall also be integrated for smooth interchange of passengers.
Station 1/Chinchwad	• Chinchwad is proposed as elevated metro station, between Chinchwad Station Chowk and Chinchwad Chowk. • The surrounding area has mixed use developments. Roads near Chinchwad metro station are Chinchwad-Bhosari Road, Chinchwad Station Road, Old Mumbai Pune Highway. • Chinchwad Metro Station Integration plan facilities smooth access of passengers by providing facilities like pedestrian pathway, bus stops, parking, pick up and drop off zone, etc. • At Chinchwad Metro station, the estimated number of boarding and alighting passengers during peak hour are 1500 and 2160 respectively in the year 2053.

7.2 Feeder Service

Feeder services are the most vital secondary public transportation systems as it enables the users with last mile connectivity and contributes to build a stronger patronage for MRT. Usually, the coverage of feeder service is about 2 to 4 Kms in radius.

Fleet requirement is based on the passenger demand who are likely to use the proposed feeder service after metro line is operational. The assessment is made considering existing bus routes shall continue. Feeder service has been planned for the areas which are not served by any public transit system to provide first & last mile connectivity.

Route planning is done targeting passengers in radial distance of 2-4 km from metro station and complementing the other public transit and Bicycle Schemes. The number of feeder buses required has been estimated for peak hours of various horizon years 2023, 2033, 2043 & 2053. The feeder buses requirement for respective years is presented in Table 77.

In Delhi, DMRC has deployed feeder buses with a sitting capacity of 18 passengers and total capacity of 30 passengers. However, feeder bus service facility has long way to go as the bus conditions are not so good to travel. Since it is handled by the private operators who normally waits to fetch more passengers, the headway become long and passengers must wait for longer time. Because of this, passengers must shift to other modes of transport (i.e. Auto/Taxi) to access the metro station. These things should be kept in mind while implementing feeder services at any metro station.

The pictures of proposed feeder routes from proposed metro stations are presented below.

Route 1 (Nigdi Metro Station)

Route 2 (Nigdi Metro Station)

Route 1 (Akurdi Metro Station)

Route1 (Chinchwad Metro Station)

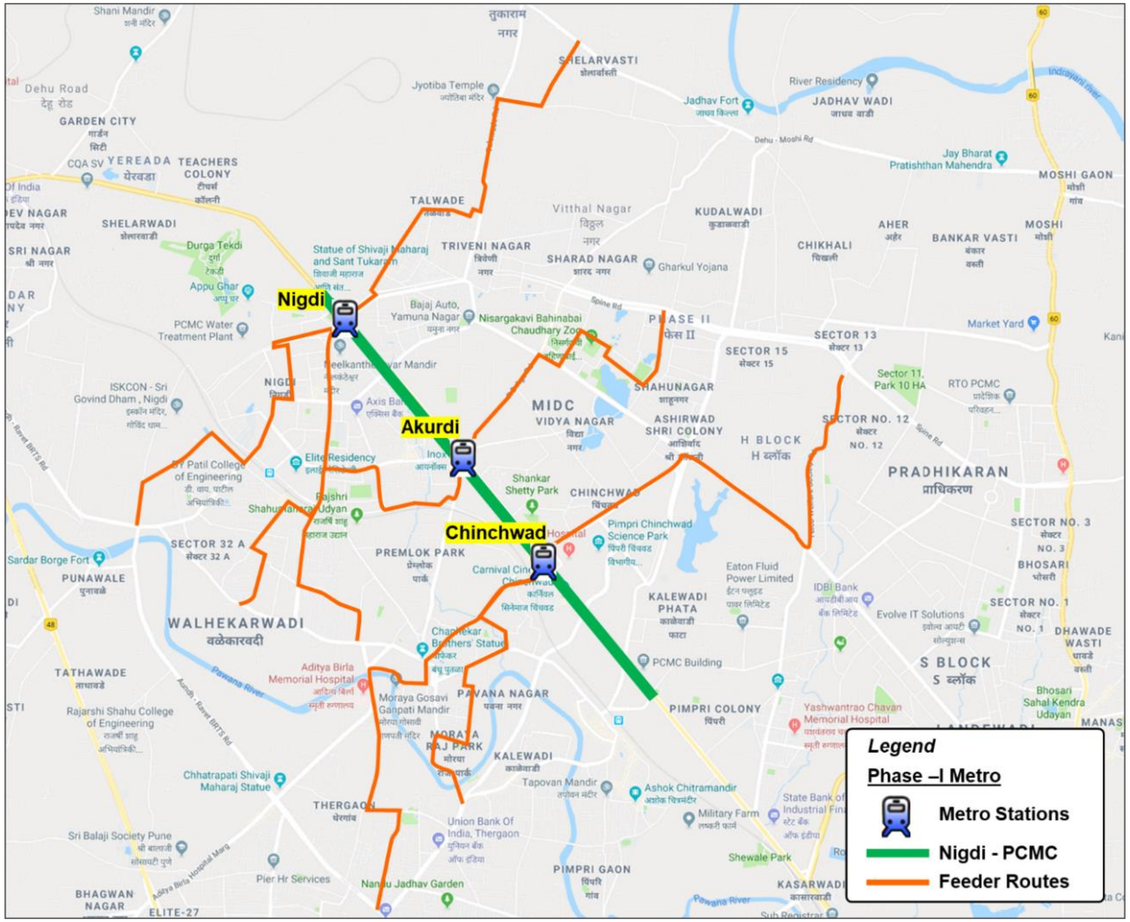


Figure 103 : Proposed Feeder Bus Routes from Metro Stations

Table 77: Feeder Bus System for Metro Corridor

<table>
<tr><th rowspan="2">SN</th><th rowspan="2">Metro Station</th><th rowspan="2">Route No</th><th rowspan="2">Feeder Bus Route Name</th><th rowspan="2">Length (Km)</th><th colspan="4">Required No. of Buses in Peak Hour</th></tr>
<tr><th>2023</th><th>2033</th><th>2043</th><th>2053</th></tr>
<tr><td rowspan="4">1</td><td rowspan="4">Nigdi</td><td>R1</td><td>Nigdi to Sector 29 via Sector 26 & Sector 25</td><td>4.68</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>R2</td><td>Nigdi to Shelarvasti via Sector 22, Ganesh Nagar & Kadolkar Colony</td><td>4.89</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>R3</td><td>Nigdi to Sambhaji Chowk</td><td>1.76</td><td>1</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td colspan="2">Total Buses</td><td>-</td><td>5</td><td>8</td><td>10</td><td>13</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Akurdi</td><td>R1</td><td>Akurdi to Chinchwade Nagar via Rail Vihar, Sector 28 & Jija Nagar</td><td>4.89</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>R2</td><td>Akurdi to Shivtej Nagar via Sambhaji Nagar, G Block and Vidya Vihar</td><td>4.11</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>R3</td><td>Akurdi to Laxmi Nagar via Sector 30, Rail Vihar and Sector 28</td><td>4.81</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="2">Total Buses</td><td>-</td><td>5</td><td>8</td><td>11</td><td>14</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">Chinchwad</td><td>R1</td><td>Chinchwad to Shriram Colony via Moraya Raj Park, Rajmata Jijau Colony, Wolf Colony, Bhoir Colony & Dhoka Colony</td><td>4.39</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>R2</td><td>Chinchwad to Kalewadi Phata via Keelas Nagar, Sainath Nagar & Gandhi Peth</td><td>6.1</td><td>2</td><td>3</td><td>4</td><td>6</td></tr>
<tr><td>R3</td><td>Chinchwad to Sector 13 via Mohan Nagar, Yashawant Nagar & Himatnagar</td><td>5.87</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="2">Total Buses</td><td>-</td><td>5</td><td>8</td><td>11</td><td>15</td></tr>
<tr><td colspan="5">Year Wise Total Buses Required</td><td>15</td><td>24</td><td>32</td><td>42</td></tr>
</table>

7.3 Physical infrastructure requirement for integration with other modes

Physical Integration integrates public transport modes with provision of jointly used facilities at intermediate points or at terminals with interchange facilities.

7.3.1 Integration with Active Mobility Users

To enhance accessibility to Metro stations, passengers are encouraged to commute to stations by walk / bicycles. This action will not only be beneficial for managing authorities, but also promotes the healthy living of citizens. Hence, the planners must create the urban living into eco-friendly zone with basic amenities.

Vulnerable user groups like differently abled, the elderly and their accessibility measures must be taken care meticulously. Some of the facilities include longer crossing time for senior citizens (Pelican signal upgradation), pedestrian sidewalks of about 1.8 m - 3 m width, bicycle lanes of 1 m - 1.2 m, walking shelters to protect commuters from rain and heat, etc. Tactile paving, elevators and ramps need to be provided within the MRT stations. Ramps with gentle slope shall be designed for pedestrians and wheelchair users. Cycle parking shall be planned at all the stations to safely park the private cycles (Docked /Turnstile). Junctions and intersections should be proposed with proper pedestrian crossings. Proper road markings, Traffic Signages, Zebra Crossings and Pedestrian Signals shall be proposed to provide safe and uninterrupted pedestrian movement.

7.3.2 Park-and-ride Facilities

A limited number of parking slots should be provided in selected stations to discourage the usage of private modes of transportation. This action encourages car commuters to use public transport automatically with a great comfort and satisfaction due to high congestion of roads during peak hours. Transport planners strive to attract huge number of users towards MRT by different modes such as walking, cycling or feeder services only.

7.3.3 Access to Stations with IPT

Auto Rickshaws contribute a significant modal share in Indian Cities. Since, autorickshaws play a very vital role, it is very important to provide well designed pick up and drop off zones near to the metro stations. The design of site-specific pick up and drop off points seem to be a most wanted feature as per current scenario in the city of Pune.

7.4 Institutional integration

Institutional integration is used to create an organizational framework for joint planning and operation of transit services. For smooth operation of metro, different groups of association (e.g.

tariff associations, transit communities, transit federations etc.) merge/integrate with each other to provide seamless public transport infrastructure.

7.5 Physical integration

Physical (or spatial) integration describes efforts to co-locate the various parts of a transport system. This generally occurs at stations, but also happens elsewhere in the network. Examples include taxi stands outside metro stations, walkways connecting stations directly to adjacent buildings, stations serving various bus and train lines, and bikeways along Metro routes, among others.

The first priorities for physical integration within a Metro network, essentially pre-requisite of good system design, is with the pedestrian and cycling environment surrounding the station, terminal or Multi Modal facility and with the different lines and services of the metro system itself by creating an easy transfer within.

Metro can be integrated with short and long-distance public transport infrastructure e.g., Bus/ BRT/ Train Stations, and, in some cases, airports. Again, physical planning is key to making this option viable. Travellers from such modes often are carrying luggage or goods and need a convenient transfer mechanism.

Please refer **Exhibit 1,** at the end of the chapter for Physical Integration Plans for Scenario 1A.

7.6 Fare integration

The absence of an integrated public transportation system causes problems and inconvenience for commuters and authorities in terms of compromising the necessities such as Comfort, Transparency, Travel time and Costs. It improves the experience of seamless mobility. Rechargeable Smart Card is the efficient fare collection system in most of the public transportation systems around the World. Integrated fare system enables the users to transit between two different modes of transport / interchange in same mode at lower cost and high comfort. Handling cash can be lessened which in turn reduces the theft complaint in Public Transportation Systems. To avoid large queue in the counters, the fare collection systems could be outsourced to a third-party operator within a radius of 1 Km to 2 Km from all the metro stations.

7.7 Operational integration

The operational integration is an application of management techniques to optimize allocation of transit resources and coordinate services. The techniques of the operational integration are enlisted below:

- Rationalization of redundant services

- Matching modes to service requirements
- Development & Scheduling of feeder route services
- Unification of fare structure
- Fare discounts
- Coordinated public information system
- Reserved bus lanes and streets
- Parking controls

7.8 Technology integration

Technology plays a very crucial role in the public transport. Technology integration deals with the information on routes, schedules, fares and transfer points for all transit modes and services throughout the urban limits which is provided by concerned authorities. Providing integrated and real time information during the journey and before the journey, with the help of intelligent transport system (ITS), helps to attracts commuters. Smartphone apps can be used to obtain the information with few clicks.

7.9 Public Bicycle Sharing Scheme

Cycle sharing provides an ideal transport solution for short trips and a feeder to other public transport options. Cycle sharing can help reduce pollution, reduce traffic noise, improve safety on the roads. For users, it is a healthy mode of transport, often quicker than other modes for short distances, without the need to maintain the cycle or worrying about where to park.
Some of the private players like Ofo, Pedal Saddle have come forward to promote and make the commuters utilize bicycle sharing scheme. These schemes will be predominantly used by commuters around 1 km to 2 km around metro stations. Also, Government has been constantly encouraging the commuters to use free and shared bicycles for a short rental period. The main motto of encouraging is for the convenience of passengers as well as for increasing the ridership of metro.
The requirement of bicycles along the PCMC-Nigdi corridor is estimated and is presented in Table 78**.** The requirement of bicycles may increase as it wholly depends on how the authorities make the policy and implement bicycle sharing scheme throughout the city.

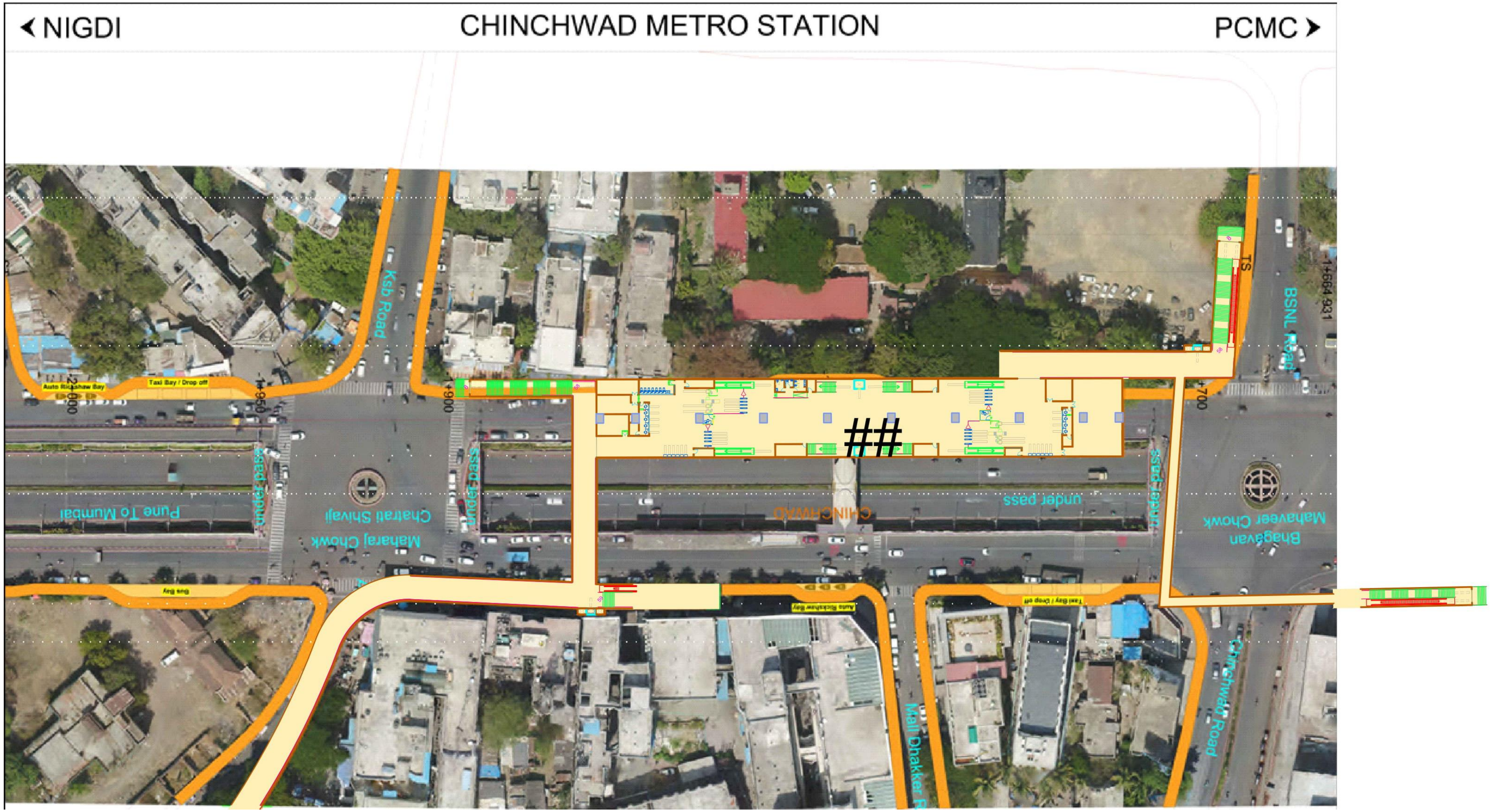
Table 78: Bicycle Sharing Scheme (PCMC-Nigdi Corridor)

SN	Metro Station	No. of Cycles required in Peak Hour			
		2023	2033	2043	2053
1	Nigdi	23	32	35	38
2	Akurdi	29	39	41	44
3	Chinchwad	25	36	41	45
Year Wise Total Bicycles Required		77	107	117	127

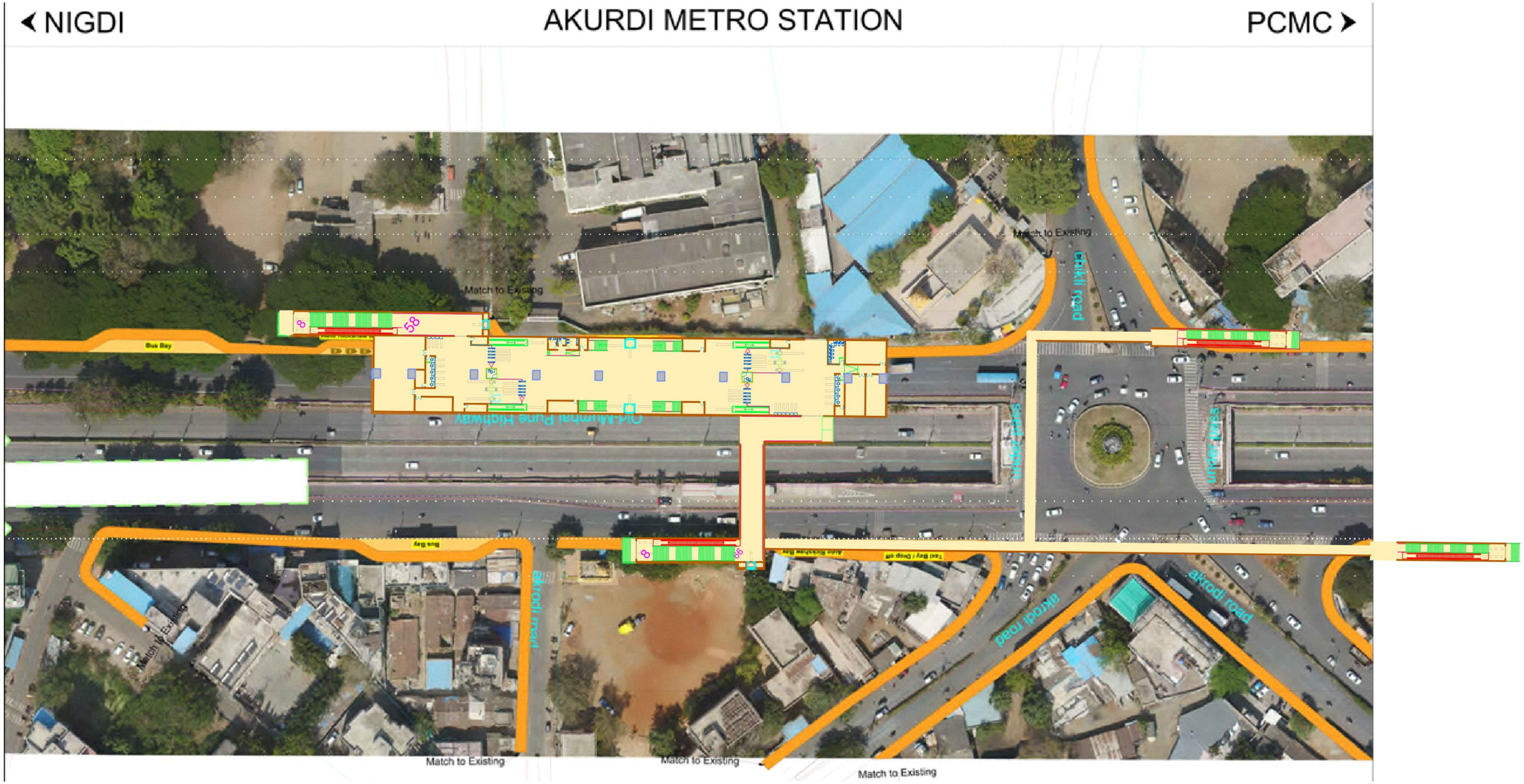
Annexure 1

Station wise **Schematic Physical Integration Plans** as mentioned below are presented in the next pages.

1) Chinchwad Station
2) Akurdi Station
3) Nigdi Station

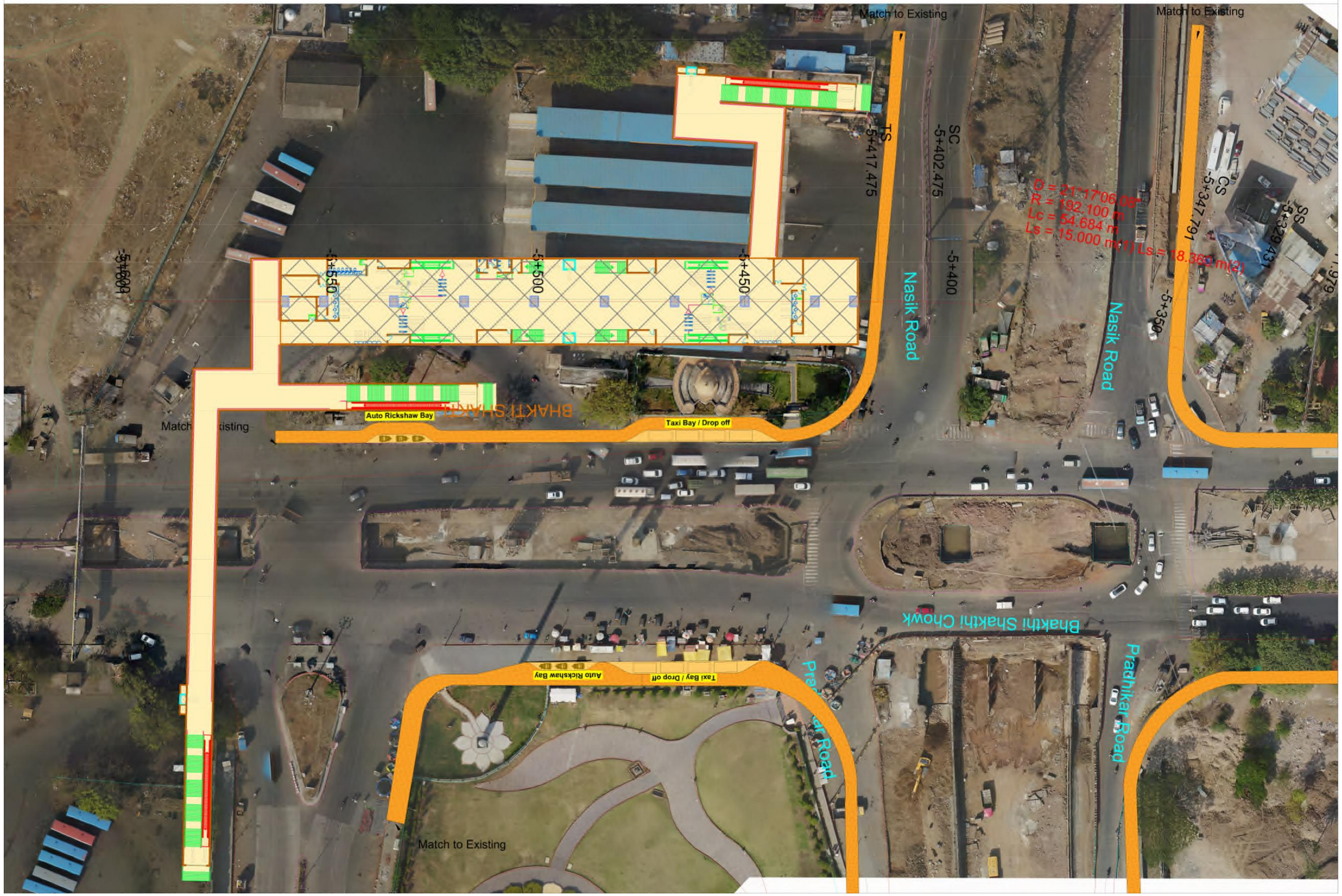

NIGDI
CHINCHWAD METRO STATION
PCMC
Ksb Road
BSNL Road
Pune To Mumbai
Chatrapati Shivaji
Maharaj Chowk
Mahaveer Chowk
Bhagavan
under pass
CHINCHWAD
Mall Dhakkar Road
Chinchwad Road
Taxi Bay / Drop off
Auto Rickshaw Bay
Bus Bay
2+000
1+950
1+900
1+700
1+664.931
TS

AKURDI METRO STATION



NIGDI METRO STATION

PCMC



8. TRAIN OPERATION PLAN

8.1 System Operation Approach

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

- Selecting the most optimum frequency of train services to meet sectional capacity requirement during peak hours on most of the sections;
- Economical & optimum train service frequency not only during peak period, but also during off-peak period;
- Short trains consist of 3 coaches with high frequency service, which can be increased to 6 coaches to meet future requirements;
- Multi-tasking of train operation and maintenance staff;
- Introduction of short loops to cater to increased passenger load during peak hours with minimum number of trains.

8.1.1 Stations

PCMC-Nigdi extension of Line-1 of Phase 1 i.e. corridor 1A (PCMC - Swargate) inlcudes 3 stations listed in table hereunder.

Table 79: Stations on line 1, including corridors 1 extension (PCMC to Nigdi)

Phase	S.No	Name of stations	Chainage (in m)	Inter-station distance (in m)	Remarks
Phase-II (1A)	1	Station03(Nigdi)	-5601.089	-	Elevated
	2	Station02 (Akurdi)	-3459.2	1670	Elevated
	3	Station01 (Chinchwad)	-1789.2	1449	Elevated
Phase-I	4	PCMC	-340	1430	Elevated
	5	ST Tukaram Nagar	1763	2103	Elevated
	6	Bhosari	2500	737	Elevated
	7	Kasarwadi	3818	1318	Elevated
	8	Fugewadi	4846	1028	Elevated
	9	Dapodi	5712	866	Elevated
	10	Bopodi	7334	1622	Elevated
	11	Khadki Station	8205	871	Elevated
	12	Range Hill	9680	1475	Elevated
	13	Shivaji Nagar	11729	2049	Underground
	14	Civil Court	12849	1120	Underground
	15	Budhwar Peth	14138	1289	Underground

	16	Mandai	15002	864	Underground
	17	Swargate	16538	1536	Underground
Total distance (m)				**22028**	

8.2 Station Yard Planning

Provision of front and rear crossovers at terminal station (at Nigdi) are advised for better operational performance and flexibility. In case rear cross-overs cannot be accommodated due to certain unavoidable circumstances, front crossovers shall be provided to make operation from both platforms feasible. The crossovers shall be provided as near to the terminal station as possible to achieve better headways when required.

Provision of train stabling facility is recommended on mainline:

- for future stabling requirements to minimize empty running of train and
- to stable train got faulty during service.

Recommended locations from operations perspective are minimum one near PCMC and one near Swargate.

8.3 Train Operation

8.3.1 Salient Features

- Running of services for 19 hours of the day (05:00Hrs to 24:00Hrs) with a maximum station dwell time of 40 seconds, which may be further optimized as per ridership trend when section is opened.
- Make up time of 5-10% with 8-12% coasting;
- Schedule speed has been taken as 33 km/hr.

8.3.2 Traffic demand

Peak hour peak direction traffic demands (PHPDT) for the Pune Metro Corridor-1A for the horizon years for the purpose of planning the network capacities are sumarised hereunder. Station Boarding/ Alighting figures and Sectional PHPDT is detailed in subsequent tables in this section. ***Summary of Ridership and PHPDT figures for horizon years :***

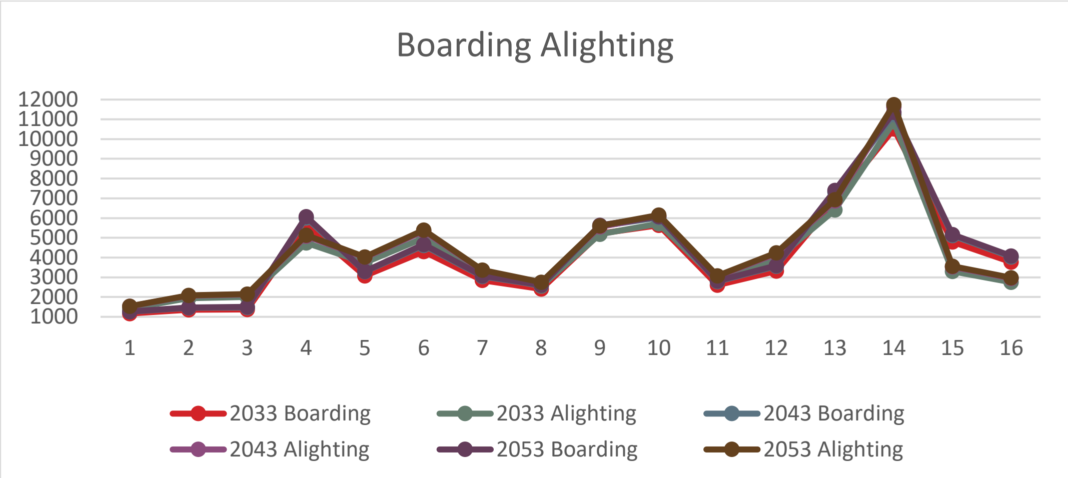
Table 80 : summary of ridership and PHPDT for Corridor 1A

	PUNE METRO DPR - PHASE-II CORRIDOR - 1A				
Scenario 1A	**Ridership**	**2023**	**2033**	**2043**	**2053**
Nigdi-Swargate	**Peak Hour**	47500	65000	77000	83200
	Daily	495000	677000	802000	866500
	PHPDT	14450	19480	23690	25600

Sectional Boarding and Alighting figures for horizon years is detailed in table hereunder.

Table 81 : Boarding- Alighting figures for – Nigdi-Swargate Corridor

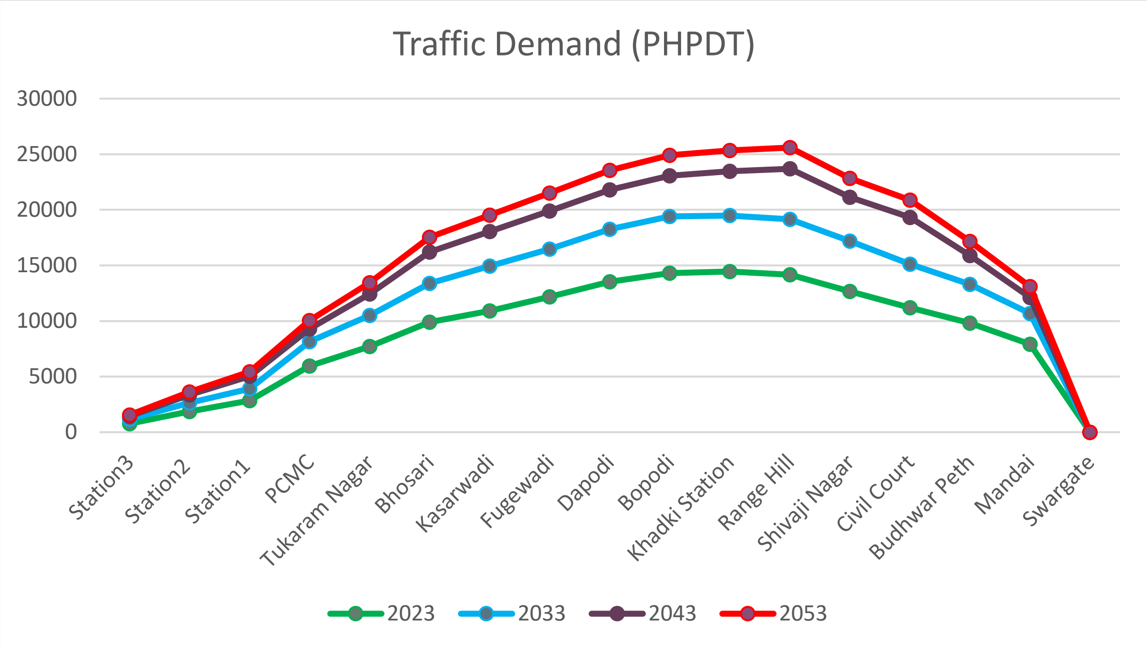
Nigdi-Swargate		Peak Hour Boarding/ Alighting							
SI No	Station	2023		2033		2043		2053	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
1	Nigdi	780	780	1170	1430	1260	1530	1270	1540
2	Akurdi	950	1070	1360	1940	1460	2070	1470	2090
3	Chinchwad	820	1070	1380	2000	1480	2140	1500	2160
4	PCMC	3820	2700	5620	4740	6010	5080	6070	5130
5	Tukaram Nagar	2100	2050	3070	3740	3280	4000	3310	4040
6	Bhosari	2970	2800	4310	4990	4620	5340	4660	5390
7	Kasarwadi	1770	1800	2850	3120	3050	3340	3080	3370
8	Fugewadi	1690	1430	2420	2560	2590	2740	2610	2760
9	Dapodi	3430	3120	5220	5190	5590	5550	5640	5610
10	Bopodi	3550	3450	5630	5710	6020	6110	6080	6160
11	Khadki Station	1660	1740	2610	2850	2790	3050	2820	3080
12	Range Hill	2010	2430	3320	3920	3560	4200	3590	4240
13	Shivaji Nagar	4030	4150	6850	6420	7330	6870	7410	6940
14	Civil Court	6320	6860	10510	10870	11250	11630	11360	11750
15	Budhwar Peth	2810	2180	4790	3300	5120	3530	5170	3560
16	Mandai	2010	1900	3770	2760	4040	2950	4080	2980
17	Swargate	6740	7910	12110	11480	12960	12290	13090	12410
Total Ridership		47460	47440	76990	77020	82410	82420	83210	83210



Sectional Traffic Demand for horizon years is given the table hereunder:

Table 82 : Sectional Traffic Demand for horizon years

Traffic Demand in PHPDT					
Section		Year			
From	To	2023	2033	2043	2053
Nigdi	Akurdi	780	1180	1430	1540
Akurdi	chinchwad	1850	2650	3360	3630
chinchwad	PCMC	2830	3920	5030	5440
PCMC	Tukaram Nagar	5960	8150	9290	10040
Tukaram Nagar	Bhosari	7720	10510	12440	13440
Bhosari	Kasarwadi	9900	13400	16220	17530
Kasarwadi	Fugewadi	10910	14950	18060	19510
Fugewadi	Dapodi	12170	16480	19900	21500
Dapodi	Bopodi	13530	18260	21800	23550
Bopodi	Khadki Station	14320	19410	23060	24910
Khadki Station	Range Hill	14450	19480	23460	25350
Range Hill	Shivaji Nagar	14150	19140	23690	25600
Shivaji Nagar	Civil Court	12670	17200	21130	22830
Civil Court	Budhwar Peth	11190	15120	19330	20880
Budhwar Peth	Mandai	9820	13310	15890	17160
Mandai	Swargate	7920	10690	12110	13090
Maximum PHPDT		14450	19500	23700	25600



8.3.3 Train Formation

To meet the projected traffic demand, the possibility of running trains with different headways has been examined.

Accordingly, for Corridor-1A, 3-car trains are proposed for the year 2023, 2033, 2043 and 2053.

<u>Composition</u>

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

3 Car Train Composition	DMC + TC + DMC
6 Car Train Composition	DMC + TC + MC + MC + TC + DMC

<u>Capacity</u>

3 Car Train:	6p/sqm standee- 764 Passengers;
	8p/sqm standee- 975 Passengers
6 Car Train:	6p/sqm standee- 1574 Passengers;
	8p/sqm standee- 2004 Passengers

8.3.4 Train Operation Plan of line 1 (from Nigdi to Swargate)

Based on the projected PHPDT demand, Train operation for Pune Metro Corridor-1 is planned with train carrying capacity calculated @6 persons per square meter of standee area in train and is detailed in following sections for years 2025, 2033, 2043 and 2053.

- **Year 2023**

Corridor-1 (Nigdi to Swargate) has peak traffic with PHPDT of **14450** in section Khadki Station-Range Hill. To cater the traffic, Train operation with **3-car trains** with headway of 3.**7** min in section PCMC-Swargate is planned with Peak Hour Peak Direction Capacity of **1222** @6 persons per square meter of standee area (Capacity of **15600** @8 persons per square meter of standee area under crush loading conditions)**.**

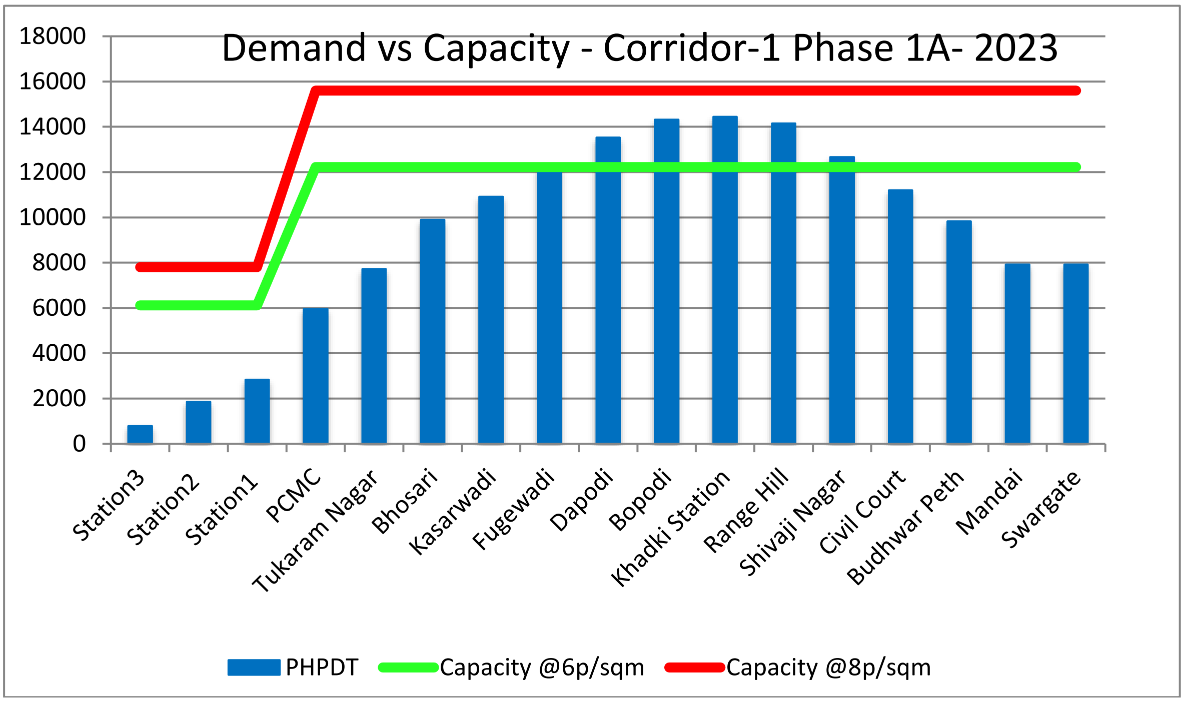
As PHPDT in section PCMC to Nigdi is very low (PHPDT of 2830), peak headway of only **7.5** min is considered sufficient in this section. Accordingly, every alternate train is planned to be short looped from PCMC towards Swargate, at least during peak hours. This has minimized Rolling Stock and Train Operator requirement.

The planned capacity of **12224** (**15600** under crush loading) is less than the PHPDT demand in six sections out of sixteen sections. With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2025 is tabulated and represented on a chart enclosed hereunder.

Table 83 : Demand (PHPDT) and Capacity Chart - Corridor-1 (Nigdi- Swargate), 2023

Demand (PHPDT) and Capacity Chart - Corridor-1 (Nigdi- Swargate)				
Year				2023
Headway (Sec)				225
No. of Cars per train				3
Passenger Capacity @6 persons/ sqm of train				764
Passenger Capacity @8 persons/ sqm of train				975
S No.	Section	PHPDT	Capacity @6p/sqm	Capacity @8p/sqm
1	Station03(Nigdi)	780	6112	7800
2	Station02 (Akurdi)	1850	6112	7800
3	Station01 (Chinchwad)	2830	6112	7800
4	PCMC	5960	12224	15600
5	Tukaram Nagar	7720	12224	15600

6	Bhosari	9900	12224	15600
7	Kasarwadi	10910	12224	15600
8	Fugewadi	12170	12224	15600
9	Dapodi	13530	12224	15600
10	Bopodi	14320	12224	15600
11	Khadki Station	14450	12224	15600
12	Range Hill	14150	12224	15600
13	Shivaji Nagar	12670	12224	15600
14	Civil Court	11190	12224	15600
15	Budhwar Peth	9820	12224	15600
16	Mandai	7920	12224	15600
17	Swargate	7920	12224	15600



- **Year 2033**

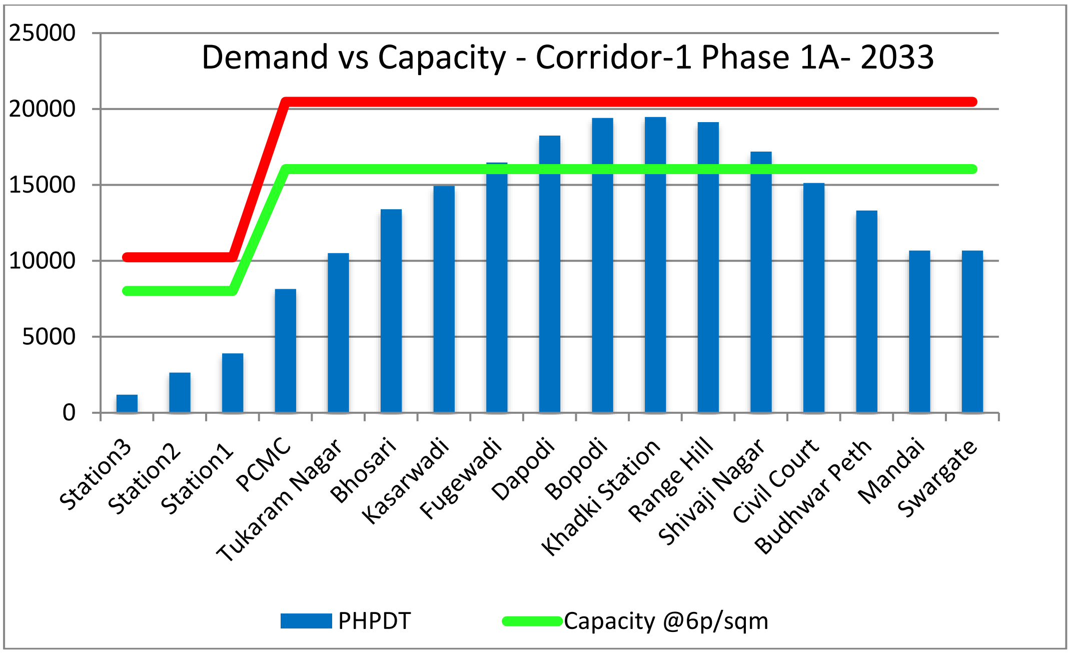
Corridor-1 (Nigdi to Swargate) has peak traffic with PHPDT of **19480** in section Khadki Station-Range Hill. To cater the traffic, Train operation with 3-car trains with headway of 2.9 min is planned in section PCMC-Swargate with Peak Hour Peak Direction Capacity of **16044** @6 persons per square meter of standee area (Capacity of **20475** @8 persons per square meter of standee area under crush loading conditions).

As PHPDT in section PCMC to Nigdi is very low (PHPDT of **3920**), peak headway of only 5.7 min is considered sufficient in this section. Accordingly, every alternate train is planned to be short looped from PCMC towards Swargate, at least during peak hours. This has minimized Rolling Stock and Train Operator requirement.

The planned capacity of **16044** (**20475** under crush loading) is less than the PHPDT demand in six sections out of sixteen sections. With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2033 is tabulated and represented on a chart enclosed hereunder.

Table 84 : Demand (PHPDT) and Capacity Chart - Corridor-1 Phase 1A (Nigdi- Swargate), 2033

Demand (PHPDT) and Capacity Chart - Corridor-1 Phase 1A (Nigdi- Swargate)				
Year				**2033**
Headway (Sec)				171
No. of Cars per train				3
Passenger Capacity @6 persons/ sqm of train				764
Passenger Capacity @8 persons/ sqm of train				975
S No.	Section	PHPDT	Capacity @6p/sqm	Capacity @8p/sqm
1	Station03(Nigdi)	1180	8022	10238
2	Station02 (Akurdi)	2650	8022	10238
3	Station01 (Chinchwad)	3920	8022	10238
4	PCMC	8150	16044	20475
5	Tukaram Nagar	10510	16044	20475
6	Bhosari	13400	16044	20475
7	Kasarwadi	14950	16044	20475
8	Fugewadi	16480	16044	20475
9	Dapodi	18260	16044	20475
10	Bopodi	19410	16044	20475
11	Khadki Station	19480	16044	20475
12	Range Hill	19140	16044	20475
13	Shivaji Nagar	17200	16044	20475
14	Civil Court	15120	16044	20475
15	Budhwar Peth	13310	16044	20475
16	Mandai	10690	16044	20475
17	Swargate	10690	16044	20475



In case of an mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by either varying the rake composition or adjusting the headway. E.g. in case of higher demand, headway may be reduced easily by injecting more trains out of reserve trains.

- **Year 2043**

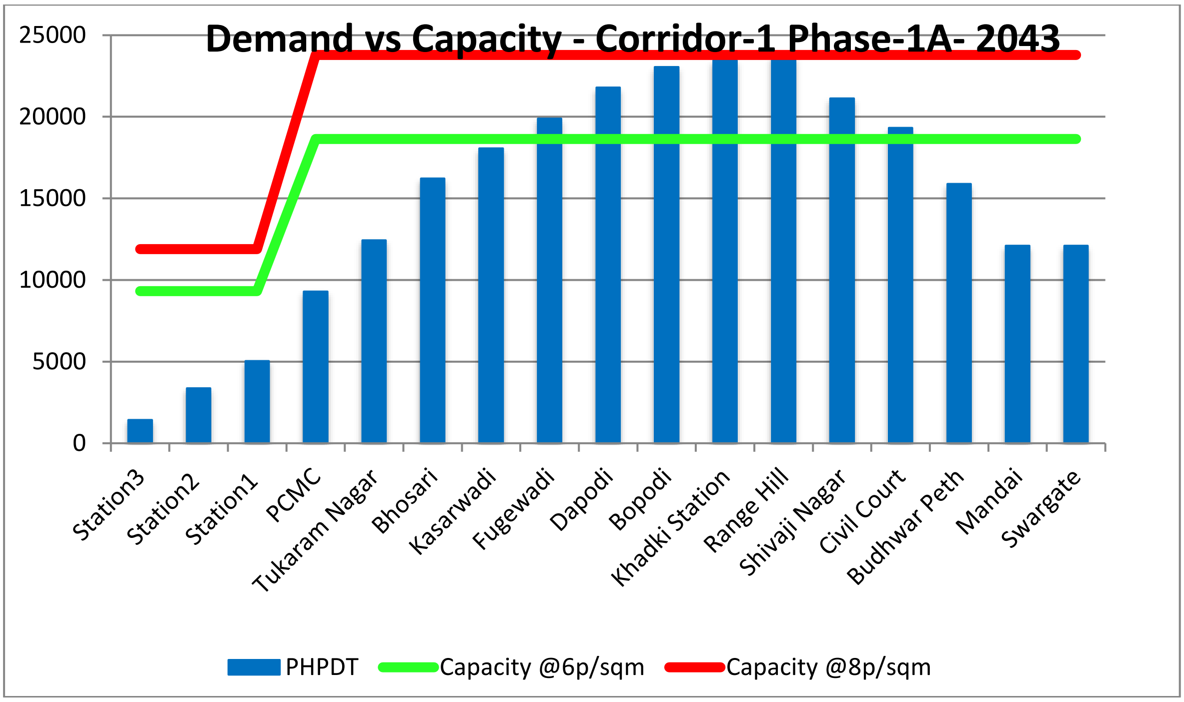
Corridor-1 (Nigdi to Swargate) has peak traffic with PHPDT of **23690** in section Range Hill- Shivaji Nagar. To cater the traffic, Train operation with 3-car trains with headway of **2.5** min is planned in section PCMC-Swargate with Peak Hour Peak Direction Capacity of **18642** @6 persons per square meter of standee area (Capacity of **23790** @8 persons per square meter of standee area under crush loading conditions).

As PHPDT in section PCMC to Nigdi is very low (PHPDT of **5030**), peak headway of only **5** min is considered sufficient in this section. Accordingly, every alternate train is planned to be short looped from PCMC towards Swargate, at least during peak hours. This has minimized Rolling Stock and Train Operator requirement.

The planned capacity of **18642** (**23790** under crush loading) is less than the PHPDT demand in seven sections out of sixteen sections. With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. In the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2043 is tabulated and represented on a chart hereunder.

Table 85 : Demand (PHPDT) and Capacity Chart - Corridor-1 (Nigdi- Swargate), 2043

Demand (PHPDT) and Capacity Chart - Corridor-1 (Nigdi- Swargate)				
Year				**2043**
Headway (Sec)				148
No. of Cars per train				3
Passenger Capacity @6 persons/ sqm of train				764
Passenger Capacity @8 persons/ sqm of train				975
S No.	Section	PHPDT	Capacity @6p/sqm	Capacity @8p/sqm
1	Station03(Nigdi)	1430	9321	11895
2	Station02 (Akurdi)	3360	9321	11895
3	Station01 (Chinchwad)	5030	9321	11895
4	PCMC	9290	18642	23790
5	Tukaram Nagar	12440	18642	23790
6	Bhosari	16220	18642	23790
7	Kasarwadi	18060	18642	23790
8	Fugewadi	19900	18642	23790
9	Dapodi	21800	18642	23790
10	Bopodi	23060	18642	23790
11	Khadki Station	23460	18642	23790
12	Range Hill	23690	18642	23790
13	Shivaji Nagar	21130	18642	23790
14	Civil Court	19330	18642	23790
15	Budhwar Peth	15890	18642	23790
16	Mandai	12110	18642	23790



In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by either varying the rake composition or adjusting the headway. E.g. in case of higher demand, headway may be reduced easily by injecting more trains out of reserve trains.

- **Year 2053**

Corridor-1 (Nigdi to Swargate) has peak traffic with PHPDT of 25600 in section Range Hill- Shivaji Nagar. To cater the traffic, Train operation with 3-car trains with headway of 2.5 min is planned in section PCMC-Swargate with Peak Hour Peak Direction Capacity of 20262 @6 persons per square meter of standee area (Capacity of 25350 @8 persons per square meter of standee area under crush loading conditions).

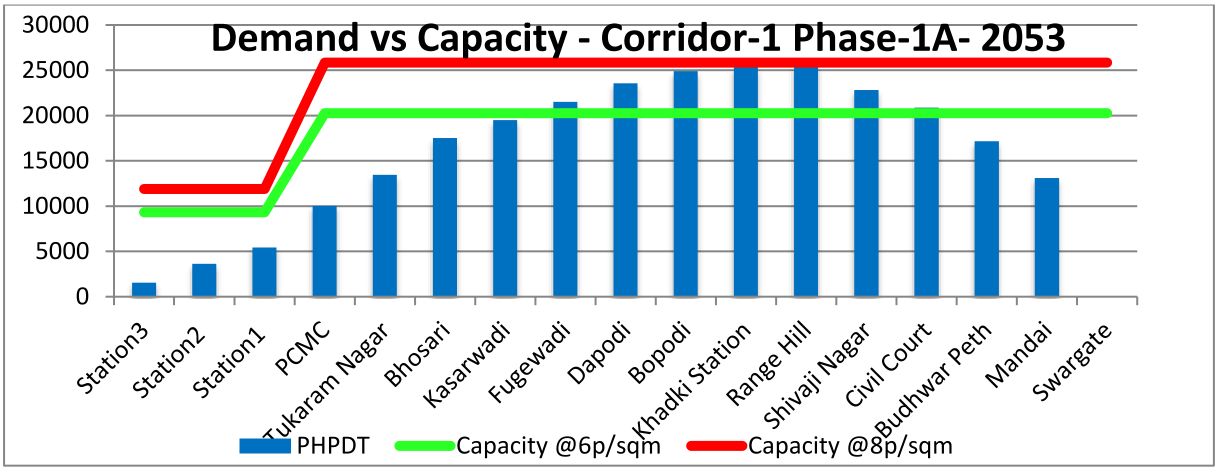
Provision for 6-car trains is required in year 2053 considering headway limitations and future lines which will add to demand estimated for existing length of corridor Phase 1A and may require introduction of 6-car train before the design year.

As PHPDT in section PCMC to Nigdi is very low (PHPDT of 5440), peak headway of only 5 min is considered sufficient in this section. Accordingly, every alternate train is planned to be short looped from PCMC towards Swargate, at least during peak hours. This has minimized Rolling Stock and Train Operator requirement.

The planned capacity of 20262 (25848 under crush loading) is less than the PHPDT demand in seven sections out of sixteen sections. With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2053 is tabulated and represented on a chart provided hereunder.

Table 86 : Demand (PHPDT) and Capacity Chart - Corridor-1 (Nigdi- Swargate), 2053

Demand (PHPDT) and Capacity Chart - Corridor-1 (Nigdi- Swargate)				
Year				**2053**
Headway (Sec)				148
No. of Cars per train				3
Passenger Capacity @6 persons/ sqm of train 3-car (6-car)				764 (1574)
Passenger Capacity @8 persons/ sqm of train 3-car (6-car)				975 (2004)
S No.	Section	PHPDT	Capacity @6p/sqm	Capacity @8p/sqm
1	Station03(Nigdi)	1540	9321	11895
2	Station02 (Akurdi)	3630	9321	11895
3	Station01 (Chinchwad)	5440	9321	11895
4	PCMC	10040	20262	25848
5	Tukaram Nagar	13440	20262	25848
6	Bhosari	17530	20262	25848
7	Kasarwadi	19510	20262	25848
8	Fugewadi	21500	20262	25848
9	Dapodi	23550	20262	25848
10	Bopodi	24910	20262	25848
11	Khadki Station	25350	20262	25848
12	Range Hill	25600	20262	25848
13	Shivaji Nagar	22830	20262	25848
14	Civil Court	20880	20262	25848
15	Budhwar Peth	17160	20262	25848
16	Mandai	13090	20262	25848
17	Swargate	0	20262	25848



In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by either varying the rake composition or adjusting the headway. E.g. in case of higher demand, headway may be reduced easily by injecting more trains out of reserve trains.

The PHPDT capacity provided on line 1 Phase 1A in horizon years of operation is tabulated in Table 87.

Table 87: capacity Provided for line 1

Demand (PHPDT) and capacity – line 1 Phase 1A (Nigdi- Swargate)								
Year	2023		2033		2043		2053	
Section	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate
Peak Headway (seconds)	450	222	340	174	295	150	295	150
No. of Cars per train	3	3	3	3	3	3	3	3/6
Peak Demand	2830	14450	3920	19450	5030	23690	5440	25600
Total Capacity @6p/sqm of standee area	6112	12224	8022	16044	9321	18642	9321	20262
Total Capacity @8p/sqm of standee area	7800	15600	10237	20475	11895	23790	11895	25848

8.3.5 Train frequency

The train operation of Pune Metro provides the train headway:

Table 88: capacity Provided for line 1

Train Frequency (Nigdi- Swargate)								
Year	2023		2033		2043		2053	
Section	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate	Nigdi-PCMC	PCMC-Swargate
Peak Headway (Minutes)	7.5	3.75	5.72	2.86	5	2.5	5	2.5
Off-Peak Headway (Minutes)	9-15	7-15	6-15	6-15	6-15	6-15	6-15	6-15

No services are proposed between 24:00 hrs to 05:00 hrs, which are reserved for maintenance of infrastructure and rolling stock.

8.3.6 Hourly Train Operation plan

The hourly distribution of daily transport capacity for Corridor -Nigdi to Swargate for horizon years are provided in following tables.

Average Trip length for operation with two loops in peak hours may be taken as 19.5km.

Table 89 : Hourly Train Operation Plan- (Nigdi-Swargate), 2023, 2033

Hourly Train Operation Plan- (Nigdi-Swargate)							
Time		2023			2033		
From	To	Headway (Min.)	No. of Trips		Headway (Min.)	No. of Trips	
			UP	DN		UP	DN
05:30	06:00	15	2	2	15	2	2
06:00	07:00	12	5	5	10	6	6
07:00	08:00	7	9	9	6	10	10
08:00	09:00	3.6	17	17	2.8	21	21
09:00	10:00	3.6	17	17	2.8	21	21
10:00	11:00	3.6	17	17	2.8	21	21
11:00	12:00	7	9	9	6	10	10
12:00	13:00	10	6	6	7	9	9
13:00	14:00	10	6	6	7	9	9
14:00	15:00	10	6	6	7	9	9
15:00	16:00	10	6	6	7	9	9
16:00	17:00	7	9	9	6	10	10
17:00	18:00	3.6	17	17	2.8	21	21

18:00	19:00	3.6	17	17	2.8	21	21
19:00	20:00	3.6	17	17	2.8	21	21
20:00	21:00	7	9	9	6	10	10
21:00	22:00	10	6	6	10	6	6
22:00	23:00	12	5	5	12	5	5
23:00	23:30	15	2	2	15	2	2
23:30							
Total Trips			**178**	**178**		**224**	**224**

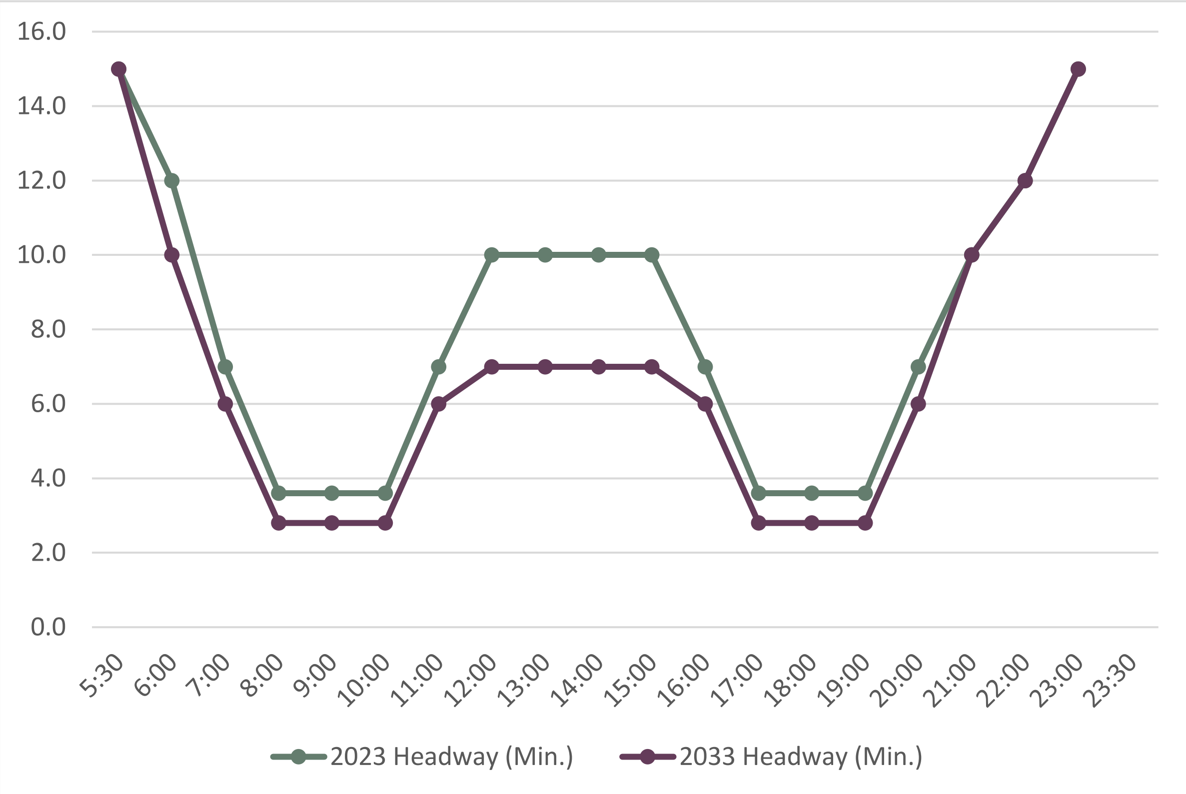
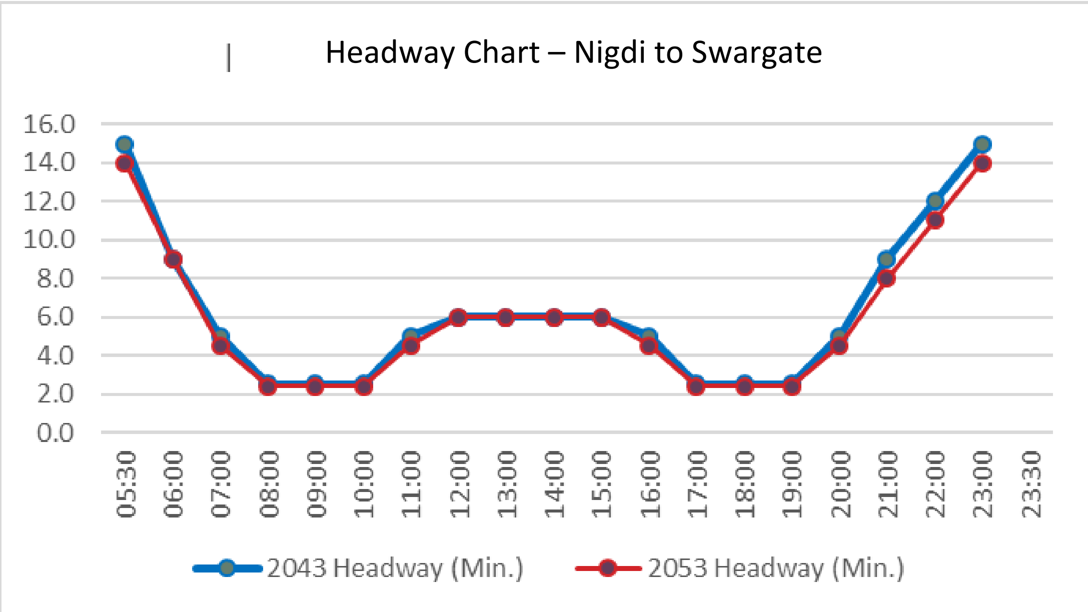
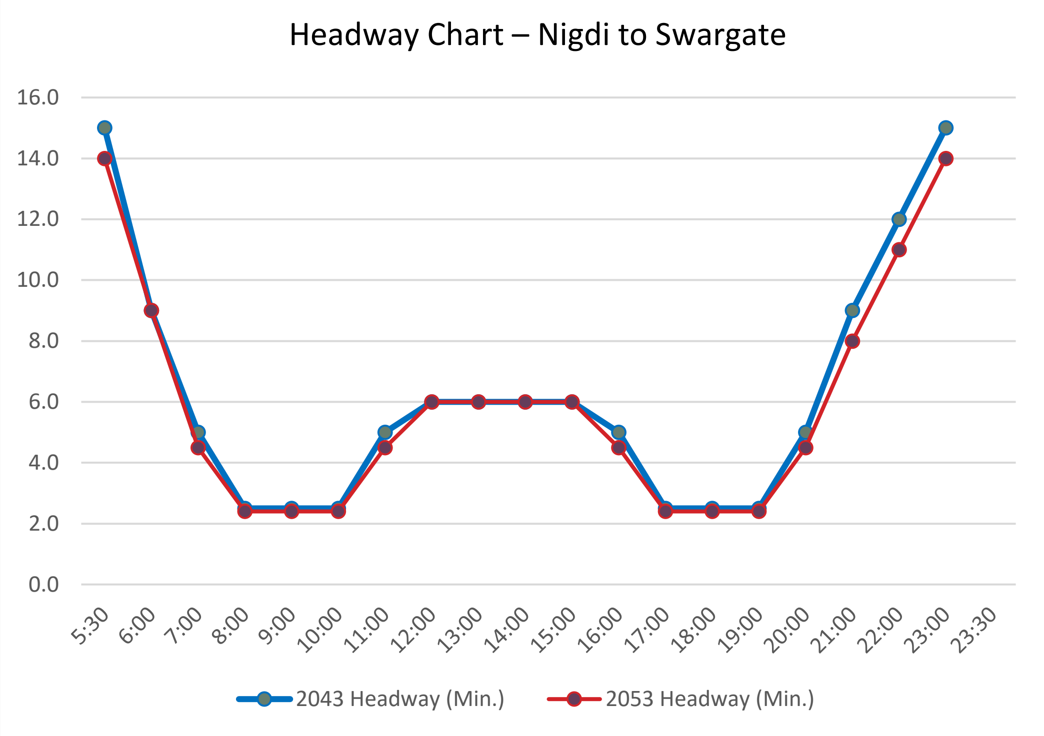


Table 90 : Hourly Train Operation Plan- (Nigdi-Swargate), 2043, 2053

Hourly Train Operation Plan- (Nigdi-Swargate)							
Time		**2043**			**2053**		
From	To	Headway (Min.)	No. of Trips		Headway (Min.)	No. of Trips	
			UP	DN		UP	DN
05:30	06:00	15	2	2	15	2	2
06:00	07:00	9	7	7	9	7	7

07:00	08:00	5	12	12	5	12	12
08:00	09:00	2.5	24	24	2.5	24	24
09:00	10:00	2.5	24	24	2.5	24	24
10:00	11:00	2.5	24	24	2.5	24	24
11:00	12:00	5	12	12	5	12	12
12:00	13:00	6	10	10	6	10	10
13:00	14:00	6	10	10	6	10	10
14:00	15:00	6	10	10	6	10	10
15:00	16:00	6	10	10	6	10	10
16:00	17:00	5	12	12	5	12	12
17:00	18:00	2.5	24	24	2.5	24	24
18:00	19:00	2.5	24	24	2.5	24	24
19:00	20:00	2.5	24	24	2.5	24	24
20:00	21:00	5	12	12	5	12	12
21:00	22:00	9	7	7	9	7	7
22:00	23:00	12	5	5	12	5	5
23:00	23:30	15	2	2	15	2	2
Total Trips			**254**	**254**			**254**




Headway Chart – Nigdi to Swargate
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5:30
6:00
7:00
8:00
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13:00
14:00
15:00
16:00
17:00
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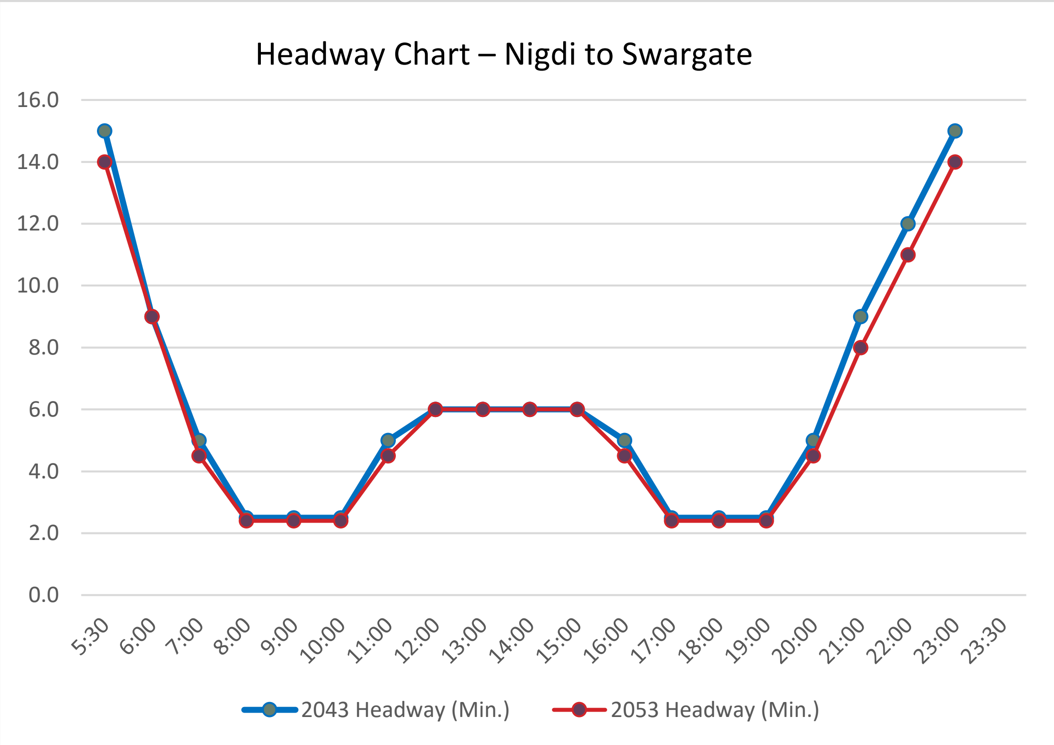
19:00
20:00
21:00
22:00
23:00
23:30
2043 Headway (Min.)
2053 Headway (Min.)


Headway Chart – Nigdi to Swargate
16.0
14.0
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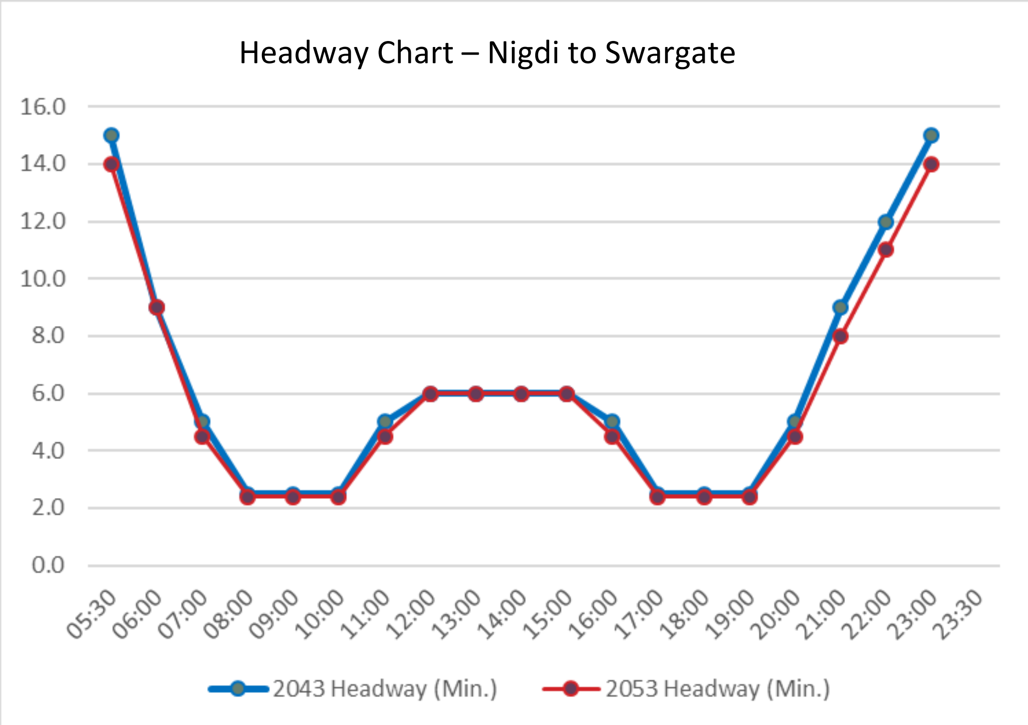
23:30
2043 Headway (Min.)
2053 Headway (Min.)



8.4 Vehicle kilometer

Based on the above planning, Vehicle Kilometers for Pune Metro corridor-1A are given in tables enclosed hereunder.

Table 91 : Vehicle Kilometer

Item	Phase 1A			
Year	**2023**	**2023**	**2043**	**2053**
No. of Cars per train	3	3	3	3
Section Length (KM)	22	22	22	22
Trip length (Long Loop)	22	22	22	22
Trip length (Short Loop)	17	17	17	17
No. of trips (Long loop)	257	319	365	384
No of trips (Short loop)	100	129	144	150
Daily Train KM	7333	9191	10453	10453
Annual Train KM (10^5)	27	34	38	38

The calculation for vehicle kilometer is based on assumption that 50% trains will be shortlooped only during peak-hours. Vehicle kilometers can be further reduced by introducing shortlooping during off-peak hours such that headway in Phase 1A is not too high for passenger convenience.

8.5 Year-wise rake requirement

Based on train formation and headway as decided above to meet PHPDT, rake requirement has been calculated tabulated below in brief:

Table 92: Rake Requirement

Corridor	Year	Headway (min)	Schedule Speed (kmph)	Average Trip Length (Peak hour)	No. of Rakes			Rake Consist	No. of Coaches*
					Bare	Reserve (Trafic+ maint.)	Total		
(Nigdi - Swargate)	2025	2.9	33	19.5km	28	2	30	3	90
	2033	2.9	33	19.5km	28	2	30	3	90
	2043	2.5	33	19.5km	30	3	34	3	102
	2053	2.5	33	19.5km	31	3	36	3/6	108

*The requirement of coaches mentioned in above table includes coaches (75) already planned for Line 1,Phase-1. The detailed calculations of Rolling Stock Requirement in the year 2025 is shown in Page 240A.

Requirements of coaches is calculated based on following assumptions:

Assumptions:

- Train composition planned as specified in section §11.1.1 Train Composition;
- Coach requirement has been calculated based on headway during peak hours;
- Traffic reserve is taken as one train per corridor to cater to failure of train on mainline and to make up for operational time lost;
- Repair and maintenance reserve has been estimated as 10 % of total requirement (Bare +Traffic Reserve);
- The calculated number of rakes in fraction is rounded off to next higher number;
- Schedule speed is taken as 33 KMPH for corridor 1A;
- Total turn-back time at terminals is taken as 3 minutes (90 second each terminal) using front cross-overs.

8.6 Stabling requirement

Maintenance facilities for PCMC-Nigdi extension can be accommodated in already planned depot near Range Hill station for Phase-1, therefore, another new depot is not required. Stabling capacity for 25 number of 3-car trains is already provisioned in phase-1 of existing Range Hill Depot with suitable augmentation.

Detailed calculations of Rolling Stock Requirement in the year 2025

Year	PHPDT		
	PCMC-Swargate	Nigdi -Swargate	Incremental PHPDT
2023	14450	17280	2830
Proportional PHPDT on 2025	15450	18498	3100
2033	19450	23370	3920
2043	23690	28720	5030
2053	25600	31040	5440

A) Rolling Stock Requirement for PCMC to Swargate section (Yr 2025)

PHPDT =15450

Capacity of one 3car train/rake = 764 Passengers

Trains/hr = (15450/764) = 20.22

Hence Headway = 2.97 min

No of trains = $\frac{\text{Turn around time (TO)}}{\text{Headway}}$

Turn Around Time = $\left(\frac{\text{Length of Corridor X 2}}{\text{Avg. Speed}}\right)$ + Switching Time

Turn Around Time = $\left(\frac{17.8 \text{ X } 2}{33}\right)$ + 10 mins = 74.7 mins

Hence No of trains = 25.15 **= 25 Nos**

B) Rolling Stock Requirement for PCMC to Nigdi section (Yr 2025)

PHPDT =3100

Capacity of one 3car train/rake = 764 Passengers

Trains/hr = (3100/764) = 4.06

Hence Headway = 14.79 min

No of trains = $\frac{\text{Turn around time (TO)}}{\text{Headway}}$

Turn Around Time = $\left(\frac{4.413 \text{ X } 2}{33}\right)$ + 10 mins = 26 mins

Hence No of trains = 1.8 **= 2 Nos**

Total trains required in 2025 = A+B = 25+2 = 27 Nos

Total trains incl/spare@10% =30 Nos trains required

Total trains to be procured **= 30 Nos of 3 Car trains = 90 Coaches**

9. SIGNALLING AND TELECOMMUNICATION SYSTEM

9.1 Signalling System

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

9.1.1 Signalling and train control

9.1.1.1 Overview

Metro carries large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability. At the same time, heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public.

These requirements of the metro are planned to be achieved by adopting 'CATC' (Continuous Automatic Train Control System) based on "CBTC" (Communication based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train. This will:

- Provide high level of safety with trains running at close headway ensuring continuous safe train separation and for bidirectional working;
- Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver;
- Provide safety and enforce speed limit on section having permanent and temporary speed restrictions;
- Improve capacity with safer and smoother operations. The driver will have continuous display of Target Speed / Distance to Go status in his cab, enabling him to optimize the speed potential of the track section. It provides signal / speed status in the cab even in bad weather;
- Increase productivity of rolling stock by increasing line capacity and train speeds and enabling train to arrive at its destination sooner. Hence more trips will be possible with the same number of rolling stock;
- Improve maintenance of signalling and telecommunication equipments by monitoring system status of trackside and trainborne equipment's and enabling preventive maintenance.

Signalling & Train Control system on the line shall be designed to meet the required headway during peak hours.

Note: Radio for CBTC shall work in License free ISM band.

9.1.1.2 System description and specifications

The Signalling and Train Control system shall be as below. Sub-system/components will conform to international standards like CENELEC, IEEE, IEC, BS, ITU-T etc:

- **Continuous Automatic Train Control**

Continuous Automatic Train Control based on CBTC will consist of - ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems:

- **Automatic Train Protection (ATP)**

Automatic Train Protection is the primary function of the train control systems. This sub-system will be inherently capable of achieving the following objectives in a fail-safe manner. Line side signals will be provided at diverging routes (i.e. at points & crossings) as well as other required locations, which shall serve as backup signalling in case of failure of ATP system.

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

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

- **Automatic Train Operation (ATO)**

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

- **Automatic Train Supervision (ATS)**

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

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

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

- **Interlocking system**

- **Computer Based Interlocking (CBI)**

The entire line including turnback track, transfer track and sidings will be equipped with CBI system for operation of points and crossings and setting of routes.

The setting of the route and clearing of the signals will be done by workstation, which can be either locally (at station) operated or operated remotely from the OCC.

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

The equipment will withstand tough environmental conditions encountered in a Mass Rapid Transit System. Suitable IEC, IEEE, BS and CENELEC standards or equivalent international standards will be followed in case wiring, installation, earthing, cabling, power supply and for material used in track circuits, axle counters, relays, point operating machines, power supply etc.

- **Track Vacancy Detection**

Primary mode for track vacancy detection system on main line may be through radio and for secondary detection it can be through Track circuit / Axle Counter.

- **Signals**

Line side signals: Multi Aspect Colour Light (LED) type Line side signals shall be installed on the Main Line and depot entry/exit.

- At stations with point and crossing for point protection catering for bidirectional working;
- At departure location at stations for normal direction of working.

- **Point Machines**

Non-Trailable Electrical Point Machine capable of operating with either 110V DC or 3-phase 380V AC will be used on main line. The depot point machine will preferably be trailable type.

- **Train Depot : signalling**

One depot at the end of Chakan area (Opposite to Swapna Nigdi). All depot lines except the one which is used for shunting and in the workshop shall be interlocked. A workstation shall be provided in the Depot Control Centre for electrical operation of the points, signals and routes of the depot yard. Audio Frequency Track Circuits will be used in the depot.

9.1.2 Standards

The standards to be adopted for the signalling system are shown in the Table 93.

Table 93: Standards of Signalling System

S/No.	Description	Standards
1	Interlocking	Computer based Interlocking adopted for station having switches and crossing. All related equipment as far as possible will be centralised in the equipment room at the station. The depot shall be interlocked except for lines mainly used for shunting, workshop/inspection shed areas.
2	Operation of Points	With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.
3	Train Detection	Primary train detection system to use bidirectional digital transmission of signal/data by radio transponder and to be provided on Main Line, sidings, test track and transfer track (Entry & Exit of Depot). Secondary train detection system to use Axle counters and

		to be provided at entry and exit of each station and in mid sections as required
4	Signals at Stations with point & crossings	Line Side signals to protect the points (switches). LED type signals for reliability and reduced maintenance cost.
5	UPS (uninterrupted power at stations as well as for OCC)	For Signalling and Telecommunications
6	Train protection system	Automatic Train Protection system.
7	Train Describer System	Automatic Train Supervision system. Movement of all trains to be logged on to a central computer and displayed on workstations in the Operational Control Centre and at the SCR. Remote control of stations from the OCC.
8	Redundancy for TP/Train Describer	Redundant Train borne equipment and ATS equipment at OCC.
9	Cables	Outdoor cables will be steel armoured as far as possible.
10	Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for signal application.
11	Immunity to External Interface	All data transmission on telecom cables/OFC/Radio. All Signalling and telecom cables will be separated from power cables. CENELEC standards to be implemented for EMC.
12	Train Working under emergency	Running on site with line side signal with speed automatically restricted between 15-25 kmph.
13	Environmental Conditions	Air-conditioners for all equipment rooms.
14	Maintenance philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling equipment's shall be followed. Card / module / sub-system level replacement shall be done in the field and repairs under taken in the central laboratory/manufacturer's premises.

9.1.3 Space requirement for signalling installations

Adequate space for proper installations of all signalling equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for signalling equipment shall be generally as follows:

- Space for UPS Room (common for signalling and telecom) - 60 sq. m
- Space for Signalling Equipment Room - 50 sq. m at interlocked station with points
- Space for Signalling Equipment Room – 20 sq. m at other stations.

9.1.4 Maintenance philosophy for signalling systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of signalling and telecommunication equipments shall be followed. Card / module / sub-system level replacement shall be done in the field.

Maintenance personnel shall be suitably placed at intervals and they shall be trained in multi-disciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station.

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

9.1.5 Technology selection and choice of automation

The CBTC system is an efficient way to increase the capacity by allowing to decrease the headway between trains with the use of moving blocks.

In urban transport systems, automation refers to the process by which responsibility for operation management of the trains is transferred from the driver to the train control system.

There are various degrees of automation (or Grades of Automation, GoA). These are defined according to which basic functions of train operation are the responsibility of staff, and which are the responsibility of the system itself.

For example, a Grade of Automation 0 would correspond to on-sight operation, like a tram running on street traffic. Grade of Automation 4 would refer to a system in which vehicles are run fully automatically without any operating staff on board.

For this project, the choice of automation is same as that of the phase I and to be made fully compatible with the proposed system of signalling and train control as in phase I.

Hence, increasing the level of GoA, will allow implicity to:

- Guarantee a high level of safety enforcement;
- Maximize the train capacity;
- Have a more efficient energy system and train movement on the network & also
- To optimize the operating costs.

9.2 Telecommunication

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

For efficient Metro railway management and operation, it is essential to have a well-organized telecommunication network covering strategic locations like OCC, BCC, passenger platforms, depot and it is equally essential to have reliable links between the strategic locations and moving trains or working staff along the railway track/Tunnel.

9.2.1 Telecommunication overview

The telecommunication facilities proposed are helpful in meeting the requirements for:

- Supplementing the signalling system for efficient train operation;
- Exchange of managerial information;
- Crisis management during emergencies;
- Passenger information system.

The proposed telecom system will cater to the following requirements:

- Train Traffic Control;
- Assistance to Train Traffic Control;
- Maintenance Control;
- Emergency Control.

9.2.2 Station to station dedicated communication

Following are the major communication requirements from station to station or station to OCC/BCC/Depot or vice versa:

- Telephone System;
- Passenger Announcement System and Passenger Information and Display System within the station and from Central Control to each station;
- Centralized Clock System;
- Radio Communication between Central Control and Moving Cars and maintenance personnel;
- CCTV Systems;
- Access Control System;
- Integrated SCADA for Telecom;
- Data Channels for Telecom subsystems, Signalling, SCADA, Automatic Fare collection etc.
- Forensic Debriefing Analysis and Cyber Security System

9.2.3 Telecommunication System and Transmission Media

- **Fibre Optic System - Main Telecommunication Bearer**

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements, four optical fiber cables of minimum 144 fibres are proposed to be laid in ring configuration with path diversity.

IP based min 10G Wide Area Network being provided under FOTS Sub-system of Contract shall provide all necessary communication channels for carrying voice, data, and video signals for Metro railway management and operation from Station/Depot TER to OCC/BCC CER.

The Transmission Backbone is also to be used for Communication Based Train Control system therefore redundancy at every level must be maintained.

- **Telephone System**

The telephone system shall also consist of a direct line or intercom telephone communication network exclusively for the train operation and maintenance functions.

There is one main node at OCC which should be in primary cluster with dual server. In the case of a failure of one of the servers, the other server will take over the load of the failed server. The main node shall be connected with FOTS to the secondary cluster with servers at individual stations.

The IP PBX's shall be installed in TER at all locations. The IP PBX switches shall be connected to each other through ethernet links of the FOTS to form the IP PBX switch network. The ethernet channels shall be provided by FOTS.

CDRS facility shall be provided in OCC & BCC. CDRS shall provide multichannel voice recording and indexing of direct line communication including communication from all direct line consoles and emergency telephone lines, two-way radio communications, emergency or fire messages broadcast on station PAS initiated from OCC/BCC and on train borne PAS initiated from OCC/BCC.

- **Mobile Radio Communication**

Mobile Radio Communication system having adequate logical channels is proposed for on-line emergency communication between moving train (Front end and Rear end of train) and the Central Control. The system shall be based on Digital Trunk Radio Technology to TETRA International standard. All the stations and the OCC/BCC/Depot will be provided with fixed radio sets. Mobile communication facility for maintenance parties and Security Personnel will be provided with handheld sets to communicate with each other as well as with central control.

The frequency band for operation of the system will be that for TETRA in 400/800 MHz band, depending on frequency availability.

The system shall provide Instant mobile radio communication between the motorman of the moving cars from any place and the Central Control. The motorman can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

To provide adequate coverage, based on the RF site survey to be carried out during detailed design stage, base stations for the system will be located at sites conveniently selected after detailed survey. The train radio system shall also be used for depot operation. Train Radio communication shall also be used for making PAS announcements from OCC & BCC to the passengers on the train.

A Centralized Digital Voice Recording System shall record all communication from OCC controller to personal having radio fixed or handheld devices.

- **Passenger Announcement System**

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

At OCC, Integrated PIDS/PAS system shall be provided.

At the stations, a suitable Public-Address System shall be provided for making announcements to passengers regarding train arrival / departure and shall work as the primary means of communication with passengers and staff during emergencies. In the normal case, audio-broadcast shall be made from Station Control Room or Platform Supervisor’s Booth/Panel and in a train by the driver/Attendant. However, it shall also be possible for the OCC & BCC to make announcement to any station, group of stations or all stations.

- **Centralized Clock System**

This will ensure an accurate display of time through a synchronization system of slave clocks driven from a Master Clock at the operation control center. Master Clock System shall also provide reference timing signals for all telecom and other systems for network synchronization Redundancy shall be maintained for master clock. NTP based clocks shall be provided and sub master clocks are not required. The System will ensure identical display of time at all locations. Clocks are to be provided at platforms, concourse, Station Master's Room, and any other location as desired at stations, Depot, OCC & BCC and other service establishments etc.

Self-illuminated analogue façade clock with hour and minutes hands shall be proposed. These clocks will be installed at station entry/ exit.

- **Passenger Information Display System**

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

At OCC, Integrated PIDS/PAS system shall be provided.

A Passenger Information Display system triggered by Signalling & train control system shall automatically provide real time visual information about train arrival/departure throughout the station. The PIDS display shall be coordinated with PAS for real time passenger audio broadcasts for train arrival/departure. PIDS shall enable the operator in SCRs , OCC & BCC to display routine and special emergency messages for passengers and staff in stations. Display boards shall be provided for each platform side at all stations and in concourse at all stations.

- **Wi-Fi**

A Wireless communication system is proposed at stations separate from any signalling Wireless Communication System. The system shall be used to connect all staff devices and laptops to a central network. The Wireless communication system shall be standard commercial-off-the-shelf system and will conform to Wi-Fi standard – 802 series of communication protocols.

The System should be secure, reliable and offer sufficient bandwidth to cater to current and future needs of the system.

- **CCTV System**

CCTV surveillance system shall be built through CCTV sub-system for supervising strategic operational locations like station car park, AFC gates, ticketing offices and lobby, escalator, lifts and staircase exits, platform operational area and PF ends, to ensure safe operation of the Metro and security locations at stations.

It shall be supervised from the station control room and Security room at each station simultaneously, and this video shall also be transmitted to the OCC & BCC, both as live and as recorded, from the stations/Depot for remote supervision. Similarly, a CCTV depot surveillance system shall also be built.

It shall be supervised locally from DCC & Security Control room and remotely from OCC & BCC.

A Centralized Digital Recording System is to be provided in CER at the OCC & BCC for minimum 30 days.

- **Access Control System**

The Access Control System shall be provided at Stations, OCC & BCC, Depots & Administrative Building. It shall be provided in important rooms like SCR, Ticket Office, Service gates (near AFC gate array), Technical rooms (Power Supply, Signalling and Low Voltage technical rooms), ASS and other important rooms. In Depots, OCC & BCC & Admin building, it shall, as a minimum, be provided in Technical rooms (Power Supply, Signalling, Telecom, AFC and Low Voltage technical rooms), DCC & OCC & BCC theatre, Security room including main entry & exit gates to control access into important equipment rooms and critical areas. Location of the ACIDS system shall be finalized during detailed design stage.

The functions of the system shall be access management, alarm management and intrusion detection. The Human Machine Interfaces (HMI) shall be located in the SCR of each station, the guard room at Depot and the OCC & BCC to ensure the safety of major equipments. The HMI of Access control shall be integrated with HMI of the CCTV system.

- **Network Monitoring and Management**

For efficient and cost-effective maintenance of the entire communication network, it is proposed to provide Integrated SCADA network, which will help in diagnosing faults of all systems in single screen immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance. The proposed system will be covering all the telecom subsystems.

- **Forensic Debriefing Analysis and Cyber Security System**

Metro Rail faces new security challenges as system has become more interconnected, integrates more and more digital technologies and increasingly uses data to deliver higher capacity & performance and thus cybersecurity is essential to the safe and reliable operation of modern Metro Rail System. Cybersecurity is required to ensure end-to-end information security, not only to prevent and to detect attacks, but also to react rapidly if they occur. Objective of Cybersecurity for Metro includes availability, integrity, confidentiality, reliability and safety of information and process of entire Metro Rail Eco-System.

Metro Rail uses heterogeneous IT technologies and software solutions and consists of following core sub-systems:

- On-Board Train Control & Management System
- Centralized Signalling & Train Control System
- Power SCADA System

- Building Management System
- Fiber Optic Transmission System
- Train Radio System
- Telephone System
- Passenger Information Display System
- Passenger Announcement System
- Video Surveillance System
- Master Clock System
- Digital Voice Recording System
- Automatic Fare Collection System
- Automatic Platform Screen Door system

Additionally Metro Rail employs other information technologies services for various uses.

- Office Network and Internet Connectivity for staff
- Email Exchange Service & website
- Enterprise Resource Services
- Document Management System
- Wi-Fi System
- Metro Mobile & Web Applications

To meet the Cyber Security Threats, a Security Policy and framework is recommended for Pune Metro to manage the cyber security needs and mitigate the project risks. The Cyber Security System shall be an integral part of the Telecom system.

9.2.4 Standards

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

Table 94: Standards of Telecommunication System

SYSTEM	STANDARD
Transmission System	IP based for the entire telecom network.
Transmission Media	Optical Fibre system as the main bearer for bulk of the telecommunication network,
Telephone Exchange	IP based Voice Communication System
Train Radio System	Digital Train radio (TETRA) communication between motorman of moving cars, stations, maintenance personnel, depots and central control.

Passenger Information Display System	LCD based boards with adequate visibility to be provided at convenient location at all stations to provide multi lingual visual indication of the status of the running trains, and also special messages in emergencies.
Centralized clock system	Accurate display of time through a synchronization system of slave clocks driven from a master clock at the OCC/BCC and in station/depots. This shall also be used for synchronization of other systems.
Passenger Announcement System	Integrated PIDS/PAS System at OCC/BCC/Depot and stations covering all platform and concourse areas with local as well as central announcement.
Access Control System	The access control system shall use contact-less smart card with ID as the access media for smart card reader. Biometrics shall also be used for high security zones.
Redundancy (Major System)	Redundancy on major equipments. Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
Environmental Conditions	All equipment rooms to be air-conditioned.
Maintenance Philosophy	System to have, as far as possible, automatic switching facility to alternate routes/circuits in the event of failure. Philosophy of preventive checks of maintenance to be followed. System networked with NMS for diagnosing faults and co-ordination. Card/module level replacement shall be done in the field and repairs undertaken in the central laboratory/manufacture's premises.

9.2.5 Space requirement for telecom installations

The following equipment rooms will be provided to install the telecommunication equipment:

- Telecommunication Equipment Room at station and Depot;
- Central Equipment Room at OCC & BCC. In present case, space already provided for existing system shall be used, provided provision for expansion is there.

Electric power to the equipment room shall be drawn from the central UPS which will not be in scope of Telecom.

Adequate space for proper installations of all Telecommunication equipment at each of the stations should be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for only telecom equipment shall be generally 40 sq.m each for Telecom Room and 50 sq.m. for UPS Room (common for signal, telecom and AFC). These areas shall also cater to local storage and space for maintenance personnel to work.

9.2.6 Maintenance philosophy for telecom systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipment shall be followed.

Card / module / sub-system level replacement shall be done in the field.

Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station.

The defective card/module/sub-system taken out from the section shall be sent for diagnostic and repair to a centralized repair lab suitably located on the section. This lab will be equipped with appropriate diagnostic and test equipment to rectify the faults and undertake minor repairs. Cards / modules / equipment requiring major repairs as specified in supplier’s documents shall be sent to manufacturer's workshop.

9.3 Platform Screen Doors

Platform screen doors are mainly provided at metro stations to ensure safety and comfort of the passengers. In case of Underground stations, PSDs saves considerabe amount of energy and improves climate control within the stations (heating, ventilation and air conditioning are more effective when station is physically isolated from the tunnel). In case of corridor 1A, the complete stretch is elevated and corridor 1A is an extension of the existing Line 1 of phase 1, thus to ensure the continuity and compatibility, PSD are not proposed at wayside stations.

For Terminal Stations due to driverless turnback, PSGs are proposed at these stations for safety purpose.

10. AUTOMATIC FARE COLLECTION SYSTEM

10.1 Overview

The Automatic Fare Collection System forms a vital part of operations of a transit system. The main objectives of an AFC system are that it shall:

- Be capable of issuing single and multiple journey tickets;
- Ensure efficient and proper operation of the system in terms of passenger flow;
- Minimize Fare Revenue evasion and fraud and maximize fare revenue protection;
- Be simple and easy to use/operate and maintain;
- Allow for easy accounting;
- Allow for fare changes easily and quickly;
- Require lesser manpower overall.

In view of the above and since the previous phase of the project has an already approved AFC system, a computer based Automatic Fare collection system is proposed for this phase of the project as well to ensure easy integration and interoperability of the new system with the one already proposed/implemented.

The System shall be capable for open loop transactions as well to further integrate the mobility solution with the advancements in technology and to allow for seamless transition from dedicated cards to common multi-use stored value fare media that can be used for financial transactions such as making purchases at shops etc. as well as a fare media in the system.

To accommodate the same, the system shall conform to the following standards as a minimum:

1. EMV (Euro Mastercard Visa)
2. PCI-DSS (Payment card Industry / Data Security Standard)
3. ISO-IEC 14443

The system shall be of open architecture to allow for the integration of multiple fare products and shall be capable of interfacing with cards from different vendors. Additionally the system shall not be proprietary as far as possible to allow multiple types of fare media from multiple sources to be integrated into the system.

The AFC system for this phase shall be of contactless smart card & token type. For multiple journeys, stored value smart cards shall be available and for single journeys, smart tokens shall be available, which shall be deposited at the exit gates at the time of exit validation.

Automatic Fare Collection Systems are proposed as the Semi-Automatic (Manual) Systems have some inherent disadvantages and the Automatic Fare Collection Systems have some advantages:

- **Disadvantages of Manual Fare Collection System**
  - Large Number of staff are required for ticket issue and validation activities;
  - Changes in fare structure and policies are time consuming as changes have to be made at each station individually;
  - System is susceptible to fare revenue evasion and frauds through tampering/vandalism of the mechanical components of the equipments;
  - 100% ticket validation and authentication at entry/exit is not possible in this system;
  - Manual System which results in greater transaction time, both for fare media purchase and authentication.

- **Advantages of Automatic Fare Collection System**
  - Fewer Staff Required for Fare media sales and Validation/Authentication;
  - System offers greater flexibility both in terms of scalability and changes in fare structure to be incorporated;
  - System offers increased fare revenue protection and minimizes fare revenue evasion/fraud;
  - Data Collection regarding system operation and ridership is simpler and easier;
  - System allows fare structure to be changed from the central processing server across the entire system quickly;
  - System is efficient and easy to operate and allows degraded and disaster mode operations to deal with emergency situations;
  - System has capability to integrate multiple modes of transport via interoperability. In addition, smart cards can be used for other applications such as payments at third party vendors/outlets etc.

The AFC system shall be of contactless smart token/card type. The equipment for the same shall be provided at each station at convenient locations.

The equipment shall be connected by a local area network to the station control unit in the Equipment Room with a terminal in the station control room (SCR).

- **Control Gates**

Control Gates shall be retractable flap type. These types of gates offer high throughput and require less maintenance. Tripod turnstile type gates and flap type gates offer less throughput and require more maintenance.

- **Passenger Operated Machine (POM)**

A minimum of two Passenger Operated Machines (Automatic Ticket Vending Machines) each are proposed at all stations. The POM's shall provide a convenient way for passengers to buy fare media and avoid standing in queues at Ticket Offices and provide services of international standard.

10.1.1 Standards

Table 95: Standards to be adopted for AFC systems

Standards	Description
Fare Media	**Contactless Smart Token** – For single journey. They shall have stored value amount for a particular journey. Tokens shall be captured at the exit gates. **Contactless smart cards –** for multiple journeys.
Gates	Computer Controlled retractable flap type automatic gates at entry and exit. Gates shall be classified in the following categories: Entry Exit Reversible – can be set to entry or exit. Wide Reversible - Gate for disabled people.
Station Computer, Central Computer and AFC Network.	All fare collection equipment shall be connected in a Local Area Network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the Operations Control Centre through the optic fibre communications 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 shall be installed in the stations for selling cards/tokens to the passengers.
Ticket Readers and Portable Ticket Decoders	Ticket reader shall be installed near EFO for passengers to check information stored in the token / cards.
UPS (uninterrupted power at station as well as for OCC)	Common UPS of S&T system will be utilized.
Maintenance Philosophy	Being fully Contactless systems, manpower requirement for maintenance is much less compared to system with magnetic tickets. However, adequate facilities to be provided similar to that of S&T systems.

10.1.2 Equipment requirement (Automatic Fare Collection System)

Assumptions:

- Each station has two accesses;
- Minimum arrangement at each access is 1 entry gate, 1 exit gate, 1 reversible gate, 1 EFO;
- Throughput of gate is 30 PPM. For Ticket Office Machine (TOM) it is 10 PPM;
- 50% passengers are assumed on smart card and 50% on single journey token;
- Each station has 1 wide gate for disabled. Exact equipment arrangement depends on final station layout;

10.1.3 AFC Space Requirements

Each station shall be designed with enough space to allow for the installation of AFC equipment such as Gates, TOM and TVMs. The design should also consider adequate space for specific rooms such as EFOs to be provided in station architecture.

For Central Equipment at the OCC/BOCC, existing equipment at these locations shall be utilized, provided adequate provision for expansion was considered in phase I of Pune Metro. No additional equipment shall be required to be installed at OCC/BOCC in case the central equipment was sized with provision of expansion. In case additional equipment is required, the existing space provided at OCC/BOCC locations shall be utilized, provided the provision for expansion was provided.

AFC equipment requirements based on available data and assumptions are given in Table 96.

Table 96: Station Equipment Requirement (Tentative)

Nigdi-Swargate Section													
Nigdi- Swargate		BOARDING	ALIGHTING	AFC REQUIREMENT 2053		Gates			TOM	EFO	TVM	TR	RCTM
SI NO	Station	2053	2053	Entry	Exit	Entry	Exit	Reversible					
NIGDI-PCMC													
1	Chinchwad	1500	2160	3	4	4	3	2	2	2	2	2	2
2	Akurdi	1470	2090	3	4	4	3	2	2	2	2	2	2
3	Nigdi	1270	1540	2	2	4	3	2	2	2	2	2	2

* PHPDT Data as available has been used. Data for the year 2053 has been considered.

** The Boarding and Alighting data presented is for peak hour.

***The number of gates is calculated considering the evacuation requirements and safety requirements.

11. ROLLING STOCK

11.1 Introduction

The required transport demand forecast is the governing factor for the choice of the Rolling Stock. The forecasted Peak Hour Peak Direction Traffic (PHPDT) calls for a Mass Rapid Transit System (MRTS).

11.1.1 Optimization of coach size

The following optimum size of the coach has been chosen in line with the existing corridor (PCMC – Swargate) design as mentioned in table:

Table 97: Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC)	21.64m	2.9m	3.9m
Trailer Car (TC)/Motor Car	21.34m	2.9m	3.9m

**Maximum length of coach over couplers/buffer:22.6m (Depending upon the Kinematic Envelope).*

11.1.2 Passenger carrying capacity

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

Therefore, for the Metro Rail Vehicles (MRV) with 2.9m maximum width and longitudinal seat arrangement, conceptually the crush capacity of 43 seated, 204 standing thus a total of 247 passengers for a Driving motor car, and 50 seated, 220 standing thus a total of 270 for a trailer/motor car is envisaged.

Train composition is recommended as 3-car DMC+TC+DMC & 6-car DMC+ TC+ MC+ MC+ TC+ DMC, below table shows the carrying capacity of medium rail vehicles.

Table 98: Carrying Capacity of Medium Rail Vehicles

Particulars	Driving Motor car			Trailer car / Motor car			3 Car Train		
	Normal*	#Crush	$Engg. Load	Normal*	#Crush	$Engg. Load	Normal*	#Crush	$Engg. Load
Seated	43	43	43	50	50	50	136	136	136
Standing	102	204	273	110	220	293	314	628	839
Total	145	247	316	160	270	343	450	764	975

Particulars	Driving Motor car			Trailer car / Motor car			6 Car Train		
	Normal*	#Crush	$Engg. Load	Normal*	#Crush	$Engg. Load	Normal*	#Crush	$Engg. Load
Seated	43	43	43	50	50	50	286	286	286
Standing	102	204	273	110	220	293	644	1288	1718
Total	145	247	316	160	270	343	930	1574	2004

** Normal Load - 3 Person/sqm of standee area*
 # Crush Load - 6 Person/sqm of standee area
$ Engineering Load - 8 Person/sqm of standee area

11.1.2.1 Weight

The weights of driving motor car and trailer car have been estimated as inTable 99, referring to the experiences in existing Metro in India. The average passenger weight has been taken as 65 kg.

Composition
DMC : Driving Motor Car
MC : Motor Car
TC : Trailer Car
3 Car Train Composition DMC + TC + DMC
6 Car Train Composition DMC + TC + MC + MC + TC + DMC

Table 99: Weight of Metro Rail Vehicles (tons)

	DMC (ton)	TC (ton)	3 Car Train (ton)
Tare Load (Maximum)	42	40	124
Passenger Load (Per Car)			
Normal Load@3p/sqm	9.425	10.4	29.25
Crush Load@6p/sqm	16.055	17.55	49.66
Engg. Load @8p/sqm	20.54	22.295	63.375
Gross Load			
Normal Load @3p/sqm	52.425	51.4	153.25
Crush Load@6p/sqm	59.055	58.55	173.66
Engg. Load @8p/sqm	63.54	63.295	187.375
Crush Axle Load @6 p/sqm	14.52	14.40	
Engg. Axle Load @8 p/sqm	15.63	15.58	

** AW0 - Without any passenger*

	DMC (ton)	TC (ton)	MC(ton)	6 Car Train (ton)
Tare Load (Maximum)	42	40	42	248
	Passenger Load (Per Car)			
Normal Load@3p/sqm	9.425	10.4	10.4	29.25
Crush Load@6p/sqm	16.055	17.55	17.55	49.66
Engg. Load @8p/sqm	20.54	22.295	22.295	63.375
	Gross Load			
Normal Load @3p/sqm	52.425	51.4	52.4	308.45
Crush Load@6p/sqm	59.055	58.55	59.55	350.31
Engg. Load @8p/sqm	63.54	63.295	64.295	378.26
Crush Axle Load @6 p/sqm	14.52	14.40	14.88	
Engg. Axle Load @8 p/sqm	15.63	15.58	16.07	

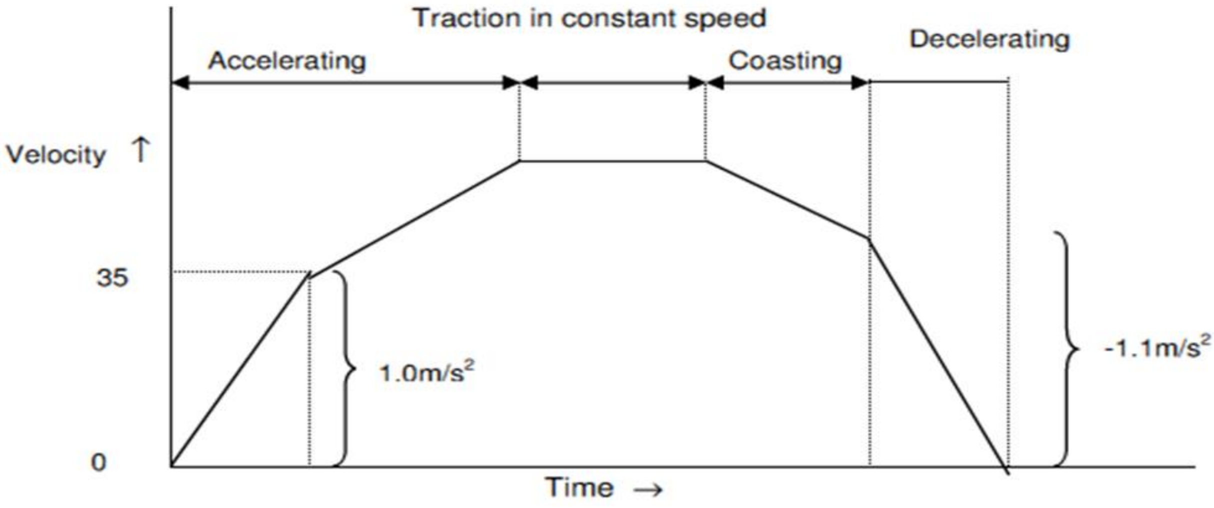
** AW0 - Without any passenger*

The axle load @ 6persons/sqm of standing area works out in the range of 14.40T to 14.52T. Heavy rush of passenger, having 8 standees per sq. meter can be experienced occasionally. It will be advisable to design the coach with sufficient strength so that even with this overload, the design will not result in over stresses in the coach. Coach and bogie should, therefore, be designed for 16T axle load.

11.1.2.2 Performance parameters

Following values of acceleration and deceleration are assumed in consideration of riding comfort, adhesion and requirement of make-up time.

- Maximum Design Speed: 90 Kmph;
- Maximum Operating Speed: 80 Kmph;
- Maximum Acceleration: 1.0m/s^2;
- Maximum Deceleration: 1.1 m/s^2 (Service Brake) ;
- Maximum Deceleration: 1.3 m/s^2 (Emergency Brake) ;
- Maximum Jerk rate: 0.75m/s^3;



Since the track on a viaduct could possibly be constructed on a level and the traction motors could be operated with overload for a short time, 8 traction motors with about 220 KW installed on a three-car train would be enough, even if the equivalent gradients on a curved section of track are considered. The train shall be propelled by a 3-phase AC asynchronous motor drive system with variable voltage and variable frequency (VVVF) Control.

11.1.2.3 Coach design and basic parameters

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

- Proven equipment with high reliability;
- Passenger safety feature;
- Energy efficiency;
- Light weight equipment and coach body;
- Optimized scheduled speed;
- Aesthetically pleasing interior and exterior;
- Low Life cycle cost;
- Flexibility to meet increase in traffic demand;
- Anti-telescopic.

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

11.1.3 Selection of technology

11.1.3.1 Low life cycle cost

Low life cycle cost is achieved by the way of reduced scheduled and unscheduled maintenance and high reliability of the sub-systems. It is possible to achieve these objectives by adopting suitable proven technologies. Following essential aspects will be considered for the achievement of low life cycle cost;

- Life Cycle cost plan with an aim to minimize the overall life cycle cost whilst meeting the safety, quality and reliability requirements;
- Life Cycle cost will include, the capital cost, cost of operation (including energy consumption), maintenance (both material and labour), depreciation, refurbishment, inflation etc. per unit energy consumption.

11.1.3.2 Car body

In the past carbon high tensile steel was invariably used for car bodies. In-fact almost all the coaches built by Indian Railways are of this type. These steel bodied coaches need frequent painting and corrosion repairs, which may have to be carried out up to 4-5 times during the service life of these coaches. It is now a standard practice to adopt stainless steel or aluminum for car body.

The car bodies with aluminum require long and complex extruded sections which are still not manufactured in India. Therefore, aluminum car body has not been considered for use. Stainless steel sections are available in India and therefore stainless-steel car bodies have been specified. No corrosion repair is necessary on stainless steel cars during their service life.

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

11.1.3.3 Bogies

Bolsterless lightweight fabricated bogies with rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 4,20,000km.

Use of air spring at secondary stage is considered with a view to keep the floor level of the cars constant irrespective of passenger loading unlike those with coil spring.

Perturbation from the track are also dampened inside the car body on account of the secondary air spring along with suitable Vertical Hydraulic Damper.

The primary suspension system improves the curve running performance by reducing lateral forces through application of conical rubber spring. A smooth curving performance with better ride index is being ensured by provision of above type of bogies.

11.1.3.4 Braking system

The braking 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;

The regenerative braking will be the main brake power of the train and will regain the maximum possible energy and pump it back to the system and thus fully utilize the advantage of 3 phase technology.

The regenerative braking should have air supplement control to bear the load of trailer car. In addition, speed sensors mounted on each axle, control the braking force of the axles with anti-skid valves, prompting re-adhesion in case of a skid.

The brake actuator shall operate either a tread brake or a wheel disc brake, preferably a wheel disc brake for better braking effectiveness and wheel life.

11.1.3.5 Propulsion System Technology

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

The brush less 3 phase A.C. induction motors has now replaced the DC 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' (VVVF) control and can be programmed to suit the track profile and operating requirements.

Another advantage of 3 phase A.C. drive and VVVF control is that regenerative braking can be introduced by lowering the frequency and the voltage to reverse the power flow and to allow braking to very low speed.

For this corridor, 3 phase A.C. traction drive that are self-ventilated, highly reliable, robust construction and back up by slip/slide control have been recommended for adoption.

The AC catenary voltage is stepped down through a transformer and converted to DC voltage through converter and supply voltage to DC link, which feeds Inverter operated with Pulse Width Modulation (PWM) control technology and using Insulated Gate Bipolar Transistors (IGBT). Thus 3 phase variable voltage variable frequency output drives the traction motors for propulsion. Recently advanced IGBT has been developed for inverter units. The advanced IGBT contains an Insulated Gate Bipolar Transistor (IGBT) and gate drive circuit and protection. The advanced IGBT incorporates its own over current protection, short circuit protection, over temperature protection and low power supply detection. The IGBT has internal protection from over current, short circuit, over temperature and low control voltage.

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

11.1.3.6 Auxiliary power System Technology

This shall consist of static converter-inverter(s) together with back-up batteries and battery charger. Auxiliary Converter shall be suitable for operation at 25kV ac single phase for the frequency variation from 48 to 52Hz.

There will be at least two auxiliary power supply equipment in the 3-car train. When any train operator's cab is activated, all the auxiliary power supply equipment in the train shall operate. In the event of failure of an auxiliary power supply equipment in the train, the remaining auxiliary power supply equipment must be capable of supplying all auxiliary power to complete 3-car train except for HVAC load which may be restricted to one HVAC per car.

11.1.3.7 Interior and gangways

Passenger capacity of a car is maximized in a Metro System by providing longitudinal seats for seating and utilizing the remaining space for standing passenger. Therefore, all the equipment 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.

11.1.3.8 Passenger doors

For swift evacuation of the passenger in short dwell period, four doors of adequate width, on each side of the coach have been considered. These doors shall be of such dimensions and location that all the 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. Passenger doors are operated electrically by a switch in the driver cab.

Electronically controlled door operating mechanism has been preferred over pneumatically operated door to avoid cases of air leakage and sluggish operation of doors.

**View shown below is one of the example for saloon interior.

Figure 104 : Example for Interior view of the car**

The door shall be of bi-parting sliding type.

**View shown below is one of the example for bi-parting door.

Figure 105 : Example for view of the passenger door**

11.1.3.9 Air-conditioning

With heavy passenger loading of 6 persons/sqm for standing area and doors being closed from consideration of safety and with windows being sealed type to avoid transmission of noise, air conditioning of coaches is considered essential.

Each coach shall be provided with two air conditioning units capable of cooling, heating and dehumidifying and thus automatically controlling interior temperature throughout the passenger area at 25°C with 65% RH all the times under varying ambient conditions up to full load.

For emergency situations such as power failure or both AC (of the same car) failures etc., ventilation provision supplied from battery will be made. Provision shall be made to shut off the fresh air intake and re-circulate the internal air of the coach, during an emergency condition, such as fire outside the train causing excessive heat and smoke to be drawn in to the coach.

11.1.3.10 Cab layout and emergency detrainment door

The modem stylish driver panel shall be FRP (Fibre Reinforced Plastic) molded which gives maximum comfort and easy accessibility of different monitoring equipment to the driver along with clear visibility. The driver seat shall be in the cabin.

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

**View shown below is one of the example for Driver's Cab.

Figure 106 : Example view of the driving cab

11.1.3.11 Communication

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

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

11.1.3.12 Noise and vibration

The trains will pass through heavily populated urban areas. The noise and vibration for a MRT become an important criterion from public acceptance viewpoint. The source of noise is (i) rail-wheel interaction (ii) noise generated from equipment like blower, compressor, air conditioner, door, inverter etc. (iii) traction motor in running train. For elimination and reduction of noise following feature are incorporated:

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

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

11.1.4 Passenger safety features

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

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

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

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

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

The salient features of the proposed Rolling Stock are detailed in Table 100.

Table 100: Salient features of Rolling Stock for MRT's parameter details

S.No.	Salient Features of Rolling Stock for MRT's Parameter Details	
1	**Gauge** (Nominal) **Traction**	1435mm
2	**system**	
2.1	Voltage	25 KV AC
2.2	Method of current	Overhead Current Collection System
3	**Train composition:**	
3.1	3 car trainset	DMC+TC+DMC
	6 car trainset	DMC + TC + MC + MC + TC + DMC
4	**Coach Body**	Stainless Steel
5	**Coach Dimensions**	
5.1	Height	3.9 m
5.2	Width	2.9 m
5.3	Length over body (approx)	21.64 m
5.4	Locked down Panto height	4048 mm
5.5	Floor height	1100mm
6	**Designed - Passenger**	
6.1	Design of Propulsion	8 Passenger/ m^2
6.2	Design of Mechanical	10 Passenger/ m^2
7	**Carrying capacity- @ 6**	
7.1	Coach carrying capacity	
	DMC	247 (seating - 43 ; standing - 204)
	TC	270 (seating - 50 ; standing - 220)

S.No.	Salient Features of Rolling Stock for MRT's Parameter Details	
	MC	270 (seating - 50 ; standing - 220)
7.2	Train Carrying capacity	
	3 car train (with the future consideration of adding Trailer car to make the rake of 6 car)	764 (seating - 136 ; standing - 628) 1574 (seating - 286 ; standing - 1288) : Train of 6 car (2-DMC, 2-TC, 2-MC)
8	**Weight (Tonnes)**	
8.1	Tare weight (maximum) in	
	DMC	42
	TC	40
	MC	42
8.2	Passenger Weight in tons @	@ 0.065 T per passenger
	DMC	16.00
	TC	17.55
	MC	17.55
8.3	Gross weight in tons	
	DMC	51.43 (Normal), 58.05 (Crush)
	TC	50.40 (Normal), 57.55 (Crush)
	MC	52.4 (Normal), 59.55 (Crush)
9	**Axle Load (Ton)**	16
10	**Maximum Train Length -**	
10.1	3 car train set	65 m approx.
10.1	Maximum Design Speed	90 Kmph
10.2	Maximum Operating Speed	80 Kmph
12	**Wheel Profile**	UIC 510-2
13	**Noise Limits (ISO 3381 and 3095 - 2005)**	
13.1	Stationary (Elevated and at	
13.1.1	Internal (cab and saloon)	L_{pAFmax} 65 dB(A)
13.1.2	External (at 7.5 mtr from	L_{pAFmax} 68 dB(A)
13.2	Running at 80 kmph	Based upon applicable standard.
13.2.1	Internal (cab and saloon)	L_{pAFmax} 72 dB(A)
13.2.2	External (at 7.5 mtr from	L_{pAFmax} 85 dB(A)
13.3	Stationary (Underground)	Based upon applicable standard.
13.3.1	Internal (cab and saloon)	L_{pAFmax} 72 dB(A)
14	**Traction Motors Ventilation**	3 Phase Induction motor
15	**Acceleration on level**	1.0 m/sec^2
16	**Deacceleration on level**	1.1 m/sec^2 (>1.3 m/sec^2 during emergency brake)
17	**Type of Bogie**	Fabricated
18	**Secondary Suspension**	Air
19	**Brakes**	- An electro-pneumatic (EP) service friction brake- An

S.No.	Salient Features of Rolling Stock for MRT's Parameter Details	
		-Provision of smooth and continuous blending of EP
		Brake Electronic Control Unit (BECU) - Independent for
20	**Coupler**	
20.1	Driving cab end of DMC	Automatic coupler with mechanical and & pneumatic
20.2	Between cars of	Semi-permanent coupler
21	**Detrainment Door**	DMC Front end
22	**Type of Doors**	Sliding (Electrically operated electronically controlled- 4 doors per side per car)
23	**Passenger Seats**	Stainless Steel
24	**Cooling**	
24.1	Transformer	Forced
24.2	CI & SIV	Self/Forced
24.3	Traction Motor	Self-ventilated
25	**Control System**	Train based Monitor & Control System (TCMS/TIMS)
26	**Traction Motors**	3 phase VVVF controlled
27	**Temperature Rise Limits**	
27.1	Traction Motor	Temperature Index **minus** 70 deg C
27.2	CI & SIV	10 deg C temperature margin for Junction temperature
27.3	Transformer	IEC specified limit **minus** 20 deg C
		- Cooling, Heating & Humidifier (As required)
		- Automatic controlling of interior temperature
28	**HVAC**	throughout the passenger area at 25°C with
		65% RH all the times under varying amblent conditions
29	**PA/PIS including PSSS**	Required
30	**Passenger Surveillance**	Required
31	**Battery**	Ni-Cd Maintenance free
32	**Headlight type**	**LED**
33	**Propulsion Equipment**	
	Pantograph	2 No. on T car
	VCB	2 No. on T car
	Transformer	1 No. on T car
	SIV	1 No. on T car
	Battery and Charger	1 No. on T car
	CI	Car bases in each DMC & MC
	Traction Motor	Axle bases in each DMC & MC
34	**Gradient (max)**	4%

12. POWER SUPPLY AND TRACTION

12.1 Selection of traction system

For Traction System, it is standard practice in India to follow and to adopt 25 KV single phase AC Traction. In addition it has the following merits:

- Lower initial cost;
- Lower operating and maintenance cost as in case of 25 KV ac traction the regeneration is up-to 30% and the line losses are around 0.5% in comparison to D.C. losses up-to 6 – 7%;
- A.C. system poses lesser Fire hazards as current levels are much lower than DC system.
- No Stray current problems and hence the corrosion is controlled.

As this is an extension of existing line (Line 1 of Phase 1), system with existing design or compatibility shall be used.

12.2 Total Projected Power Demand

Electricity is obtained from the utility supply systems, at transmission or sub transmission voltage level, through traction feeding substation. This electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signalling & telecom, firefighting etc.) workshops, depots & other maintenance infrastructure within premises of the metro system.

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

- Specific energy consumption of rolling stock – 70 KWhr/1000 GTKM;
- Regeneration by rolling stock – 30%;
- Elevated station load – For Year 2023, 2033, 2043 and 2053 – 300 kW load is considered
- Underground station load – initially Year 2023 and 2033 - 2000 kW, which will increase to 2500 kW in the year 2043 and 2053;
- Depot auxiliary load - initially Year 2023 and 2033 - 2000 KW, which will increase to 2500 KW in the year 2043 and 2053.

Keeping in view the train operation plan, the demand of auxiliary and traction power requirements projected for the years 2023, 2033, 2043 and 2053 are summarized in the following table.

Table 101: Power Demand (MVA) for PCMC-Nigdi extension

Corridor		Year 2023	Year 2033	Year 2043	Year 2053
Extension Corridor- 1 PCMC-NIGDI Route Length – 4.413 km, Number of Stations – 3 (Elevated – 3)	Traction	0.7 MVA	0.9 MVA	1.0 MVA	1.1 MVA
	Auxiliary	1.1 MVA	1.1 MVA	1.1 MVA	1.1 MVA
	Total	**1.8 MVA**	**2.0 MVA**	**2.1 MVA**	**2.2 MVA**

Detailed calculations of power demand estimation for PCMC – NIGDI is as below:

Table 102: Deatiled Power Estimation for PCMC-Nigdi extension

POWER REQUIREMENTS - For year 2023, 2033, 2043 and 2053 for PCMC to Nigdi								
A. Traction Power Requirements	**Year 2023**		**Year 2033**		**Year 2043**		**Year 2053**	
No of Cars	3	(DMC-TC-DMC)	3	(DMC-TC-DMC)	3	(DMC-TC-MC-TC-MC-DMC)	3	(DMC-TC-MC-TC-MC-DMC)
Tare weight of train	124	T	124	T	124	T	124	T
Passenger weight	50	T	50	T	50	T	50	T
Total Train weight	174	T	174	T	174	T	174	T
Section length	4.413	KM	4.413	KM	4.413	KM	4.413	KM
Average Speed	33.00	KM/H	33.00	KM/H	33.00	KM/H	33.00	KM/H
Headway	7.5	min	5.71667	min	5	min	4.8	min
Specific Energy Consumption	70	KWhr/1000 GTKM	70	KWhr/1000 GTKM	70	KWhr/1000 GTKM	70	KWhr/1000 GTKM
No. of Trains/hr	16	Nos.	21	Nos.	24	Nos.	25	Nos.
Peak traction power requirement	0.9	MW	1.2	MW	1.3	MW	1.4	MW
Less Regeneration @ 30%	0.3	MW	0.3	MW	0.4	MW	0.4	MW
Depot Power Requirement	0.0	MW	0.0	MW	0.0	MW	0.0	MW
Net Traction Power Requirement	0.6	MW	0.8	MW	0.9	MW	1.0	MW
Total Traction Power Requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	**0.7**	**MVA**	**0.9**	**MVA**	**1.0**	**MVA**	**1.1**	**MVA**
Yearly Traction Energy Consumption with 18hrs a day, 365 days working and 30% regen	**4.0**	**Million units**	**5.3**	**Million units**	**6.1**	**Million units**	**6.3**	**Million units**
B. Station Aux. Power Requirement								
Elevated Station	0.30	MW	0.30	MW	0.30	MW	0.30	MW
Station at underground	2.00	MW	2.00	MW	2.50	MW	2.50	MW

No. of Elevated Stations	3		3		3		3	
No. of Station at underground	0		0		0		0	
Total Station Aux Power requirement	0.9	MW	0.9	MW	0.9	MW	0.9	MW
Depot Aux. power requirement	0.0	MW	0.0	MW	0.0	MW	0.0	MW
Total Aux. Power requirement	0.9	MW	0.9	MW	0.9	MW	0.9	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	**1.1**	**MVA**	**1.1**	**MVA**	**1.1**	**MVA**	**1.1**	**MVA**
Total traction & aux power requirement (MW)	1.52	MW	1.71	MW	1.82	MW	1.86	MW
Diversity Factor	0.50		0.50		0.60		0.60	
Yearly Auxiliary Power Consumption with 20hrs a day, 365 days working	**3.3**	**Million units**	**3.3**	**Million units**	**3.9**	**Million units**	**3.9**	**Million units**
C. Total Power Requirement								
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	**1.8**	**MVA**	**2.0**	**MVA**	**2.1**	**MVA**	**2.2**	**MVA**

Note: The requirement of Property development is not considered in estimation of power calculation.

Diversity factor is considered 0.50 in 2023 & 2033 and 0.60 in 2043 and 2053 for auxiliary power requirements.

Also the power demand calculation for the Existing corridor (PCMC to Swargate) of auxiliary and traction power requirements projected for the years 2023, 2033, 2043 and 2053 are summarized in table below due to increased headway.

Table 103 : Auxillary and Traction Power spply requirements till year 2053

Corridor		Year			
		2023	2033	2043	2053
Existing Corridor- 1 PCMC-Swargate Route Length – 17.8 km, Number of Stations – 14 (Elevated – 9, Underground - 5)	Traction	6.5 MVA	8 MVA	9.2 MVA	9.5 MVA
	Auxiliary	18.2 MVA	18.8 MVA	21.9 MVA	21.9 MVA
	Total	**24.7 MVA**	**26.8 MVA**	**31.1 MVA**	**31.4 MVA**

Detailed calculations of power demand estimation for PCMC – SWARGATE is as below:

POWER REQUIREMENTS - For year 2023, 2033, 2043 and 2053 for Swargate to PCMC								
A. Traction Power Requirements	**Year 2023**		**Year 2033**		**Year 2043**		**Year 2053**	
No of Cars	3	(DMC-TC-DMC)	3	(DMC-TC-DMC)	3	(DMC-TC-DMC)	3	(DMC-TC-DMC)
Tare weight of train	124	T	124	T	124	T	124	T
Passenger weight	50	T	50	T	50	T	50	T
Total Train weight	174	T	174	T	174	T	174	T
Section length	17.80	KM	17.80	KM	17.80	KM	17.80	KM
Average Speed	33.00	KM/H	33.00	KM/H	33.00	KM/H	33.00	KM/H
Headway	3.7	min	2.9	min	2.5	min	2.4*	min
Specific Energy Consumption	70	KWhr/1000 GTKM	70	KWhr/1000 GTKM	70	KWhr/1000 GTKM	70	KWhr/1000 GTKM
No. of Trains/hr	32	Nos.	41	Nos.	48	Nos.	50	Nos.
Peak traction power requirement	7.0	MW	9.0	MW	10.4	MW	10.8	MW
Less Regeneration @ 30%	2.1	MW	2.7	MW	3.1	MW	3.3	MW
Depot Power Requirement	1.0	MW	1.0	MW	1.0	MW	1.0	MW
Net Traction Power Requirement	5.9	MW	7.3	MW	8.3	MW	8.6	MW
Total Traction Power Requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	**6.5**	**MVA**	**8.0**	**MVA**	**9.2**	**MVA**	**9.5**	**MVA**
Yearly Traction Energy Consumption with 18hrs a day, 365 days working and 30% regen	**38.8**	**Million units**	**47.8**	**Million units**	**54.4**	**Million units**	**56.4**	**Million units**
B. Station Aux. Power Requirement								
Elevated Station	0.30	MW	0.30	MW	0.30	MW	0.30	MW
Station at underground	2.00	MW	2.00	MW	2.50	MW	2.50	MW
No. of Elevated Stations	9		9		9		9	
No. of Station at underground	5		5		5		5	
Total Station Aux Power requirement	12.7	MW	12.7	MW	15.2	MW	15.2	MW
Depot Aux. power requirement	2.0	MW	2.5	MW	2.5	MW	2.5	MW
Total Aux. Power requirement	14.7	MW	15.2	MW	17.7	MW	17.7	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	**18.2**	**MVA**	**18.8**	**MVA**	**21.9**	**MVA**	**21.9**	**MVA**
Total traction & aux power requirement (MW)	20.61	MW	22.48	MW	25.98	MW	26.29	MW
Diversity Factor	0.50		0.50		0.60		0.60	
Yearly Auxiliary Power Consumption with 20hrs a day, 365 days working	**53.7**	**Million units**	**55.5**	**Million units**	**77.5**	**Million units**	**77.5**	**Million units**
C. Total Power Requirement								
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	**24.7**	**MVA**	**26.8**	**MVA**	**31.1**	**MVA**	**31.4**	**MVA**

*Note:Average headway is considered for 3 car trains assuming 2 trains (6 car) as 4 trains (3 car) for simplifying the calculation.

The total power Requirement for the complete corridor (NIGDI - SWARGATE) is as below:

Table 104 : Total power requirement for complete corridor – Nigdi-Swargate

<table>
<tr><th colspan="2" rowspan="2">Corridor</th><th colspan="4">Year</th></tr>
<tr><th>2023</th><th>2033</th><th>2043</th><th>2053</th></tr>
<tr><td rowspan="2">PCMC-NIGDI
Route Length – 4.413 km,
Number of Stations – 3
(Elevated – 3)</td><td>Traction</td><td>0.7 MVA</td><td>0.9 MVA</td><td>1.0 MVA</td><td>1.1 MVA</td></tr>
<tr><td>Auxiliary</td><td>1.1 MVA</td><td>1.1 MVA</td><td>1.1 MVA</td><td>1.1 MVA</td></tr>
<tr><td rowspan="2">PCMC-SWARGATE
Route Length – 17.8 km,
Number of Stations – 14
(Elevated – 9,
Underground - 5)</td><td>Traction</td><td>6.5 MVA</td><td>8 MVA</td><td>9.2 MVA</td><td>9.5 MVA</td></tr>
<tr><td>Auxiliary</td><td>18.2 MVA</td><td>18.8 MVA</td><td>21.9 MVA</td><td>21.9 MVA</td></tr>
<tr><td rowspan="2">Total Power Demand
(NIGDI-SWARGATE)</td><td>Traction</td><td>7.2 MVA</td><td>8.9 MVA</td><td>10.2 MVA</td><td>10.6 MVA</td></tr>
<tr><td>Auxiliary</td><td>19.3 MVA</td><td>19.9 MVA</td><td>23 MVA</td><td>23 MVA</td></tr>
</table>

12.3 Need for high reliability of power supply

The Pune metro system is being designed to cater to crush load about 176.66 ton and 25600 passengers per direction during peak hours when trains are expected to run at 7.5 minutes intervals in 2023, 5.7 minutes interval in 2033, 5 minutes interval in 2043 and 4.8 minutes interval in 2053 respectively in the corridor 1A(PCMC – Nigdi) and also for the existing corridor (PCMC-Swargate) with decresed headway trains are expected to run at 3.6 minutes interval in 2023, 2.8 minutes interval in 2033, 2.5 minutes interval in 2043, 2.4 minutes interval in 2053.

Incidences of any power interruption, apart from affecting train running, will cause congestion at stations. Interruption of power at night during train operation hours is likely to cause alarm and increased risk to travelling public. Lack of sufficient illumination at stations, non-visibility of appropriate signage, disruption of operation of lifts and escalators is likely to cause confusion, anxiety and ire in commuters, whose tolerance level are low on account of stress.

Effect on signal and communication may affect train operation and passenger safety as well. Therefore, reliable and continuous power supply is mandatory for efficient metro operations.

To ensure reliability of power supply, it is essential that both the sources of Power Supply and connected transmission & distribution networks are reliable and have adequate redundancies built in itself. It is desirable to obtain power supply at grid voltage of 220KV, 132 KV or 66 kV from stable grid sub-stations of Power Supply authority and further transmission & distribution is done by the Pune Metro.

12.4 Sources of power supply

The high voltage power supply network of Pune City has only 220kV and 132kV network on the periphery of the city to cater to various types of power supply demand in vicinity of the proposed corridor. 220/132 kV substations are far away from the alignment and therefore, it involves substantial cable and it's laying cost.

12.4.1 For extension of line 1 (PCMC to Swargate)

Keeping in view the reliability requirements, two input sources of 220 kV or 132KV Voltage level are normally considered for each corridor. Therefore, to achieve the desired reliability, two existing receiving substations (132/33/25 kV) are there to feed extension corridors i.e. PCMC to Nigdi . The intersection of the extension corridors will be at PCMC for extension of PCMC to Nigdi.

Table 105: Sources of Power Supply

Corridor	Grid sub-station (with Input voltage)	Location of RSS of Metro Authority	Approx. length of cables
PCMC-Nigdi	132 kV Chinchwad SS	Near PCMC	4.5 km approx. from chinchwad to PCMC
	132 kV Ganeshkhind SS	Near Agri. College	3 km approx. from Ganeshkhind to Range hill

*the exact length of cables from GSS to RSS will be provided after the cable route survey, if required

The above sub-stations are being considered as a conventional sub-stations. In case a 132 kV GIS to be provided, there will be an additional cost of Rs. 20 Crores or 15 Crores per sub-station respectively.

Summary of expected power demand at various sources is given in Table 106.

Table 106: Power demand projection for various sources

Extension Corridor and New Corridor	Input Source / Receiving Sub Station (RSS)	Peak Demand - Normal* (MVA)		Peak Demand - Emergency (MVA)	
		2023	2053	2023	2053
PCMC- Nigdi	**RSS near PCMC**				
	Traction	7.2	10.6	7.2	10.6
	Auxiliary	19.3	23	19.3	23
	Sub – Total (A)	26.5	33.6	26.5	33.6
	Range hill depot RSS				
	Traction	7.2	10.6	7.2	10.6
	Auxiliary	19.3	23	19.3	23
	Sub – Total (B)	26.5	33.6	26.5	33.6

* It is assumed that in normal operation the complete load shall be fed by only one RSS at a time.

This power demand calculation represent the peak demand of load (MVA) to PCMC RSS in normal mode while in emergency scenario when PCMC RSS fails, the Rangehill RSS shall cater the entire load of line in emergency situations.

However, for the traction power requirement as the peak traction power requirement is 10.3 MVA in year 2053 which shall be taken care by any of the traction transformer of 21.6 MVA capacity in each RSS while for the auxiliary power requirement is 26 MVA in year 2053 which shall be taken care by the 2 auxiliary transformer of 20 MVA rating in each RSS. So the existing RSSs is enough to support power supply requirement of the proposed extension from PCMC to Nigdi, additional cost for RSS may not be incurred.

The 132 KV power supply will be stepped down to 25kV single phase for traction purpose at the RSS of Pune Metro and the 25kV traction supply will be fed to the OHE at viaduct through cable feeders.

For feeding the auxiliary loads, the 132/33 kV or 132/33 KV power supply received will be stepped down to 33 kV and will be distributed along the alignment through 33kV Ring main cable network. These cables will be laid along the viaduct. If one RSS trips on fault or input supply failure, train services can be maintained from the other RSS

In case of total grid failure, all trains may come to a halt but station lighting & other essential services can be catered to by stand-by DG sets. Therefore, while the proposed scheme is expected to ensure adequate reliability, it would cater to emergency situations as well.

Figure 107 : Typical high voltage receiving sub-station

The 132 KV cables will be laid through public pathways of Maharashtra Grid Sub-stations to RSS of Metro Authority.

For corridor – 1A extension PCMC- NIGDI, both existing substations viz PCMC RSS and Depot RSS shall be provided with 2nos. (one as standby) 220/132/25 kV, 21.6 MVA single-phase traction transformers for feeding traction and 2nos. (one as standby) 220/132/33 KV, 20 MVA three phase transformers for feeding auxiliary loads.

12.5 Auxiliary supply arrangements for stations and depot

Existing power supply arrangement at depot shall be considered for the extension line also, as in the existing line, the Auxiliary sub-stations (ASS) are envisaged to be provided at each station (1 ASS for elevated station) for stepping down 33 kV supply to 415 V for auxiliary applications. No extra ASS is required in depot for the extension line as the existing depot ASS can cater the 2.5 MW load in year 2053. The station ASS's will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 200kW for elevated / at-grade stations which is likely to increase up to 500 kW in the year 2053. In order to meet the requirement of auxiliary power, two dry type cast resin transformers (33/0.415kV) of 500 kVA capacity are proposed to be installed at the elevated stations (one transformer as standby) and two transformer of 2.5 MVA at Depot ASS. For Property Development within the footprints of the station, a provision to add third transformer at a later date may be kept at elevated station.

Figure 108 : Typical Indoor Auxiliary Sub-station

12.6 Electromagnetic interference (EMI) and electromagnetic compatibility (EMC)

25kV ac traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Booster Transformer and Return Conductor (BT/RC) System is proposed for EMI mitigation. Concrete structures of elevated viaducts are not good electrical earths and therefore, Earthing and Bonding of the traction system shall be in accordance with the latest standards EN50122-1, IEEE80 and other relevant standards. Two earth conductors –Overhead Protection Cable (OPC) and Buried Earth Conductor (BEC) are proposed to be laid along with elevated viaduct and all the metallic structures, structural reinforcement, running rails etc. will be connected to these conductors to form an equi-potential surface & least resistance path to the fault currents. The overhead protection cable will also provide protection against lightning to the 25kV OHE and the elevated viaduct.

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 & telecom, traction power supply, E&M system etc.) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMI/EMC plan will be required to be developed during project implementation stage.

12.1 25KV flexible overhead equipment (OHE) system

25kV ac flexible OHE system shall comprise 150 sq.mm Hard drawn copper contact wire and 65 sq.mm Cd-copper catenary wire. Return conductor (RC) shall be All Aluminum Conductor (AAC) of 233 sq.mm cross section. From safety considerations, Hydraulic type Anti-Tensioning Device (ATDs) are proposed on mainlines which does not require use of balance weight for tensioning of OHE conductors. Proven catenary fittings are proposed similar to existing corridor under construction.

12.2 Rating of major equipment

25kV ac Overhead Equipment (OHE) shall comprise 107mm^2 HD-copper contact wire and 65 mm^2 Cd-copper catenary wire. Return conductor (RC) shall be all of OHE conductors.

Based on emergency demand expected at each RSS as shown in Table 106, two nos. 220 or 132/25kV traction transformers of 21.6 MVA capacity and 2 nos. 132/33 KV, 20MVA capacity Auxiliary transformers shall be provided at each RSS in Corridor –I for PCMC- NIGDI . The 132kV incoming cable 3-phase single core XLPE insulated with 630 mm^2 Aluminum conductor and 220kV, 3-phase single core XLPE insulated with 800 mm^2 Aluminum conductor for corridor-1 shall be used to meet the normal & emergency loading requirements and fault level of the 132 kV and 220 KV supply.

33kV and 25kV switchgear shall be rated for 1250 A being standard design. 33kV cable ring network shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations and accordingly 3 number of Single core 300 mm^2 FRLS Aluminum conductor cable XLPE insulated 33kV cable is proposed for ring main network.

Adequate number of cables are required for transfer of traction power from Metro's RSS to 25kV OHE. Single-phase XLPE insulated cables with 240 mm^2 copper conductor are proposed for traction power. Based on current requirements, 2 cables are required for each of the two circuits to feed power to OHE.

The above capacities of transformers, switchgear, cables etc. have been worked out based on the conceptual design. Therefore, these may be required to be revised for better accuracy during design stage of project implementation.

12.3 Standby Diesel Generator (DG) sets

In the unlikely event of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide a standby DG set of 500 KVA capacity at the elevated stations to cater to the following essential services:

(i) Essential lighting
(ii) Signalling & telecommunications
(iii) Fire fighting system
(iv) Lift operation
(v) Fare collection system
(vi) Tunnel Ventilation (for Underground Stations)

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

12.4 Supervisory Control and Data Acquisition (SCADA) system

For the smooth functioning, high reliability and safety of the transit system, the SCADA system plays a vital role in supervision, control and acquisition of various specified data from the 'controlled station' along the line such as receiving substation(RSS), auxiliary substation(ASS), traction substation (TSS), metro stations, OHE system switching stations along the line, depot etc. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided for control and monitoring of the whole power supply system from a centralized Operation Control Centre (OCC). Existing OCC & BOCC shall be updated based on the extension line corridor 1A (PCMC-NIGDI).

Redundant Fiber optics transmission system is provided by telecommunications and shall be used as communication backbone carrier for SCADA system from field side to the central control center. In addition, the system shall be fully integrated with the SCADA system implemented for Phase I.

The Digital Protection Control System (DPCS) is 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 interface with SCADA system.

SCADA system allows the Power Operator to control and monitor the HV (High Voltage), MV (Medium Voltage) and LV (Low Voltage) equipment. The purpose of this system is to manage: the incoming lines to provide reliable electrical supply to all the equipment, the Auxiliary power supply sub-stations: transformers from high voltage to medium and low voltage. The traction power supply sub-stations: transformers from high voltage to 25 kV traction power. The control of the Traction Power shall be done through the Traction Power Supply function. The Power as a whole is managed from the Energy Control Centre ECC, from where centralized Operation of the line is carried out.

12.5 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 Pune Metro Extension.

12.5.1 Solar PV Power Generation Potential

The roof top on the elevated stations of Pune 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/m2 . Based on the solar radiation intensity in the city of Pune, the peak solar power generation of Pune Metro corridor is expected to be about 200 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 usable 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 Pune metro corridors is required to be reviewed and finalized during detail design stage.

It is proposed that the solar PV installation for Pune 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 MAHA Metro shall sublet the rooftop to the project developer who will be responsible for the solar PV installation. The power shall be purchased by MAHA metro on the basis of the unit rate specified by Power Purchase Agreement (PPA).

12.6 Energy saving measures

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

(i) Modern rolling stock with 3-phase VVVF drive and lightweight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor.

(ii) Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 25kV ac OHE to be consumed by nearby trains.

(iii) Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66% & 100%) and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc.).

(iv) Machine-room less type lifts with gearless drive have been proposed with 3-phase VVVF drive. These lifts are highly energy efficient.

(v) The proposed heavy-duty public services escalators will be provided with 3-phase VVVF drive, which is energy efficient & improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by passengers.

(vi) The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc.) has been incorporated in the system design.

(vii) Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.

(viii) LED lighting is proposed in certain areas.

12.7 Electric power tariff

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 25 – 35% of total annual working cost. Therefore, it is the key element for the financial viability of the project. For Extension corridor-1A, the annual energy consumption is assessed to be about 7.3 million units in initial years (2023), which will increase to about 10.2 Million Units by year 2053. For existing Corridor of line the annual energy consumption is assessed to be about 92.5 million units in initial years (2023), which will increase to about 133.9 Million Units by year 2053. The total annual energy consumption for line 1, Phase 1 with extension is assessed to be about 99.8 Million Units by year 2023 which will increase upto 144.1 Million units by year 2053. In addition to ensuring optimum energy consumption, it is also necessary that the electric power tariff be kept at a minimum in order to contain the O&M costs. Therefore, the power tariff for this corridor should be at effective rate of purchase price (at 132/220 kV voltage level) plus nominal administrative charges i.e. on a no profit no loss basis. This is expected to be in the range of Rs. 5.6 per unit (Grid supply charges = Rs. 6 per unit and 20% of supplies from solar (@ Rs 4 per unit) as per RESCO model) with Rs. 250/KVA/month fixed charges. It is proposed that Government of Maharashtra will take necessary steps to fix power tariff for Pune Metro at “No Profit No Loss” basis.

13. MAINTENANCE DEPOT

13.1 Depot Location and Number

Maintenance facilities for PCMC-Nigdi extension can be accommodated in already planned depot near Range Hill station for Phase-1, therefore, another new depot is not required. Stabling capacity for 25 number of 3-car trains is already provisioned in phase-1 of existing Range Hill Depot with suitable augmentation.

The depot planning is based on following assumptions:

- Enough space should be available for establishment of a depot- cum- workshop;
- All inspection, workshop lines, test track and stabling lines are designed to accommodate at least two trainsets of 3 car each;
- All stabling lines are planned in the proposed depot-cum-workshop assuming adequate space availability. In case of space constraints, if any, stabling facilities may need to be created at terminal stations or elsewhere to cater to the required stability facilities;

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

- Layout of stabling-shed, inspection-shed, minor repairs and heavy repair overhauling workshop and cleaning of Rolling Stock;
- Operational and functional safety requirements;
- Ancillary buildings for other maintenance facilities;
- Electrical & mechanical services, power supply and distribution system;
- Water supplies, drainage & sewerage.

13.2 Approach to Maintenance

- Monitoring of the performance of equipment by condition monitoring of key parameters. The concept is to evolve the need-based maintenance regime, which can be suitably configured in the form of schedules like daily check, "A" checks, "B" and “C” type checks, “IOH – Intermediate Overhaul” and “POH - Periodic Overhaul”.
- Labour intensive procedures are kept to the minimum. Automation with state of the art machinery to ensure quality with reliability;
- Multi skilling of the maintenance staff to ensure quality and productivity in their performance;
- Energy conservation is given due attention.

13.3 Rolling stock maintenance needs

13.3.1 Maintenance schedule

The following maintenance schedule has been envisaged for conceptual design of depots:

Table 107: Maintenance schedule

Type of	Interval	Work Content	Location
Daily	Daily	Check on the train condition and function at every daily service completion. Interval cleaning/mopping of floor and walls with vacuum cleaner.	Stabling Lines
'A' service check	5,000 Km (approx. 15 days)	Detailed inspection and testing of sub-systems, under frame, replacement / topping up of oils & lubricants.	Inspection bays
'B' service check	15,000 Km (approx. 45 days)	Detailed inspection of 'A' type tasks plus items at multiples of 15,000 Km ('B' type tasks)	Inspection bays
Intermediate Overhaul (IOH)	420,000Km, (3 and half years approx.)	Check and testing of all sub-assemblies (Electrical + Mechanical). Overhaul of pneumatic valves, compressor. Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
Periodical Overhaul (POH)	840,000 Km,(7 Years approx.)	Dismantling of all sub-assemblies, bogies suspension system, traction motor, gear, control equipment, air- conditioning units etc. Overhauling to bring them to original condition. Checking repair and replacement as necessary. Inspection and trial.	Workshop
Heavy Repairs	-	Changing of heavy item such as bogies, traction motor, axles, gear cases & axle boxes etc.	Workshop

The above schedule may need slight revision based on the actual earned KM per train and the specific maintenance requirements of Rolling Stock finally procured.

13.3.2 Washing needs

Cleanliness of the trains is essential. Following schedules are recommended for Indian environment:

Table 108: Train cleaning schedule

S.No.	Kind Inspection	Maint. Cycle	Time	Maintenance Place
1	Outside cleaning (wet washing on automatic washing plant)	3 Days	10 mins	Single pass through Automatic washing plant of Depot
2	Outside heavy cleaning (wet washing on automatic washing plant and front face, vestibule/buffer area. Floor, walls inside/outside of cars and roof. Manually)	30 days	2 - 3 hrs	Automatic washing plant & cleaning & washing shed

13.4 Inspection requirements at depot

13.4.1 Facilities for inspection activities

Facilities for carrying out inspection activities shall be provided in the inspection bay for the following systems / equipment of a train:

- Electronics ; PA/PIS;
- Mechanical components, couplers etc;
- Batteries;
- Air conditioner;
- Brake modules;
- Doors;
- Bogie;
- Traction Motors, Transformer, VCB;
- Vehicle doors, windows and internal fittings;
- Power system including converter, circuit breaker etc.

13.4.2 Inspection activities categorization

These activities shall be grouped into "A" checks and "B" checks:

- The minor scheduled inspections ("A" checks) shall be carried out during the day off-peak and at night;
- Since "B" checks take longer time, these cannot be completed in the off-peak times.

Certain inspection lines will be nominated for "A" checks. For "B" checks, separate line will be nominated where the rakes may be kept for long time.

One dedicated line in the shed will be used for minor repairs and for adjustment and testing after the I0H and POH. There shall be a spare line in inspection bay for this purpose.

13.5 Design of Depot-Cum-Workshop

The design of Workshop shall include following key features:

- The unscheduled lifting and heavy repair line shall be fitted with jack system capable to lift the 3-Car unit simultaneously for quick change of bogie, thereby saving down time of Rolling Stock.
- The arrangement of jack system shall be such that lifting of any coach in train formation for replacement of bogie/equipment is also individually possible.
- One line shall be available for stocking of bogies and wheels.
- These lines are to be provided with pits at regular intervals for inspection of undercarriage with turn tables.
- Each workshop bay shall be equipped with two trains 15T and 3T overhead cranes, each spanning the entire length of the workshop bay.
- There shall be provided space for repairs of HVAC, door, and traction motor etc. repairs. Distinct spaces shall be earmarked for dismantling, repairs, assembling and testing of each of these equipments. Related machinery for Overhauling / Repairs & testing activities of every equipment are also to be housed in the space earmarked.
- There shall be washing and cleaning equipment on the workshop floor.
- Bogie test stand shall be provided in the workshop.
- Other heavy machinery shall also be suitably installed on the workshop floor.
- Air-circulators, lights, powers supply points and compressed air supply line shall be provided on each workshop column.
- Workshop lines shall be inter-linked through turn tables, each suitable for movement of a train in unloaded condition and shall also be capable to rotate with a fully loaded bogie on it.
- Repair of heavy equipment such as air conditioners shall be so located so that it does not affect the movement inside workshop.
- There shall be walkways on columns for roof inspections, along the workshop lines. These walkways shall not infringe with cars being lifted/ lowered by means of mobile jacks. Suitable space between the nearest exterior of a car and farthest

edge of the walkway has to be ensured to avoid conflict in lifting and lowering of cars.

- The small component, bogie painting and battery maintenance cells shall be located in the workshop with arrangement that fumes are extracted by suitable exhaust systems
- Workshop will have service building with array of rooms along its length. Rooms can be made by column and beam structure and architecture made of brick works. These shall cater for overhauling sections, offices, costly store item, locker rooms, toilets etc.
- Two trains opposite sides width wise shall be open to facilitate natural air circulation and cross ventilation besides the egress & ingress for coaches.
- The sidewalls shall also have sufficient width of louvers for providing adequate ventilation.
- There shall be space for bogie/ axle repair shop with necessary infrastructure for disassembly, overhead, assembly and testing of mechanical components of bogies/ axle.
- The repair shop shall be easily approachable from the workshop for transportation of components.

Following equipment repair/overhaul facilities are planned in the workshop and wheel repairs shop at the workshops depots:

- Bogie;
- Body furnishing
- Wheels;
- Traction Motors;
- Axle Box and Axle Bearing, Gearbox;
- Pantographs, PT, CT, VCB;
- Transformer, Converter/Inverter (CI), SIV (Auxiliary Converter/Inverter) ;
- Battery and Charger;
- Relay, MCB, Electronic sensor, switches and PCBs;
- Gangway and Coupler;
- Air compressor;
- Air-conditioner;
- Brake equipment;
- Door actuators;
- Control and measuring Equipment;
- Pneumatic Equipment;
- Dampers and Springs;
- Couplers/Gangways;
- Coach Painting (Applicable only for Aluminum coaches, if any).

13.6 List of plants & equipment at Depot-Cum-Workshop

Table 109: List of Plants & Equipments at Depot- Cum-Workshop

S.NO.	Equipment
1.	Under floor Pit wheel lathe, Chip crusher and conveyor for lathe on pit Electric tractor for movement over under floor wheel lathe
2.	Under floor lifting systems for 3-car unit for replacement of bogie
3.	Mobile jacks 15T for lifting cars (set of 12 jacks)
4.	Re-railing equipment consisting of rail cum road vehicle and associated jack system etc.
5.	Run through type Automatic Washing plant for Metro cars.
6.	Rail fed Bogie wash plant
7.	Bogie test stand
8.	Work lift platform
9.	Electric bogie tractor for pulling cars and bogies inside workshop
10.	Chemical cleaning tanks, ultrasonic cleaning tanks, etc
11.	Compressor for Inspection shed & shop air supply
12.	Travelling 0/H crane Workshop 15T/3T
13.	Mobile jib crane
14.	Mobile lifting table
15.	Carbody stands
16.	Bogie turn tables
17.	Underframe & Bogie blowing plant & small parts/equipment
18.	AC filter cleaning machine
19.	Portable cleaning plant for rolling stock
20.	High-pressure washing pump for front and rear end cleaning of car
21.	Industrial furniture (Work Test Benches)
22.	Minor diagnostic equipment and collective tools
23.	Induction heater
24.	Oven for the motors
25.	EMU battery charger
26.	Welding equipment (Mobile welding, oxyacetylene, fixed arc welding)
27.	Electric and pneumatic tools
28.	Measuring and testing equipment
29.	Tool Kits
30.	Mobile safety steps
31.	Fork lift tractor
32.	Pallet trucks
33.	RRV
34.	Road vehicles (pickup van/ truck)
35.	Miscellaneous office equipment
36.	Vertical Boring Mainline for wheel discs

S.NO.	Equipment
37.	Press for removal and pressing of the wheel on axles
38.	Axle journal turning and burnishing lathe
39.	Special jigs and fixtures and test benches for Rolling Stock
40.	Stackers (1T for DCOS)
41.	Storage Racks (W/shop & DCOS stores)
42.	Test benches
43.	Auto panto strip thickness meter
44.	Vehicle mounted crane
45.	Impulse Tester for TMs
46.	Bearing puller

13.7 Design of Depot Infrastructure facilities

The design of other infrastructure depot facilities are described in following section.

- **Car Delivery Area**

There shall be rail connectivity between the Depot-Cum-Workshop and mainline and all trains due for scheduled/unscheduled works shall reach the depot-cum-workshop by rail.

However, in case of newly procured coaches, which are transported by road, these shall reach the Depot-Cum-Workshop by the road on trailers. To unload the coaches and bring them to the track, provision of space, along the side of shunting neck, has to be made for unloading of cars and other heavy materials. This area shall have an insulated track embedded in the floor facilitating the movement of road trawler, which brings in the cars. The length of the track embedded area shall be about 100m long. There should be enough space available for movement of heavy cranes for lifting of coaches. The unloading area should be easily accessible for heavy duty hydraulic trailers.

- **Automatic Coach Washing Plant (AWP)**

Provision to be made for Rolling Stock exterior surfaces to be washed using a fully automated Train Washing System, with a throughput capacity of approximately ten trains per hour. The AWP shall be situated at such a convenient point on the incoming route so that incoming trains can be washed before entry to the depot and undesirable movement/shunting over ingress and egress routes within the depot is avoided. Additional space for plant room for AWP system shall be earmarked alongside the washing apron.

- **Train Operators Booking Office**

Suitable office facility adjacent to the stabling lines at each depot should be provided so that train operators reporting 'On' duty or going 'Off' duty can obtain updates regarding 'Special Notices', `Safety Circulars' and other technical updates/information in vogue. These offices should have an attached a cycle/scooter/car stand facility for convenience of the train operating staff.

- **Test Track**

A test track of about 800 mts. in length covered & fenced should be provided beside workshop in the depot. It shall be equipped with signalling equipment (ATP/ATO). It shall be used for the commissioning of the new trains, their trials and testing of the trains after the IOH and POH. Entry into the test track shall be planned for a 3-car train. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized trespassing across or along the track.

- **Heavy Cleaning Shed**

Monthly heavy cleaning of interior walls, floors, seats, windows glasses etc, outside heavy cleaning, Front/rear Face, Vestibule/ Buffer area, outside walls and roof shall be done manually in the interior cleaning plant designed for cleaning of one at a time. A line adjacent to inspection shed should be so provided that placement of rakes is possible from workshop or inspection lines & vice — versa conveniently and with ease.

- **Power Supply**

Auxiliary substations are planned for catering to the power supply requirement of the whole depot and workshop. Details of connected load feeder shall be worked out. Taking diversity factor of 0.5 the maximum demands shall be computed. One trains Auxiliary substations are proposed, as the demand by machines in Workshop area would be very large. The standby power supply is proposed through DG set with AMF panel. The capacity of DG set will be adequate to supply all essential loads without over loading.

- **Compressed Air Supply**

Silent type compressor units shall be suitably installed inside the depots at convenient location for the supply of compressed air to workshop and Inspection sheds. Thus, the pneumatic pipeline shall run within the workshop and inspection bays as to have compressed air supply line at all convenient points.

- **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 emphasis to charge the underground reserves.

- **Ancillary Workshop**

This workshop will have a line at floor level with provision of pits. Arrangement for repairs of shunters, Rail Road Vehicles and other ancillary vehicles will be provided. These vehicles will also be housed here itself. Heavy lifting works can be carried out in main workshop.

Ancillary workshop will be used for storing OHE / rigid OHE parts and their maintenance / repair for restoration of 25 kV feed system.

- **Watch Towers**

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

- **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:

- Ample parking space shall be provided for the two wheelers and four wheelers at the following points.
  - Close to the depot entry;
  - Close to the stabling lines;
  - Close to the Workshop/IBL.
- Space for parking of road and re-railing equipment. 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 equipment will have to be made close to the main exit gate of the Depot.

- **Shed and Buildings**

At the detailed design stage depending upon the land availability, the decision to locate these buildings can be taken. These can then be architecturally and functionally grouped.

- **Plant and Machinery**

A separate building is planned for housing pit wheel lathe (PWL), approachable from workshop, inspection bay and stabling lines through rail and road for placement of cars for re-profiling of wheels within the depot along with space for depot of scrap.

The following safety features should be incorporated in the design of the Maintenance Depot-Cum-Workshop:

- 1.5 EOT cranes in the inspection bay should be interlocked with 25 kV ac OHE in such a way that the cranes become operational only when the OHE is isolated and grounded;
- Red flasher lights should be installed along the inspection lines at conspicuous location to indicate the OHE is 'Live';
- Multi-level wheel and TM stacking arrangement should be an inbuilt feature at the end of workshop Lines;
- Pillars in the inspection bay & workshop should have provision for power sockets;
- Placement of rakes from inspection/workshop lines on to washing lines for interior cleaning on their own power should be possible. Linking of OHE and its isolation at the cleaning area should be provided. Necessary requirements of safety should be kept in view;
- The roof inspection platform should have open-able doors to facilitate staff to go up the roof for cleaning of roof. Suitable safety interlock should be provided to ensure maintenance staff are enabled to climb on the roof inspection platform only after the OHE is isolated.
- Control Centre, PPIO & store depot must be close to workshop;
- Width of the doors of the sections wherein repairs of equipment are done should be at least 2 meters wide to allow free passage of equipment through them;
- Provision of water hydrants should be done in workshops & stabling yards also;
- Compressed air points along with water taps should be available in interior of buildings for cleaning.
- Ventilation arrangement inside the inspection shed and workshop should be ensured. Arrangement for natural cross ventilation from one side to another of inspection & workshop bays to be incorporated along with optimum availability of natural light at floor level.

13.8 Operational features

The rake induction and withdrawal to main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to main line from Inspection Shed/workshop area.

Movement from depot to the main line is so planned that the headway of main line is not affected. Simultaneous receipt and dispatch of trains from depot to main line is feasible in the present site scenario. Both activities will be done effectively without affecting the train operation on the main line.

The stabling lines would be interlocked with the main line thereby induction of train from the stabling would be safe and without loss of time. The proposition for a transfer track on the incoming line as well as on the outgoing line to facilitate the movement of rake in the depot by Operation Control Centre (OCC) even though the further path inside the depot is not clear shall be explored in the detailed design stage depending on the actual availability of land.

An emergency line is also provided from which an emergency rescue vehicle may be dispatched to main line in the event of emergency if necessary.

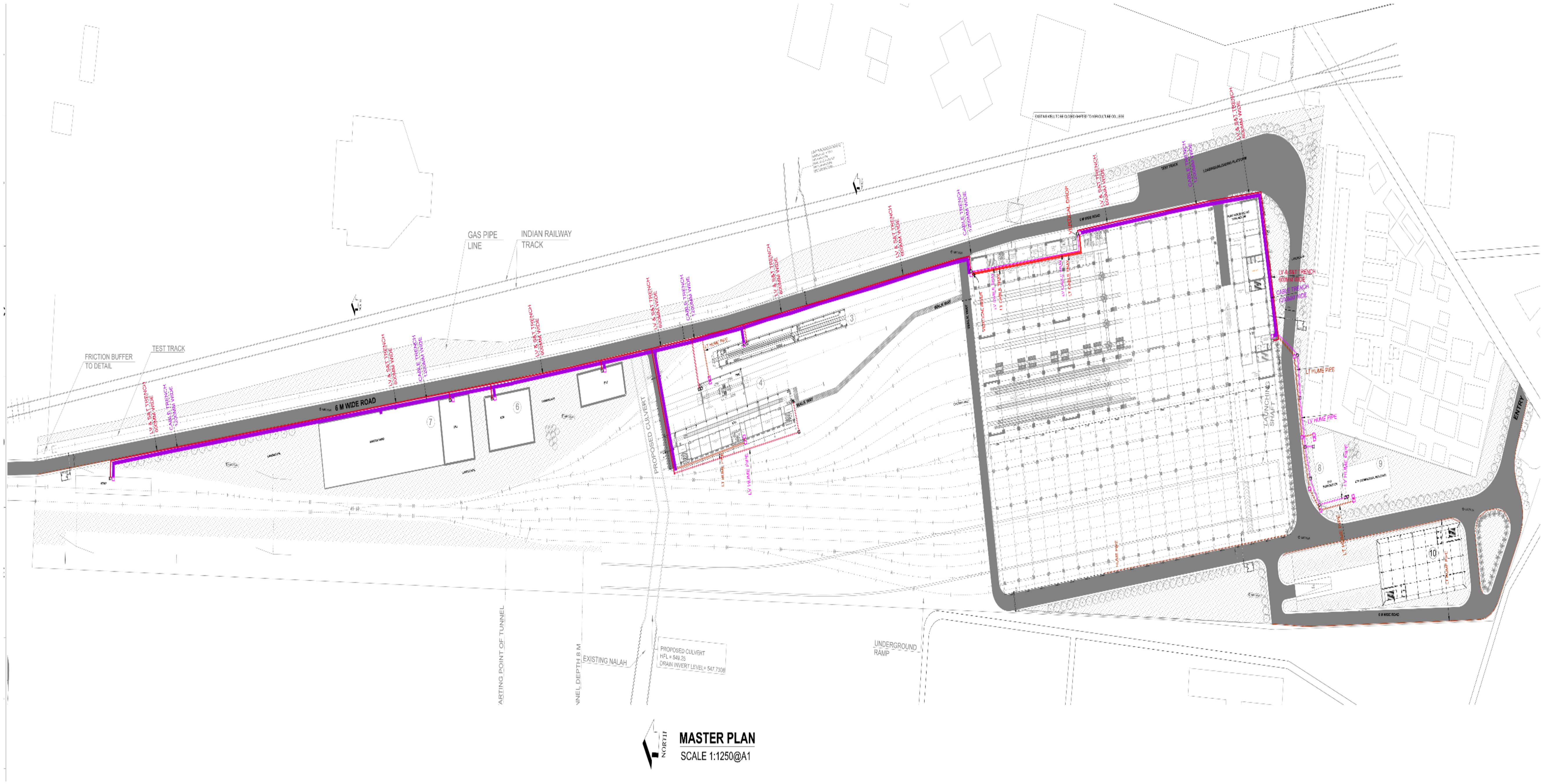


Figure 109 : Depot Layout

14. ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

14.1 Preamble

Large-scale urbanization in IT/ITES and industrialization with rapid growth of vehicular population has laid severe stress on urban transport system in Pune City over the years. As per Census 2011, the population of PCMC area is 17.27 Lakh For the last two decades, the decadal growth rate of population has been in the range of 100% while the previous two decades witnessed population growth in the range of 150%. Source: City Development Plan, PCMC. The City has a total of about 15.68 lakhs vehicles as per Maharashtra government vehicle statistics. The usage of private modes is increasing unabated mainly due to inadequate public transport facilities.

With a view of developing effective and efficient mass transit system towards improving the share of public transport trips, the Government of Maharashtra conceived and implemented Metro rail system covering 17.8 km (Phase 1, NS Corridor) with an extension of further 4.413 km as part of Phase-IA. There is a need for extension of Phase 1 in order to meet the future traffic demand. Nationally and globally it is seen that the metro network expands progressively to serve entire City. Hence, it is essential that in Pune also, such expansion of Metrorail network is taken up.

The present chapter is dedicated to Environmental Impact Assessment of corridor 1-A PCMC to Nigdi and the total length of this corridor is 4.413 km along the old Mumbai Pune Highway.

Corridor – 1A: PCMC to Nigdi

- Proposed alignment of corridor-1A starts from PCMC and goes up to Nigdi station near Bhakti shakti Udyan. Total length of the corridor is 4.413 km which is completely elevated.
- This corridor is an extension of existing corridor 1 under Phase 1 i.e. PCMC to Swargate.
- 3 Stations have been proposed in Phase 1 A, all of which are elevated stations. Summary of the section is given below:

Table 110 : List of stations in Phase 1A

PCMC-Nigdi Right option		
Station	**Chainage**	**Type**
Chinchwad	1789.2	Elevated
Akurdi	3459.2	Elevated
Nigdi	5489.4	Elevated

14.2 Objective of Environment Impact Assessment

The objective of the EIA study is:

- Collection of baseline data on various components of the environment.
- Determination of the magnitude of environmental impacts so that due consideration is given to them during planning, construction and operational phases of the project implementation.
- Identification of areas and aspects, which are environmentally or socio-economically significant.
- Submission of environmental enhancement plan and environmental management plans for enhancing and mitigating the negative impacts.
- Development of the alignment in such a way that the environment and settlements are least affected.

14.3 Scope of The Study

Environmental Assessment Report is prepared for the present assignment in order to identify the baseline environmental status of the proposed Metro Rail alignment & stations, assessment of impact due to the proposed project on various Environmental parameters and preparation of Environmental Management Plan to mitigate the negative impact on these parameters. The scope of the study includes:

- Review of policies and legal framework.
- Identification of the potential impacts during pre-construction, construction and operation phases.
- Developing mitigative measures to sustain and maintain the environmental scenario.
- Providing compensatory developments wherever necessary, including plans for tree plantation.
- Designing and monitoring the Environmental Management Plan.
- Suggesting the Environmental Enhancement Scheme and its monitoring.

14.4 Methodology

Suitable methodology was adopted to accomplish the study. As the first step, scoping exercise was undertaken to identify the parameters needed to be considered for the study and to outline the activities for collecting data on each parameter. Data pertaining to all facets of environment viz. physical, ecological and socioeconomic environment both through primary and secondary sources were collected. The step wise activities include:

- Review of legal requirements

- Reconnaissance survey for identification of key issues data requirement and preliminary consultation.
- Primary and secondary data collection
- Identification of impacts and mitigation measures
- Finalisation of EMP.

14.5 Applicable legal framework and policies

A review of the all applicable laws, regulations, notification and existing institutions relevant to the environmental issues in this project at the National/State levels policies are presented in this chapter.

India has a well-defined institutional and legislative framework. The legislation covers all components of environment viz air, water, noise, soil, terrestrial and aquatic flora and fauna, natural resources, and sensitive habitats. The environmental legislations in India are framed to protect the valued environmental components and comply with its commitment to the international community under various conventions and protocols as well. Review of Indian legal system has been carried out to identify its applicability to the project. WB/ADB has also defined their Environmental and Social Safeguard policies.

The Acts, Rules and Norms which are generally relevant to Metro rail projects are listed below;

- Amendment dated 9 December 2016 to EIA Notification 2006: Integration of environmental Conditions in local building byelaws;
- Workmen's Compensation Act 1923: The Act provides for compensation in case of injury by accident arising out of and during the course of employment;
- Contract Labour (Regulation and Abolition) Act, 1970: The Act provides for certain welfare measures to be provided by the contractor to contract Labour;
- Minimum Wages Act, 1948: The employer is supposed to pay not less than the Minimum Wages fixed by appropriate Government as per provisions of the Act;
- Payment of Wages Act, 1936: It lays down as to by what date the wages are to be paid, when it will' be paid and what deductions can be made from the wages of the workers;
- Equal Remuneration Act, 1979: The Act provides for payment of equal wages for work of equal nature to Male and Female workers and not for making discrimination against Female employees;
- Child Labour (Prohibition and Regulation) Act, 1986: The Act prohibits employment of children below 14 years of age in certain occupations and processes and provides for regulation of employment of children in all other occupations and processes. Employment of child labour is prohibited in Building and Construction Industry;

- Inter-State Migrant Workmen's (Regulation of Employment and Conditions of Service) Act, 1979: The inter-state migrant workers, in an establishment to which this Act becomes applicable, are required to be provided certain facilities such as housing, medical aid, travelling expenses from home to the establishment and back, etc.;
- The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 and the Cess Act of 1996: All the establishments who carry on any building or other construction work and employs 10 or more workers are covered under this Act; the employer of the establishment is required to provide safety measures at the building or construction work and other welfare measures, such as canteens, first-aid facilities, ambulance, housing accommodation for Workers near the workplace, etc.;
- The Factories Act, 1948: The Act lays down the procedure for approval of plans before setting up a factory, health and safety provisions, welfare provisions, working hours and rendering information-regarding accidents or dangerous occurrences to designated authorities;
- Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996: The Rules provide for mandatory preparation of On-Site Emergency Plans by the industry and Off-Site Plans by the district collector and the constitution of four tier crisis groups at the centre, district, and local levels for the management of chemical disaster.
- Amendment dated 9 December 2016 to EIA Notification 2006: Integration of environmental Conditions in local building byelaws;
- The Air (Prevention and Control of Pollution) (Union Territories) Rules 1982, 1983 (Consent to establish and operate);
- The Water (Prevention and Control of Pollution) Rules 1975 (Consent to establish and operate);
- 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 Guide Manual – Water and waste water analysis, CPCB;
- Construction and Demolition Waste Management Rules 2016
- Hazardous and Other Wastes (Management and Transboundary Movement) Rules 2016 ;
- Solid Waste Management Rules 2016;
- Protocol for Ambient Level Noise Monitoring, CPCB, 2015;
- Drinking water – Specifications IS 10500: 2012 and CPHEEO Manual 2012;
- Energy Conservation Building Code 2017 & IGBC Green MRTS Abridged reference guide;

- Noise Pollution (Regulation and Control) Rules, 2000 amendment in 2010 ISO/ TC 108 (vibration);
- Metro Rail Transit System, Guidelines for Noise and Vibrations, RDSO, Ministry of Railways, September 2015;
- 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;
- 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;
- World Bank, Operational policy OP 4.12 , involuntary resettlement
- World Bank, Environmental Assessment OP 4.01
- ADB Safeguard Policy Statement, July 2009

14.5.1 Key Applicable National Laws and Regulation

14.5.1.1 Environment (Protection) Act, 1986

This Act was passed as an overall comprehensive act "for protection and improvement of environment". According to this Act, the Central Government has the power to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of environment and preventing, controlling and abating environmental pollution. Under this act rules have been specified for discharge/emission of effluents and different standards for environmental quality. These include Ambient Noise Standard, Emission from Motor Vehicles, Mass Emission Standard for Petrol Driven Vehicles, General Effluent Standards etc. especially important for Metro project.

14.5.1.1.1 EIA Notification 2006 and Subsequent Amendments

Metro rail projects are not included as a sector in the Schedule of the Environmental Impact Assessment (EIA) Notification 2006 that provides a list of projects which need to undergo EIA studies. However, Metro projects include components that may individually qualify for obtaining Environmental Clearance.

For elevated metro rail projects, station buildings are required to be developed. If the built-up area of any of these station buildings is >50,000 square metres, then an Environmental

Clearance is required to be obtained under Item 8(a) of the Schedule of EIA Notification 2006 & its amendment 15th November 2018.

Train maintenance depots would need to be developed as part of the projects. The depots would include administrative buildings and occupy a large area for undertaking maintenance of the rolling stock. If the built-up area of the buildings in the depot will be >50,000 square metres, then an Environmental Clearance may required to be obtained under Item 8(a) of the Schedule of EIA Notification 2006.

14.5.1.2 Forest (Conservation) Act, 1980

The Forest (Conservation) Act, 1960 came in to force with effect from October 25, 1980. Under the provision of this act, prior approval of the Central Government is essential for de-reservation of forest lands and / or diversion of forest lands for non-forestry purposes. There is no reserve/protected forest along the proposed project alignment.

14.5.1.3 Wild Life (Protection) Act, 1972

The Wildlife (Protection) Act, 1972 has allowed the Government to establish a number of National Parks and Sanctuaries to protect and conserve the flora and fauna of the state. The Wildlife Protection Act, (1972) is the first comprehensive act enacted to protect the wild animals and their habitats. It will improve protection measures of the existing National Parks and Sanctuaries and strengthen the Protected Areas (PA). The objectives of the act include to protect the rapidly declining wild animal and birds of the country, control trade in wildlife products, streamline and strengthen wildlife setup at Central and State level and establishment of Wildlife Advisory Board. In the extensive amendment in 1991, endangered wild plants have also been included within the protective umbrella of this Act.

Any Developmental Activities Will requires “Wildlife Clearance”, if it is Proposed to be Located in or Within 10 Km of any “Wildlife Sanctuary” or “National Park” as Notified Under the Wildlife (Protection) Act (1972). There is no Wildlife protected area , along the proposed Metro Rail project alignment

14.5.1.4 Water and Air (Prevention and Control of Pollution) Acts

Water Act and Air Acts provide for the prevention and control of water and air pollution respectively. These acts empower the Pollution Control Boards to collect effluent and emission samples, entry to industrial units for inspection, power to prohibit on use of any water bodies for waste disposal and creation of new discharge outlets, provide consent to set up and operate certain facilities likely to create air and water pollution including power to give directions and prosecuting offenders.

The Air and Water Act are particularly applicable to all civil works activities. All construction work contractors need to obtain the consent-to-establish and consent-to-operate for plants and other machinery that they may be required for the purpose of construction. The NOC certificates need to be obtained from the regional offices of the SPCB. Wherein the existing plants are used, the contractor shall ensure that all applicable consents are obtained for operating the plant/equipment.

14.5.1.5 Central Motor Vehicle Act -1988 and Central Motor Vehicle Rules 1989

In 1988, the Indian Motor Vehicles Act empowered the State Transport Authority to enforce standards f or vehicular pollution and prevention control. The Authority also checks emission standards of registered vehicles, collects road taxes, and issues licenses. In August 1997, the Pollution Under Control Certificate (P U C) programme was launched in an attempt to crackdown on the vehicular emissions in the states.

Central Motor Vehicle Rules 1989 provide for working rules for licensing of drivers of motor vehicles, registration of motor vehicles, overall dimensions of motor vehicles, rules & regulations, etc.

14.5.1.6 Ancient Monuments and Archaeological Sites and Remains Rules, 1959 and 2010

As per the Act, area within a radius of 100m and 200m from the "protected property" are designated as "protected area" and "regulated area" respectively. No development activity (including mining operations and construction) is permitted in the "protected area" and all development activities likely to damage the protected property are not permitted in the "regulated area" without prior permission of the Archaeological Survey of India (ASI). Protected property entails the site/remains/ monuments are protected by ASI or the State Department of Archaeology.

Alignment does not pass through any prohibited, protected, restricted area of heritage structure/ Monument area'.

14.5.1.7 Environmental Assessment (OP 4.01)

Environmental Assessment is used in the World Bank to identify, avoid, and mitigate the potential negative environmental impacts associated with Bank's lending operations early-on in the project cycle. The policy states that Environment Assessment (EA) and mitigation plans are required for all projects having significant adverse environmental impacts or involuntary resettlement. Assessment should include analysis of alternative designs and sites, or consideration of "no option" and require public participation and information disclosure before the Bank approves the project.

In World Bank operations, the purpose of Environmental Assessment is to improve decision making, to ensure that project options under consideration are sound and sustainable, and that potentially affected people have been properly consulted and their concerns addressed.

The World Bank's environmental assessment policy and recommended processing are described in Operational Policy (OP)/Bank Procedure (BP) 4.01: Environmental Assessment.

14.5.2 Summary of Statutory Clearance Requirement

The project requires a number of statutory clearances under different Acts and Rules a different stage of the project. These are listed in Table 111.

Table 111 : Summary of Environment Legislation Applicable for this Project

Act	Year	Objective	Applicability Yes/No	Responsible Institution
Environment (Protection) Act.	1986	To protect and improve the overall environment	Yes	MoEF&CC, CPCB
Notification on Environment Impact Assessment of Development projects (and amendments) (referred to as the Notification on Environmental Clearance)	2006 2009 2010 2013	To provide environmental clearance to new development activities following environmental impact assessment.	No	MoEF&CC, CPCB
Wildlife Protection Act	1972	To protect wild animals and birds through the creation of National Parks and Sanctuaries	No	MoEF&CC
Water (Prevention and Control of Pollution) Act (and subsequent amendments)	1974	To provide for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water.	Yes	SPCB

Act	Year	Objective	Applicability Yes/No	Responsible Institution
Air (Prevention and Control of Pollution) Act (and subsequent amendments)	1981	To provide for the prevention, control and abatement of air pollution, and for the establishment of Boards to carry out these purposes.	Yes	SPCB and Metro Authority
Forest (Conservation) Act	1980	To protect and manage forests	No	MoEF&CC
Clearance for cutting trees and transporting	1964/ 71	Maharashtra Tree felling act. Tree removal will be guided as per state government rules.	Yes	Forest Department, /District Level Committee constituted by the State Govt.
Central Motor Vehicle Act Central Motor Vehicle Rules	1988 1989	To control vehicular air and noise pollution. To regulate development of the transport sector, check and control vehicular air and noise pollution.	Yes	State Transport Department
Dismantling of structure falling within right of way/Land Acquisition	2013	As per GOM act, Right to fair compensation and transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013	Yes	Competent Land Acquisition Authority
Ancient Monuments and Archaeological Sites and Remains Act	1958and 2010	Conservation of Cultural and historical remains found in India.	No	Archaeological Dept. GOI
Hazardous and Other Wastes (Management	2016	To handle & dispose Hazardous Wastes	Yes	SPCB

Act	Year	Objective	Applicability Yes/No	Responsible Institution
and Transboundary Movement)				
Construction and Demolition Waste Management Rules, 2016	2016	To handle & dispose Construction and Demolition Waste	Yes	SPCB
e-waste (Management) Rules, 2016	2016	To handle & dispose E waste	Yes	SPCB

14.6 Ambient Air Quality, Noise and Water Quality Standards

14.6.10 Ambient Air Quality Standards (AAQS)

Ambient air quality standards/limits provide a legal framework for the control of air pollution and the protection of public health.

The Ministry of Environment and Forest (MoEF&CC), Govt. of India, vide gazette notification, G.S.R826 (E), dated 16.11.2009 have notified/amended the National Ambient Air Quality Standards by amending the Environment (Protection) Rules 1986. The National Ambient Air Quality Standards (NAAQS) prescribed by CPCB are given in Table 112.

Table 112 : National Ambient Air Quality Standards (NAAQS)

	Concentration in Ambient Air			
Pollutants	Time Weighted Average	Industrial, Residential, Rural and other areas	Ecologically sensitive area (notified by central government)	Method of Measurement
1	2	3	4	5
Sulphur Dioxide (SO_2) µg/m^3	Annual*	50	20	Improved West & Gaeke method
	24 hours**	80	80	Ultraviolet fluorescence
Oxides of Nitrogen (NO_x) µg/m^3	Annual	40	30	Jacob & Hochheiser (Na-Arsenite)
	24 hours**	80	80	Gas Phase Chemiluminescence's
Carbon Monoxide (CO) mg/m^3	8 hours**	02	02	NonDispersive infraredspectroscopy
	1 hour	04	04	

Pollutants	Concentration in Ambient Air			
	Time Weighted Average	Industrial, Residential, Rural and other areas	Ecologically sensitive area (notified by central government)	Method of Measurement
PM_{10} µg/m^3 Particulate Matter size less than 10µm	Annual*	60	60	-Gravimetric - TOEM -Beta attenuation
	24 hours**	100	100	
$PM_{2.5}$ µg/m^3 Particulate Matter size less than 2.5µm	Annual*	40	40	-Gravimetric - TOEM -Beta attenuation
	24 hours**	60	60	

Source: *National Ambient Air Quality standards, CPCB Notification dated18thNovember 2009*
* Average Arithmetic mean of minimum 104 measurements in a year taken for a week 24 hourly at uniform interval.
** 24 hourly / 8 hourly values should meet 98 percent of the time in a year

14.6.11 Noise Quality Standards

Realizing the need to control and regulate noise levels, the Ministry of Environment & Forest, Government of India, have notified Noise Level Standards and Guidelines under Environment (Protection) Rules, 1986, known as Noise Pollution (Regulation & Control) Rules, 2000. The specific standards described in the rules are given in Table 113.

Table 113 : National Ambient Noise Quality Standards

Sr. No.	Area Code	Category of Zone	Leq*** in dB (A)	
			*Day	**Night
1	A	Industrial	75	70
2	B	Commercial	65	55
3	C	Residential	55	45
4	D	Silence Zone	50	40

* Day Time – 6.00 am – 10.00 pm (16 hours)
** Night Time – 10.00 pm – 6.00 am (8 hours)
*** Leq – Equivalent noise level
(Source: Noise pollution (Regulation and control) Rules, 2000)

14.6.12 Water Quality Standards

14.6.12.1 Surface Water Quality Standards

The CPCB has identified water quality requirements in terms of few chemical characteristics, known as primary water quality criteria. The "designated best uses" along with respective water quality criteria is given in Table 114.

Table 114 : Use Based Classification of Surface Waters in India

Designated Best Use	Class of Water	Criteria
Drinking Water source (with conventional treatment)	A	▪ Total Coliforms MPN/100 ml shall be 50 or less ▪ pH between 6.5 to 8.5 ▪ Dissolved Oxygen 6 mg / 1 or more ▪ Biological Oxygen demand (BOD) 5 days 200C, 2 mg/l or less
Outdoor bathing (organized)	B	▪ Total Coliforms Organism MPN/100 ml shall be 500 or less ▪ pHbetween 6.5 to 8.5 ▪ Dissolved Oxygen 5 mg / l or more ▪ Biological Oxygen demand (BOD) 5 days 200C 3 mg/1 or less
Drinking Water source (without conventional treatment)	C	▪ Total Coliforms MPN/100 ml shall be 5000 or less ▪ pH between 6.5 to 8.5 ▪ Dissolved Oxygen 4 mg / 1 or more ▪ Biological Oxygen demand (BOD) 5 days 200C 3 mg/1 or less
Propagation of Wildlife	D	▪ pH between 6.5 to 8.5 for fisheries ▪ Dissolved Oxygen 4 mg / 1 or more ▪ Free Ammonia (as N) 1.2 mg/1 or less
0Irrigation, Industrial Cooling, Controlled Waste	E	▪ pH between 6.0 to 8.5 ▪ Electrical Conductivity at 250C µmhos/cm Max. 2250 ▪ Sodium absorption ratio Max. 26 ▪ Boron, Max.2 mg/1

*(**Source:** Guidelines for Water Quality Management – CPCB 2008)*

14.10.1.1 Ground Water Quality Standards

Since all groundwater resources of the State are classified for more than one use and therefore, the most stringent or protective criteria will be applicable. Therefore, its qualities have been compared with Bureau of Indian standards: IS :10500:1991 and WHO Guideline for Groundwater Sources for Drinking Water which is presented in the form of Table 115:

Table 115 : Indian Standards for Drinking Water-Specification BIS:IS 10500:2012

Sr. No.	Substance or Characteristics/Parameter	BIS, Indian Standards (IS 10500:2012)	
		Desirable Limit	Permissible Limit in the absence of Alternate Source
(1)	(2)	(3)	(4)
	Essential Characteristics		
1	Colour,(HazenUnits, Max)	5	15
2	Odour	Unobjectionable	---
3	Taste	Agreeable	---
4	Turbidity, NTU, Max	1	5
5	pH value	6.5 to 8.5	No relaxations
6	Total hardness (as $CaCO2$) mg/L, Max	200	600
7	Iron (as Fe) mg/L, Max	0.3	No relaxations
8	Chloramines (as $Cl2$), mg/l, Max	4	No relaxations
9	Chlorides (as Cl) mg/L , Max	250	1000
10	Free residual chlorine, mg/l, Min	0.2	1
	DesirableCharacteristics		
11	Dissolved solids mg/L, Max	500	2000
12	Calcium (as Ca) mg/L, Max	75	200
13	Copper (as Cu) mg/L, Max	0.05	1.5
14	Magnesium(as Mg),mg/L,Max	30	100
15	Manganese (as Me) mg/L, Max	0.1	0.3
16	Sulphide (as $H2$ S), mg/l, Max	0.05	No relaxation
17	Sulphate (as $SO4$) mg/L, Max	200	400
18	Silver (as Ag), mg/l, Max	0.1	No relaxation
19	Nitrate (as $NO3$) mg/L, Max	45	No relaxation
20	Fluoride (as F) mg/L, Max	1	1.5
21	Phenolic compounds (as$C6H5OH$) mg/L, Max	0.001	0.002
22	Mercury (as Hg) mg/L, Max	0.001	No relaxation
23	Cadmium (as Cd), mg/L, Max	0.003	No relaxation
24	Selenium (as Se), mg/L, Max	0.01	No relaxation
25	Total Arsenic (as As) mg/L, Max	0.01	0.05
26	Cyanide (as CN), mg/L, Max	0.05	No relaxation
27	Lead (as Pb), mg/L, Max	0.01	No relaxation
28	Zinc (as Zn), mg/L, Max	5	15
29	Amonic detergents (as MBAS) mg/L, Max	0.2	1
30	Total Chromium (as $Cr6+$) mg/L, Max	0.05	No relaxation

Sr. No.	Substance or Characteristics/Parameter	BIS, Indian Standards (IS 10500:2012)	
		Desirable Limit	Permissible Limit in the absence of Alternate Source
31	Polynuclear aromatic hydrocarbons (as PAH) g/L, Max	0.0001	---
32	Mineral oil mg/L, Max	0.01	0.03
33	Pesticides mg/L, Max	Absent	0.001
34	Radioactive Materials:	0.1	No relaxation
	a) Alpha emitters Bq/L, Max	1	
	b) Beta emitterspci/L, Max		
35	Total alkalinity as calcium carbonate mg/L, Max	200	600
36	Aluminum (as Al), mg/L, Max	0.03	0. 2
37	Ammonia (as total ammonia-N), mg/l, Max	0.5	No relaxation
38	Barium (as Ba), mg/l, Max	0.7	No relaxation
39	Boron, mg/L, Max	0.5	1
	Bacteriological Quality of Drinking Water		
1	All water intended for drinking:	Shall not be detectable in any 100 ml sample	
	a)E. coli or thermotolerantcoliformbacteria		
2	Treated water entering the distribution system:	Shall not be detectable in any 100 ml sample	
	a)E. coli or thermotolerantcoliformbacteria		
	b)Total coliformbacteria		
3	Treated water in the distribution system	Shall not be detectable in any 100 ml sample	
	a)E. coli or thermotolerantcoliformbacteria		
	b)Total coliformbacteria		

14.11 Description of the environment

Collection of baseline information on bio-physical, social and economic aspects of the project area is the most important reference for conducting EIA study, Based on the existing environmental scenario, potential impacts of project will be identified and accordingly management plan will be proposed so as applicability of Government of India (GoI) regulatory requirements. The baseline environmental conditions will help in comparing and to monitor the predicted negative and positive impacts resulting from the project during construction and operation phases.

Data was collected from secondary sources for the macro-environmental setting like climate, physiography (Geology and slope), biological and socio-economic environment. First-hand information have been collected to record the micro-environmental features within and adjacent to the project corridor. Collection of first hand (Primary) information includes preparation of base maps, extrapolating environmental features on proposed Metro Track & Station design, tree inventories, location and measurement of socio-cultural features abutting proposed project. Scope of this exercise was 10 kilometres on both sides from the centre of the project location as per guidelines of Ministry of Environment and Forests, Government of India. However, the focus of the study was on the areas within and directly adjacent to the corridor of impact and ROW.

Following section describes the nature, type and characteristics of the physical, biological, cultural and socioeconomic components along the project Stretch.

14.11.1 Location and physiography

Pune is the second largest district of Maharashtra State in respect of area. The district has a geographical area of 15642 sq.km., which is 5.08% of the total area of State. It is situated in the western part of the State and lies between north latitude 17°54’ and 19°24’ and east longitudes 73°29’ and 75°10’.

It is bounded by Ahmadnagar district in the north and east. Satara and Solapur districts in south and south east respectively and Thane and Raigarh districts in north west and west respectively. For administrative convenience it is divided in 14 talukas namely Pune City, Haveli, Khed, Ambegaon, Junnar, Shirur, Daund, Indapur, Baramati, Purandhar, Bhor, Velhe, Mulsi and Maval (refer Figure 110).

Municipal Limit identified with length distribution of the project is shown in the Table 116 hereafter:

Table 116 : District wise distribution of the project alignment

State	District	Chainage	Tentative Length(km)	Taluka
Maharashtra	Pune	PCMC to Nigdi	4.413	Pune City Taluka (Pimpri Chinchwad Municipal Corporation)

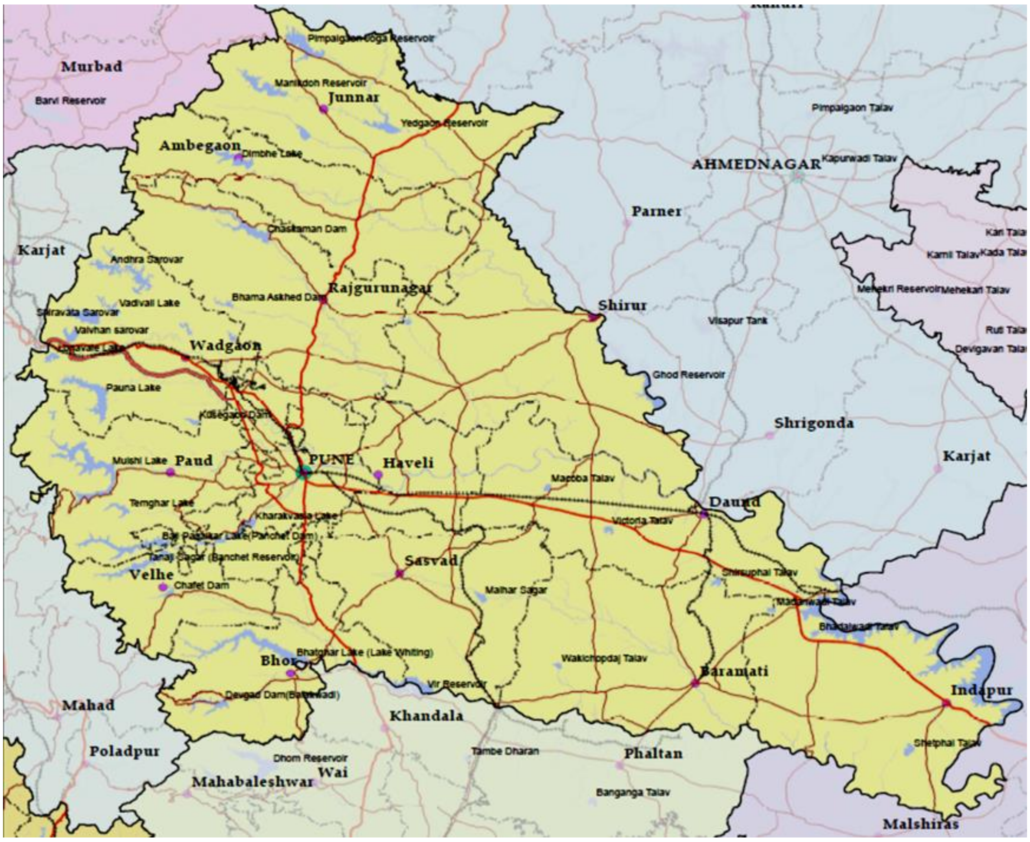


Figure 110 : Pune district map
(Source : http://www.mrsac.gov.in)

14.11.2 Geology and Soil Type

"The district forms part of Western Ghat and Deccan Plateau. Physiographically the district can be divided in to three distinct belts i.e.,

(1) The western belt stretching from 16 to 31 km. east of Sahayadri –an extremely rugged country cut by deep valleys, divided and crossed by hill ranges.

(2) The central belt extending for about 30 km. east of the western belt across the tract whose eastern boundary is roughly marked by a line drawn from Pabal in the north, southwards through Pune to Purandhar. In this belt a series of small hills stretch in to valleys and large spurs from Plateau and

(3) The eastern belt with a rolling topography and the low hills sinking slowly in to the plains with relatively broader valleys.

Therefore, the physiography of the district has given rise to four major characteristic land forms namely; (1) The hills and ghats (2) the foot hills (3) the plateau and (4) the plains." (Source: cgwb.gov.in/District Profile)

From the riverbed of Mutha, highest portion in the Pune City is Kedareshwar hill, which is about 612 meters from the riverbed. The Western portion from Mulshi, Maval, Tahsil in Pune District, contains black soil where the main crop is paddy. All lands to the north, west south and east have generally reddish soil.

Figure 111 : Geomorphology map of Pune District
(*Source: krishi.maharashtra.gov.in)*

14.11.3 Topography:

Pune district lies in the Bhima and Nira basins. It has a shape of triangle with its base in Sahyadri mountains on the West and its apex in the extreme South-East corner near Nira River. Taking into consideration the height from sea level, rainfall, soil pattern etc. it is divided into three zones viz. Western Zone, Central Zone and Eastern Zone. The Sahayadri ranges are spread from North to South in the district. Pune district lies in Seismic Zoning III. This zone is classified as Moderate Damage Risk Zone.

14.11.4 Land-use pattern and land holdings

It can be seen from the LULC map below that out of geographical area, about 23 percent of land is under nonagricultural usage i.e. forest, land under non-agricultural use, cultivable waste, permanent pasture and miscellaneous trees and groves.

About 7 percent land is as current and other fallow and about 64 percent of land is sown. Thus, altogether about 14.71 percent of land is available in the form of cultivable waste, permanent pastures, land under tree crops and grooves, current as well as other follows, which can be brought under productive use with a proper wasteland development programme.

The land use along the project corridor is principally of the following categories: Urban, Industrial and Agricultural. The principal industrial estates along the project metro corridor are Automobile Factory, and Oil industries in Akrudi, Bhosari, Moshi and Chaakan.

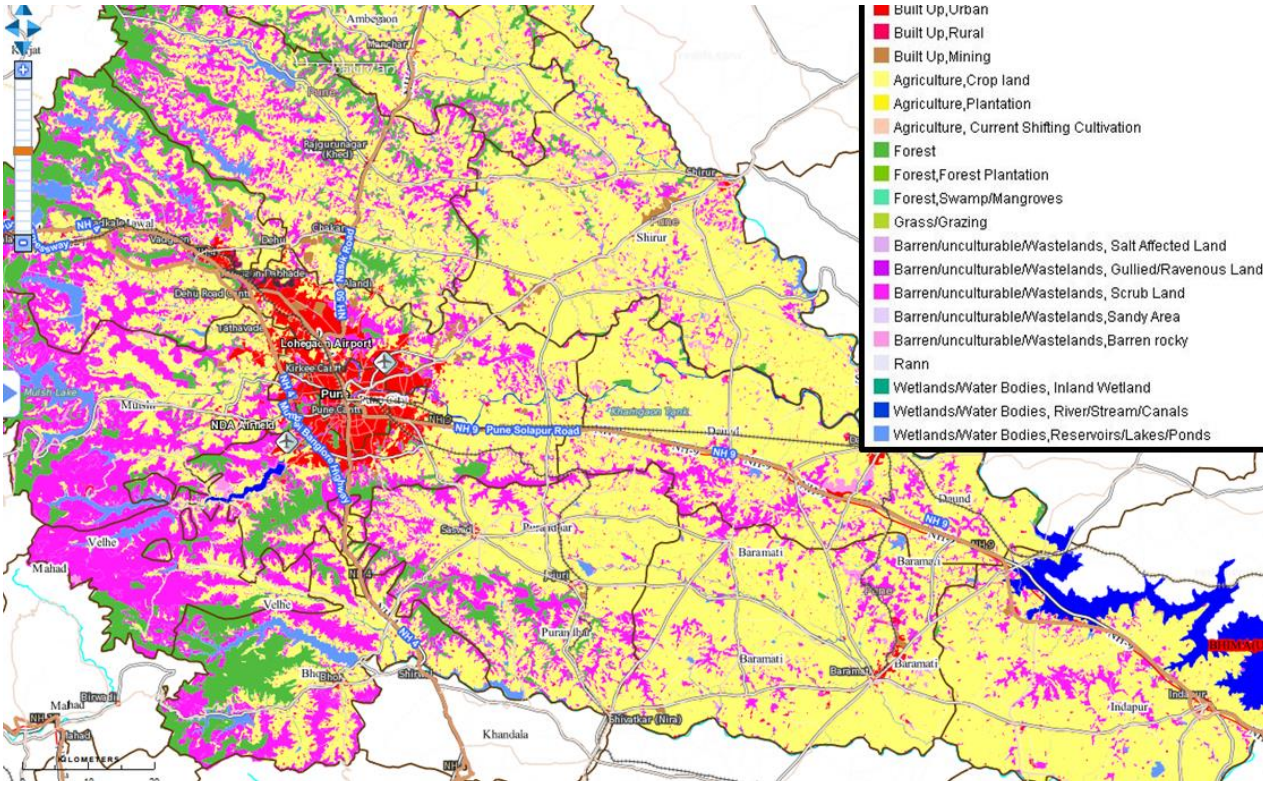
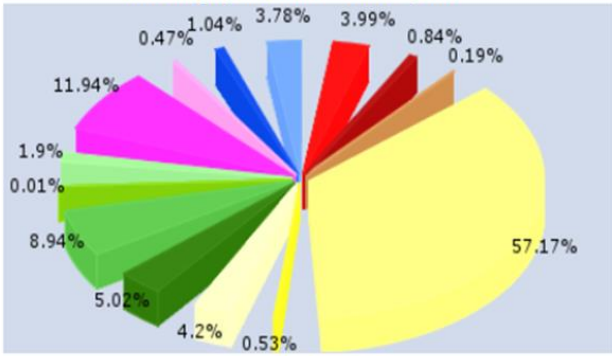


Figure 112 : Landuse Landcover map of Pune District

LULC Information (2011-12) for Pune
Total Geographical Area : 15642 Sq. Km



LULC Class	Area (Sq.Km)	LULC Class	Area (Sq.Km)
Builtup,Urban	623.43	Builtup,Rural	131.08
Builtup,Mining	29.39	Agriculture,Crop land	8942.82
Agriculture,Plantation	82.21	Agriculture,Fallow	657.21
Forest,Evergreen/ Semi evergreen	784.88	Forest,Deciduous	1398.96
Forest,Forest Plantation	1.59	Forest,Scrub Forest	296.49
Barren/unculturable/ Wastelands, Scrub land	1866.92	Barren/unculturable/ Wastelands, Barren rocky	72.74
Wetlands/Water Bodies, River/Stream/canals	163.1	Wetlands/Water Bodies, Reservoir/Lakes/Ponds	591.18
Total			15642.00

Figure 113 : Landuse Landcover Statistics of Pune District

14.11.5 Meteorology

The ambient environment is responsible for the health of human beings, animals, wildlife and vegetation. All 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.

Pune District forms a part of the tropical monsoon land and therefore shows a significant seasonal variation in temperature as well as rainfall conditions. The climate of the Western region of Pune District is cool, whereas the Eastern part is hot and dry.

14.11.5.1 Seasons

The winter season is from December to about the middle of February followed by summer season which last up to May. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season.

14.11.5.2 Temperatures

The mean minimum temperature is about 12°C and mean maximum temperature is about 39°C.

14.11.5.3 Rainfall

The normal annual rainfall over the district varies from about 468 mm to 4659 mm.

Table 117 : Rainfall for last five years in Pune District (in mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F
2013	0.5	0.3	0.9	0	0.8	293	397	129	233	32	13.6	5.4
2014	1.2	1.2	36.9	4.3	21.8	42.6	386	345	105	29	22.7	12
2015	0	0.6	50.2	13	29.3	230	142	53.8	157	83	45.3	0
2016	0	0.2	4.4	0.5	13.9	77.8	446	418	197	58	0	0
2017	0	0	0	0	24.6	289	513	290	211	116	13.9	0.7

(Source: www.imd.gov.in)

14.11.5.4 Humidity levels

Humidity is low during the summer months due to increased evaporation losses from the atmosphere. The diurnal variations in humidity during this period are high, water vapor gets condensed due to falling nighttime temperatures and the daytime temperatures are high.

In the summer months the relative humidity ranges from a minimum of 20% to maximum of 67% during the day.

During the monsoon period, the relative humidity varies from 68% to 87%. The relative humidity during winter shows maximum diurnal variation varying from 37% to 88%.

Table 118 : Met Data, Pune (1981-2010)

Month	Temperature°C		Humidity %		Monthly Rainfall (mm)
	Min	Max	08.30hr	17.30 hr	
January	11.2	29.8	85	34	1.1
February	12.2	32.1	72	26	0.3
March	15.7	35.6	55	21	2.2
April	19.6	37.6	48	24	8.5
May	22.6	36.9	59	37	16.8
June	23.1	31.9	77	66	173.4
July	22.4	28.3	83	76	181.4
August	21.7	27.6	86	79	145.2

September	20.9	29.4	84	73	146.1
October	18.4	31.5	79	53	86.3
November	14.5	30.4	76	43	25.0
December	11.5	29.2	82	39	7.0

Source: Environment Impact Assessment Report for proposed expansion of IT Park Infosys Limited November 2017

14.11.5.5 Wind Rose

For Pune station, wind rose diagram available for period of 1981 to 1994 The wind rose diagram for 8.30 hrs in the morning and 5.30 hrs the evening is shown below:

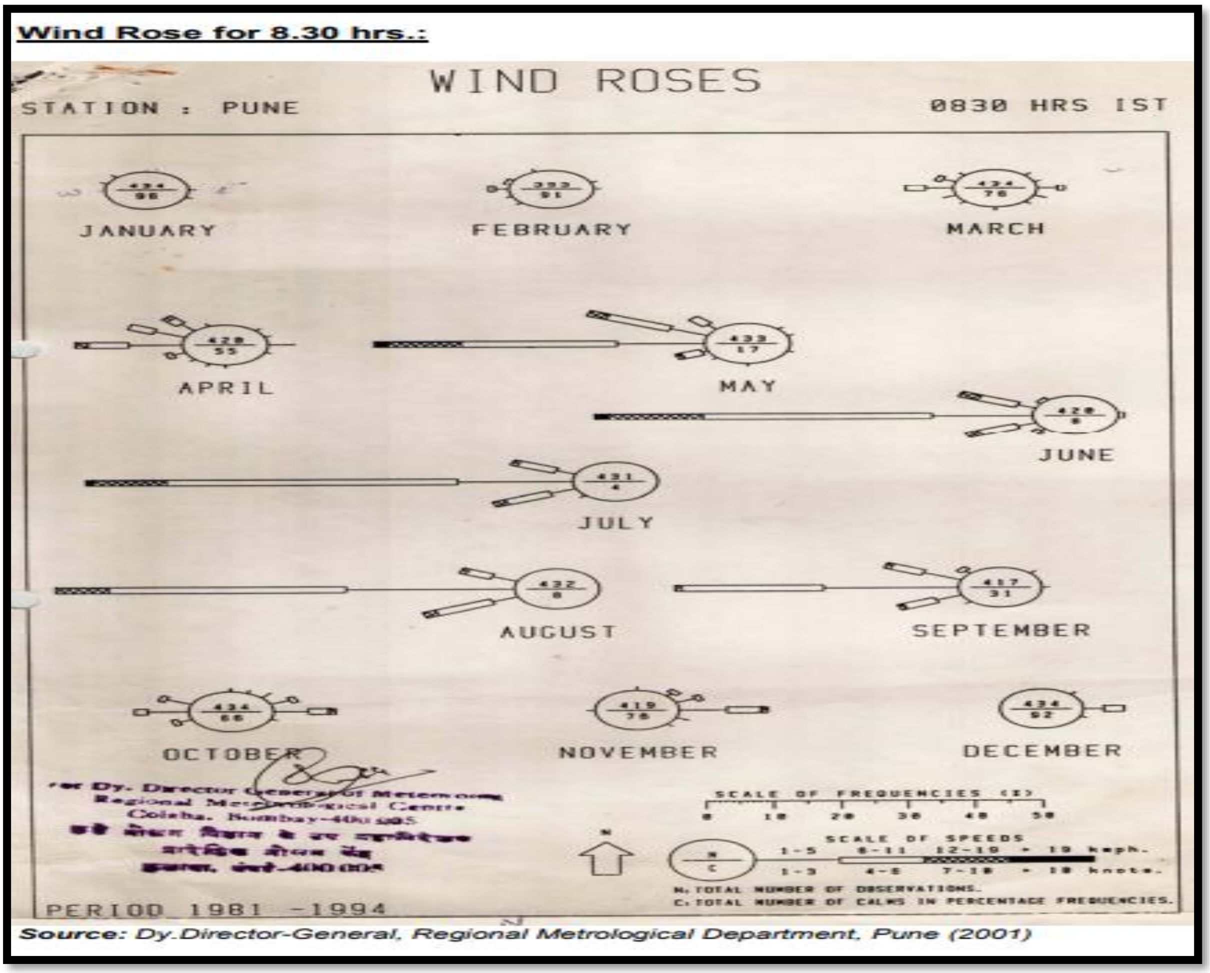


Figure 114 : Windrose Diagram of Pune District for 8.30 Hrs

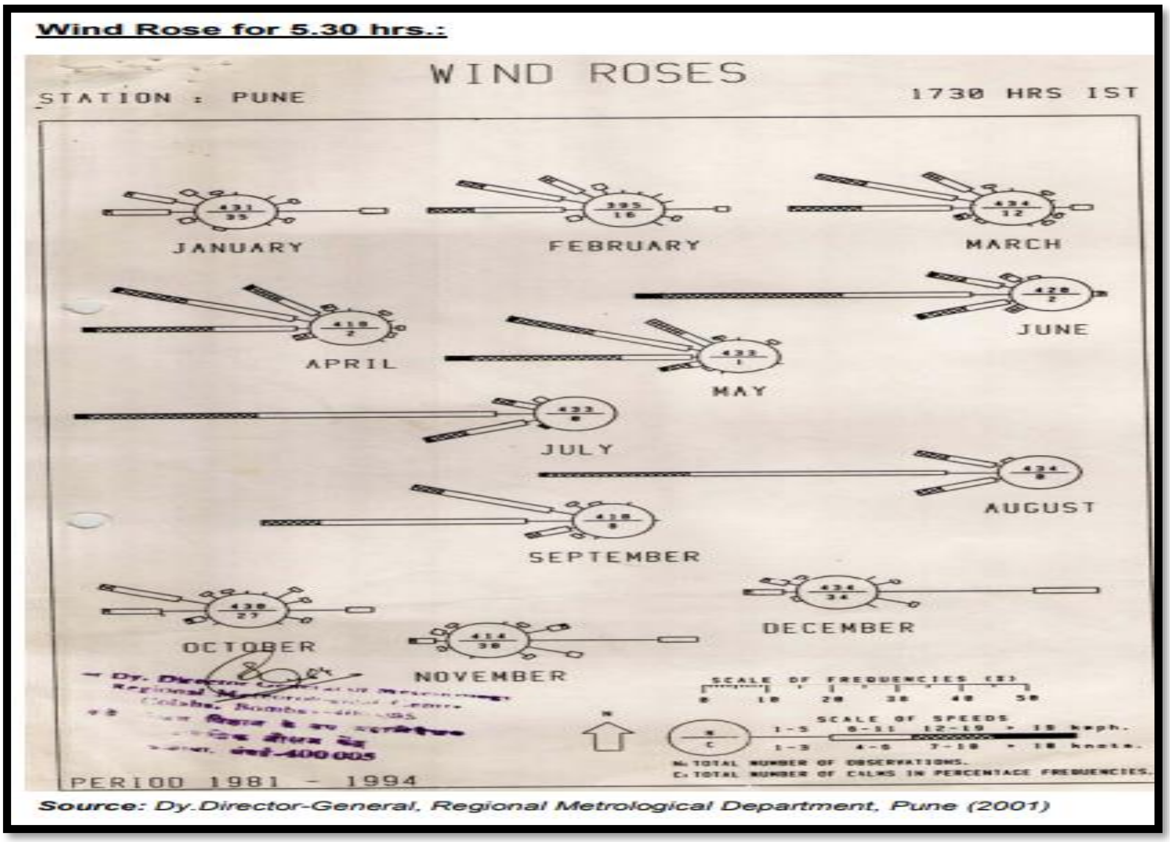


Figure 115 : Windrose Diagram of Pune District

Based on the evaluation of the wind rose for morning and evening time, it can be said that the overall wind direction for the district is from the West to South West, with absolutely no wind from the South and an infinitesimal percentage of wind from the North direction .The predominant winds from the West and South West direction are responsible for the monsoons as they carry moisture-laden clouds from the Arabian Sea.

14.11.6 Air quality, water quality and noise

Baseline conditions define the characteristics of the existing environment and shape projected future conditions, assuming no project is undertaken. They provide the basis from which project impact comparison are made. Existing ambient air, noise and water quality data on various sections of the project corridors has been collected from secondary sources to establish a baseline database.

14.11.6.1 Air quality monitoring

Ambient air quality refers to the background air quality levels in a region, characterised by concentrations of various pollutants in the atmosphere. In most cases vehicular emissions are the predominant source of air pollution. Existing ambient air quality data on various sections of the project corridors was collected to establish a baseline database. The aim was to identify areas that already have high pollution levels or are expected to experience so, on account of the project, and to design adequate mitigation measures, as applicable.

The activities, which generate modify atmospheric air quality, are transportation (i.e., motor vehicle emissions, which are addressed in this study); industry; domestic and construction. The principal sources of air pollution due to metro projects are machineries used during construction phase and the vehicles that ply over it during the operation phase. The monitoring locations should be selected based on the sensitivity of the receptors to vehicular traffic and to obtain baseline concentrations of the various representative land uses along the corridors. The baseline data of air environment need to be monitored for the below mentioned parameters:

- Particulate Matter (PM_{10});
- Particulate Matter ($PM_{2.5}$);
- Sulphur oxide (SOx);
- Oxides of Nitrogen (NOx); and
- Carbon monoxides(CO);

Dispersal of pollutants depends upon factors like prevailing wind direction and other weather conditions, height of the source, and characteristics of plantation and presence of other sinks along the project corridor.

Existing air quality data within vicinity of the Pune district has been examined to establish the base line scenario for the project corridor. The sources of air pollution in the region are identified as industries, vehicular traffic, dust arising from unpaved roads etc.

Table 119 : Ambient Air Quality of Pune District

S. No	Location	Parameter μg/m3			
		PM10	PM 2.5	SO2	NOx
1	NashikPhata	290.1	135.8	12.6	9.45
2	Sangavi	200	93.21	10.34	4.99
3	Pimple Gurav	170.2	78.2	8.4	6.2
4	Pimple Nilkh	161.9	75.19	10.2	5.82
5	KaspateWasti	149	72.3	7.4	7.92
6	Wakad	164	77.4	8.46	5.2
7	KalewadiPhata	224	102.98	12.69	4.16
8	SawantPetrol Pump	360	177.44	16.14	4.93
9	Pimpri Camp	380	192.1	20.4	3.88
10	Link Road	230.2	120.4	11.6	18.4
11	Empire Estate	199.8	104.18	19.07	26.5

12	KSB Chowk	330	170.2	20.23	29.8
13	TelcoGate	150	80.54	8.5	9.3

Source: Environment Impact Assessment for Proposed Bus-Based Rapid Transit System for PCMC 2010

Ambient Air Quality Monitored at Pimpri-Chinchwad

Location :Pimpri-Chinchwad Municipal corporation | Type :Residential
Program Name :SAMP | Status:In operation
Frequency:Six days in a week

AQI	Quality classification	Remarks	Colour code
0-50	Minimal Impact	Good	
51-100	Minor breathing discomfort to sensitive people	Satisfactory	
101-200	Breathing discomfort to the people with lung, heart disease, children and older adults	Moderate	
201-300	Breathing discomfort to people on prolonged exposure	Poor	
301-400	Respiratory illness to the people on prolonged exposure	Very Poor	
>401	Respiratory effects even on healthy people	Severe	

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Concentration of Air Pollutants

Sr.No.	Date	SO2 µg/m^3			NOx µg/m^3			RSPM µg/m^3			AQI
Standards		80.00			80.00			100.00			
August											
1	20-08-2018	51			42			17			64
2	21-08-2018	56			95			46			115
3	23-08-2018	35			43			46			54
4	24-08-2018	44			46			28			58
5	25-08-2018	9			31			20			39
6	27-08-2018	72			73			17			91
7	28-08-2018	41			24			21			51
8	29-08-2018	48			48			17			60
9	30-08-2018	15			40			34			
10	31-08-2018	67			78			23			98
Total		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	
10		9	72	43.80	24	95	52.00	17	46	26.90	

Figure 116 : Ambient Air Quality Index at PCMC

Source : MPCB pollution Control Board

14.11.6.2 Noise Quality Monitoring

Along the proposed project construction proposals, there is significant industrial activity and significant vehicular traffic contributing to ambient noise levels. Therefore, the ambient noise levels may be higher than the noise quality standards. Project development results in increase in noise levels due to movement and operation of machinery, heavy vehicles, loading and unloading of construction materials, apart from high noise levels at the asphalt plants (90 - 100 dB(A). These activities are intermittent and localised.

During the operation phase, noise will be generated from Metro Rail movement in three ways, namely from the vehicle body parts, from the Wheel-Track system (also known as the rolling noise) and from the driver behaviour, such as use of horns.

To assess background noise levels in the study area, existing ambient noise monitoring data has been collected. Description of the noise monitoring stations and the Leq values at each station are given in Table 120.

The day noise level monitored during 6 A.M. to 10 P.M. and night levels 10 P.M. to 6 A.M. reviewed from existing data of Pune District. The major source of noise identified in the study area has been predominantly the vehicular movement and the construction activities.

Table 120 : Ambient Noise Quality

S. No	Location	Day Time		Night Time	
		Leq	Limit	Leq	Limit
1	Nashik Phata	86.76	65	58	55
2	Sangavi	74.3	65	53.2	55
3	Pimple Gurav	72.13	65	52.8	55
4	Pimple Nilkh	52.4	55	43.2	45
5	Kaspate Wasti	54.7	55	44.1	45
6	Wakad	69.8	65	51.4	55
7	Kalewadi Phata	77.85	65	54	55
8	Sawant Petrol Pump	69.4	65	56.3	55
9	Pimpri Camp	70.5	55	48	45
10	Link Road	88.61	65	59.2	55
11	Empire Estate	78.88	65	52.4	55
12	KSB Chowk	84.28	65	53.2	55
13	Telco Gate	66.5	75	49.8	65

Source: Environment Impact Assessment for Proposed Bus-Based Rapid Transit System for PCMC 2010

Noise Levels observed at all the locations are above the standard day time limits. Noise levels at some locations are exceeding the standard night time limit; however; this is attributable to vehicular traffic.

14.11.6.3 Water Resources & Quality

Water environment consists of water resources and its quality. Its study is important from the point of view to assess the adequacy of water resources for the needs of the project in its various stages of the project cycle and also to assess the impact of the project on water environment.

The Pune district has three major drainage systems namely:

- The BhimaGhod River System in northern, north-eastern and eastern part of which Bhima River has a total length of about 355 km and Ghod river has a drainage of about 196 km.

- Mula-Mutha River System covering the central part and having total length of 242 km in the district.
- Nira River system covering south, south-east and eastern part and has total length of about 231 km in the district.

The Mutha River flows from western side to eastern side towards Daund. Mula River, which is coming from Western side of Pune City, meets the Mutha river near Sangamwadi and then the combined rivers flow towards Solapur side. Width of Mutha River bed is 200 meters (660 feet). The northwestern outskirts of Pune's urban area serve as the crossway for two other rivers, namely Pavana and Indrayani. The Bhima River also flows from the northwestern part about 8-9 km away from the main city.Most of the talukas in Pune district are flood prone. The rivers likely to cause flooding are:

- River Bhima (Tal. Shirur, Daund, Indapur and Haveli);
- River Mula (Pune city);
- River Mutha (Tal.Punecity and Mulshi);
- River Indrayani (Tal. Khed, Haveli and Maval);
- River Ghod (Tal. Ambegaon);
- River Mina and Pushpavati (talJunnar);
- River Nira (Tal. IndapurandPurandar);
- River Pavana (Tal. Haveli).

Prime source of ground water in the district are Dug wells and tube wells. Ground water Bearing Formations in Pune district are: Weathered, fractured, jointed and vesicular Basalts. The depth to water level in the district shows wide variation:

- Pre-Monsoon Depth to Water Level (May-2011): 0.40 to 20.10 mbgl
- Post-Monsoon Depth to Water Level (Nov.2011): 0.09 to 14.65 mbgl
- Pre-Monsoon Water Level Trend (2002-11): Rise- Negligible to 0.75 m/yr : Fall- Negligible to 0.56 m/yr
- Post-Monsoon Water Level Trend (2002-11): Rise- Negligible to 0.63 m/yr : Fall- Negligible to 0.27 m/yr

Baseline information on the quality of surface and ground water sources along the alignment of proposed project is required before predictions can be made of the future quality. The proposed project may contaminate the surface/ground water during the construction, operation as well as maintenance phases. A plan for monitoring and mitigation will, therefore, be required to avoid the pollution or deterioration of the water sources.

Figure 117 : River map of Pune District

14.11.6.3.1 Ground Water

Ground water of the area may be impacted due to leaching of contaminants from stored raw materials at site & sewage generated due to labor activity, excess draft of ground water. Run-off from project site may contains high quantity of suspended solids due to presence of sediments from excavated area & other pollutants due to presence of contaminants like oil, paints etc. This run-off on reaching surface water body will degrade the surface water quality which in turn may impact aquatic flora & fauna. Secondary data for the Ground water Quality of Pune City is given in Table 121.

Table 121 : Physico-chemical Characteristics Ground Water Monitoring

Sr. No	Parameters	units	Khadki station	Kunbisahkari Bank (durbankar)	Shivaji nagar	Ashoka mall	Bharat petrol pump (karve road)	Agricultural college	water Desirable Limit
1.	Colour	Hazen	C/L	C/L	C/L	C/L	C/L	C/L	5
2.	Odour	-	U/O	U/O	U/O	U/O	U/O	OU/	U/O
3.	Turbidity	NTU	1	1	1	1	1	1	5
4.	pH	--	7.65	8.05	7.25	7.35	7.46	7.9 2	6.5-8.5
5.	Conductivity	us/cm	1072	170	420	795	660	692	-
6.	Total Dissolve Solids	mg/l	697	104	265	511	424	450	500
7	Alkalinity as CaCO3	mg/l	328	40	116	256	216	232	200
8.	Total Hardness as	mg/l	368	88	160	256	216	216	300
9	Calcium as Ca	mg/l	115	16	58	96	74	74	75
10	Magnesium as Mg	mg/l	20	12	4	4	8	8	30
11	Bicarbonate	mg/l	400	49	142	312	264	283	
12	Chloride as Cl	mg/l	65	11	22	31	26	37	250
13	Sulphate as SO4	mg/l	80	15	34	56	45	40	200
14	Nitrate as NO3	mg/l	17	2	6	12	8	8.5	45
15	Fluorides as F	mg/l	1.2	0.6	0.85	0.85	0.75	0.6 5	1
16	Phenolic compound as C6H5OH	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.001
17	Cyanide	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.05
18	Aluminium	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.03
19	Arsenic	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.05
20	Cadmium	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.01
21	Chromium as Cr+6	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.05
22	Iron	mg/l	0.7	0.1	0.16	0.17	0.2	0.1 5	0.3
23	Copper	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.05
24	Lead	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.05
25	Manganese	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.1
26	Mercury	mg/l	BDL	BDL	BDL	BDL	BDL	BD L	0.001
27	Zinc	mg/l	1	BDL	0.5	1	0.6	0.7	5

Source: Detail project report of Pune Metro 2009

The quality of the well water was inferred in comparison with the National Standards of Drinking Water Quality (IS: 10500). All the well water samples were colourless, odourless and with agreeable taste. One sample had high turbidity and the samples showed well-balanced pH. The chemical characteristics such as total hardness, chlorides, dissolved solids, sulphates and nitrates were within limits. Among the metals analyzed iron, copper, zinc, chromium, magnesium, cadmium, selenium, mercury and arsenic were not detected or were within stipulated limit.

14.11.6.3.2 SURFACE WATER

The source of surface water of Pune is the Mula and Mutha river. Secondary data of Surface water quality of the Pune City is given in Table 122.

Table 122 Physico-chemical Characteristics Surface Water Monitoring

S. No.	Parameters	Unit	Vitthalwadi (Mutha river)	GarwareBridge (Mula river)	Sangam Bridge (Mutha river)	Bund Garden (Mula - Mutha)	Desirable limit
1	Colour	Hazan	Brownish	Light darkish	Light darkish	Light greyish	5
2	Odour	-	Objectionable	Objectionable	Objectionable	Objectionable	U/O
3	Turbidity	NTU	26	32	30	28	5
4	pH	--	7.50	7.35	7.30	7.40	6.5-8.5
5	Conductivity	uS/cm	550	640	690	460	-
6	Total Dissolve Solids sum	mg/l	360	448	476	325	
7	Alkalinity as CaCO3	mg/l	140	165	173	115	200
8	Total Hardness as CaCo3	mg/l	162	188	195	113	300
9	Calcium as Ca	mg/l	35	52	60	27	75
10	Magnesium as Mg	mg/l	18	14	11	11	30
11	Sodium	mg/l	29.0	45.0	52.0	21.0	_
12	Potassium	mg/l	8.0	11.0	9.0	11.0	_
13	Bicarbonate	mg/l	171	201	211	140	_
14	Chloride as Cl	mg/l	43	67	58	35	250
15	Sulphate as SO4	mg/l	35	42	47	23	200
16	Nitrate as NO3	mg/l	3.5	11.4	14	3	45
17	Fluorides as F	mg/l	0.2	0.4	0.5	0.3	1
18	Phenolic compound as C6H5OH	mg/l	BDL	BDL	BDL	BDL	0.001
19	Cyanide	mg/l	BDL	BDL	BDL	BDL	0.0 5
20	Aluminium	mg/l	BDL	BDL	BDL	BDL	0.0 3
21	Arsenic	mg/l	BDL	BDL	BDL	BDL	0.0 5
22	Cadmium	mg/l	BDL	BDL	BDL	BDL	0.01

23	Chromium as Cr+6	mg/l	BDL	0.02	0.035	BDL	0.05
24	Iron	mg/l	0.25	0.6	0.48	0.05	0.3
25	Copper	mg/l	BDL	BDL	BDL	0.02	0.05
26	Lead	mg/l	BDL	BDL	BDL	BDL	0.05
27	Manganese	mg/l	BDL	BDL	BDL	BDL	0.1
28	Mercury	mg/l	BDL	BDL	BDL	BDL	0.001
29	Zinc	mg/l	0.4	1.6	1.5	0.8	5
30	DO	mg/l	1.2	0.6	0.5	2.5	_
31	COD	mg/l	21	35	42	16	–
32	BOD	mg/l	12	12	15	5	_

Source: Detail project report of Pune Metro 2009

14.11.7 Ecology & Biodiversity

14.11.7.1 Reserve and protected forests

The proposed corridors do not pass through any reserve/protected forest in their entire lengths. Moreover, no protected areas/environmentally sensitive areas are found in their indirect impact zones as well (10 km radius).

The main tree species in the area are Madhuca, Erythrina, Terminalia elliptica, Brideliaretusa, Tectonagrandis, Meynalaxiflora, Dalbergiasisoo, Holarrhenapubescens, Grewiatilifolia, Lagerstroemia sp. Eucalyptus, Peltophorum, Bombax ceiba, Butea monosperma, Mangiferaindica, GliricidiaseMetro Authoritym, Cassia fistula, Careyaarborea, Terminalia chebula, Ficus sp. Melia azadirecta Diospyros melanoxylon, HolopteliaXantolis, Acacia chundra, Sterculiaurens, Lannea&Emblica officinalis etc.

Fauna- The wild fauna found in study area are Semnopithecushypoleucos, Macaca radiata, Herpestesedwardsii, Pteropusgiganteus, Funambuluspalmarum

Birds- The Avi Fauna found in study area are Milvus migrans, Accipiter badius, Alcedoatthis, Halcyon smymensi, Ardeolagrayii, Bubulcuscoromandus, Egretta intermedia, Vanellus indicus, Spilopeliachinensis, Streptopelia senegalensis, Corvus culminates, Corvussplendens, Eudynamysscolopaceus, Dicrurusmacrocercus, Meropsorientalis, Cinnyrisasiaticus, Passer domesticus, Phalacrocoraxniger, Pavocristatus, Ploceusphillippinus, Pycnonotuscafer, Pycnonotusjocosus, Turdoidesmalcolmi

Reptiles- Indian Monitor (Varanus bengalensis), Garden Lizard (Calotes versicolor), Common Rat Snake (Ptyasmucosus), Common tree Snake (Dendrelaphistristis), etc.

14.11.7.2 Vegetation Along the Project Stretch

However, significant amounts of vegetation are observed within proposed ROW of metro corridors. 342* trees will be impacted due to proposed project construction. Impacted Tree species along the project stretch are: Amaltash, Apta Ashok Bada Neem Banyan Berry (Ber Coconut Gulmohar Banyan Jamun Karanjia Mango Neem Neergudi Palm Guava Papdi Pipal Plant Shai Shevaga Shevri Sirish Umber.

Table 123 : Summary of Girth Wise Trees Impacted Along the Project Stretch

Side	Girth (Cm)						
	0-30	31-60	61-90	91-120	121-150	>150	Total
Right	14	52	41	23	12	28	170
Left	59	19	31	30	12	21	172
Total	**73**	71	72	53	24	**49**	**342***

*Approximatey, 342 no. of trees will be impacted due to the project. However, the no. of trees might be less. Exact no. of trees will be identified at the time of joint verification with the concerned department

14.11.8 Seismicity

Pune lies very close to the seismically active zone around Koyna Dam, about 100 km (62 mi) south of the city and has been rated in Zone 3 by the India Meteorological Department. Pune has experienced some moderate- and many low-intensity earthquakes in its history. Suitable seismic factor as per the India Meteorological Department (IMD) to be adequate needs to be considered for design purpose for Civil Engineering structures and while finishing civil designs.

14.12 Demographic Profile

14.12.1 Population

The proposed project falls in Pune district of Maharashtra State and it is expected that about 5,057,709 of the State population will benefit. The population percentage of the project influence district is reflected in the Table 124.

Table 124 Affected Population

S. No	State/District	Total Population
1	Maharashtra	11,23,74,333
2	Pune	94,29,408
3	Pune Metropolitan Region	5,057,709

Source: PCA, Census of India 2011

14.12.2 Population Density

Population density of the project influenced district varies considerably as per the census data of 2011, which clearly indicate that the density of population in Pune district (603 persons/ sq.km.), has increased during 2001-2011. Any significant increase in population density brings in two demographic factors that determines it i.e. natural increase in population and migration. Further, natural increase depends on the fertility and mortality rates. This is evident from the Table 125.

Table 125 Population Density

S. No	STATE/ District	Density/km2	
		2001	2011
1	Maharashtra	315	365
2	Pune	462	603

Source: PCA, Census of India 2011

14.13 Environmental & Social Impacts

Based on the project particulars and existing environmental conditions, potential impacts have been identified that are likely to result from the proposed metro rail project.

The positive environmental impacts typically include reduction in traffic congestion, quick public transport service and safety, less fuel consumption, reduction in air pollution, reduction of noise level etc. Due to the Proposed project possible impacts are identified and assessed based on the activities associated with project location, design, construction & operation phase.This segment identifies and evaluate the harmful impacts on the environment, likely to consequence of the proposed development.The various potential environmental impacts envisaged from the various project activities are enlisted below:

(1) Air Environment

(2) Water Environment

(3) Noise & Vibration

(4) Land Environment

(5) Ecological Impacts

(6) Socio-Economic Impacts

14.13.1 Components of Impact Assessment

The construction and operational phases of the proposed project comprises various activities each of which may have an impact on environmental parameters. Various impacts during the construction and operation phases on the environment have been studied to estimate the impact on the environmental attributes and are discussed in the subsequent section. The probable impacts of each of these activities on various sectors of environment have been mentioned below under three headings:

- Impacts due to project location
- Impacts during construction phase
- Impacts during operational phase

14.13.1.1 Impacts due to project location

Landuse changes: the alignment will not have much effect on the landuse of the city. The alignment contains only elevated section. The efforts will be made to keep both the land requirement and change of land use minimum.

Land acquisition impacts: The proposed project requires land. The acquisition of land for the project shall displace people from their home, livelihood base since land is a scarce commodity in Metropolitan areas. Acquisition of the private land may cause social disruption and economic loss for the project affected families/people. While implementing the project, there is a need to take into account these disturbances and losses due to the project, their impact on socio-economic condition of the people and plan for their mitigation measures to minimize any negative impacts. Efforts have been made to keep land requirement (Govt. and private land) to the barest minimum by so choosing the alignments that the acquisition of private property is minimal. Land need to be acquired for the proposed Depot/ Station locations however alignment will run through the BRTS corridor hence LA will involve only at the location where alignment is deviating from BRT corridor.

Land is mainly required for route alignment of rail tracks, station buildings, platforms, entry/exit structures, traffic integration, Depot, power sub-stations, ventilation shafts, administrative buildings, and temporary construction depots and work sites etc.

Relocation impacts: the project will involve relocation of shops, commercial-cum-residential buildings and hutments along the proposed corridors. The policy framework and entitlements for the project will be based on national laws: The Land Acquisition Act, 1894 (LAA, amended in 1984) and The National Rehabilitation and Resettlement Policy, 2007 (NRRP); The Maharashtra Project Affected Persons Rehabilitation Act, 1999' as modified up to 2006 and Involuntary Resettlement Policy of the WB/ADB. Compensation shall be paid accordingly, for relocation of shops, commercial-cum-residential buildings and hutments that will be affected due to the proposed project.

Loss of trees: The proposed metro lines are in urban/city area and will not pass through any forests. However, due to the proposed metro construction some trees are likely to be lost. With removal of these trees the process for CO_2 conversion will get affected: The main species are Githithi, Babul, Seshum, Neem, Peepal, Keekar, Pilkhan, Kakri, Chokar, Laspasia, Sahtut, Bargad, Gulmohar, Baikan, Rudrakash, etc.

Shifting of utilities and drainages: there will be shifting of existing water supply pipelines, electrical lines and sewerage lines.

Impact on Historical and Cultural Monuments, The proposed project will affect residential and commercial structures at some of the portion of alignment. No Archeological Monuments are directly affected. Utmost care needs be taken so that no significant impact is anticipated on the historical structures due to project activities during construction and operation.

Impact on Local Transport Facilities

The project has been proposed to cater the additional demand of present and future traffic requirement. Hence, no loss of job to the existing transport facilities is anticipated. The drivers of local transport facilities like buses, taxis, autos and rickshaws may be utilized to cater the requirement of transport from stations to work place and vice-versa. Additional employment opportunities are also anticipated due to the proposed project.

14.13.1.2 Impacts during construction phase

The most likely negative impacts related to the construction works are listed below:

- Pressure on local Infrastructure;
- Soil erosion problems;
- Solid waste generation;
- Health risk at construction site;
- Traffic congestion and diversion problems;
- Excavated and construction material disposal problems;
- Water contamination problems;
- Impact on air quality;
- Noise Impact;
- Displacement.

Pressure on local infrastructure: considering the nature and the magnitude of the project, impacts shall be short term and low in magnitude and will be limited to the construction phase only.

Soil erosion/contamination: the vegetation and top soil shall be disturbed during the construction stage due to excavation and movement of vehicles and equipment. Run off from unprotected excavated areas, and underground construction can result in excessive soil erosion. The spillage of oil from machinery or cement residual from concrete mixer plants might contaminate the soil if not properly collected and disposed off.

Construction solid waste generation: problems could arise from dumping of construction spoils (concrete, bricks) waste materials (from contractor camps) etc. causing surface and ground water pollution. However, it is proposed to have mix concrete directly from batching plant for use at site. Batching plants will be located away from the site. The other construction materials such as steel, bricks, etc. will be housed in a fenced stored yard. The balance material from these yards will be removed for use/disposal.

Health risk at construction site: at the project site, direct exposure to dust generation is likely to cause health-related impact especially dust-related diseases. This would be minimized by providing suitable respiratory personal protective equipments (PPE) such as nose masks with suitable filters etc.

Dust mitigation plan has to be adopted for the local population. Health risks include disease hazards due to lack of sanitation facilities (water supply and human waste disposal) and insect vector disease hazards of local workers and disease hazards to the local population. Mitigation measures should include proper water supply, sanitation, drainage, health care and human waste disposal facilities. In addition to these, efforts need to be made to avoid water spills, adopt disease control measures and employment of local labour. Problems could arise due to difference in customs of imported workers and local residents. These risks could be reduced by providing adequate facilities in worker's camps and by employment of preferably local labour.

Traffic congestion and diversion problems: most of the roads of the project area are broad with traffic signals in proper places but some areas have congested stretches where traffic movement is very slow. Hence, traffic congestion during the construction phase may be a major issue.

Water contamination problems: within the vicinity of project site no major / designated water body are present. Since all construction-related activities will primarily be confined to the enclosed corridor, no major impacts are anticipated.

Impact on air quality: potential impacts on the air quality during the construction stage will be due to the fugitive dust and the exhaust gases generated in and around the construction site.

Impact on noise quality: due to the various construction activities, there will be short-term noise impacts in the immediate vicinity of the project corridor. The impact will be felt more in the congested areas where utmost care has to be taken to reduce noise generation by using acoustic enclosures.

Social impact: as local labour will be hired from the vicinity of the project site and shall be utilized for the construction purpose and all the activities shall be confined to the project site only, no adverse social impacts are envisaged due to the proposed project.

14.13.1.3 Impacts during operation phase

The project may cause the following negative impacts during operation of the project due to the increase in the number of passengers and trains at the stations:

- Impact on land environment;
- Noise pollution;
- Air Pollution;
- Water supply and sanitation at stations;
- Safety.

Noise pollution: during the operation phase, the main source of noise will be from running of metro trains. Noise radiated from train operations and track structures generally constitute the major noise sources. Airborne noise is radiated from at-grade and elevated structures, while ground-borne noise and vibration are of primary concern in underground operations. Underground metros are not known to generate audible sound at the ground level. However, since the metro has elevated sections, some noise attenuation measures from the moving trains need to be integrated in the design to minimize noise . For example the ballast-less track which is supported on two layers of rubber pads reduces track noise and ground vibrations. The concept of a "low-noise" electric locomotive must be adopted at a very early state of planning and must be followed up with detailed work throughout the project execution and operation.

Vibration emanates from rail - wheel interaction and the same can be reduced by minimizing surface irregularities of wheel and rail, improving track geometry, providing elastic fastenings, and separation of rail seat assembly from the concrete plinth with insertion of resilient and shock absorbing pad.

Air pollution: metro operation will cause no air pollution in the city and reduce congestion on the roads there by contributing to improvement in the overall pollution levels in the city.

Water supply and sanitation: the metro's operation will require substantial groundwater. The Client shall install rainwater harvesting facilities at the stations in compliance to the Mandatory Roof Top Rain Harvesting regulations. All stations shall employ a cooling water recirculation system for air conditioning. Recycled water shall be used for facility cleaning and landscape irrigation. All toilets will be equipped with low-flow fixtures.

Safety: during operation, accidents related to train operation like collision, derailment, fire, power outages, or operation stoppage may occur. In the unlikely event of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. A standby silent type DG set at underground stations shall be installed. To provide a high level of safety with trains running at close headway ensuring continuous safe train separation, eliminate accidents continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver, and

provides safety and enforces speed limit on section having permanent and temporary speed restrictions .

14.13.2 Beneficial impacts of the proposed project

Positive impacts have been listed under the following headings:

- Employment opportunity
- Impact on Land Environment
- Traffic flow Improvement/ Less air pollution;
- Quick service and safety
- Less fuel consumption and carbon dioxide reduction.
- Reduction in air pollution

14.13.2.1 Employment opportunities

The project is expected to generate employment in the secondary and tertiary sectors during the construction and operation phases. Thus the project would provide substantial direct employment; besides, more people would be indirectly employed in allied activities and trades.

14.13.2.2 Impact on land environment

There would be increased scope for commercial, industrial and residential development along the project corridor.

14.13.2.3 Less air pollution

Introduction of Mass Rapid Transport System will reduce the traffic load on the roads. Many vehicle owners and users of auto-rickshaws will shift to metro rail as it will be a faster and convenient mode of transport. Thus, reduction of traffic will lead to reduction of automobile emission and consequently air pollution.

14.13.2.4 Quick service and safety

The metro rail system would be more efficient and faster as compared to the traditional modes of travel. In addition, reduction of congestion will make the roads safer and will reduce the incidence of accidents.

14.13.2.5 Less fuel consumption

On implementation of the project, it is estimated that both petrol and diesel consumption will get reduced. The saving will be due to two factors namely Reduction in vehicles and decongestion on roads.

14.13.3 Summary of impacts and mitigation measures

A summary of the potential environmental impacts during construction and operation phases along with recommended mitigation measures is presented in a matrix format in Table 126.

Table 126: Summary of environmental impacts and mitigation measures

Area	Impacts	Mitigation measures
	Construction phase	
Topography & geology	• Change in existing profile of the land-use • Disturbance on geological setting due to quarrying	• The overall topography of the area is not going to alter due to the proposed alignment.s • . No new quarry will be proposed for the Project requirements only existing, live, licensed quarries will be used as sources of aggregates. It will be ensured the aggregates procured during construction stage will be from the authorized or licensed suppliers
Water use	• Impact on the local water sources due to use of construction water	• Maximum rainwater harvesting and minimum use of existing water sources for construction will be ensured to minimize likely impacts on other users
Water Quality	• Increase of sediment load in the run off from construction sites • Water pollution due to sewage from construction camps	• Sediment traps will be provided to reduce sediment load in construction wastewater • Proper sanitation facilities will be provided in construction camps.
Air Quality	• Deterioration of air quality due to fugitive dusts emission from construction activities and vehicular movement along unpaved roads	• Construction materials will be stored in enclosed spaces to prevent fugitive emissions • Truck carrying soil, sand and stone will be duly covered to avoid spilling

	• Deterioration of air quality due to gaseous emissions from construction equipment & vehicular traffic. • Deterioration of air quality due to emission from asphalt and hot mix plants	• Adequate dust suppression measures will be undertaken to control fugitive dust • Low emission construction equipment & vehicles will be used
Noise level	• Increase in noise level due to operation of construction equipment & vehicular traffic	• Protective gears such as ear plugs etc. will be provided to construction personnel exposed to high noise levels as preventive measure • Low noise construction equipment will be used • Construction activities carried out near residential areas will be scheduled to the day time only so that minimum disturbances are caused to people
Floral & fauna	• Loss of trees due to construction of proposed metro corridor	• Preferential plantation of flowering trees with less timber & fruit value will be carried out • Cooking fuel will be provided to construction workers to avoid cutting /felling of trees for fuel wood • Compensatory afforestation cost for compensatory plantation will be provided
Rehabilitation & Resettlement	• Loss of private structures	• Some of the residential/commercial structures will be impacted. Proper Rehabilitation and Resettlement measures will be adopted
Employment & trading opportunities	• loss of source of livelihood for the PAP's losing commercial structures. • The construction will improve the job opportunities	• Most of the construction labourers will be recruited from local areas to alleviate social tension of migration

		• Some of the construction materials like stone chips & sand will be procured locally
	Operation Phase	
Land-use & Encroachment	• Change of land use by squatter/ encroachment within the ROW and induced development outside the ROW	• Planning agencies and Collector/ Revenue Officer will be made involved for controlled development and prohibiting squatter/ encroachment within ROW
Drainage	• ·Filthy environment due to improper maintenance of drainage	• Drainage system will be properly maintained
Air quality	• The proposed project will provide a reduced vehicular emission load atmosphere	•
Noise level	• Noise pollution due to operation phase of proposed metro rail corridors	• Regular monitoring of noise level at specified locations will be conducted
Access	• The proposed corridors will help to increase the accessibility of the project site	•

14.13.4 Impact Matrix

A matrix is a grid-like table that is used to identify the interaction between project activities, which are displayed along one axis, and environmental characteristics, which are displayed along the other axis. Using the table, environment-activity interactions can be noted in the appropriate cells or intersecting points in the grid. Impact matrix summarizing environmental parameters impact and nature of impact for the project is given in Table 127.

Environmental Parameters Impact	Nature of Potential Impacts during Construction and Operation Phases								
	Local	Regional	Short Term	Long Term	Reversible	Irreversible	Negative	Positive	Significant	Insignificant
Topography		No Impact								
Drainage	√						√			√
Soil	√			√		√	√ (construction)	√ (operation)	√	
Water Resources	√			√			√			√
Water Quality	√			√			√		√	
Land Use	√			√		√	√ (construction)	√ (operation)		√
Ambient Air Quality	√		√				√		√	
Noise & Vibration	√		√				√			√
Flora	√			√			√ (construction)	√ (operation)	√	
Fauna	√			√			√ (construction)	√ (operation)	√	
Employment	√			√		√		√	√	
Aesthetic	√		√ (construction)	√ (operation)				√	√	

Table 127 : Potential Environmental Impacts of Project

14.13.5 Environmental Assessment Checklist

Based on the environmental screening, a checklist has been prepared (see table below) to assess the Environmental & Social Sensitivity of Project:

Table 128: Environmental Assessment Checklist for Environmental & Social Sensitivity of Project

Screening Questions	Yes	No	Remarks
Project siting **Is the project adjacent to or within any of the following environmentally sensitive areas?**			
Cultural heritage site		√	No cultural heritage site is existed in proximity of project.
Protected area		√	No forest is in the vicinity of the project. No wildlife-protected area is located close to the alignment and nearby (assessment made up to 10 Km) area.
Wetland		√	No designated Wetland
Mangrove		√	No mangrove area is located in the project site
Estuarine		√	Not applicable
Buffer zone of protected area		√	No protected area or its buffer Zone
Special area for protecting biodiversity		√	No special biodiversity area is located within the ROW
Potential environmental impacts *Will the Project cause…*			
Encroachment on historical/cultural areas,		√	No encroachment on historical or cultural areas.

Screening Questions	Yes	No	Remarks
disfiguration of landscape by road embankments, cuts, fills, and quarries?			The topography of project is passing through plain terrain and rolling terrain at some of the location. Minor impacts on landscape by embankments to improve profile. Cuts and fills are not ruled out. Opening of New Quarries is not envisaged. Only operational and licensed quarry will be used for sourcing materials for the project Proper environmental management plan will be adopted during construction to sustain the quarries.
Encroachment on precious ecology (e.g. sensitive or protected areas)?		√	There is no National Parks, Wild Life Sanctuaries or any other similar eco-sensitive areas in the project area. Only cutting of small number of trees is involved. Attempts have been made to minimise the cutting of trees.
Deterioration of surface water quality due to silt run off and sanitary wastes from worker-based camps and chemicals used in construction?		√	Adequate sanitary facilities and drainage in the workers camps will help to avoid this possibility. As the construction activity in this project will not contain any harmful ingredients, no impact on surface water quality is anticipated.
Increased local air pollution due to rock crushing, cutting and filling works, and	√		Localised air pollution level is likely to increase for a short duration during the construction period due to construction vehicle movement and asphalt processing.

Screening Questions	Yes	No	Remarks
chemicals from asphalt processing?			The asphalt mixing plant (hot mix plant) will be located away from habitat areas with adequately high stack for effective dispersion of likely emissions. Dust separation measures like spraying of water on unpaved vehicle movement areas are proposed to minimise the dust generation.
Risks and vulnerabilities related to occupational health and safety due to physical, chemical, biological, and radiological hazards during project construction and operation?	√		Workers may get exposed to dust and noise during construction activities. However, the exposure levels are likely to be short and insignificant. Workers will be provided requisite PPEs to minimise such exposure and associated harmful occupational health effects. As such, no occupational health hazard is anticipated during operation phase.
Noise and vibration due to civil works?	√		Suitable mitigation measures such as use of Personal Protective Equipments will be taken to minimize the adverse effects.
Dislocation or involuntary resettlement of people?	√		The project-affected persons are expected to be very less as the metro corridor will generally follow underground and elevated alignment. However at stations and depot areas. There will be need for small land acquisition. This aspect will be addressed as per Govt. rules and ADB‟s Social Safeguard Policies (SPS-09) separately.

Screening Questions	Yes	No	Remarks
Other social concerns relating to inconveniences in living conditions in the project areas that may trigger cases of upper respiratory problems and stress?		√	Appropriate mitigation measures to curb the air pollution within permissible levels will keep a check on this problem. Deterioration in ambient air quality will be localised and temporarily during construction activity. The project area is largely located in open areas.
Hazardous driving conditions where construction interferes with pre-existing roads?		√	To minimize the construction interference, suitable traffic management plan will be designed and implemented by the contractor.
Poor sanitation and solid waste disposal in construction camps and work sites, and possible transmission of communicable diseases from workers to local population?		√	Provisions for sanitation, health care and solid waste disposal facilities such as disposal of sewage in soak pit, first aid facility will be done to avoid such possibility. Awareness plan for workers will be prepared to educate them about communicable diseases.
Creation of temporary breeding habitats for mosquito vectors of disease?		√	No such condition is anticipated.
Dislocation and compulsory resettlement of people living in right-of-way?	√		Proper resettlement action plan will be proposed.
Accident risks associated with increased vehicular traffic leading to loss of life?		√	Adequate safety measures will be adopted to avoid accidents during construction and operation stages. Measures, like signage, speed control; crash barriers will be taken close to sensitive locations such as schools, temple or hospitals.

Screening Questions	Yes	No	Remarks
Increased noise and air pollution resulting from traffic volume?	√	√	Increase in noise and air pollution is expected during construction phase but is likely to be confined within few meters of either side of the project alignment. Adequate mitigation measures will be adopted as per the prescribed Environmental Management Plan to minimise the same. During operation stage, metro will provided a comfortable travel and provide pollution free alternate mode for commuters.
Increased risk of water pollution from oil, grease and fuel spills, and other materials from vehicles using the road?	√		This possibility is minimal but cannot be ruled out. Controlled construction activities and proper drainage system will reduce this possibility.
Large population influx during project construction and operation that causes increased burden on social infrastructure and services (such as water supply and sanitation systems)?		√	Most of the workers will be hired locally. The small construction camps are unlikely to cause any significant burden on social infrastructure and services.
Social conflicts if workers from other regions or countries are hired?		√	Most of the workers will be hired locally.
Risks to community health and safety due to the transport, storage, and use and/or disposal of materials such as explosives, fuel and other		√	The construction material (aggregate from approved quarries, borrow earth, bitumen) will be sourced from nearby and approved sources. No explosive or chemicals are likely to be used. Bitumen waste if any generated during construction and garbage from

Screening Questions	Yes	No	Remarks
chemicals during construction and operation?			stations will either be recycled or disposed of in controlled manner.
Community safety risks due to both accidental and natural causes, especially where the structural elements or components of the project are accessible to members of the affected community or where their failure could result in injury to the community throughout project construction, operation and decommissioning.		√	No such impacts are anticipated. Adequate awareness will be created amongst people and workers through information disclosure, safety signage and public consultation about safety aspects.

Table 129 : Environmental Assessment Checklist for Climate Change and Disaster Risk of Project

Climate Change and Disaster Risk	Yes	No	Remarks
Is the Project area subject to hazards such as earthquakes, floods, landslides, tropical cyclone winds, storm surges, tsunami or volcanic eruptions and climate changes?		√	As per BIS categorization project area falls in Zone III indicating Moderate- low earthquake hazard risk. The area is not subject to natural hazards like tropical cyclone winds, storm surges, tsunami or volcanic eruptions and climate changes.
Could changes in temperature, precipitation, or extreme events patterns over the Project lifespan affect technical or financial sustainability (eg. increased		√	The project design was based on projects already in operation in other cities with similar climatic conditions. The project area is not subject to erosion or landslide etc. Technical or financial sustainability of

erosion or landslides could increase maintenance costs, permafrost melting or increased soil moisture content could affect sub-grade).			the project is unlikely to be affected due to any extreme event pattern.
Are there any demographic or socio-economic aspects of the Project area that are already vulnerable (eg., high incidence of marginalized populations, rural-urban migrants, illegal settlements, ethnic minorities, women or children)?		√	No such condition exists or anticipated.
Could the Project potentially increase the climate or disaster vulnerability of the surrounding area (e.g., by encouraging settlement in areas that will be more affected by floods in the future, or encouraging settlement in earthquake zones)?		√	No such condition is anticipated.

No significant Social and Environmental impact has been found due to the proposed project in the project influence area.

14.14 Environmental Management Plan

The main purpose of the Environmental Management Plan (EMP) is to delineate all the measures to be undertaken during various phases of the project to offset or mitigate the adverse environmental Impacts (if any) to acceptable level to protect the environment especially the community likely to be affected by the proposed project. The EMP should necessarily cover all phases of project cycles i.e. planning and design, construction and operation. The potential Impacts on the environment due to the proposed project were Identified based on the nature of activities undertaken during its construction and those envisaged to occur during Its operation in the light of present status of the environment and legal compliance required. The mitigation measures required to be taken already taken during various stages of the project have been described below. The Environment Management measures shall be implemented during the various stages of the project – Pre-construction stage, Construction Stage and Operation Stage.

A description of the various management measures suggested during different stages of construction is provided in Table 130.

14.14.1 EMP Matrix

14.14.1.1 Pre-Construction Stage

Pre-construction activities by Metro Authorities

Prior to Contractor mobilization, the Metro Authority will ensure that an encumbrance free Corridor of Impact is handed over to enable the start of construction. Clearance involves the following activities:

- Removal and felling of trees,
- Relocation of common property resources and utilities that will be impacted.
- Formal arrangements for maintenance of enhancement sites. This includes plantation of trees and barricades along the project site.

Pre-construction activities by Contractor

Pre-construction stage involves mobilisation of the Contractor and the activities undertaken by the Contractor pertaining to the planning of logistics and site preparation necessary for commencing construction activities. The activities include:

- Joint field verification of EMP by the Environment Specialist of the Supervision Consultant and Contractor.
- Identification and selection of material sources (quarry and borrow material, water, sand etc).
- Procurement of construction equipment / machinery such as crushers, plants and other construction equipment and machinery.
- Selection, design and layout of construction areas, plants, labour camps etc.
- Apply for and obtain all the necessary clearances/ NOCs/ consents from the agencies concerned.

- Planning traffic diversions and detours including arrangements for temporary land acquisition.

14.14.1.2 Construction Stage

Construction activities by the Contractor

Construction stage is the most crucial stage in terms of activities that require careful management to avoid environmental impacts.

There are several other environmental issues that have been addressed as part of good engineering practices, the costs for which have been accounted for in the Engineering Costs. They include providing drainage, provision of cross-drainage structures etc.

Construction activities by the Metro Authority/Supervision Consultant

The Metro Authorities /Supervision Consultant shall be involved in the smooth execution of the project and assisting the EPC Contractor during this phase. Their work shall include but not limited to:

- Monitoring and guiding the EPC Contractor on adopting good environmental and engineering practices.
- Arranging training to the EPC Contractor and other stakeholders according to the needs arising.

14.14.1.3 Operation Stage

The operation stage involves the following activities by Metro Authority:

- Monitoring of environmental conditions through approved monitoring agency.
- Monitoring of operational performance of the various mitigation/enhancement measures carriedout.

Table 130 : Environmental Management Plan (EMP)

Environmental parameters / Issues	Mitigation measures	Parameters for Monitoring	Responsibility of Implementation
Pre-Construction/ Design Phase			
Energy conservation/ natural ventilation	Energy conservation through provision of energy efficient fittings, maximize use of natural light.	Periodic energy auditing, electricity usage bills	DPR/ Design Consultant Environmental Management Cell/ Unit
Water Conservation	Reduce water requirements through water efficient plumbing fittings, by making provision for rain water harvesting, Recycle and reuse of waste water to the maximum extent possible, using alternative sources of water e.g. bore well etc.) for non - drinking purpose	Water consumption estimates and its compliance/status during construction /operation phase	DPR/ Design Consultant or Design unit of Metro Authority
Reduction in incremental air pollution through traffic management	Designing proper traffic management plan around the proposed project to facilitate smooth flow of traffic, removal of encroachments /unauthorized hawkers on footpaths/roads to increase the carrying capacity of the roads.	Air Pollution monitoring	DPR/ Design Consultant or Design Unit of Metro Authority in Consultation with SPCB and Traffic Police
Environmental Enhancement	Development of Green belt as a part of Station building land scaping	DPR/ Land Scaping plan	DPR/ Design Consultant or Design unit of Metro Authority in consultation with Environmental Management
Fire Management	Providing Firefighting facilities as per National Building Code (2004) provisions, Periodic maintenance /checking of the fire & educate the occupants for fighting facilities.	DPR/ Work contracts included in the Tender documents	DPR/ Design Consultant or Design unit of Metro Authority

Inclusion of environmental management related clauses in work contract	Inclusion of various environmental related aspect (viz., disposal/ management of spoils during construction phase, monitoring of environmental parameters during pre-construction /construction/Operation Phase) of project, appointment of environmental consultants to advise on environmental matters	DPR/ Work Contractor	DPR/ Design Consultant or Design unit of Metro Authority in consultation with Environmental Management Cell/ Unit of Metro Authority
Construction Phase			
Air Emissions	All equipment's will be operated within specified design parameters	Random check of equipment log & Manuals	Engineering unit at the Project site
	Vehicle trips to be minimized to the extent possible	Vehicle Logs	Contractor/CivilEngg unit at the Project site
	Any dry, dusty materials stored in Sealed containers or prevented from blowing	Absence of stockpiles or open containers of dusty containers of dusty materials	Contractor/Civil Engg unit at the Project site/ Environmental Management
	Compaction of soil during various construction activities	Construction logs	Contractor/Civil Engg unit at the Project site
	Ambient Air Quality Monitoring within construction zone to be monitored	The Ambient Air Quality will conform to the standards for SPM, SO2, and NOx, CO a	Contractor/ Environmental Management Cell/ Unit of Metro Authority
Noise Pollution	List of all noise generating machinery onsite along with age to be prepared. Equipment to be maintained in good working order	Equipment logs, noise reading	Contractor/ Environmental Management Cell of Metro Authority

	Night working to be minimized	Working hours records	Contractor/Civil Engg. unit at the Project site
	Generation of vehicular noise	Maintenance records of vehicles	
	Implement good working practices (equipment selection and siting) to minimize	Site working practices records, noise reading	DPR/ Design Consultant / Civil Engg. unit of Metro Authority
	Noise and also reduce its impacts on human health (ear muffs, safe distances, enclosures)		
	No machinery running when not required	Log books/ physical supervision	Contractor/Civil Engg unit at the Project site
	Acoustic mufflers/ enclosures to be provided in large engines	Mufflers/ enclosures in place	Contractor/ Environment Management Cell/ Unit of Metro Authority
	Noise to be monitored in ambient atmosphere within the premises	Noise reading	as per PCC requirement or half yearly, whichever is lesser
	The noise level not to exceed the permissible limit both during day and night times	Noise level monitoring	Contractor/ Environmental Management Cell/ Unit of Metro Authority
	All equipment operated within specified design parameters	Random checks of equipment logs/ manuals	Contractor/CivilEngg unit at the Project site

	Vehicle trips to be minimized to the extent possible	Vehicle logs	Contractor/Civil Engg unit at the Project site
Soil Erosion	Minimize area of site clearance to the extent possible, Compensatory plantations as apart of land scaping to compensate the loss of trees/vegetation, development of green belt, avoid providing concrete flooring outside the Station building to the extent possible	Physical inspection /supervision	Contractor/CivilEngg unit at the Project site in consultation with Environmental Management Cell/ Unit of Metro Authority
Surface Runoff	Covering the spoils to prevent the wash out during rainy seasons, provision of green belt to minimize surface run off	Physical inspection /supervision	Contractor/Civil Engg unit of Metro Authority at the Project site
Disposal/ Recycle of Construction Waste	Providing sufficient no. of garbage bins, segregate biodegradable and non-biodegradable wastes and dispose off them accordingly including disposal of spoils/waste generated during construction phase at the pre - designated site by the contractor, reuse of construction waste at the construction site itself.	Log books of disposal truks, Physical inspection /supervision	Contractor/Civil Engg unit of Metro Authority at the Project site
Non - Routine Events and Accidental Release	Preparation/ inclusion of emergency preparedness plan in the work contract to avoid/manage emergencies	DPR/Work Contract	Contractor/Civil Engg unit at the Project site
Workers Safety/ Health Hazard	First aid facilities at the work/construction site, provision of safe drinking water and sanitation facilities for construction workers, safety/health related issues for construction workers to be included in the civil/electrical work contract awards	DPR/Work Contract	Contractor/CivilEngg unit of Metro Authority at the Project site

Environmental Management Cell/ Unit	Setting up of Environmental Management Cell/ Unit to be set up to ensure implementation and monitoring of environmental safeguards	DPR/Work Contract	Environmental Management Cell/ Unit of Metro Authority
Operation Phase			
Air Emissions	Stack emissions from DG sets to be optimized and monitored, periodic ambient	Air pollution monitoring	Environmental Management Cell/ Unit of
	Air quality monitoring at the project site as per the Post Project Monitoring (PPM) details, Incentives/encouragement to the Staff to use public transport instead of private vehicles		Metro Authority
Noise Pollution (DG sets and Vehicles)	Noise generated from operation of DG sets to be optimized and monitored, Dg sets to generate less than 75dB(A) Leq at 0.5m from the source, DG sets to be provided at basement with proper acoustic enclosures /mufflers, Chimney height of 8m above the roof top, no-horn zone inside the Station building complex	Noise Pollution monitoring	Environmental Management Cell/ Unit of Metro Authority
Wastewater Discharge	All the wastewater generated in the station building complex to be collected through the internal sewer line and ultimately discharging it to municipal; sewage line to be taken to sewage treatment plan, Separate lines for surface run off arid its disposal into drainage system	Physical inspection as a part of periodic maintenance	Contractor/Civil Engg and Environmental Management Cell/ Unit of Metro Authority

Solid Waste Management	Provision of adequate no. of bins in the Station building, segregation and collection of bio-Degradable (kitchen wastes) and non-biodegradable wastepaper and computer stationery), Disposal of solid wastes as a part of maintenance and included in the work contract	Physical inspection as a part of periodic maintenance	Contractor/Building Maintenance unit of METRO AUTHORITY
Indoor Air Pollution (Inside Station building and Parking lots)	Indoor air pollutants (viz., CO, VOC, RSPM to be reduced by providing proper ventilation and to be monitored periodically as per the stipulated PPM, declaring whole Station building as "No Smoking Zone"	Indoor Air Pollution Monitoring	Environmental Management Cell/ Unit of METRO AUTHORITY
Energy Uses	Energy usage for AC's and other electrical appliances to be minimized, conduct energy auditing of the Station building annually, use of solar energy for different usages	Energy usage quantity, bills trends over a period of time	Energy Auditors, maintenance section of the Station building
Emergency Preparedness including Fire Management	Fire protection and safety measures to take care of fire and explosion hazards, mock drills to check the emergency preparedness in case of fire, earthquake etc.	Mock drills/ safety auditing by the consultant	Maintenance section of the Station building (METRO AUTHORITY)
Environmental Management Cell/ Unit	Setting up of Environmental Management Cell/ Unit to be set up to ensure implementation and monitoring of environmental safeguards	DPR	Environmental Management Cell/ Unit of METRO AUTHORITY

Table 131 : Environmental Monitoring Plan

Environmental Component	Project Stage	Monitoring						Institutional Responsibility	
		Parameters	Special Guidance	Standards	Location	Frequency	Duration	Implementation	Supervision
Air	Construction Stage	PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, HC (non-methane)	High volume sampler to be located 50 m from the plant in the downwind direction. Use method specified by CPCB for analysis	The Air (Prevention and Control of Pollution) Rules, CPCB, 1994	Plant Site	Once in year for three seasons (except monsoons)	Continuous 24 hours- Weekly twice for two non-consecutive day.	Contractor through approved monitoring agency	Engineer, Metro Authority
	Construction Stage	PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO,	High volume Sampler to be located 40 m from the earthworks site downwind direction. Use method specified by CPCB for analysis	The Air (Prevention and Control of Pollution) Rules, CPCB, 1994	Stretch of the project where construction is in progress at the site At 3 Locations	Once in year for three seasons (except monsoons)	Continuous 24 hours/ Weekly twice for two non-consecutive day.	Contractor through approved monitoring agency	Engineer, Metro Authority
	Operation Stage	PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, HC	High Volume Sampler to be located at 15m from edge of the pavement	The Air (Prevention and Control of Pollution) Rules, CPCB, 1994	At 4 locations as per requirement.	Once in year for three seasons (except monsoons)	Continuous 24 hours/or for 1 full working day.	Contractor through approved monitoring agency	Engineer, Metro Authority

Environmental Component	Project Stage	Monitoring						Institutional Responsibility	
		Parameters	Special Guidance	Standards	Location	Frequency	Duration	Implementation	Supervision
Water Quality	Construction Stage	pH, BOD, COD, TDS, TSS, DO, total coliform, conductivity Oil & Grease and Pb	Grab sample collected from source and analyze as per Standard Methods for Examination of Water and Wastewater	Water quality standards by CPCB	At 2 locations as per requirement.	Once in year for three seasons (except monsoons)	-	Contractor through approved monitoring agency	Engineer, Metro Authority
	Operation Stage	pH, TDS, TSS, DO, Temp, Pb, Oil and Grease	Grab sample collected from source and analyze as per Standard Methods for Examination of Water and Wastewater	Water quality standards by CPCB	At 2 locations as per requirement.	Once in a year	-	Metro Authority	Metro Authority
Noise Levels	Construction Stage	Noise levels on dB (A) scale	Free field at 1 m from the equipment whose noise levels are being determined.	Noise standards by CPCB	Plant Site	Once in year for three seasons (except monsoons)	Continuous over 24 hours	Contractor through approved monitoring agency	Engineer, Metro Authority

Environmental Component	Project Stage	Monitoring						Institutional Responsibility	
		Parameters	Special Guidance	Standards	Location	Frequency	Duration	Implementation	Supervision
		Noise levels on dB (A) scale	Equivalent Noise levels using an integrated noise level meter kept at a distance of 9m & 15m from edge of Pavement	Noise standards by CPCB	Stretch of the project where construction is in progress at the site At 3 Locations	Once in year for three seasons (except monsoons)	Continuous over 24 hours	Contractor through approved monitoring agency	Engineer, METRO AUTHORITY
	Operation Stage	Noise levels on dB (A) scale	Equivalent Noise levels using an integrated noise level meter kept at a distance of 9 m and 15 m from edge of Pavement	Noise standards by CPCB	At selected 4 locations	Once a year	Continuous over 24 hours	Contractor through approved monitoring agency	Engineer, Metro Authority
Soil Quality	Construction Stage	Monitoring of heavy metals	Contamination standards given by EPA	As per IRC code of practice	At Selected 2 locations	Once in year for three seasons (except monsoons)	One time sample	Contractor through approved monitoring agency	Engineer, Metro Authority

14.15 Environmental Budget

Mitigation measures proposed in the EMP will be implemented by the Contractor. The budgetary provisions for the implementation of the environmental management plan of the Project are presented in Table 132.

Table 132: Environmental Management Cost Construction & Operation Phase

Environmental Aspect	Frequency Of monitoring	No. of sampling locations	Total Samples	Rates per sample (Rs.)	Total Cost
Construction Phase					
Air Pollution Monitoring	Quarterly	4	24	10,000	240000
Noise Pollution Monitoring	Quarterly	4	24	4,000	96000
Ground Water Quality Monitoring	Quarterly	2	6	10,000	60000
Surface Water Quality Monitoring	Quarterly	2	6	10000	60000
Soil Monitoring	Quarterly	2	6	8000	48000
Waste Management					1000000
Water Conservation Rain Water Harvesting			3	500000	1500000
Training & Education to Workers for Environment Conservation & Awareness					1000000
Dust Suppression & Air & Noise Pollution Control Measure					1000000
Green Cover/Afforestation& Maintenance					1500000
Tentative Tree Cutting Cost for 342* no. of trees					128748
Tentative Tree Transplantation Cost (However the cost shall be as per the availability of the land and as per the concern forest department)			100	150000	15000000
Sub Total (A)					**21632748**
Opération Phase					

Air Pollution Monitoring	Quarterly	4	24	10,000	240000
Noise Pollution Monitoring	Quarterly	4	24	4,000	48000
Ground Water Quality Monitoring	Yearly	2	2	10,000	20000
Surface Water Quality Monitoring	Yearly	2	2	10000	20000
Soil Monitoring	Yearly	2	2	8000	16000
Maintenance Cost for Plantation					500000
Training & Education to Workers for Environment Conservation & Awareness					1000000
Maintenance cost for Environment Safeguard					1000000
Sub Total (B)					**2844000**
Total Cost (A)+(B)					**8848000**
Contingency @5%					**442400**
Total Environmental Mitigation Measures Cost					**9290400**
Tentative tree cutting cost for 342 number of trees					**128748**
					9419148

*Approximatey, 342 no. of trees will be impacted due to the project. However, the no. of trees might be less. Exact no. of trees will be identified at the time of joint verification with the concerned department.

14.16 Conclusion & Recommendation:

The preliminary environmental studies along the project corridor based on the secondary baseline data and field survey has revealed some of the environmental issues along the project corridor as well as potential adverse impacts due to the project. The negative impacts due to location of proposed corridor IA 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.

Mitigation measures and management plan for Compensatory Afforestation, Construction Material, Housekeeping, Air Pollution Control, Noise and vibration Control are suggested for early consideration in designing and decision of most appropriate alignment.

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.

14.17 Social Impact Assessment

This secion deals with the Social Impact Assessment and the Short Resettlement Action Plan as a part of the Detailed Project Report.

Social impact assessment aims to identify likely impacts on the local communities and other existing settlements, congested and built up areas including community property resources (CPRs) and any other impacts on the population within project corridor etc., so that the basic information could be provided to the engineering design team. The objective of this study is to minimize the adverse impacts on the targeted population, if any, with the best possible engineering solutions and the most appropriate cost, with complete coordination between the engineering, social and environmental teams during the design process. At this stage, social impact assessment of the project area has been carried out and steps have been taken to minimize adverse impacts at the design stage itself to make the project people friendly and economically viable. Wherever avoidance/ reduction of the adverse social impact is not possible, the affected population has been compensated, resettled and rehabilitated properly by adopting adequate mitigation measures, with an objective of improving the living conditions of the project affected people (PAPs).

The following key steps were taken, while preparing social impact assessment report and, thereafter, short resettlement action plan for the project including options for mitigation measures at the time of project implementation:

- Avoid/ reduce the adverse social impacts at the initial design stage, especially while finalizing the alignments;
- Mitigate the unavoidable adverse impacts at planning, designing and implementation phase; and
- Provide compensation to project affected persons (PAPs) and common properties at replacement costs by adopting appropriate rehabilitation and resettlement measures in the light of Government of India policies RFCTLARR Act, 2013, ADB Safeguard Policy Statement, 2009 (SPS) on the Invlountary Resettlement guidelines and concerned State Government rules and regulations.

This Social Impact Assessment is based on social analysis and initial social impact assessment of the PAPs and properties affected due to the project. In view of the human dimensions involved, the possible social impacts have been integrated into the improved alternative engineering designs to minimize the task of involuntary resettlement. This task has been achieved by adopting engineering techniques in terms of the provisions of concentric & geometric widening, realignments and de-tours etc.

14.18 Scope & Objectives of the Project

The Social Impact Assessment process generally begins with screening at the time of project identification where steps are taken from the beginning and plans/ designs/ alignments are finalized in such a way that to the extent possible adverse impacts are avoided at the designing stage itself and make these projects people friendly. These steps are:

- Avoiding the adverse social impact at the designing stage especially while finalising the alignments and station locations.
- Mitigating the adverse impacts at designing stage and construction /operation phase.
- Compensating the affected people/common properties and rehabilitation and resettlement measures.

The overall objective of conducting social impact assessment is to provide input of social concerns to be dovetailed in design and to avoid or minimize the adverse social impacts with the best possible engineering solutions at the most optimal cost with complete co-ordination between the engineering, environmental and social teams during the entire design process.

In brief, keeping in mind the scope and objectives of the study, the following main tasks has been considered for accomplishment:

- To highlight the need for a proposed metro project;
- To describe the proposed project and alternatives;
- To evaluate the potential impacts of proposed metro project options on the valued ecosystem components within the project study area;
- To consult the local people, officials and experts on options and impacts in order to establish institutional capacity;
- To encourage the public participation during consultation;
- To select the preferred project option and suggest mitigation plan.

14.19 Approach and Methodology

The social impact assessment at this stage is based on 'Social Survey', conducted within the corridor.

The social survey of the affected properties has been carried out by using a questionnaire format, conducted within the corridor in the light of up-to-date project design.

The approach and methodology involves the following:

- To understand the settlement pattern and the physical features along the project corridor to identify the critical sections of the metro stretch and to develop an understanding of socio-economic profile.
- A social survey was carried out, administering a questionnaire for collection of information on affected population, properties/structures, likely impact on land, type of ownership and social groups etc.
- Documentation of the PAP's perception regarding the adverse impacts that may be caused due to the project.
- Developing a database with estimates of different categories of PAPs irrespective of their legal holdings.

- Analysis of census and socio-econmic data collected for the purpose of social impact assessment and short resettlement action plan.

14.20 Project Benefits and Beneficiaries

The proposed metro project is expected to bring positive benefits for the users and act as a development stimulant for the country in terms of overall socio-economic development in the region as discussed in the subsequent paragraph.

14.20.1 Direct Project Benefits

Major benefits that are likely to accrue from the project include:

- Stimulus for further development in the region along with increase in employment opportunities;
- Improved metro network benefiting the local people including businessmen, traders, merchant, tourists and short distance motorists;
- Reduction in travel time, distance as well as transportation cost will be reduced;
- Boost for socio-economic and tourism development along the project;
- Vulnerable and poor people's income will be increased and;
- Facilitate the provision of extension and social services by the government, NGOs and other voluntary institutions;

14.20.2 Indirect Project Benefits

As quantified above, the most direct beneficiaries of this project are users, i.e., the population living along project, as well as passengers travelling in private and public transport etc.. There will be benefit from reduced transportation costs and travel times between the connected regions, and much improved travelling comfort. However, the communities located along the project corridor will also get economic benefit indirectly mainly because of two main reasons;

1. During the construction period a large number of skilled and unskilled workers will be employed by private contractors, resulting in important income generation. Unskilled workers will be recruited from the area for physical works, resulting in direct income generation for this group in the area of the project.

2. Private contractors and consultants will get benefit from the contracts that will arise from project execution and from the subsequent operation. Both women and men are expected to benefit from the improved mobility, safety and access to markets and services along the project corridor. However, in terms of safety benefits women and children will be benefitted from the increased safety related measures generated by the project at the time of travelling, since they tend to constitute the majority of commuters in the proposed metro project, in order to access social services, markets and shopping stores..

14.21 Social and Resettlement Impacts

The social impact assessment at this stage aims to record impact on the settlement and community in order to document the adverse impact on population with the aim to minimize and mitigate the adverse impacts on the population with the best possible socio-economic mitigation measure and engineering solutions at the most appropriate cost. The objective of this study is also meant for preparation of appropriate Short Resettlement Action Plan documents, considering the approved resettlement and rehabilitation framework for the project.

The present exercise will explore the impact on the population as well as on the properties, reported in this section as follows:

This report will assess the social impacts and land acquisition requirement for the project section Corridor-1A i.e. PCMC to Nigdi which traverses through the Chinchwad, Akurdi and Nigdi of Haveli Taluka in Pune District. The present report has considered those persons, who are losing their structures, due to project implementation.

As per findings of the census survey of affected land and non-land assets, the project impacts can be broadly classified as (i) impacts on private structures (ii) impacts on livelihoods due to loss of private properties and (iii) loss of common property resources. From the analysis of impacts, it is noted that altogether 49 structures including 10 private structures and 25 squatters will be affected due to the project. As per the survey, total 10 households will be affected in the project. The details of project impacts are presented in the following table:

Table 133 : Summary of Project Impacts

S. No.	Impacts	Number
1	Total land acquisition including Govt. and Pvt. Land (in hectare)	0.7446
2	Total no. affected Structures	49
3	Total no. affected Private Structures (7 Households)	10
4	Total no. Squatters	25
5	Total no. Govt. Properties	12
6	Total no. of Religious Properties	2
7	Fully Displaced Structures	31
8	Losing Commercial & Resi-cum-commercial Structures (TH) Fully displaced	29

Source: Census Survey, Systra Faridabad, 2018

14.21.1 Scope of Land Acquisition

The scope of land acquisition is quite significant in the project because of limited availability of RoW. Since, the finalization of calculation of land acquisition is under process and it is being finalized. At this juncture, the final evaluation and assessment of area of land is not identified as village and plot wise. According to the latest Land Acquisition Plan (LAP), prepared as a part of Detailed Design Report, **0.7446 hectares** of land including private land and govt. land will be acquired for the project.

All the information, which has been reported here are on the basis of preliminary data collected from the field, of the data has been assessed and analysed by professional expert.

Census survey of affected structure owners is carried out to identify the persons who would be affected by the project and to make an inventory of their assets that would be lost to the project, which would be the basis of calculation of compensation.

At this juncture, the landownership details has been identified for the private landowners. However the further details can be assessed during the joint verification process. Here, the social composition of affected persons has been analyzed, considering the data collected from the structure's owner.

The major findings and magnitude of impacts are discussed in the following sections.

14.21.2 Ownership of Land Being Acquired for the Project

The land acquisition for the project section has been calculated considering the proposed ROW. The area of land to be acquired is around 0.7446 hectares in PCMC-NIGDI Section. The land, which has to be acquired, includes private as well as government land are documented in Table 134.

Table 134 : Land Acquisition details

S. NO	Name of Station	Gata No	Area of Acquisition	Area	ASR (Per sqm)	Multiple	Acquisition cost as per ASR	Land Cost (In Cr.)	Type of Land
1	FOB	200	971.39	0.0971	70650	2	137257407	13.73	PVT
		Road	147.51	0.0148	11640	1	1717016.4	0.17	GOVT
		244	327.16	0.0327	70650	2	46227708	4.62	PVT
	Station 01 (Chinchwad)	244	416	0.0416	70650	2	58780800	5.88	PVT
		218A	345	0.0345	11640	1	4015800	0.4	GOVT
		218b	3	0.0003	11640	1	34920	0.003	GOVT
		202	208	0.0208	44070	2	18333120	1.83	PVT
		Total	2418.06	0.2418			266366771	26.64	
2	Station 02 (Akurdi)	169	337	0.0337	50000	2	33700000	3.37	PVT
		51	383	0.0383	50000	2	38300000	3.83	PVT
		61	77	0.0077	50000	2	7700000	0.77	PVT
		Total	797	0.0797			79700000	7.97	
3	Station 03 (Nigdi)	4+925-4+960	329.28	0.0329	50000	2	32928390	3.29	PVT
		Ford Showroom	1618.94	0.1619	58410	2	189124618	18.91	PVT
		Open Land	187	0.0187	18780	2	7023720	0.7	GOVT
		43	642	0.0642	58410	2	74998440	7.5	PVT
		Bus Depot	380	0.038	10360	1	3936800	0.39	GOVT
		Temple Area	623	0.0623	18780	2	23399880	2.34	PVT
		Open land with temporary structure	451.06	0.0451	17660	2	15931612	1.59	PVT
		Total	4231.29	0.4231			347343460	34.73	

Grand Total	**7446.35**	**0.7446**			**693410231**	**69.34**	
Contingency@5%					**34670512**	**3.47**	
Total Land Cost with Contingency@5%					**728080743**	**72.81**	

Source: Preliminary Assessment of Land acquisition

14.21.3 Impacted Properties

The properties to be affected by the proposed project include shops, or any other structure. It has been attempted to get the details of various structures that are located within the proposed RoW of the project.

The census survey, within proposed Right of Way, has been carried out to enumerate the properties, falling within proposed ROW. The finding of the survey revealed that there are significant numbers of structures, i.e., a total of 49 structures are going to be affected within the proposed right of the way. Structures include the private properties, squatters, government properties, community properties. The following sections deals with the details of the affected structures along the project. The number of properties and its distance from the existing centreline is depicted in Table 135.

Table 135 : Distance of affected structures from Centreline

S. No	Distance from Centreline	Left	Right	Total
1	Up to 4.5m & Station Location	42	7	49

Source: Census Survey, Systra Faridabad, 2018

The properties falling within the corridor of impact as per its type of ownership have been documented in Table 136.

Table 136 : Ownership of Properties to be affected

S. No	Type of Properties	Left	Right	Total	%
1	Private	5	5	10	20.41
2	Squatters	25	0	25	51.02
3	Government	11	1	12	24.49
4	Relegious	1	1	2	4.08
Total		**42**	**7**	**49**	**100**

Source: Census Survey, Systra Faridabad, 2018

The details of type of construction of the structures are summarized in the Table 137.

Table 137 : Type of Construction of Private Structures

S. No	Type of Construction	Left	Right	Total	%
1	Kutcha	23	0	23	65.71%
2	Pucca	2	5	7	20%
3	Kiosks	5	0	5	14.28%
Total		**30**	**5**	**35**	**100**

Source: Census Survey, Systra Faridabad, 2018

The total number of private properties will be affected due to the project is 35 in number. These private properties are used for commercial & residential purpose. It was revealed during social survey that most of the structures along the project are commercial structures as shown in Table 138.

Table 138 : Type of Private Properties to be Affected

S. No	Type of Private Properties	Left	Right	Total	%
1	Commercial	3	4	7	87.5%
2	Residential	0	1	1	12.5%
3	Resi-cum-commercial	1	0	1	2.86%
Total		**4**	**5**	**9**	**100**

Source: Census Survey, Systra Faridabad, 2018

Data collected through field survey shows that there are 12 government properties are to be affected due to the proposed project. The details of such properties are summarized in the Table 139.

Table 139 : Type of Government Properties to be Affected

S. No	Type of Government Properties	Left	Right	Total	%
1	BRT	7	0	7	58.33
2	Bus Stand	2	0	2	16.67
3	Bus Stand Boundary wall	1	0	1	8.33
4	Foot over Bridge	1	0	1	8.33
5	Toilet	0	1	1	8.33
Total		**11**	**1**	**12**	**100**

Source: Census Survey, Systra Faridabad, 2018

14.21.4 Impacted Public/Community Properties

The impact on religious structures is generally considered as an area of concern due to its association with the religious sentiments of the people. The total number of religious properties to be affected due to this project is 1. The details of such properties are summarized below:

S. No.	Type of Religious Properties	Left	Right	Total	%
1	Temple Gate and Room	0	1	1	100%

14.22 Legal Status of the Ownership of the Properties/ Structures

Due to loss of structures many people will be losing their properties/ livelihoods and will be economically affected. As per the census survey of structures, 10 households will be losing their properties/ livelihood due to loss of structures under titleholders' category and 25 are squatters. The details of the affected households are shown in Table 140.

Table 140 : : Entitlement of Properties

			Number of PAPs	Total

S. No	Category of Affected Households	Description	Left	Right	
1	Title Holders	Structures	5	5	10
2	Squatters	Structures	25	0	25
Total			**30**	**5**	**35**

Source: Census Survey, Systra Faridabad, 2018

14.22.1 Level of impact on Affected Private Structures

The level of impact has been considered under two categories namely, partial impact and fully impact. The structure, which is getting affected are falling in fully displacement category and leads to physical displacement, detailed in Table 141

Table 141 : Impact Level on Structures

S. No	Impact Level	Category	Total	%
1	**Fully Displacement**	Commercial	28	88.57
		Residential	2	
		Resi-cum-commercial	1	
2	**Partially Displacement**	Commercial	3	11.43%
		Residential	1	
Total			**35**	**100**

Source: Census Survey, Systra Faridabad, 2018

14.22.2 Social profile of the PAPs along the Project

The purpose of our census survey was to create a broad database of the affected properties as well as the project-affected persons (PAPs) in order to understand the social profile of the project-affected area. It helps to appraise the positive as well as negative change in the life style of the communities in the project influence area due to implementation of the project as an external intervention. Based on the primary data collected during census survey, an assessment of the social profile of the affected population of structures only has been outlined in the following paragraphs and tables.

14.22.2.1 Total Affected Households

Due to loss of structures many people will be loosing their properties/ livelihoods and will be adversely affected. The data reveals that as many as total **35** households are getting affected due to the proposed project. The details for the same are shown in Table 142.

Table 142 : Number of Affected Households

S. No	Type of Impacts	Category of PAHs	Number of PAPs		
			Left	Right	Total
1	Structure Only	Owner (TH)	5	5	10
2	Structure Only	Squatters (NTH)	25	0	25
Total			**30**	**5**	**35**

Source: Census Survey, Systra Faridabad, 2018

14.22.2.2 Religious Category of PAHs along the Project

Social customs and tradition play a major role in determining the socio-economic development as well as occupational pattern in the influence area, keeping this in mind a social analysis has been conducted considering the religious profile of the PAHs within the corridor of impact. In the project, majority of the PAHs belong to Hindu population (97.14%) followed by Muslim population (2.86%). Table 143 delineates the religious cluster of the affected households.

Table 143 : Religious Categories of PAHs along the Project

S. No	Religious Group	Left	Right	Total	%
1	Hindu	29	5	34	97.14%
2	Muslim	1	0	1	2.86%
Total		**30**	**5**	**35**	**100**

Source: Census Survey, Systra Faridabad, 2018

14.22.2.3 Social Category of PAHs along the Project

In many places, especially in rural India, the social category plays a dominant role in determining the accessibility to resources. People from Schedule Tribe or Schedule caste are deprived of their rights. Such sections of the society need special concern while rehabilitating them. At this stage, the socio-economic profile of structures owner has been updated, who are losing their property due to the project. Here, the social composition of affected persons has been analyzed, considering the data collected from the structures owners. The analysis of collected data indicates that PAH's belongs to General category (94.29%) and (5.71%) are OBC category. Data was collected regarding social classification of PAHs and the same has been presented in Table 144**.**

Table 144 : Social Stratification of PAHs along the Project

S. No	Social Category	Left	Right	Total	%
1	General	28	5	33	94.29%
2	OBC	2	0	2	5.71%
Total		**30**	**5**	**35**	**100**

Source: Census Survey, Systra Faridabad, 2018

14.22.2.4 Type of family of PAHs along the Project

The analysis of collected data indicates that majority of PAH's lives in Joint Family (77.14%) followed by Nuclear Family (22.86%). Data was collected regarding type of family has been presented in Table 145**.**

Table 145 : Type of family of PAHs along the Project

S. No	Type of Family	Left	Right	Total	%
1	Joint	24	3	27	77.14%
2	Nuclear	6	2	8	22.86%
Total		**30**	**5**	**35**	**100**

Source: Census Survey Systra Faridabad, 2018

14.22.2.5 Occupation Pattern in the family along the Project

The project is dominated by families which are involved in commercial activities. Table 146 gives the detail explanation.

Table 146 : Occupation Pattern of PAHs along the Project

S. No	Occupation Pattern	Left	Right	Total	%
1	Business	4	5	9	25.71
2	Commercial Activities	26	0	26	74.29
Total		**30**	**5**	**35**	**100**

Source: Census Survey, Systra Faridabad, 2018

14.23 Appicable Resettlement Policy and Regulations

The Social Assessment describes the approach to be followed in minimizing and mitigating negative social and economic impacts caused by the project. In addition, social assessment identifies categories of expected project impacts, including loss of property and assets, loss of livelihood, and other social and economic impacts on roadside communities. All people and households adversely affected by the project would be enumerated and supported as per the Entitlement Matrix which is under preparation. The outcomes of consultation with community with regards to relocation of religious and community structures, if any constructed encroaching on Government lands would be duly documented. Over the years, R&R policies have been developed at international, national and organizational levels. The Acts and Policies relevant to the SIA are:

- Asian Development Bank's Safeguard Policy Statement (SPS), 2009
- The notifications of Department of Revenue and Forest, Maharashtra Government for Resettlement and Rehabilitation dated 13/08/2014, 27/08/ 2014 (2 Nos.)
- Order of CBDT, Ministry of Finance, Govt. Of India dated 25/10/2016
- The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (No. 30 of 2013)

The following section deals with these policies with a comparison and subsequently deals with the entitlements and eligibility for compensation and other resettlement entitlements.

14.23.1 ADB's Safeguard Policy Statement (SPS), 2009 on Involuntary Resettlement

Objectives: To avoid involuntary resettlement wherever possible; to minimize involuntary resettlement by exploring project and design alternatives; to enhance, or at least restore, the livelihoods of all displaced persons in real terms relative to pre-project levels; and to improve the standards of living of the displaced poor and other vulnerable groups.

Scope and Triggers: The involuntary resettlement safeguards cover physical displacement (relocation, loss of residential land, or loss of shelter) and economic displacement (loss of land, assets, access to assets, income sources, or means of livelihoods) as a result of (i) involuntary acquisition of land, or (ii) involuntary restrictions on land use or on access to legally designated parks and protected areas. It covers them whether such losses and involuntary restrictions are full or partial, permanent or temporary.

Policy Principles:

- Screen the project early on to identify past, present, and future involuntary resettlement impacts and risks. Determine the scope of resettlement planning through a survey and/or census of displaced persons, including a gender analysis, specifically related to resettlement impacts and risks.

- Carry out meaningful consultations with affected persons, host communities, and concerned non-government organizations. Inform all displaced persons of their entitlements and resettlement options. Ensure their participation in planning, implementation, and monitoring and evaluation of resettlement programs. Pay particular attention to the needs of vulnerable groups, especially those below the poverty line, the landless, the elderly, women and children, and indigenous Peoples, and those without legal title to land, and ensure their participation in consultations. Establish a grievance redress mechanism to receive and facilitate resolution of the affected persons' concerns. Support the social and cultural institutions of displaced persons and their host population. Where involuntary resettlement impacts and risks are highly complex and sensitive, compensation and resettlement decisions should be preceded by a social preparation phase.

- Improve, or at least restore, the livelihoods of all displaced persons through (i) land-based resettlement strategies when affected livelihoods are land based where possible or cash compensation at replacement value for land when the loss of land does not undermine livelihoods, (ii) prompt replacement of assets with access to assets of equal or higher value, (iii) prompt compensation at full replacement cost for assets that cannot be restored, and (iv) additional revenues and services through benefit sharing schemes where possible.

- Provide physically and economically displaced persons with needed assistance, including the following: (i) if there is relocation, secured tenure to relocation land, better housing at resettlement sites with comparable access to employment and production opportunities, integration of resettled persons economically and socially into their host communities, and extension of project benefits to host communities; (ii) transitional support and development assistance, such as land development, credit facilities, training, or employment opportunities; and (iii) civic infrastructure and community services, as required.

- Improve the standards of living of the displaced poor and other vulnerable groups, including women, to at least national minimum standards. In rural areas provide them with legal and affordable access to land and resources, and in urban areas provide them with appropriate income sources and legal and affordable access to adequate housing.

- Develop procedures in a transparent, consistent, and equitable manner if land acquisition is through negotiated settlement to ensure that those people who enter into negotiated settlements will maintain the same or better income and livelihood status.

- Ensure that displaced persons without titles to land or any recognizable legal rights to land are eligible for resettlement assistance and compensation for loss of non-land assets.

- Prepare a resettlement plan elaborating on displaced persons' entitlements, the income and livelihood restoration strategy, institutional arrangements, monitoring and reporting framework, budget, and time-bound implementation schedule.

- Disclose a draft resettlement plan, including documentation of the consultation process in a timely manner, before project appraisal, in an accessible place and a form and language(s) understandable to affected persons and other stakeholders. Disclose the final resettlement plan and its updates to affected persons and other stakeholders.

- Conceive and execute involuntary resettlement as part of a development project or program. Include the full costs of resettlement in the presentation of project's costs and benefits. For a project with significant involuntary resettlement impacts, consider implementing the involuntary resettlement component of the project as a stand-alone operation.

- Pay compensation and provide other resettlement entitlements before physical or economic displacement. Implement the resettlement plan under close supervision throughout project implementation.

- Monitor and assess resettlement outcomes, their impacts on the standards of living of displaced persons, and whether the objectives of the resettlement plan have been achieved by taking into account the baseline conditions and the results of resettlement monitoring. Disclose monitoring reports.

Involuntary Resettlement Categorization

A proposed project is assigned to one of the following categories depending on the significance of the probable involuntary resettlement impacts:

- Category A: A proposed project is classified as category A if it is likely to have significant involuntary resettlement impacts. A resettlement plan, including assessment of social impacts, is required.

- Category B: A proposed project is classified as category B if it includes involuntary resettlement impacts that are not deemed significant. A resettlement plan, including assessment of social impacts, is required.

- Category C: A proposed project is classified as category C if it has no involuntary resettlement impacts. No further action is required.

- A project's involuntary resettlement category is determined by the category of its most sensitive component in terms of involuntary resettlement impacts. The involuntary resettlement impacts of an ADB-supported project are considered significant if 200 or more persons will experience major impacts, which are defined as (i) being physically displaced from housing, or (ii) losing 10% or more of their productive assets (income generating). The level of detail and comprehensiveness of the resettlement plan are commensurate with the significance of the potential impacts and risks.

The Mumbai Metro 7 project falls in "Category B" based on Asian Development Bank's Safeguard Policy Statement (SPS), 2009 since the project is likely to have involuntary resettlement impacts with more than 200 persons will be physically displaced from housing or will lose 10% or more of their productive assets (income generating).

14.23.2 MAHARASHTRA NOTIFICATION ON RESTTLEMENT AND REHABILITATION

Revenue and Forest Department of Maharashtra Government has issued Notification No. LQN. 12/2013/C.R. 190/A-2 on 27th August 2014 for Resettlement and Rehabilitation of PAPs for projects in the state of Maharashtra as per Section 108 of the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 to provide higher compensation. The details of the notification are given in the following paragraphs:

Part-1. Land Valuation:

1. The market value of land to be acquired will be determined by ready reckoner value fixed under the Maharashtra Stamp Act (59 of 1958) and the Maharashtra Stamp (Determination of True Market Value of Property) Rules, 1995.
2. The multiplication factor by which market value of the land is multiplied will be 2 in case of rural areas and 1 for urban areas. (This factor should be at least 10% higher than the state approved multiplier.)
3. Compensation of the land to be acquired in rural area: (market value x 2) *plus* value of assets attached to land or building) *Plus (*100% solatium) = Land Compensation Price;

   Compensation of the land to be acquired in urban area: (market value x 1) *plus* value of assets attached to land or building) *plus* (100% solatium) = Land Compensation.
4. In case the land is acquired for urbanization purpose 20% of the developed land will be reserved and offered to the landowner at price equal to cost of acquisition and cost of development. The net land reserved and offered will be excluding the land required for infrastructure development by recovering the cost of acquisition and cost of development gross land i.e. 20%. The land required for infrastructure development and cost of the same as per norms prescribed by Public Works Department or Irrigation Department or Rural Development Department or Municipal Corporations or City and Industrial Development Corporation of Maharashtra (CIDCO) or Mumbai Metropolitan Region Development Authority (MMRDA) or Maharashtra Industrial Development Corporation (MIDC). The actual area required for development of infrastructural facilities will be taken into consideration at the time of calculation of land to be allotted.

The net land to be reserved or offered to land owner will be:—

20% of the gross land-land required for infrastructural development as per norms prescribed by Public Works Department or Irrigation Department or Rural Development Department or Municipal Corporations or City and Industrial Development Corporation of Maharashtra (CIDCO) or Mumbai Metropolitan Region Development Authority (MMRDA) or Maharashtra Industrial Development Corporation (MIDC) norms-recovery of cost of acquisition as per Right to Fair Compensation and Transparency in Land Acquisition. Rehabilitation and

Resettlement Act, 2013 and cost of development as per norms prescribed by Public Works Department or Irrigation Department or Rural Development Department or Municipal Corporations or City and Industrial Development Corporation of Maharashtra (CIDCO) or Mumbai Metropolitan Region Development Authority (MMRDA) or Maharashtra Industrial Development Corporation (MIDC) for gross 20% land.

Explanation.— As per the City and Industrial Development Corporation of Maharashtra (CIDCO) norms, the area required for infrastructure development considered is 30%., then the net land to be reserved or offered to land owner will be : 20% of the gross land-7% area required for infrastructure development=14% of the land acquired-(recovery of cost of acquisition and cost of development as per City and Industrial Development Corporation of Maharashtra (CIDCO) norms for gross 20% land.

The acquiring body may also give monetary value equivalent of the net developed land in lieu of actually providing the land to the displaced persons or his family.

Part-2. Rehabilitation and Resettlement components:

- If a house is lost in rural area, a constructed house shall be provided as per the specifications of *Indira AawasYojana* or Rs. 1.65 lacs in lieu of house.

  Explanation. - In case *of Indira Aawas Yojana,* a house of 25 sq.mt. will be provided. Considering the low specifications, the construction cost will be minimum Rs. 600 per sq. ft. which gives Rs. 1,61,400 excluding the cost of the developed land.
- If a house is lost in urban area, a constructed house shall be provided of 50 sq.mt. plinth area as per Public Works Department norms or Rs. 5.5 lacs in lieu of house.

  Explanation, —Considering the construction cost of Rs. 1000 per sq.ft., the cost of house will bs Rs. 5,38,000 excluding the cost of the developed land.
- Onetime payment of Rs. 5 lacs to each affected family to those who have eligible candidate for employment.
- Subsistence allowance to the affected displaced families of Rs. 3000 per month for a year after displacement date. For the families belonging to Scheduled Castes or Scheduled Tribes such families will get additional Rs. 50,000.
- Transportation cost of Rs. 50,000 per affected displaced families.
- Those families having cattle shed or petty shops will get Rs. 25,000 one-time financial assistance.
- One-time grant for artisans, small traders of Rs. 50,000.
- One-time resettlement allowance of Rs. 50,000 after shifting of house.
- Stamp duty and registration charges will be borne by Requiring Body for the first transaction of the rehabilitated person only.
- The Requiring Body will provide the infrastructure in Rehabilitation and Resettlement area, which includes the roads, drainage, *Panchayatghar,* post office, *Samajmandir* and other facilities as mentioned in the THIRD SCHEDULE of the Right to Fair Compensation and Transparency in Land Acquisition. Rehabilitation and Resettlement Act, 2013. However, if the Requiring Body monetize the amenities as per family costs of constructing these amenities as per cost norms developed by Public Works Department or Rehabilitation Department or Irrigation Department or Rural Development Department or Urban Development Department or Municipal Corporations or City and Industrial Development Corporation of Maharashtra (CIDCO) or Mumbai Metropolitan

Region Development Authority (MMRDA) or Maharashtra Industrial Development Corporation (MIDC). In such an eventuality, the Requiring Body shall offer 10% plus the total per family cost of all the amenities to be provided under the THIRD SCHEDULE of the said Act.

- All monetary value fixed above shall be entitled to be increased by 5% on the 1st January of each year unless the rate of inflation index is less than 5 % for that year.
- Above package will be applicable if the affected person accepts the same through a written consent.

[*Note:* - The explanations provided above are only the supportive information on the basis of City and Industrial Development Corporation of Maharashtra (CIDCO) practice and shall not be included part of the Guidelines]

It may be seen that the Government of Maharashtra has further prescribed entitlements for families affected due to acquisition of land, which are currently applicable.

The Revenue and Forest Dept., Govt. of Maharashtra, vide Notification dated 27/08/2014, has prescribed rules for various matters under Section 109 of the RFCTLARR Act

14.23.3 The Right To Fair Compensation And Transparency In Land Acquisition, Rehabilitation And Resettlement Act, 2013 (No. 30 Of 2013)

The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (RFCTLARR) Act, 2013 is effective from January 1, 2014 after receiving the assent of the President of Republic of India, repealing the Land Acquisition Act, 1894. The new Act extends to the whole of India except the state of Jammu and Kashmir. The aim of the new act is to minimize displacement and promote, as far as possible, non-displacing or least displacing alternatives and also aims to ensure adequate compensation including rehabilitation package and expeditious implementation of the rehabilitation process with the active participation of those affected. The Act also recognizes the need for protecting the weaker sections of the society especially members of the scheduled castes and scheduled tribes.

The aims and objectives of the Act include: (i) to ensure, in consultation with institutions of local self-government and Gram Sabhas established under the Constitution of India, a humane, participative, informed and transparent process for land acquisition for industrialization, development of essential infrastructural facilities and urbanization with the least disturbance to the owners of the land and other affected families; (ii) provide just and fair compensation to the affected families whose land has been acquired or proposed to be acquired or are affected by such acquisition; (iii) make adequate provisions for such affected persons for their rehabilitation and resettlement; (iv) ensure that the cumulative outcome of compulsory acquisition should be that affected persons become partners in development leading to an improvement in their post-acquisition social and economic status and for matters connected therewith or incidental thereto.

The key features of the new land acquisition act are as follows: Schedule I outlines the proposed minimum compensation based on a multiple of market value. Schedule II and III outline the resettlement and rehabilitation (R&R) entitlements to land owners and livelihood losers, which shall be in addition to the minimum compensation per Schedule I. The Schedules

IV lists out other land acquisition acts, which will be repealed with 1 year after LAAR is effective.

The salient provisions of the RTFCTLARR Act relevant to the Metro project are as follows:

- The Act (Section 105) specifies that the provision of the Act shall not apply to the enactments relating to land acquisition specified in the Fourth schedule of the Act which includes Metro Railways (Construction of Works) Act, 1978. However, as stipulated in Sub Section (3) of Section 105 and as subsequently notified by the GoI, the compensation for acquisition of private land and rehabilitation and resettlement benefits specified under the new LARR Act remain applicable even for such activities taken up under the Metro Railways Act.
- Preparation of Social Impact Assessment study including assessment of public purpose through a process of public consultation and disclosure for land acquisition proposals covered under the Act.
- Transparent procedures to be followed in the acquisition of land from preliminary notification to award and possession and preparation and implementation of rehabilitation and resettlement schemes for those affected by acquisition of land for public purpose.
- Procedure and methodology for determination of market value for compensation to be provided to legal title holders.
- Infrastructural facilities to be provided in resettlement areas and special provision for Scheduled Castes and Tribes.
- Institutional mechanism for implementing the provision of the Act, monitoring of R&R and grievance redressal.
- Procedure for payment of compensation.
- Temporary possession of land.
- The owners of land and structures (including those having certain legal rights) proposed to be acquired and, in urban areas, those who are staying on or whose livelihood is dependent on such land for a period of 3 years prior to acquisition of land are entitled for certain compensation and benefits under the Act.
- For legal title holders in urban areas, the compensation for land is equivalent to market value of land, value of assets attached to the land or buildings and 100% solatium on value of land.
- For houses lost as a result of acquisition of land in urban areas, a constructed house of not less than 50 sq.m. plinth area (if required in multi-storied building) is to be provided for a family. Alternatively, if so desired by the PAP, a one-time financial assistance of not less than Rs. 1.5 lakhs is to be given for construction of a house. However, the location of house in terms of the distance from lost house is not prescribed.
- In addition, the affected family is to be provided (i) training and skill development for job to one family member in the project or one-time payment of Rs. 5 lakhs or annuity policies that pay Rs. 2,000 per month per family for 20 years indexed to CPI (ii) monthly subsistence allowance of Rs. 3,000 per month for a period of one year (iii) one-time financial assistance of Rs. 50,000 towards transportation cost for shifting (iv) one-time resettlement allowance of Rs. 50,000.

- Each petty shop owner / small trader / self-employed person and family owning non-agricultural land, or commercial, industrial or institutional structure is to be provided one-time financial assistance of minimum Rs. 25,000 for construction of shop.
- The stamp duty and registration charges for the land and house to be provided to the PAPs shall be borne by the acquiring body.

It may be seen that while elaborate provisions for compensation and R&R benefits are made for those affected due to the acquisition of land for the project, the Act does not prescribe any benefits for occupants of structures located on public (Government) land and affected by the project. Further, the Act does not envisage any resettlement benefit for occupants / owners of structures used for other than residential purposes and affected by the project.

The Central Board of Direct Taxes vide Order dated 25/10/2016 has clarified that the compensation received in respect of award or agreement, which has been exempted from levy of income tax vide Section 96 of the RFCTLARR Act shall also not be taxable under the provisions of Income Tax Act, 1961.

14.24 Community Consultation And Stakeholder Analysis

Extensive public consultations were carried out with various stakeholders at various locations throughout the length of the project corridor. The consultations were undertaken with PAPs, in selected area. The locations, number of people that participated and the consultation methods are summarized in Table 147.

Table 147 : Summary of Consultation Sessions

Date	State	District	Tehsil	Village	No. of person	Type of Consultation
27/11/2018	Maharashtra	Pune	Haveli	Nigdi (Near Bhakti Shakti Chowk)	10	Consultation and interview
27/11/2018	Maharashtra	Pune	Haveli	Nigdi (Near Bhakti Shakti Chowk)	4	Consultation and interview
28/11/2018	Maharashtra	Pune	Haveli	Near Chinchwad Railway Station	7	Consultation
28/11/2018	Maharashtra	Pune	Haveli	Near Chinchwad Railway Station	5	Consultation

**Source: Public consultation during social assessment.*

The purpose of public participation and consultation for this resettlement planning study was to create awareness on the project and involve those persons in the study who are to be affected positively or negatively and involve also other stakeholders by giving them opportunities to express their views and concerns about expected and perceived impacts and about the most suitable ways for mitigating negative effects and enhancing positive project effects.

The consultations intended to create a sense of commitment towards implementing the social safeguard plan for the project. With due consideration of vulnerable PAPs including SC, PH, Aged (60+) and WHH, consultations were carried out through various methods including individual interviews, consultation meetings, and informal and formal group discussions.

A list of participants' location/place wise is provided in this report. The photographs of public consultations are shown below.

Figure 118 : A view of people's participation during census survey and public consultation along the project road corridor near bhakti shakti (Top), Chinchwad Railway station (Bottom)

14.24.1 Issues Raised and Responses

Various topics were covered in the consultations with villagers, project affected people, community leaders and village sarpanches. The issues raised, and the responses given are summarized in Table 148.

Table 148:Issues raised and responses

Issues raised	Reponses
Land acquisition minimization	People were informed that within the broader corridor alignment, several alternatives were studied taking into consideration of social and environmental impacts, including the land acquisition. The option selected is with the least land acquisition impacts.

Issues raised	Reponses
Provision of new bypass construction	The PAPs suggestions will be discussed with the design Engineers and accordingly incorporated if technically feasible.
Resettlement impacts mitigation measures	A resettlement action plan will be prepared in line with relevant LARR Act, 2013.
Underpasses at schools and hospitals	The exact location of underpasses will be discussed with the design engineer. The final location will select by taking into account people’s concerns and needs, as much as technically viable.
Wayside amenities and public facilities including toilets and drinking water	The locations of road side amenities and public services such as rest areas, service areas, bus shelter, urinals and drinking water facilities will be incorporated in the project design.
Road safety measures	Adequate road safety measures will be incorporated in the project design. If needed, additional road safety measures can be added during construction, taking into account local people’s concerns.
Pedestrian pathways	The design includes pedestrian pathways for crossing the highway at populated locations. Local people’s suggestions can still be incorporated in the project, if technically feasible.
Resettlement assistance package	Compensation will be paid to the eligible PAPs and assistance will be given for relocation and livelihood rehabilitation as set to be forth in the LARR Act, 2013.
Compensation should be computed at current market price of land and structures	Compensation rate of lost assets will be determined based on the prevailing market value in the project area.

Issues raised	Reponses
Avoidance of the demolition of religious properties	PAPs suggestions will be incorporated in the project design if technically feasible. However, relocation of religious structures will be done at proper place after consensus with the local communities.
Income and employment generation schemes should be launched all along the project influence area	Contractors typically hire most unskilled workers locally for construction activities and maintenance work. Other different options will be provided to PAPs for income restoration, such as land-for-land compensation, cash for land, and combination of land and cash for land. These measures would help the PAPs to restore or enhance their income and livelihood.
Special signage near schools, college and road turnings and crossings	The signage near the prominent locations has been incorporated in the road design. Additional signs can be added as needed.
During construction local people should be preferred for employment by the contractor	Contractors typically give priority to local people when hiring workers, both during construction and operational phases.

*Source: Public consultation during social assessment

14.25 TOTAL R & R COST

The R&R budget for the proposed project including cost of land acquisition worked out approximately for **Corridor 1A** is **Rs. 114.43 Crores,** which includes the cost of land and structure, relocation or enhancement of religious and government structures and R & R Assistance given to affected people, Dismantling & Restoration of BRTS. The details of the tentative budget are given in Table 149

Table 149 : R&R COST

Sl. No.	Item	Eligibility	Quantity (Sqm.)	Unit Rate (Rs)	Amount (cr.)	Compensation (Factors to be multiplied) (Urban= 1* MV)	100% Solatium of column 6	Total (In Crores)
1	2		3	4	5	6	7	8
A	Compensation for Land							

Sl. No.	Item	Eligibility	Quantity (Sqm.)	Unit Rate (Rs)	Amount (cr.)	Compensation (Factors to be multiplied) (Urban= 1* MV)	100% Solatium of column 6	Total (In Crores)
1	Cost of land	-	7446.35	As per circle DLC Rate	346705115.6	346705115.6	693410231.2	69.34
Sub-total (A)								**69.34**
B	**Compensation for Structure**							
1	Pucca	-	996	As per DLC rate	49866772	No factor Applicable	49866772	**9.97**
Sub-total (B)								**9.97**
C	**R&R Assistance**							
1	Annuity allowance, losing primary source of Income	Land and structure Owner	10	500000	500000			0.50
2	Substance Assistance for displaced family	Losing Commercial Structures	30	36000	1080000			0.11
3	Transportation cost for displaced family	TH Losing Residential and Commercial Structures	30	50000	1500000			0.15
4	Resettlement Allowance	TH Losing Residential and Commercial Structures	35	50000	1750000			0.18
5	One-Time Financial Assistance	Losing Cattle Shed or Petty Shops		25,000	125000			0.01
Sub-total (C)								**0.95**
D	**Administrative and other Costs**							
1	NGO (RAP Implementation)			150000	0.15			0.15

Sl. No.	Item	Eligibility	Quantity (Sqm.)	Unit Rate (Rs)	Amount (cr.)	Compensation (Factors to be multiplied) (Urban= 1* MV)	100% Solatium of column 6	Total (In Crores)
Sub-total (D)								**0.15**
Total (A+B+C+D)								80.41
Contingency @ 5%								4.02
TOTAL (Cr.)								**84.43**
Cost for Dismantling & Restoration of BRTS								**30.00**
GRAND TOTAL (Cr.)								**114.43**

15. DISASTER MANAGEMENT MEASURES

15.1 Introduction

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

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

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

15.2 Need For Disaster Management Measures

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

15.3 Objectives

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

- Save life and alleviate suffering.
- Provide help to stranded passengers and arrange their prompt evacuation.
- Instill a sense of security amongst all concerned by providing accurate information.
- Protect Metro Rail property.
- Expedite restoration of train operation.

- Lay down the actions required to be taken by staff in the event of a disaster in Pune Metro in order to ensure handling of crisis situation in coordinated manner.
- To ensure that all officials who are responsible to deal with the situation are thoroughly conversant with their duties and responsibilities in advance. It is important that these officials and workers are adequately trained in anticipation to avoid any kind of confusion and chaos at the time of the actual situation and to enable them to discharge their responsibilities with alertness and promptness.

15.4 List of serious Incidents Requiring use of Provisions of the Disaster Management Measures

Metro specific disasters can be classified into two broad categories e.g.: Man-made and Natural.

A. Man-made Disasters.

1. Terrorist attack
2. Bomb threat/ Bomb blast
3. Hostage
4. Release of Chemical or biological gas in trains, stations or tunnels
5. Fire in metro buildings, underground/ elevated infrastructures, power stations, train depots etc.
6. Train accident and train collision/derailment of a passenger carrying train
7. Sabotage
8. Stampede

B. Natural Disasters.

1. Earthquakes
2. Floods
3. Cyclone

15.5 Authorities to be contacted in case of disaster - Provisions under Disaster Management Authority

A. The National Disasters Management Authority (NDMA)

Establishment of National Disaster Management Authority:-

(1) With effect from such date as the Central Government may, by notification in the Official Gazette appoint in this behalf, there shall be established for the purposes of this Act *(The Disaster Management Act, 2005),* an authority to be known as the National Disaster Management Authority.

(2) The National Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the Central Government and, unless the rules otherwise provide, the National Authority shall consist of the following:-

(a) The Prime Minister of India, who shall be the Chairperson of the National Authority, ex officio;

(b) Other members, not exceeding nine, to be nominated by the Chairperson of the National Authority.

(3) The Chairperson of the National Authority may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice- Chairperson of the National Authority.

(4) The term of office and conditions of service of members of the National Authority shall be such as may be prescribed.

B. State Disasters Management Authority (SDMA)

Establishment of State Disaster Management Authority:-

(1) Every State Government shall, as soon as may be after the issue of the notification under sub-section (1) of section 3, by notification in the Official Gazette, establish a State Disaster Management Authority for the State with such name as may be specified in the notification of the State Government.

(2) A State Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the State Government and, unless the rules otherwise provide, the State Authority shall consist of the following members, namely:-

(a) The Chief Minister of the State, who shall be Chairperson, ex officio;

(b) Other members, not exceeding eight, to be nominated by the Chairperson of the State Authority;

(c) The Chairperson of the State Executive Committee, ex officio.

(3) The Chairperson of the State Authority may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice- Chairperson of the State Authority.

(4) The Chairperson of the State Executive Committee shall be the Chief Executive Officer of the State Authority, the Chief Minister shall be the Chairperson of the Authority established under this section.

(5) The term of office and conditions of service of members of the State Authority shall be such as may be prescribed.

C. Command & Control at National, State & District Level

The mechanism to deal with natural as well as manmade crisis already exists and that it has a four tier structure as stated below:-

(1) National Crisis Management Committee (NCMC) under the chairmanship of Cabinet Secretary

(2) Crisis Management Group (CMG) under the chairmanship of Union Home Secretary.

(3) State Level Committee under the chairmanship of Chief Secretary.

(4) District Level Committee under the Chairmanship of District Magistrate.

All agencies of the Government at the National, State and district levels will function in accordance with the guidelines and directions given by these committees.

D. Plans by different Authorities at District Level and their Implementation

Every office of the Government of India and of the State Government at the district level and the local authorities shall, subject to the supervision of the District Authority:-

(a) Prepare a disaster management plan setting out the following, namely:-

(i) Provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;

(ii) Provisions for taking measures relating to capacity-building and preparedness as laid down in the District Plan;

(iii)The response plans and procedures, in the event of, any threatening disaster situation or disaster;

(b) Coordinate the preparation and the implementation of its plan with those of the other organizations at the district level including local authority, communities and other stakeholders;

(c) Regularly review and update the plan; and

(d) Submit a copy of its disaster management plan, and of any amendment thereto, to the District Authority.

15.6 Provisions at Metro Stations/ Other installations

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

i) Fire detection and suppression system
ii) Smoke management
iii) Environmental control system (ECS)
iv) Tunnel ventilation system
v) Track-way exhaust system (TES)
vi) Station power supply system
vii) DG sets & UPS
viii) Lighting system
ix) Station area lights
x) Tunnel lighting
xi) Tunnel lighting control
xii) Seepage system
xiii) Water supply and drainage system
xiv) Sewage system
xv) Any other system deemed necessary

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

Certain measures are suggested in the following sections which need to be selected/ tailored according to local conditions, regulations and O&M practices for safety and effectiveness.

15.6.1 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. For better management and safety from fire disaster on metro system, various signages like prohibition signs, warning signs, emergency escape signs etc. shall be installed as mentioned in NFPA 130, Standard for Fixed Guideway Transit and Passenger Rail Systems and National Building Code of India,2016 part 4. Universally accepted measures for fire prevention include:

- Rigid observance of non-smoking regulations
- Total ban on carriage of inflammable/ explosive substance within metro premises and in trains
- Non accumulation of garbage in the metro station premises and inside trains

- All staffs posted at stations must ensure instructions are rigidly enforced by regular checks.
- Installation of fire alarms and detection systems.

15.6.1.1 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,

- Report the occurrence to the nearest Station Controller (SC) or Chief Controller (OCC). A reporting system shall be developed as per NFPA Guidelines and officials shall be trained accordingly.
- Take all possible steps to extinguish fire like using portable fire extinguishers, blankets, water, sand etc. that is available on site depending on the source of fire. Standards steps/measures to extinguish may be followed from NBC of India, 2016 and NFPA 130.
- Disconnect electricity supply if necessary
- Prevent the fire from spreading
- Seek assistance of Fire services.

15.6.1.2 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:

The nature of fire whether localized or widespread in passenger area.

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.

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.

15.6.1.3 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.

Cut off power 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 equipment. The system is operated from a panel located in the Station Control Room.

15.6.1.4 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.

Appropriate O&M procedures should be in place taking into account past experience of other metro systems to handle fire incidents.

15.6.1.5 Fire at Metro Station Premises

The fire can be at the following locations:

- In areas, where the passengers enter for purchasing tickets or leave the station after performing their train journey including lifts, staircases and escalators.
- Concourse
- 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.

15.6.2 Measures in Case of Collision of Trains or derailment

Collision of Metro trains is a rare occurrence, particularly at high speeds as signalling system provides protection from such incidents. Only in case signalling system is disabled, train collision is possible at low speed, except in case of wrong side failure or poor design/ maintenance.

Appropriate O&M procedures should be in place taking into account past experience of other metro systems to avert collision scenario and to handle the event of a train collision if it happens.

15.6.2.1 Medical Assistance

Provisions for Medical assistance and procedures for O&M staff to handle injured and casualties in case of collision or derailment shall be in place. External medical help in case of such incidents shall be planned in advance and called for immediately when required.

15.6.3 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.

15.6.3.1 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.

Appropriate O&M procedures shall be in place to handle bomb threat or suspicion, bomb detection and rescue operation and medical assistance in case bomb explosion takes place. A coordinated effort along with bomb squad may be required to neutralise further threat and for restoration to normal operation.

15.6.3.2 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.

15.6.4 Appropriate O&M procedures and training of O&M staff

Appropriate O&M procedures and training of O&M staff shall be carried out to detect and act to neutralise the effects of such attack. Passenger awareness measures shall be taken to help them in case they are caught in such scenario, and coorperate with O&M staff. Measures in Case of Natural Calamities

Traction Power supply shall be switched off in a manner which does not shut down station supplies unless it unsafe for occupants.

In the event of a significant earthquake, train should be stopped until earthquake is confirmed subsided.

Passenger evacuation shall be done following appropriate operating procedures for such scenario.

15.7 Preparedness for Disaster Management

Being a technological complex system worked by new set of staff, with a learning curve to improve and stabilize with time, intensive mock drills for the staff concerned is very essential to train them to become fully conversant with the action required to be taken while handling emergencies.

They also need to be trained in appropriate communication skills while addressing passengers during incident management to assure them about their well being seeking their cooperation.

Since learning can only be perfected by 'doing' the following Mock Drills are considered essential:

a. Fire Drill
b. Rescue of a disabled train
c. Detrainment of passengers between stations
d. Passenger evacuation from station
e. Drill for use of rescue & relief train.

Hot line telephone communication with state disaster management

15.8 Security measures in metro

15.8.1 Introduction

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.

15.8.2 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:

- The Human factor;
- Procedures;
- 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 must 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.

15.8.3 Different phases of security

There are 3 different phases associated with the security system in metro as under:

- **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 must be given in controlling unused, damaged properties which could otherwise prove to be a breeding ground for more serious crimes.

- **Preparedness**

Plans must be prepared to respond to incidents and to mitigate the impacts. Staff must be accordingly trained to carry out the exercises. The results of the risk assessment will give basis for such plans.

- **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.

15.8.4 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 Pune Metro.

15.8.5 Proposed provisions for security system

For providing an efficient security system in metro station areas the following provisions are suggested:

- 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.
- 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.
- 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.
- 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.
- Bomb Detection Equipment's with modified vehicle as per requirement of security agency.
- Bomb Blanket at least one per station and depot.
- Wireless sets (Static and Handheld) as per requirement of security agency.
- Dragon light at least one per metro station
- Mobile phones, land lines and EPBX phone connections for senior security officers and control room etc.
- Dog Squads (Sniffer Dog), at least one dog for 4 metro stations. Dog Kennels along with provision for dog handlers and MI room will also be provided by metro train depot administration including land at suitable places line wise.
- Bullet proof Morcha one per security check point (i.e. AFC array) and entry gate of metro train depot administration.
- Bullet proof jackets and helmets for Quick Response Team (QRTs) and riot control equipment's 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.

- 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.
- Ladies frisking booth - 1 per security check point (AFC) Wooden Ramp - 1 per DFMD for security check points.
- Wall mounted/ pedestal fan at security check point, ladies frisking booth and bullet proof morcha, as per requirement.
- Physical barriers for anti-scaling at Ramp area, low height of viaduct by providing iron grill of appropriate height & design/concertina wire.
- Adequate number of ropes. Queue managers, cordoning tapes, dragon search lights for contingency.
- Iron grill at station entrance staircases, proper segregation of paid and unpaid areas by providing appropriate design grills etc.
- Proper design of emergency staircase and fireman entry to prevent unauthorized entry.

16. DETAILED PROJECT COST ESTIMATE

16.1 Introduction

16.1.1 Preliminary cost estimates of Pune MRT have been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, etc. considering 25 kV ac Overhead Traction System at FY 2019 price level and escalated @5% PA.

16.1.2 While preparing the capital cost estimates, various items have generally been grouped under three major heads on the basis of (i) route km length of alignment, (ii) number of units of that item, and (iii) item being an independent entity. All items related to main line and maintenance depot related to alignment including traction power supply, signalling, viaduct, ballastless track have been estimated at rate per route Km. Cost of station structures, telecommunication other electrical services at these stations including Lifts & Escalators and Automatic Fare Collection (AFC) installations at all stations have been assessed in terms of each station as a unit. Similarly, rolling stock costs have been estimated in terms of number of units required. In remaining items, viz. Land, utility diversions, rehabilitation, EIA, R&R etc. the costs are assessed on the basis of each item, taken as an independent entity.

16.1.3 In order to arrive at realistic cost of various items, costs of the project have been derived from similar executed project in similar scenario in India.

Capital cost estimate – Pune metro line

Table 150 : Capital cost estimate of Pune Metro Phase 1A (@FY 2019 Price Levels)

S. No	Item	Unit	Rate	Quantity	Amount (in INR Cr)
1	**Alignment & Formation**				
1.1	Viaduct	R. Km.	37.00	4.413	163.28
	Sub Total - alignment & formation				**163.28**
2	**Station Buildings (6 Car) Elevated Station Buildings including Architectural Finishes, Lifts & Escalators**				
2.1	Elevated station (Civil including finishes) excluding viaduct in station portion	Each	26.00	3	78.00
2.2	FOB for Chinchwad Station	Each	2.68	1	2.68
2.3	Elevated Station (E&M including lift & escalator)	Each	8.00	3	24.00
	Sub- total Station Building				**104.68**
3	**Depot Augmentation**				
3.1	Augmentation of existing Range Hill Depot	LS	12.88	1	12.88

	Sub-total Depot				**12.88**
4	**Permanent Way**				
4.1	Ballastless track for main line	R.Km	6.60	4.413	29.13
	Sub-total Permanent Way				**29.13**
5	**Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators**				
5.1	Elevated Section (viaduct) including in station portion	R. Km.	7.50	4.413	33.10
	Sub-total Traction and Power Supply				**33.10**
6	**Signaling and Telecom**				
6.1	**Signaling**				
a	Main Line including OCC	R.Km	4.40	4.413	19.42
b	On Board Equipment	per train	1.70	5	8.50
	Sub-total Signaling				**27.92**
6.2	**Telecommunication**				
a	Station	Per station	4.50	3	13.50
	Sub-total Telecom				**13.50**
7	**Environment Cost**				
7.1	Environmental Cost				1.79
	Sub-total Environment				**1.79**
8	**Misc. utilities etc.**				
8.1	Civil works	R. Km.	3.00	4.413	13.24
8.2	Electrical Works	R. Km.	3.00	4.413	13.24
	Sub-total Misc.				**26.48**
9	**Security**				
9.1	Civil works	Per Station	0.37	3	1.11
	Sub-total Security				**1.11**
10	**AFC**	Per Station	3.50	0	0.00
	Sub-total AFC				**0.00**
11	Multimodal Integration and Last mile connectivity	Per station	3.00	3	9.00
12	Rolling Stock	Per coach	8.00	15	120.00
13	**Total Cost at FY '19 price level (Excluding Land, R&R, General Charges, Contingencies, Central & State Taxes)**				**542.86**

14	General Charges @ 5%	27.14
15	Contingencies @ 3 % on Sr.No. 13 i.e. on Basic Cost	16.29
16	**Total Cost at FY '19 price levels incl. General Charges and Contingencies (Excluding Land, R&R, Central & State Taxes)**	**586.29**
17	Central and State Taxes @ FY '19 Price Level	79.28
18	Total Cost incl. General Charges, Contingencies, Central and state Taxes @ FY '19 Price Levels (Excl. Land and R&R)	665.57
19	Land	72.81
20	R&R	41.62
21	**Total Cost incl. General Charges, Contingencies, Central and state Taxes @ FY '19 Price Levels (Incl. Land and R&R)**	**780.00**
22	Escalation at 5 % per annum on the above (S. No: 21)	107.66
23	Total Completion Cost incl. Land and R&R Costs	887.66
24	Interest During Construction (IDC)	11.02
25	**Total Completion cost including IDC**	**898.68**
26	PPP component (AFC)	11.50
27	**Total Completion Cost**	**910.18**

Note: FY 2019 Price Level is considered and the Prices are escalated till the completion period to arrive at the completion cost. (Ref: Page 400)

16.2 Civil Engineering Works

16.2.1 Land

i) Land requirements have been kept to the barest minimum & worked out on area basis. For elevated alignment, no land acquisition is proposed, except small areas for locating entry/exit structures, traffic integration, etc. at stations, and wherever the alignment is off the road. For Each Elevated station Permanent Land acquisition is required for entry-exit structure.
ii) Total land requirement have been worked out to 7446.35 sqm, which comprises 6383.84 sqm of private land and 1062.51 sqm of government land.
iii) Cost of land has been worked out based on the rates published by department of registration and stamps, Government of Maharashtra. For private land and structures, the cost of aquisition is taken as 2 times the published rates.
iv) The total cost of land aquisition works out to 72.81 Cr.

16.2.2 Utility Diversion

The provision of utility diversion has been taken as Rs 6 Cr/km as per benchmarking cost, which works out to Rs 26.48 Cr for the project length of 4.413 Km.

16.2.3 Environmental Impact Assessment

Cost provision for environmental impacts has been made to cover various protection works, additional compensatory measures, compensation for loss of 342[5] trees, compensatory afforestation and fencing, monitoring of water quality, air/noise pollution during construction, establishment of Environmental Division. The total cost works out to 1.79 Cr.

16.2.4 Rehabilitation and Resettlement

Private structure:

Efforts has been made to keep the acquisition of private land to the minimum. Provision towards compensation of rehabilitation of properties on private land, likely to be affected has been assessed after site inspection. Total of 49 structures will be affected out of which 34 no. of structures are fully affected.

R&R assistance has been worked out including annuity allowance, loosing primary source of income, substance assisatance for displaced family, transportation cost and resettlement allowance. Administrative and other cost for implementation of RAP is also considered. Provision amount based on compensation rates works out to ~11.62 Cr.

The cost for dismantling & restoration of BRTS is considered as Rs 30 Cr (based on actual expenses incurred in Phase-1).

Hence total cost of R&R is Rs 41.62 Cr.

16.2.5 Other Components

The cost of other components are considered as per the Benchmarking Cost.

16.2.6 Taxes & Duties

The total cost of the project at FY 19 prices along with the tax estimates are detailed in Table 156.

[5] Approximatey, 342 no. of trees will be impacted due to the project. However, the no. of trees might be less. Exact no. of trees will be identified at the time of joint verification with the concerned department

Table 151 : Detailed Tax estimate at FY 19 prices for the extension of Pune Phase 1A

S No	Description	Total cost (Cr.)	Imported Materials (%)	Indigenous Materials (%)	Taxes and Duties							
					Basic Customs Duty (Cr.)	IGST (CGST portion) (Cr.)	IGST (SGST portion) (Cr.)	Total Customs Duty (Cr.)	CGST (Cr.)	SGST (Cr.)	Total GST (CGST & SGST) (Cr.)	Total GST (Taxes & Duties) (Cr.)
1	Alignment & Formation											
1.1	Viaduct	163.28	0	100	0.00	0.00	0.00	0.00	9.80	9.80	19.59	19.59
2	Station Buildings (6 Car) Elevated Station Buildings including Architectural Finishes, Lifts & Escalators											
2.1	Elevated station (Civil including finishes) excluding viaduct in station portion	78.00	0	100	0.00	0.01	0.01	0.02	4.68	4.68	9.35	9.37
2.2	FOB for Chinchwad Station	2.68	0	100	0.00	0.00	0.00	0.00	0.16	0.16	0.32	0.32
2.3	Elevated Station (E&M including lift & escalator)	24.00	10	90	0.12	0.23	0.23	0.58	1.30	1.30	2.59	3.17
3	Depot Augmentation											
3.1	Augmentation of existing Range Hill Depot	12.88	10	90	0.07	0.12	0.12	0.31	0.70	0.70	1.39	1.70
4	Permanent Way				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.1	Ballastless track for main line	29.13	10	90	0.15	0.28	0.28	0.70	1.57	1.57	3.15	3.85
5	Traction & power supply incl. OHE, ASS etc. Excl. lifts & Escalators											
5.1	Elevated Section (viaduct) including in station portion	33.10	40	60	0.68	1.25	1.25	3.19	1.19	1.19	2.38	5.57
6	Signaling and Telecom											

6.1	Signalling											
a	Main Line including OCC	19.42	50	50	0.50	0.92	0.92	2.34	0.58	0.58	1.17	3.50
b	On Board Equipment	8.50	50	50	0.22	0.40	0.40	1.02	0.26	0.26	0.51	1.53
6.2	Telecommunication											
a	Station	13.50	50	50	0.35	0.64	0.64	1.63	0.41	0.41	0.81	2.44
7	Enviornment & R & R incl. Hutments etc.											
7.1	Environmental Cost	1.79	0	100	0.00	0.00	0.00	0.00	0.11	0.11	0.21	0.21
8	Misc. utilities etc											
8.1	Civil works	13.24	0	100	0.00	0.00	0.00	0.00	0.79	0.79	1.59	1.59
8.2	Electrical Works	13.24	0	100	0.00	0.00	0.00	0.00	0.79	0.79	1.59	1.59
8.3	Dismantling & Restoration of BRTS	0.00	0	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Security											
9.1	Civil works	1.11	0	100	0.00	0.00	0.00	0.00	0.07	0.07	0.13	0.13
10	Multimodal Integration and Last mile connectivity	9.00	0	100	0.00	0.00	0.00	0.00	0.54	0.54	1.08	1.08
11	Rolling Stock	120.00	30	70	1.85	3.41	3.41	8.67	5.04	5.04	10.08	18.75
12	General Charges	27.14	0	100	0.00	0.00	0.00	0.00	2.44	2.44	4.89	4.89
	TOTAL	**570.00**			**3.95**	**7.25**	**7.25**	**18.45**	**30.42**	**30.42**	**60.83**	**79.28**
											Total Central GST & Basic Custom Duty	**41.61**
											Total State GST	**37.67**
											Total Taxes & Duties	**79.28**
											Total Taxes & Duties (incl. Escalation)	**90.63**

COMPONENT WISE ESCALATION (RS. IN CRORE)

Yr	Year	Cost Distribution	Land Distribution	Cost at FY 2019 Price Level					Escalation Factor	Completion Cost				
				Component Cost without Taxes, Land and R&R	Central Taxes	State Taxes	Land and R&R	Total Cost		Completion Cost without Taxes, Land and R&R	Central Taxes with escalation	State Taxes with escalation	Land and R&R	Total Completion Cost
Y1	2021-22	15.0%	20%	87.94	6.24	5.65	22.89	122.72	1.050	92.34	6.55	5.93	24.03	128.86
Y2	2022-23	25.0%	50%	146.57	10.40	9.42	57.22	223.61	1.103	161.60	11.47	10.38	63.08	246.53
Y3	2023-24	33.4%	30%	195.82	13.90	12.58	34.33	256.63	1.158	226.69	16.09	14.56	39.74	297.08
Y4	2024-25	26.6%		155.95	11.07	10.02		177.04	1.216	189.56	13.46	12.18		215.20
Total		**100%**		**586.29**	**41.61**	**37.67**	**114.43**	**780.00**		**670.18**	**47.57**	**43.06**	**126.85**	**887.66**

17. TRANSIT ORIENTED DEVELOPMENT PLAN

Transit Oriented Development is essentially development, macro or micro that is focused around a transit node and facilitates complete ease of access to the transit facility thereby inducing people to prefer to walk and use public transportation over personal modes of transport. It could be located within a quarter- to half-mile radius of a transit station that offers a mix of housing, offices, shopping, and transportation choices within a neighborhood or business district. The primary goals of TOD are to:

1. Reduce/discourage private vehicle dependency and induce public transport use – through design, policy measures & enforcement.
2. Provide easy public transport access to the maximum number of people within walking distance /through densification and enhanced connectivity.

The above goals can be addressed by two steps. Firstly, by getting more people close to the station, which can be done through densification and modifying mix of uses around the station. Following this, second step would be to facilitate the existing and proposed population to access the stations by addition and improvement of transport infrastructure. To achieve this paradigm shift, TOD offer attractive alternatives to the use of personal modes – pleasurable walking experiences, very easily accessible and comfortable mass transportation with easy, convenient and comfortable intermodal transfers for last mile connectivity and other low cost, comfortable, non- motorized transportation options. Figure 119 shows some of the transit-oriented development facilities.

Figure 119 : Transit Oriented Development Facilities

Pedestrian Crossing, Segregated Lanes, Lane Markings, Bike Lanes
Source: The NACTO Urban Street Design Guide

17.1 TOD - OBJECTIVES

- Increase 'location efficiency' to provide multi-modal transportation
- Boost transit ridership and minimize vehicular traffic.
- Provide a rich mix of housing, shopping, and transportation choices.
- Generate revenue for the public and private sectors.

- Provide value for both new and existing residents.
- Pedestrian and NMT friendly environment
- Manage parking, bus and vehicular traffic, parking for PT/IPT and NMT modes has been prioritized at-grade and on-street, within the station vicinity area.
- Design for pedestrian safety, comfort and convenience on all streets connectivity.
- Design infrastructure to ensure rapid and comfortable transfers.

17.2 National TOD Policy, UTTIPEC

17.2.1 Elements of TOD Policy

- The "TOD influence zones" shall be plotted at each Station area level by drawing the travel distance from the Centre of the Station in following manner:
  Intense TOD Zone - 300m buffer from transit stop/ station
  Standard TOD Zone – 800m buffer from transit stop/ station
- The types of planned and unplanned development within the Zone 1 Standard TOD and Zone 2 Intense TOD influence zones may be categorized into three broad categories: Redevelopment, Greenfield and brownfield development.
- Redevelopment/ Infill: Infill Sites are empty sites within Existing Urban Area which may have opened for development.
  Redevelopment sites could be any of the following:
  i. Low density areas with gross density less than 250 du/ha
  ii. Shopping/ Commercial centres
  iii. Industrial areas/ clusters
  iv. Resettlement Colonies
  v. Unauthorized colonies
  vi. Urban Villages
  vii. JJ clusters
- Redevelopment projects with FAR above 1.5 to be located only within Intense TOD zone. For commercial development, at least 50% of total street frontage length to be active frontage.
- FAR below 3 is not desirable (Within 800m influence zone)
- Non-Permissible Uses for all new projects within TOD Intense Zone as per above policy:
  i. Car-sales showrooms
  ii. Banquet halls
  iii. Automobile-repair/ services/ vehicular servicing shops
  iv. LPG Godowns
  v. Electric Substation 220 KV (Check Buffer requirement/restriction)
  vi. Bus Depot (permitted only if clubbed with terminal and in the form of mixed-use development site)
  vii. Cremation ground
  viii. Stand-alone Multi Level Parking without on-site mixed use.
  ix. Open ground parking lot (if provided shall be counted as FAR consumption)

x. Any trade or activity involving any kind of obnoxious, hazardous, inflammable, non-compatible and polluting substance or process shall not be permitted.

17.3 TOD Proposal for Pune Metro Corridor 1A: PCMC to Nigdi

To make the Transit system successful and to absorb the development potential created due to transit system , pre-requisite is for the population to shift from private mode of travel to the mass transit. Such condition can be satisfied if more population and trip attracting activities are concentrated in the vicinity of transit line. Thus, by bringing people close to the transit system, they are facilitated to shift to public mode of travel. Such development can be encouraged by proposing high density residential, commercial and mixed-use development close to the transit system. Thus, by integrating land use and transport planning, planned sustainable urban growth centres can be promoted, having walkable and liveable communes with high density mixed land-use.

TOD proposal will increase 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. The transit corridor will have 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.

17.3.1 Integrating Land use and Transportation and Using Land as a resource: Approach for TOD Implementation

17.3.1.1 Influence area demarcation

The area in the immediate vicinity of the transit station or transit line, i.e. within a walking distance, having high density compact development with mixed land use to support all basic needs of the residents is called the influence zone of a transit station/ corridor. Influence zone is established along the transit corridor. It has been identified as a delineated zone (around 500m) on either side of the transit corridor within 10 - 12 minutes walking distance.. This area of influence is demarcated as planning area for TOD implementation. Development control rules of Pune Municipal corporation have been referred to demarcate the TOD influence zone (500m on either side of transit line) as Maharshtra Governemnt is considering uniform Development and control rules for all urban bodes in Pune Metopolitian Region.

17.3.1.2 Densification

Densification is promoted in the influence area by providing higher Floor Area Ratio (FAR)/ Floor Space Index (FSI) and higher population & job density as compared to the area around and beyond the influence areas. Density and FAR is not kept consistent across the influence area. To ensure sustainable development, the minimum FAR proposed is 2.5 to 4 , depending on the accessibility of the locality. This will promote higher concentration of people within the walking distances of transit station, thereby increasing the ridership of the public transport and resulting in increased fare revenue, pollution and congestion reduction.

17.3.1.3 Mixed use development

Mixed land use is stipulated for development/ redevelopment in the TOD zone as it would reduce the need for travel by providing most of the activities such as shopping, entertainment and public amenities. Within the walking distance of the residents. It would also link origins and destinations, i.e. residences with work places or activity nodes. This would ensure better utilization of transit fleet by distributing loads in both directions, rather than creating unidirectional peak hour flows.

To promote such development, following approach is adopted.

<table>
<tr><th colspan="2">Commercial Development</th><th>Residential Development</th></tr>
<tr><td colspan="3">1. Existing Industrial Area is proposed to be coverted to high grade commercial development and high density residential development.
2. Existing commerial areas are proposed to be developed with high FAR.
3. Existing PSP and Resiential areas are left un-touched.
4. Existing Slums are proposed to be redeveloped with high FAR.</td></tr>
<tr><td colspan="2">200m buffer from the transit corridor is reserved for high grade commercial development, which will be used for mix of uses.</td><td>Following the commercial belt, high density residential development is envisaged.</td></tr>
<tr><td colspan="2">Two options for commercial densification is studied. In case I, FAR of 4 is proposed, in case II, FAR 3 is permissible</td><td>FAR of 2.5 and 3 is proposed depending on the distance from the transit station.</td></tr>
<tr><td>Option 1 - Permissible FAR = 4</td><td>Option 2 - Permissible FAR = 3</td><td>FAR 3 is proposed in Areas within 500m buffer from the transit station</td></tr>
<tr><td colspan="2">Commercial development is proposed along the existing arterial road i.e. Old Mumbai-Pune road, to minimise the requirement of Road Widening.</td><td>For areas beyond 500m buffer, FAR of 2.5 is proposed</td></tr>
<tr><td colspan="2">Existing arterial road with ROW of 61m can easily serve the high density commercial development with FAR 3 to 4.</td><td></td></tr>
<tr><td colspan="2">This commercial corridor will have an ‘active frontage’ which will provide for pedestrian safety. This will satisfy the TOD principle which says ‘At least 50% of total street frontage length needs to be active frontage’</td><td></td></tr>
</table>

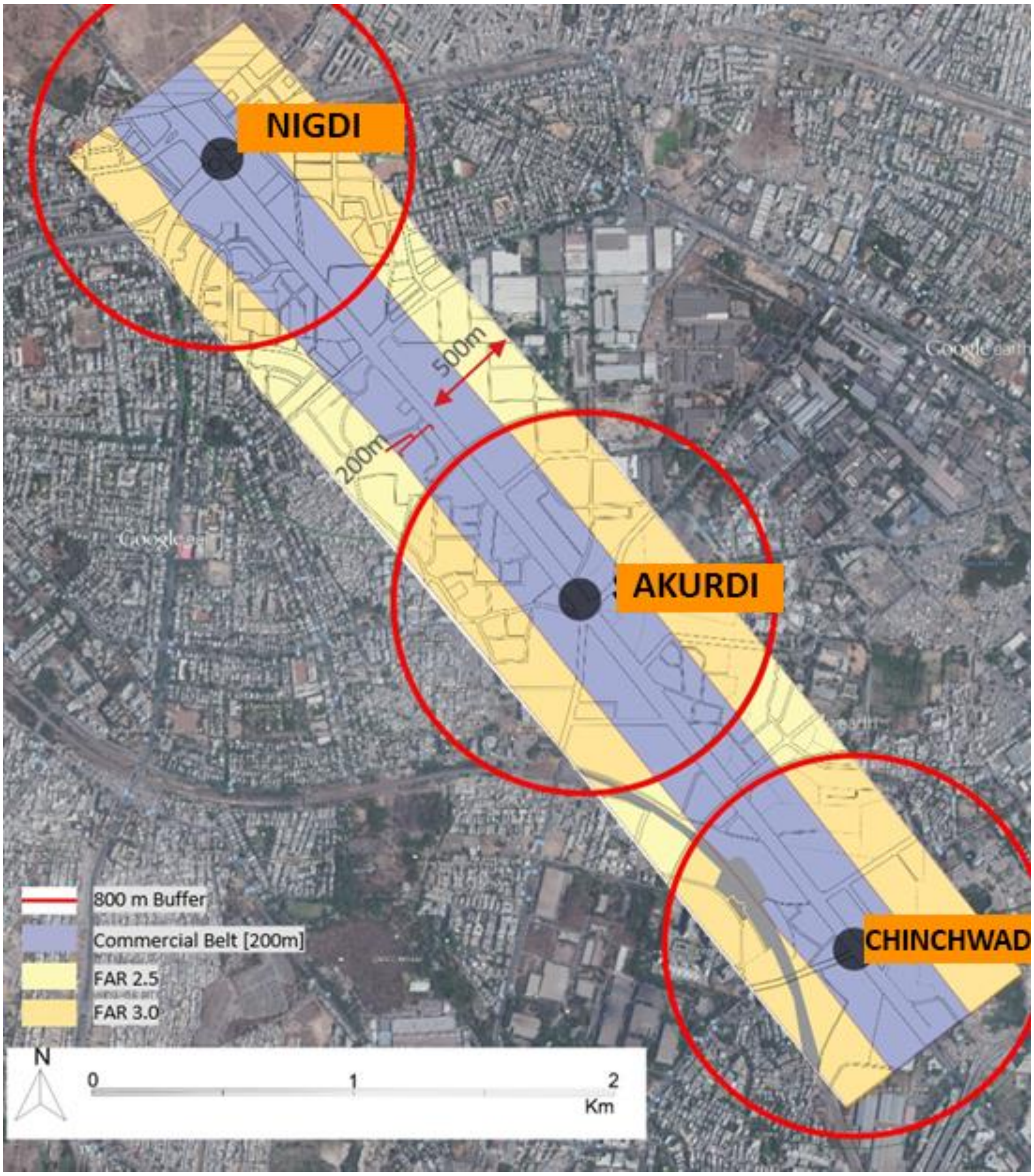


Figure 120 : Approach for TOD Implementation of Maha Metro corridor 1a: PCMC to Nigdi)

17.4 Inventory (within 500 M either side) & Overall Activity Pattern

Existing spatial distribution of the influence zone is studied to identify the potential for development in TOD Influence Zone. Administrative division of the influence zone shows that 89.1% influence zone lies within the jurisdiction of PCMC and remaining 10.9% lies under PCNTD administration.

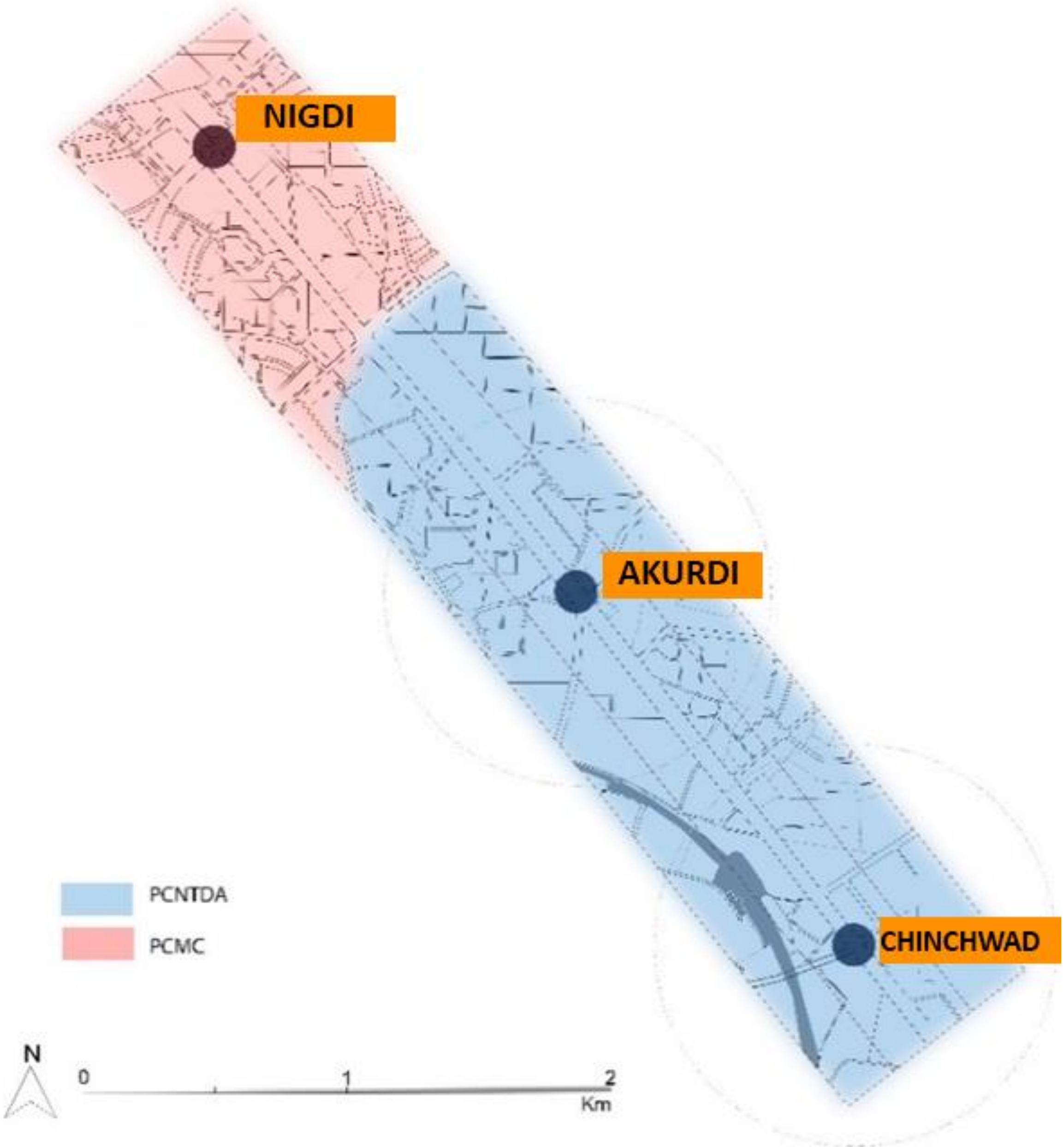


Figure 121 : Administrative structure of TOD influence zone

17.4.1 Overall Activity and Land use pattern

Land use distribution in the influence zone reflects that a large chunk of land is reserved under industrial use, which comprises to be low density development. This 33.38% of industrial land has potential for re-development under TOD principals as no rehabilitation will be involved. Thus, the area has high development potential as per TOD norms. Commercial land use comprises of just 4.59% of land use share, which indicates that economic potential generated due to transit line is untapped.

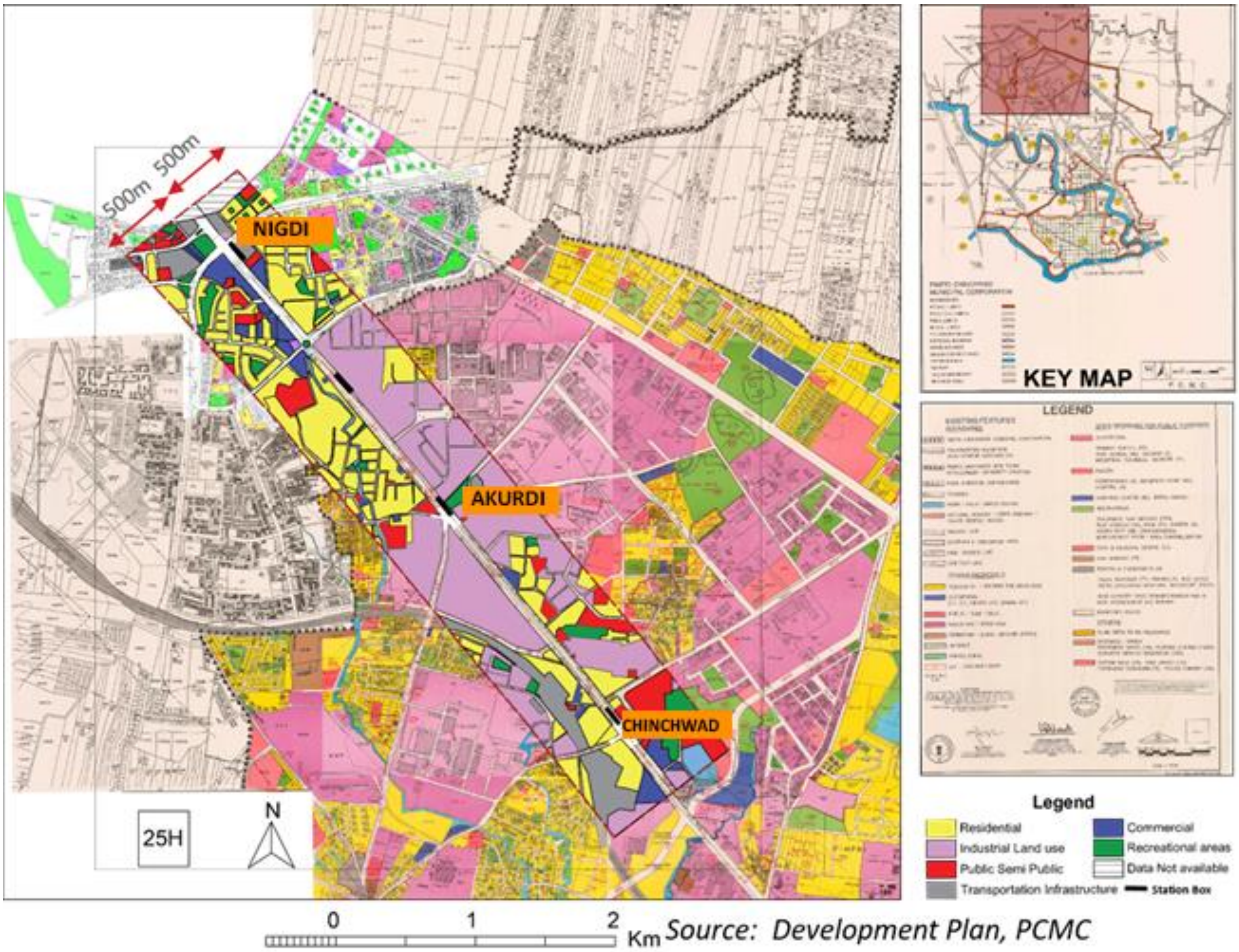


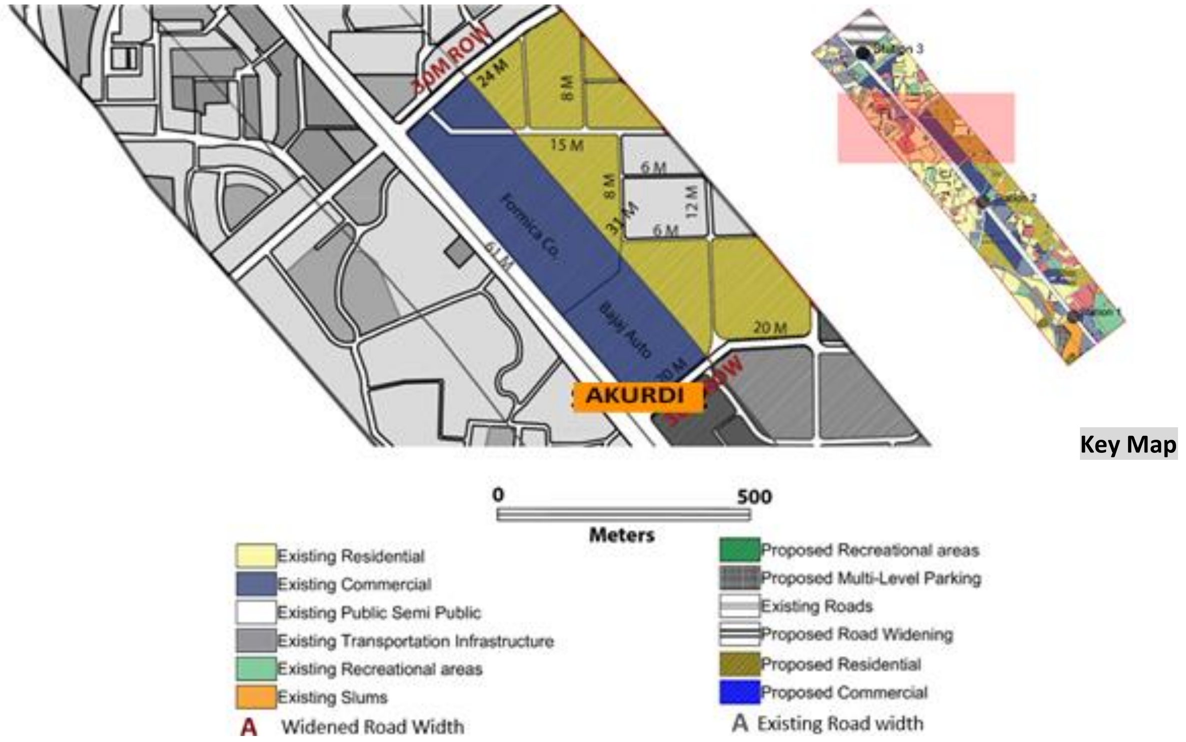
Figure 122 : Existing Land use distribution of TOD influence zone

17.5 Assessment of Development Potential

Study area is divided into 6 sites and thus Redevelopment Proposal is given for each site.

17.5.1 Site 1 of 6

Redevelopment of Formica Co. has potential to generate 3105336 square feet of commercial developable space and 687967.5 square feet of residential developable space, with 51648sq of space to be surrendered for Road widening. Similarly, Redevelopment of Bajaj Industries has potential to generate 2207952 square feet of commercial developable space and 2899147.5 square feet of residential developable space, with 2152sq ft of space to be surrendered for road widening.



17.5.2 Site 2 of 6

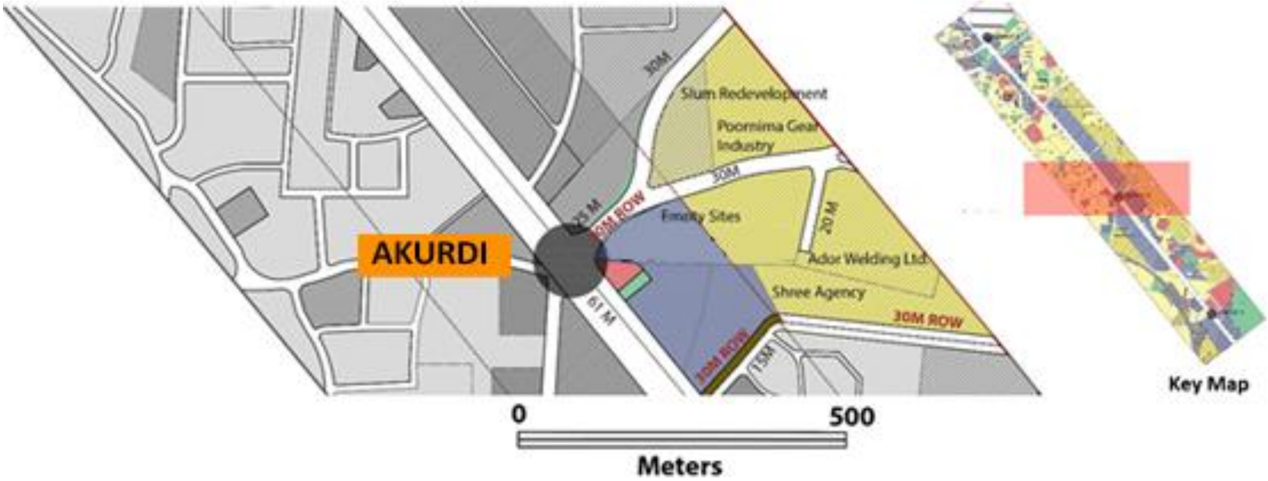
Redevelopment of Force Motors has potential to generate 2869692 square feet of commercial developable space and 2554155 square feet of residential developable space, with 51648 square feet of space to be surrendered for Road widening. Similarly, Redevelopment of Jai Hind Co. has potential to generate 188084.8 square feet of commercial developable space and 82798.2 square feet of residential developable space.

Existing Residential
Existing Commercial
Existing Public Semi Public
Existing Transportation Infrastructure
Existing Recreational areas
Existing Slums
A Widened Road Width

Proposed Recreational areas
Proposed Multi-Level Parking
Existing Roads
Proposed Road Widening
Proposed Residential
Proposed Commercial
A Existing Road width

17.5.3 Site 3 of 6

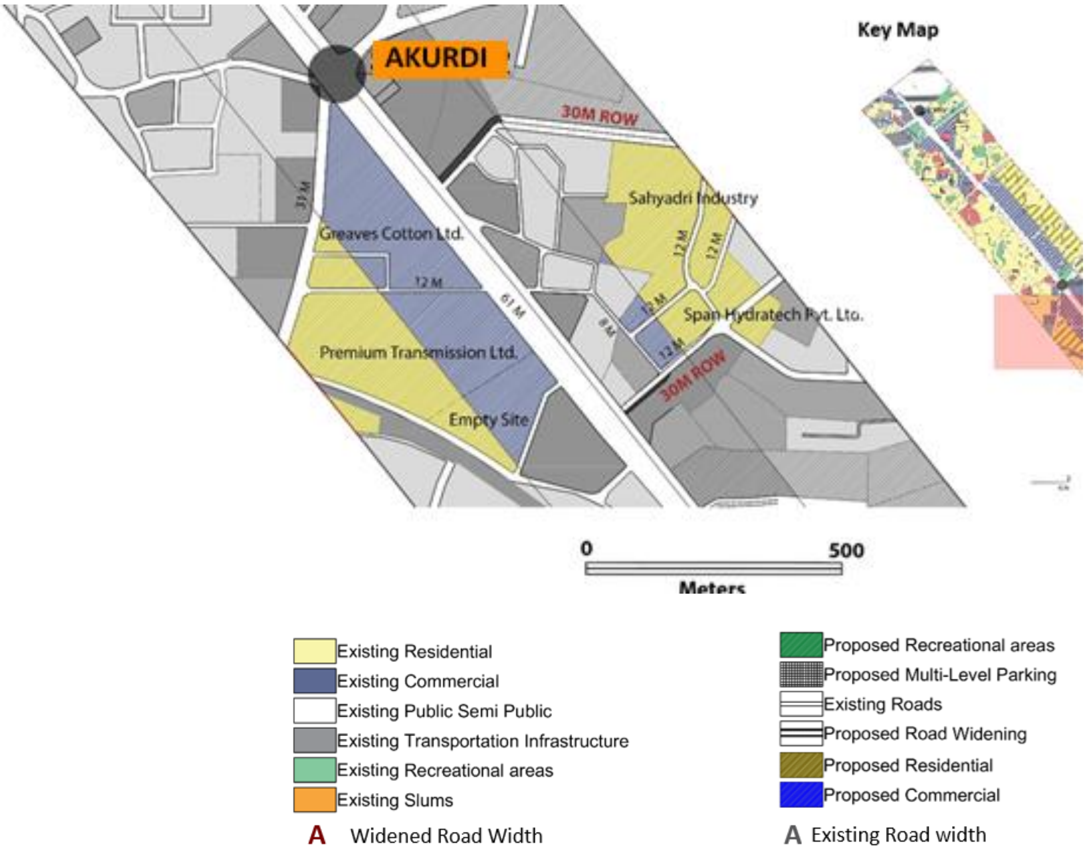
Provision of high FAR will generate 10760 square feet of commercial developable space from an empty plot. Residential developable space of 369068 square feet will be generated from Poona Gear industry, 355080 square feet, 352938 square feet, 498188 square feet of residential space from Poona Gear industry, Ador Welding Ltd. and Shree agency respecivity. 498188 square feet, 188368.432 square feet of residential space can be generated from an empty plot and slum redevelopment respectively. 62408 square feet area will have to be surrendered by shree agency for road widening.



Existing Residential
Existing Commercial
Existing Public Semi Public
Existing Transportation Infrastructure
Existing Recreational areas
Existing Slums
A Widened Road Width

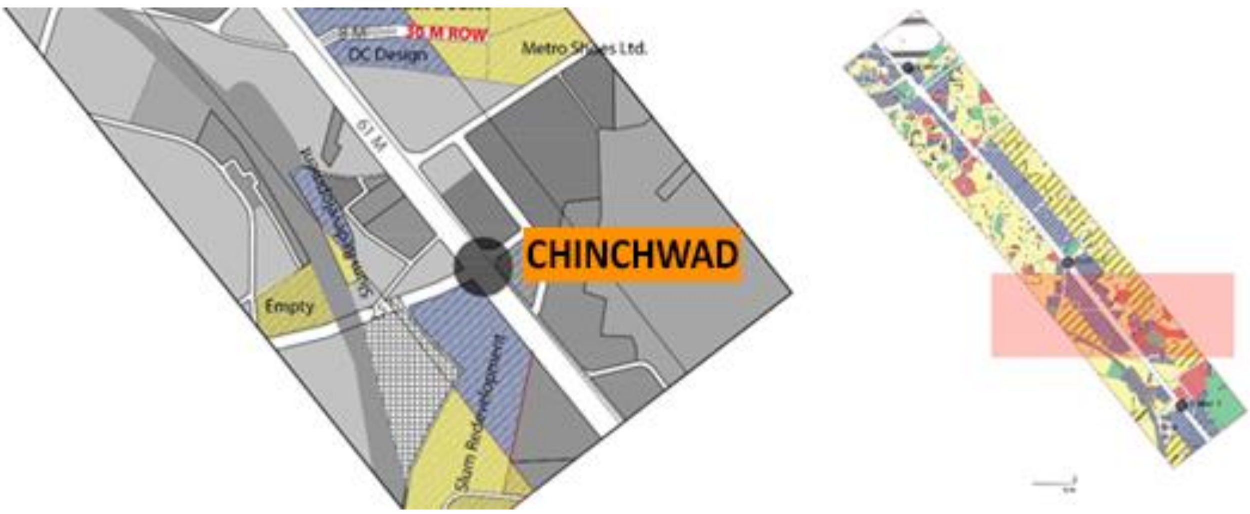
Proposed Recreational areas
Proposed Multi-Level Parking
Existing Roads
Proposed Road Widening
Proposed Residential
Proposed Commercial
A Existing Road width

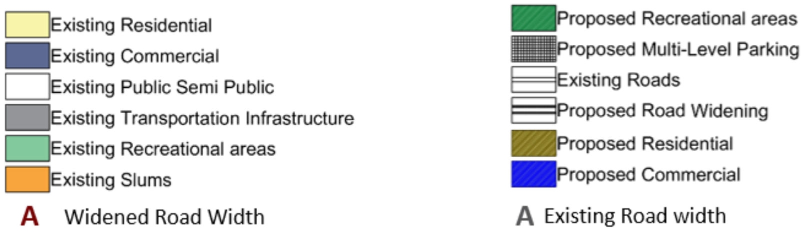
17.5.4 Site 4 of 6



5234524.8 square feet of commercial developable space, and 486922.2 square feet of residential developable space are generated by redevelopment of Sahyadri Industry, Span Hydratech Pvt Ltd, Premium industry and Greaves cotton Ltd. 4304 square feet of space will have to be surrendered for road widening by Span Hydratech Pvt. Ltd.

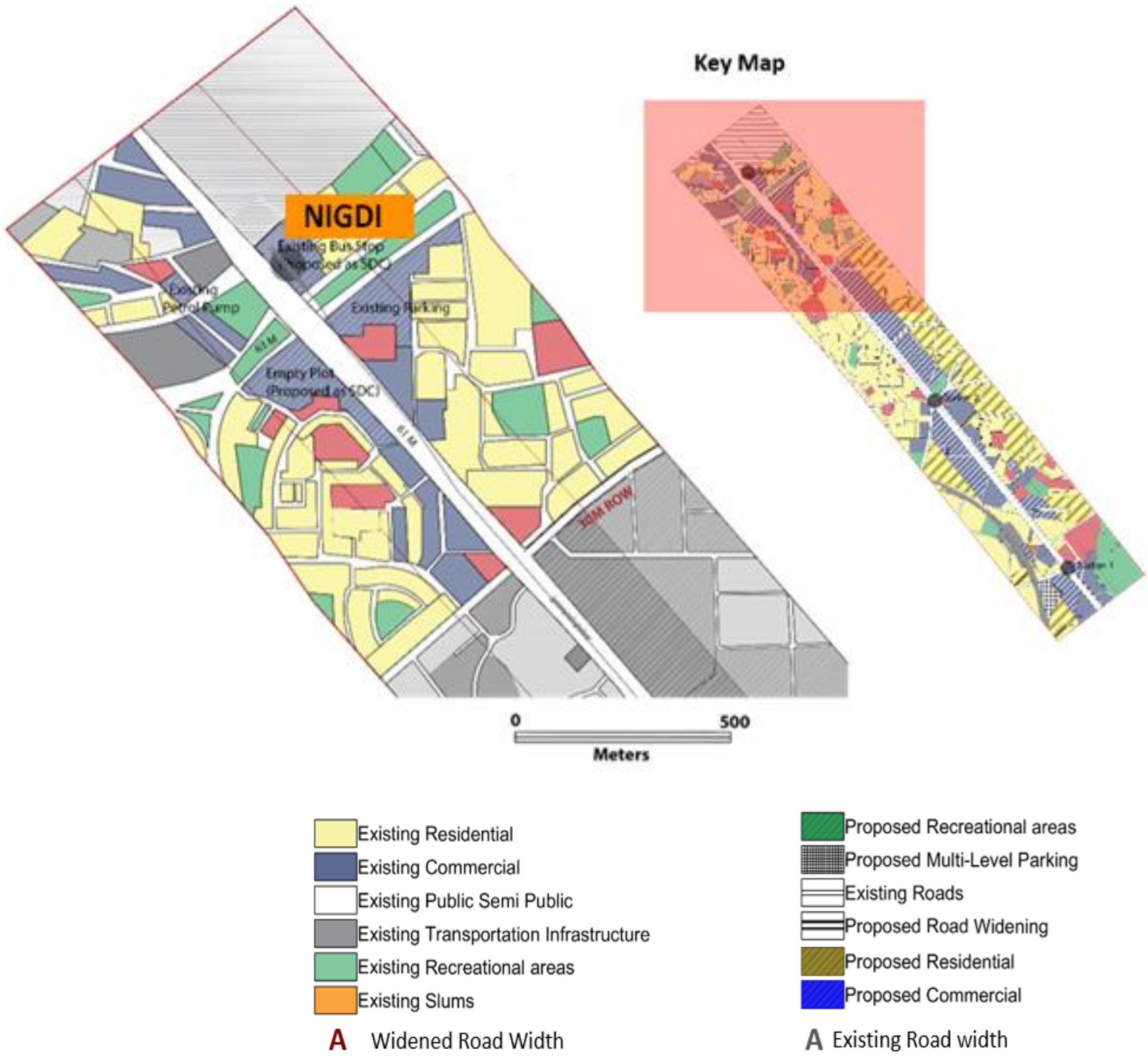
17.5.5 Site 5 of 6





836052 square feet and 575014.4 square feet of commercial developable space can be generated by redevelopment of Mahindra Truck and Buses and DC Design respectively. Total of 1666320.50 square feet of residential developable space are generated by redevelopment of Mahindra Truck and Buses, DC Design, Shanghai Steel complex and Metro shoes limited. Slum redevelopment will generate 832050.27 square feet of residential developable space. 26909.776 square feet for space will have to be surrendered by both Mahindra Truck and Buses and DC Design.

17.5.6 Site 6 of 6



As per national TOD Policy, Petrol Pumps, Bus Depots, Parking lots are not permissible in TOD influence zone. Thus, such are reserved for commercial and residential development. Total of 1148509.242 square feet of residential developable space can be generated.

Summary of Commercial development Potential with FAR 4 (Case I) is summarised in the table below:

Table 152 : Summary of Commercial Development Potential as a result of TOD Policy application (Case I Commercial FAR -4)

	Industries	Site Area (ha)	% area reserved for Amenities	Commercial Development			Effective built up area for conversion (deducting space for amenities) square feet
				Area (square feet)	FAR	Total Built up area (square feet)	
PCMC	Formica Co.	13.03	25%	1035112	4	4140448	3105336
	Bajaj Auto	16.85	25%	735984	4	2943936	2207952
	Force Motors	21.81	25%	956564	4	3826256	2869692
	Jai Hind Corp.	0.46	5%	49496	4	197984	188084.8
	Poona Gear Industries	3.43	20%	0	4	0	0
	Ador Welding Ltd.	3.3	20%	0	4	0	0
	shree agency	2.98	20%	0	4	0	0
	Sahyadri Industries Ltd.	6.54	25%	44116	4	176464	132348
	Span Hydratech pvt. Ltd.	4.76	20%	76396	4	288368	230694.4
	Mahindra Truck and Buses	4.85	25%	278684	4	1114736	836052
	DC Design	2.54	20%	179692	4	718768	575014.4
	shanghai Steel Company	1.73	5%	0	4	0	0
	Metro shoes Company	2.25	20%	0	4	0	0
	Greaves Cotton Ltd.	8.83	20%	796240	4	3184960	2547968
	Premium Transmission Ltd.	11.78	25%	512176	4	2048704	1536528
	Empty Industrial Plots	2 to 5	20%	482048	4	1928192	1542554
	Old Commercial areas			2603920	4	10415680	10415680
PCNTDA	Proposed commercial areas	<2hA	10%	668196	4	2672784	2405505.6
	Proposed commercial areas	2 to 5	10%	428248	4	1712992	1541692.8
	Old Commercial areas			1130876	4	4523504	4523504

	Slum Redevelopment	<2hA	5%	158172	4	632688	601053.6
	Slum Redevelopment	>5hA	25%	576736	4	2306944	1730208
	Total					42833408	36,989867.2

Summary of Commercial development Potential with FAR 3 (Case II) is summarised in the table below:

Table 153 : Summary of Commercial Development Potential as a result of TOD Policy application (Case II Commercial FAR -3)

	Industries	Site Area (ha)	% area reserved for Amenities	Commercial Development			Effective built up area for conversion (deducting space for amenities) square feet
				Area (square feet)	FAR	Total Built up area (square feet)	
PCMC	Formica Co.	13.03	25%	1035112	3	3105336	2329002
PCMC	Bajaj Auto	16.85	25%	735984	3	2207952	1655964
PCMC	Force Motors	21.81	25%	956564	3	2869692	2152269
PCMC	Jai Hind Corp.	0.46	5%	49496	3	148488	141063.6
PCMC	Poona Gear Industries	3.43	20%	0	3	0	0
PCMC	Ador Welding Ltd.	3.3	20%	0	3	0	0
PCMC	shree agency	2.98	20%	0	3	0	0
PCMC	Sahyadri Industries Ltd.	6.54	25%	44116	3	132348	99261
PCMC	Span Hydratech pvt. Ltd.	4.76	20%	76396	3	216276	173020.8
PCMC	Mahindra Truck and Buses	4.85	25%	278684	3	836052	627039
PCMC	DC Design	2.54	20%	179692	3	539076	431260.8
PCMC	shanghai Steel Company	1.73	5%	0	3	0	0
PCMC	Metro shoes Company	2.25	20%	0	3	0	0
PCMC	Greaves Cotton Ltd.	8.83	20%	796240	3	2388720	1910976
PCMC	Premium Transmission Ltd.	11.78	25%	512176	3	1536528	1152396
PCMC	Empty Industrial Plots	Ranges - 2 to 5	20%	482048	3	1446144	1156915.2
PCMC	Old Commercial areas			2603920	3	7811760	7811760
PC	Proposed commercial areas	<2hA	10%	668196	3	2004588	1804129.2

	Proposed commercial areas	2 to 5	10%	428248	3	1284744	1156269.6
	Old Commercial areas			1130876	3	3637956	3637956
	Slum Redevelopment	<2hA	5%	158172	3	474516	450790.2
	Slum Redevelopment	>5hA	25%	576736	3	1730208	1297656
	Total					**32370384**	**27,987728.4**

Summary of residential development Potential is summarised in the table below:

Table 154 : Summary of Residential Development Potential as a result of TOD Policy application

	Industries	Site Area (ha)	% area reserved for Amenities	Residential Development			Effective built up area for conversion (deducting space for amenities) square feet
				Area (square feet)	FAR	Total Built up area (square feet)	
PCMC	Formica Co.	13.03	25%	366916	2.5	917290	687967.5
	Bajaj Auto	16.85	25%	1546212	2.5	3865530	2899147.5
	Force Motors	21.81	25%	1135180	3	3405540	2554155
	Jai Hind Corp.	0.46	5%	29052	3	87156	82798.2
	Poona Gear Industries	3.43	20%	369068	3	1107204	885763.2
	Ador Welding Ltd.	3.3	20%	355080	3	1065240	852192
	shree agency	2.98	20%	320648	3	961944	769555.2
	Sahyadri Industries Ltd.	6.54	25%	659588	3	1978764	1484073
	Span Hydratech pvt. Ltd.	4.76	20%	440084	3	1320252	1056201.6
	Mahindra Truck and Buses	4.85	25%	243176	2.5	607940	455955
	DC Design	2.54	20%	93612	2.5	234030	187224
	shanghai Steel Company	1.73	5%	186148	2.5	465370	442101.5
	Metro shoes Company	2.25	20%	242100	3	726300	581040
	Greaves Cotton Ltd.	8.83	20%	133424	3	400272	320217.6
	Premium Transmission Ltd.	11.78	25%	755352	3	2266056	1699542
	Empty Industrial Plots	2 to 5	20%	842508	3	2527524	2527524

	Old Commercial areas			0	3	0	0
PCNTDA	Proposed commercial areas	<2hA	10%	0	3	0	0
	Proposed commercial areas	2 to 5	10%	0	3	0	0
	Old Commercial areas			0	3	0	0
	Slum Redevelopment	<2hA	5%	275456	3	826368	785049.6
	Slum Redevelopment	5hA	25%	432552	3	1297656	973242
Total						24060436	**18,738244.1**

Total commercial development potential in TOD influence area is 36.98 Million square feet in case I and 27.98 Million square feet in case II. Total residential development potential is 18.73 million square feet. Annual absorption trend of Pune city is 61million square feet per year of commercial development and 3 million square feet per year of residential development. Thus, TOD Proposal will supply 41% (with FAR 4) & 30% (with FAR 3) of total absorption of commercial space and 0.98% of Residential space in Pune**.**

17.6 Land Value Assessment & Revenue Potential

Evidence from around the world demonstrates that well-conceived infrastructure investment generates benefits that exceed costs. This is a result of the indirect benefits offered by the investment. . In other words, large scale public infrastructure investment leads to an increment in land and property valuation. Value capture refers to the recovery of a share of this increment. The appreciation usually occurs due to regulatory changes such as higher permissible densities and change in land use, investments in public goods infrastructure that increases quality of housing, jobs access and transportation, or social benefits and emergence of an important commercial, cultural, institutional, or residential developments in the neighbourhood. Land/ property owners in the proximity then become indirect beneficiaries of the appreciation in value without any effort. This appreciation is also in business opportunities. Value Capture Financing (VCF) is the mechanism of capturing the increment due to the appreciation in value. This fee levied, wherein a share of increased property value is levied as a charge is called as Premium levy.

TOD creates additional value to land, property and businesses, with better accessibility and more efficient use of land with higher density, leading to agglomeration benefits. VCF mechanisms gives opportunity to capture the value of these benefits from the beneficiaries. In TOD influence area, premium levy can be charged on incremental FAR provided. 30% of the value of incrementable developable space is charged as premium levy. 30% of the revenue thus generated will be shared with the municipality, and balance will assist in Metro funding. Total premium collection area is 11.9 Million square feet from residential development and 11.09 million square feet and 1.86 million square feet of commercial development in case I (FAR 4) and case II (FAR 3) respectively. Industry wise summary of premium collection area is given below:

a. Case I (FAR 4)

Table 155 : Premium Collection area summary (Case I – Commerical FAR 4)

	INDUSTRIES	RESIDENTIAL		COMMERCIAL	
		Incremental FAR	Premium Collection Area (square feet)	Incremental FAR	Premium Collection Area (square feet)
PCMC	Formica Co.	1.2	931600.8	1.5	412780.5
	Bajaj Auto	1.2	662385.6	1.5	1739489
	Force Motors	1.2	860907.6	2	1702770
	Jai Hind Corp.	1.2	56425.44	2	55198.8
	Poona Gear Industries	1.2	0	2	590508.8
	Ador Welding Ltd.	1.2	0	2	568128
	Shree agency	1.2	0	2	513036.8
	Sahyadri Industries Ltd.	1.2	39704.4	2	989382
	Span Hydratech pvt. Ltd.	1.2	69208.32	2	704134.4
	Mahindra Truck and Buses	1.2	250815.6	1.5	273573
	DC Design	1.2	172504.32	1.5	112334.4
	shanghai Steel Company	1.2	0	1.5	265260.9
	Metro shoes Company	1.2	0	2	387360
	Greaves Cotton Ltd.	1.2	764390.4	2	213478.4
	Premium Transmission Ltd.	1.2	460958.4	2	1133028
	Empty Industrial Plots	1.2		2	1348013
	Old Commercial areas	1.2	3124704	2	0
PCNTDA	Proposed commercial areas	1.2	721651.68	2	0
	Proposed commercial areas	1.2	462507.84	2	0
	Old Commercial areas	1.2	1357051.2	2	0
	Slum Redevelopment	1.2	180316.08	2	0
	Slum Redevelopment	1.2	519062.4	2	0
Total Premium Collection Area (square feet) = 11,096960.16 square feet					

B. case II (FAR 3)

Table 156 : Premium Collection area summary (Case II – Commercial FAR 3)

	INDUSTRIES	RESIDENTIAL		COMMERICAL	
		Incremental FAR	Premium Collection Area (square feet)	Incremental FAR	Premium Collection Area (square feet)
PCMC	Formica Co.	0.2	155266.8	1.5	412780.5
	Bajaj Auto	0.2	110397.6	1.5	1739488.5
	Force Motors	0.2	143484.6	2	1702770
	Jai Hind Corp.	0.2	9404.24	2	55198.8
	Poona Gear Industries	0.2	0	2	590508.8
	Ador Welding Ltd.	0.2	0	2	568128
	Shree agency	0.2	0	2	513036.8
	Sahyadri Industries Ltd.	0.2	6617.4	2	989382
	Span Hydratech pvt. Ltd.	0.2	11534.72	2	704134.4
	Mahindra Truck and Buses	0.2	41802.6	1.5	273573
	DC Design	0.2	28750.72	1.5	112334.4
	shanghai Steel Company	0.2	0	1.5	265260.9
	Metro shoes Company	0.2	0	2	387360
	Greaves Cotton Ltd.	0.2	127398.4	2	213478.4
	Premium Transmission Ltd.	0.2	76826.4	2	1133028
	Empty Industrial Plots	0.2	77127.68	2	1348012.8
	Old Commercial areas	0.2	520784	2	0
PCNTDA	Proposed commercial areas	0.2	120275.28	2	0
	Proposed commercial areas	0.2	77084.64	2	0
	Old Commercial areas	0.2	242530.4	2	0
	Slum Redevelopment	0.2	30052.68	2	418693.12
	Slum Redevelopment	0.2	86510.4	2	519062.4

Premium levy charge taken will be 1440 INR/ square feet for commercial areas and 1350INR/ square feet for residential area. Thus, Revenue from Premium Levy over the development period (30 Years) will be Rs. 3082 crore in case I and Rs 1755 in case II. Per year revenue generated will be Rs. 62 crore and Rs. 35 Crore for case I and case II respectively. 25% of the revenue generated will be shared with the municipality. Per year premium earned by Maha Metro by application of TOD Policy is summarized in the Table 157:

Table 157 : Per year premium earned by Maha Metro

FY	Revenue Generated (Cr.) (Case I)	Revenue Generated (Cr.) (Case II)
2030-31	104	59
2031-32	106	60
2032-33	109	62
2033-34	112	63
2034-35	114	65
2035-36	117	67
2036-37	120	68
2037-38	123	70
2038-39	126	72
2039-40	129	74
2040-41	133	75
2041-42	136	77
2042-43	139	79
2043-44	143	81
2044-45	146	83
2045-46	150	85
2046-47	337	137
2047-48	345	141
2048-49	354	144
2049-50	363	147
2050-51	372	152
2051-52	381	155
2052-53	391	158

17.7 PPP Potential

17.7.1 Property Development in Government Identified Land

Property with clear title of land with government under PCNTDA has been proposed for the said development. The land area is approximately 30,000 square meters. There is another open land identified at the back of City One mall measuring 24,000 square meters. An FSI of 4 is assumed for the proposed development.

One of the best ways to realize upfront revenues for the project is by giving the land to a private developer on lease for 50 years. The full value of clear ownership of the land works out to 229 Crores.

Table 158 : Land Value from Property Development

Government land available for PD	SQM	FAR
Govt land under PCNTDA	30000	4
Open land at the back of City one mall	24000	4
Commercial B/U Area	2160000	square feet
Rental	40	INR/ square feet
Annual Rental	103.68	
Operating Profit/ Rev	95%	
Annual Operating Profit	98.50	Crores
Cap Rate	10%	
Property Value	984.96	Crores
Construction Cost @ 3500 INR per square feet	756.00	Crores
Land Value	228.96	Crores

Additionally, market rate at 1.75 times ASR is also worked out from similar models applied in Mumbai, with developers paying 1.5 to 1.75 times the ASR value for a 50-year lease.

~70% of 229 Cr (from table above) works out to 1.75 times ASR value which **equals 155 crores**. This amount is expected to be realized in FY 24 when the metro becomes operational so that the developer does not price the construction risk of the project into his quote and maximum possible value is realized.

From an accounting treatment perspective, this is treated as other equity in the balance sheet and not as Other Income. The other equity can be treated as deferred revenue year on year. However, in this model, the other equity item is not phased out.

17.8 Impact Assessment of TOD Proposal

Population growth is bound to happen with TOD. Increases residential FAR implies densification of the area. Population density proposed will range between 220-320PPH for areas which are proposed to be developed with FAR 3 and 180-280 PPH for areas which are proposed to be developed with FAR 2.5. Thus, average Projected population after 30 years will be 1.05 Lakh Persons. This Projected Population was then compared with the population projected in the comprehensive mobility Plan of Pune. Pune average density in 2011 is 30.4 DU/Ha and is projected to be 40.1 DU/Ha in 2031 and 51.3 DU/Ha in 2031 in CMP. This density is thus projected to year 2051 through curve fitting method.

Population density thus came out to be 71.99 DU/Ha. Correlation factor for such curve is coming out to be 0.99, depicting the reliability of the relation. This projected density is applicable for very low-rise development with the basic FAR of 1.1. Population density came out be 216 DU/Ha and 180 DU/Ha, when calculated for proposed residential FAR 3 and 2.5 respectively. Projected population in such a case will be 0.94 Lakh. This population as per the methodology adopted in CMP is comparable 1.05 Lakh as per methodology used in this report.

Demand for infrastructure will increase with this incremental population, thus cost of development of the area will increase. Cost of development will comprise of two components i.e. Infrastructure Provision and Road Widening, which are discussed in detail in next section.

17.9 Implementation Mechanism

Land use structure of the influence zone is proposed, wherein high-density residential development and high-grade commercial development is encouraged. Industrial uses are replaced with commercial development along the arterial corridor and residential development beyond 200m distance from the transit corridor. Existing slums are proposed to be redeveloped.

Land required for Road widening is to be acquired from industrial and commercial land uses, where higher FAR is prescribed. Land must be reserved for amenities and public services in order develop the plot with high FAR as per DCPR Rule Clause M 6.5. Area will be reserved for public amenities based on plot size in following manner:

Plot Size	% Area Reserved
< 2Ha	5%
2-5Ha	20%
>5Ha	25%

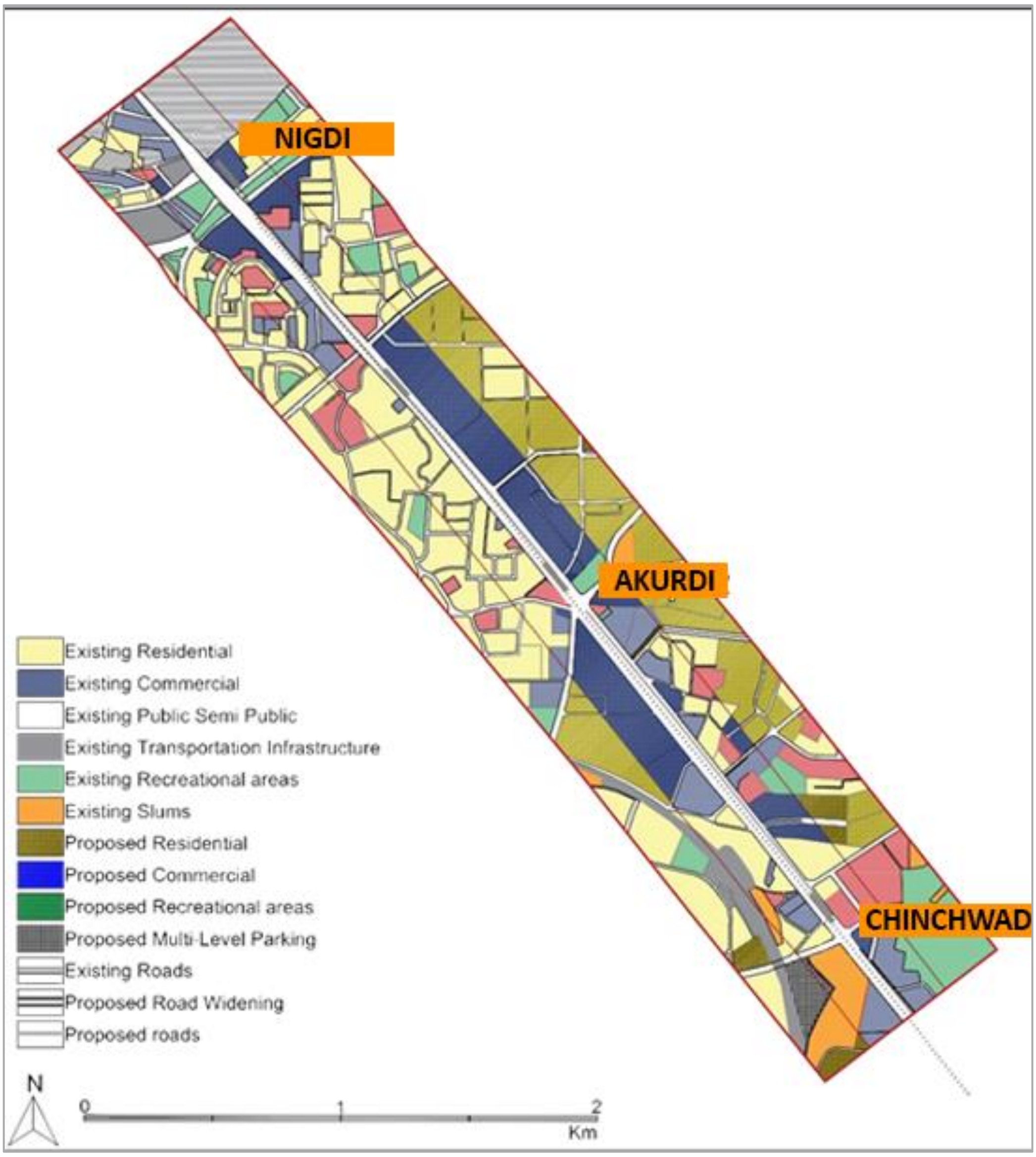


Figure 123 : Proposed development pattern for TOD influence area over 30 years

Road widening is proposed to accommodate the proposed dense development. As per The Hindu, Maharashtra government stipulates that the FSI of 3 will be allowed only where roads are 30 meters or more in width. This applies to commercial development as well. For FSI 4, access road is provided with ROW 61m. 30m wide access road is ensured for areas proposed to be developed with FAR 3 and for areas with FAR 2.5, 20m wide road is proposed In accordance to said stipulations, Road widening is proposed.

Figure 124: Road widening proposed while redevelopment

Five stretches are proposed to be widened to ensure that every plot is accessed through a 30m wide road. Nomenclature is given to the proposed stretches as 1A, 1B, 1C, 1D and 1E. Road widening details are summarized in the table given below:

Table 159 : Summary of Road Widening Requirement as part of TOD Proposal

	Length of Roads to be widened (m)	Widening width (m)
1A	474	6
1B	452.3	5
1C	51.8	10
1D	436.8	20
1E	297.5	10

Cost of Road Widening: Cost incurred due to land acquisition for Road widening will be Rs. 153.200 Crore* and cost incurred due to Road widening will be Rs. 4.218 Crore (Per km road widening cost is assumed as INR 2.5 cr./Km. Summary of land acquisition cost for road widening is given in Table 160:

Table 160 : Summary of land acquisition cost for road widening

	Owner	Land Use	Area (sq	Per Unit cost(ASR)	Cost of Land (INR)
1A	Formica Co.	Industrial	400	46460	23230000
1A,1B	Bajaj Auto	Industrial	5200	46460	241592000
1B	Force Motors	Industrial	2100	46460	97566000
1C	Shree agency	Industrial	5900	46460	274114000
1E	Mahindra Truck and Buses	Industrial	4800	46460	223008000
1E	DC Design	Industrial	4600	46460	213716000
1D	Sahyadri Industries Ltd.	Industrial	3600	46460	167256000
1C	Star Bazaar	Commercial	3100	94040	291524000
TOTAL					**153.200 Crore**

Apart from Road widening, Other utilities and infrastructure will also have to be proposed to provide for increment population. Infrastructure cost is assumed to be Rs. 50INR/ square feet of developable area proposed. Thus, total cost for infrastructure provision will be 183.3 crore.

Thus, at the expense of Rs 340.78 Cr, Premium Levy over the development period (30 Years) of Rs. 3082 crores in case I and Rs 1755 in case II will be earned.

For the project to be viable, case I will be preferred i.e. promoting commercial development with FAR 4 within intense TOD Zone. Study of case II is conducted for academic purpose only. Therefore, Share of Premium levy for the finance of Maha metro will be 87 Cr from the year of operation i.e. FY 2023-2024. In case, case II is selected then the share of cess on stamp duty for Maha Metro will have to be increased to make the project viable and meet the revenue support amount of 130 Crore at FY 24 prices. However, this will be explored in greater detail in the chapter on financial analysis (Chapter 18).

18. FINANCIAL ANALYSIS AND NON FARE BOX REVENUE ASSESSMENT

18.1 Introduction

The chapter seeks to examine the financial viability of the proposal to add to the existing metro network planned for Pune city. Based on the optimum routes discussed with Maha Metro and covered in the previous chapters, the existing metro line is proposed to be extended from PCMC to Nigdi on one end and Swargate to Katraj on the other. Chakan is an industrial suburb of Pune – having emerged as a major automobile hub. A new line connecting Chakan to Nashik phata is also proposed.

This chapter evaluates the financial feasibility of this extention line. The proposed extension would be constructed at an approximate cost of Rs 791.02 Crores at FY 19 prices. This includes all central and state taxes. The total completion cost (excl. PPP component) works out to Rs Rs 898.68 Crores.

Table 161 : Project Cost Details

Sl. No	PCMC to Nigdi Corridor	FY 19 Prices (Cr.)	Completion Cost basis (Cr.)
1	Without Land, R&R and taxes (Excl. PPP Component)	597.31	681.21
2	With Land, R&R and taxes (Excl. PPP Component)	791.02	898.68

Construction period start is assumed in FY 21-22 and period of construction is assumed as 3 years. Start of operations is assumed 2024-25.

The total investment of Rs 887.66 Crores (Total project completion cost: Rs 898.68 minus IDC of Rs 11.02 Cr) is broken down yearwise and presented in the table below.

Table 162 : Project Cost Phasing

Yr	Year	Cost Distribution	Land Distribution	Cost at FY 2019 Price Level					Escalation Factor	Completion Cost				
				Component Cost without Taxes, Land and R&R	Central Taxes	State Taxes	Land and R&R	Total Cost		Completion Cost without Taxes, Land and R&R	Central Taxes with escalation	State Taxes with escalation	Land and R&R	Total Completion Cost
Y1	2021-22	15.0%	20%	87.94	6.24	5.65	22.89	122.72	1.050	92.34	6.55	5.93	24.03	128.86
Y2	2022-23	25.0%	50%	146.57	10.40	9.42	57.22	223.61	1.103	161.60	11.47	10.38	63.08	246.53
Y3	2023-24	33.4%	30%	195.82	13.90	12.58	34.33	256.63	1.158	226.69	16.09	14.56	39.74	297.08
Y4	2024-25	26.6%		155.95	11.07	10.02		177.04	1.216	189.56	13.46	12.18		215.20
Total		**100%**		**586.29**	**41.61**	**37.67**	**114.43**	**780.00**		**670.18**	**47.57**	**43.06**	**126.85**	**887.66**

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18.1.1 Investment towards Rolling Stock

Total investment provided in the FIRR calculation towards requirement of additional rolling stock duly escalated @ 5% per annum to cater increased ridership is placed in table as follows:

Financial Year	No.of cars – Nigdi Swargate Corridor	Incremental Cars	Investment including taxes at escalated levels
FY 43	102	12	Rs 309.61 Cr
FY 53	108	6	Rs 252.16 Cr

18.1.2 O&M Costs

Energy Charges – Energy consumption figures for traction and auxiliary power over a 30 year period has been detailed below

Description	Traction		Auxilliary		Units
	Value (year 2023-2024)	Value (year 2052 - 2053)	Value (year 2023-2024)	Value (year 2052 - 2053)	
Load	0.68	1.06	1.11	1.11	MVA
Energy usage (annual)	4.04	6.33	3.29	3.94	million Units

Grid electricity charges are taken as 6 INR per KWH. 80% is assumed to be drawn from the grid and 20% from solar as per RESCO model. Solar charges are taken as 4 INR/KWH.

18.1.3 Employee Costs

Annual salary of employee @2012 levels from report published by Institute of Urban Transport (India) funded by Bangalore Metro Rail Corporation Limited in 2012 stands at 9 lakh per annum. It is suitably escalated to 12.5 Lakh P.A. at FY 19 prices. Escalation rate then onwards have been taken @9% P.A. in line with the DPR in the existing stretch. Number of employees per km in MRTS is taken as 32.

18.1.4 Maintenance Costs

Maintenance costs have been arrived at basis the table below. Escalation of 5% has been assumed to arrive at 2024-25 costs.

Table 163 : Per unit cost of repairs and Maintainance of DMRC (2010 prices)

Unit Cost of Repairs and Maintainance of DMRC (2010 Prices)		
	2010 Prices	
Building	26.74	Lakhs per Station
Plant and Machinary	11.4	Lakhs per Car
Other R&M	2.20%	of Building, Plant and machinary Costs

Other O&M Costs	11%	Of Energy Staff and R&M Costs
Report - Life Cycle Cost Analysis of Five Urban Transport Systems jointly carried out by Bangalore Metro Rail Corporation Ltd. And Institute of Urban Transport (India)		

Summary of O & M expenditure is as follows:

Table 164 : Year wise summary of Operation and Maintainance expenses

Financial Year	Energy Expense (Cr.)	Employee benefit expense (Cr.)	O & M Expenditure (Cr.)
FY 25	5	28	11
FY 26	5	30	11
FY 27	5	33	12
FY 28	6	36	13
FY 29	6	39	14
FY 30	6	43	15
FY 31	6	47	15
FY 32	7	51	16
FY 33	7	56	18
FY 34	7	61	19
FY 35	7	66	20
FY 36	8	72	21
FY 37	8	78	22
FY 38	8	85	24
FY 39	8	93	25
FY 40	9	101	27
FY 41	9	111	29
FY 42	9	121	31
FY 43	10	131	33
FY 44	10	143	35
FY 45	10	156	37
FY 46	10	170	40
FY 47	11	186	43
FY 48	11	202	46
FY 49	11	220	49
FY 50	11	240	52
FY 51	12	262	56
FY 52	12	285	60
FY 53	12	311	64
FY 54	12	339	68

18.1.5 Depreciation

Depreciation has been calculated both as per Companies Act and Income tax Act in order to account for:

a. benefit from the depreciation tax shield
b. Calculate unabsoarbed depreciation and pass on benefit to tax payable

However, deferred tax asset/ deferred tax liability is not routed through the balance sheet as it is a non cash item.

Salvage value is considered as 0 for ease of calculation.

18.1.6 Replacement Cost

The replacement cost are provided for meeting the cost on account of replacement of equipment due to wear and tear. With the nature of equipment proposed to be provided, it is expected that only 50% of signalling and telecom and 25% of electrical works would require replacement after 15 years.

18.2 Revenue

The revenue streams for the project are detailed as under:

1.1 Fare Box Revenue

1.2 Non Fare Box Revenue

1.2.1 Premium levy from property development along the development corridor

1.2.2 Sharing of Cess on stamp duty with PCMC

1.2.3 Property Development on available Government Land

1.2.4 Advertising Revenue

1.2.5 ATMs/ Kiosks on Stations

18.2.1 Fare Box Revenue

The incremental trips per day on the Nigdi Swargate corridor and the trip length distribution is detailed in the following tables:

Table 165 : Projected Metro Ridership

Year	Incremental Trips per Day - 80% of total Volume
2024-25	29000
2033-34	43000
2043-44	64000
2052-53	72000

Table 166 : ***Average Trip length for incremental corridor***

Year	Without extension (PCMC – Swargate)	With Extension (Nigdi – Swargate)
2024-25	7.33	7.83
2033-34	7.51	8.05

2043-44	7.65	8.21
2052-53	7.76	8.36

The fare structure has been taken in accordance with Government Resolution No.PMR-3313/C.R.29/UD-7 and letter dated 29th October 2013 (refer Exhibit 1 at the end of chapter) vide which sanction was accorded to Sanction to the revised proposal of Pimpri- Chinchwad to Swargate and Vanaz to Ramwadi Metro Rail corridor of Pune Mahanagar Metro Rail Project. The letter also accorded in principal sanction to implement commuter fares as tabulated below as the Pune Mahanagar Metro Rail Project is proposed to be implemented under the provisions of Metro Railway Act enacted by the Government of India. The fares at 2018-2019 prices are detailed in Table 167:

Table 167 : Fare structure

Sr. No.	Distance in K.M.	Fare (Rs.) @ 2018-2019 Prices
1	0-2	13
2	2-4	17
3	4-6	20
4	6-9	25
5	9-12	27
6	12-15	30
7	15-18	32
8	18-21	35
9	21-24	37
10	24-27	38
11	27-30	42
12	More than 30 K.M.	45

The average incremental trip length is between 7 to 9 kms for the corridor – Nigdi to Swargate. Hence, the applicable fare slab is 6 to 9.

Escalation in fare of 15% is assumed every 3 years. The above table is at 2018 price levels.

Table 168 : Fare structure Matrix

Distance (Km)	Fare as per table above	Fare @ start of project 2024-25	Fare Revision – FY 27
6 to 9	25	34	40

18.2.2 Non Fare Box Revenue

>90% of non fare box revenue for the extension would come in the form of revenue support from PCMC – classified as Other Income in the Profit and Loss Statement. The project to be viable would need 135 crores annually. This would be realized with a combination of:

- Share of premium levy on property development
- Share of cess on property registrations
- Development charges from PCNTDA

The following section analyses and presents findings to make this practically realizable.

18.2.2.1 Premium levy from property development along the development corridor

TOD policy envisages extensive development for a width of 500 meters on either side of the transit corridor. This development potential has been analysed by an in-depth study of existing land use of plots along development corridor. The study of spatial distribution from PCMC to Nigdi yielded the result that more than 30% of the land comprises plots having industrial land use. Post this, a rigorous methodology was followed with a plot wise analysis to arrive at the true development potential of the development corridor. An assessment of associated costs that will have to be borne by the municipality in order to realize this development potential was also taken out. While this is covered in detail in the application of TOD policy chapter i.e. Chapter 16, given below is a summary of the methodology followed:

- The area was divided into development zones based on distance from the station and distance from the transit line
- The individual plot end use was assessed.
- The width of the access road to the plot was assessed.
- Based on the above criterion, FAR of 3/ 4/ 2.5 and residential/ commercial was accorded to the individual plots.

	Commercial/ Residential – FAR 4/ 3	Residential - FAR 2/2.5
Total area absorption in million square feet	37.0	18.7
Per year area absorption (million square feet)	1.2	0.6

We also looked at the demand side of the real estate. There were several encouraging factors like:

- The annual absorption of real estate in Pune stood at 72 million square feet.
- There is rapid real estate development already happening along the corridor due to FAR of 2.8 being made available upto 200 meters on either side of the BRT in the same corridor.

Based on the above absorption trends, 1.8 million square feet per year is only 2 to 3% of the aggregate demand. This seemed reasonably achievable from a demand perspective.

Based on primary surveys and ASR, we could see that sale price of 4000 to 4300 per square feet on residential/ commercial in the vicinity was achievable. Therefore we have fixed the premium on incremental FAR at 1350 to 1450 INR per square feet. Revenue from premium levy stood at 3082 Crores . This additional revenue from higher FSI is assumed to be realized over a 30 year period. The same is escalated @2.5%.

Table 169 : Year wise share of Premium with Maha Metro

Year	Revenue to Metro from Premium Levy with Max FAR 4 (INR Cr.)
2030-31	104
2031-32	106

2032-33	109
2033-34	112
2034-35	114
2035-36	117
2036-37	120
2037-38	123
2038-39	126
2039-40	129
2040-41	133
2041-42	136
2042-43	139
2043-44	143
2044-45	146
2045-46	150
2046-47	337
2047-48	345
2048-49	354
2049-50	363
2050-51	372
2051-52	381
2052-53	391

18.2.3 Sharing of Cess on stamp duty with PCMC

FY 19 – 1% cess collection on stamp duty in PCMC stood at 155 Crores. 25% share per year from the same is proposed to be given as revenue support to the extension from PCMC to Nigdi over a 30 year period and assumed to be escalated at 2.5%.

Table 170 : Year wise share of cess on stamp duty with Maha Metro

Year	Revenue to Metro from Cess on Stamp Duty (INR Cr.)
2030-31	52
2031-32	53
2032-33	55
2033-34	56
2034-35	57
2035-36	59
2036-37	60
2037-38	62
2038-39	63
2039-40	65
2040-41	66

2041-42	68
2042-43	70
2043-44	72
2044-45	73
2045-46	75
2046-47	169
2047-48	173
2048-49	177
2049-50	182
2050-51	186
2051-52	191
2052-53	196

At FY 31 Price levels, the cess and Premium sharing with Maha Metro would translate into an annual revenue grant of 156 Crores.

18.2.4 Sharing of development Charge with PCNTDA

1 km of the alignment extension falls in PCNTDA limits. 100% increase in Development cess collected from PCNTDA will augment the non fare box revenues . Development cess collected in FY 19 stands at 4 Cr. The same has been suitably escalated and included in other income.

18.2.5 Property Development in Government Identified Land

Property with clear title of land with government under PCNTDA has been proposed for the said development. The land area is approximately 30,000 square meters. There is another open land identified at the back of City One mall measuring 24,000 square meters. An FSI of 4 is assumed for the proposed development.

One of the best ways to realize upfront revenues for the project is by giving the land to a private developer on lease for 50 years. The full value of clear ownership of the land works out to 229 Crores.

Table 171 : Land value

Government land available for PD	SQM	FSI
Govt land under PCNTDA	30000	4
Open land at the back of City one mall	24000	4
Commercial B/U Area	2160000	square feet
Rental	40	INR/ square feet
Annual Rental	103.68	
Operating Profit/ Rev	95%	
Annual Operating Profit	98.50	Crores
Cap Rate	10%	

Property Value	984.96	Crores
Construction Cost @ 3500 INR per square feet	756.00	Crores
Land Value	228.96	Crores

Additionally market rate at 1.75 times ASR is also worked out from similar models applied in Mumbai, with developers paying 1.5 to 1.75 times the ASR value for a 50 year lease.

~70% of 229 Cr (from table above) works out to 1.75 times ASR value which **equals 155 crores**. This amount is expected to be realized in FY 24 when the metro becomes operational so that the developer does not price the construction risk of the project into his quote and maximum possible value is realized.

From an accounting treatment perspective, this is treated as other equity in the balance sheet and not as Other Income. The other equity can be treated as deferred revenue year on year. However in this model, the other equity item is not phased out.

18.2.6 Advertising Revenues

The following sources of advertising revenues are evaluated in the said report:

Station boards – Based on typical station alignment - 120 Sqm of advertising space is identified per station. Occupancy rate from start of operation has been identified as below with occupancy rates remaining constant at 85% FY 34 onwards:

Table 172 : Year wise occupancy rate of ststion boards on stations

2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
50%	60%	60%	60%	60%	60%	70%	70%	80%	85%

Viaduct boards – Based on the number of piers available, space for 122 board of 2X2 Sqm have been identified. Occupancy rate from start of operation has been identified as below with occupancy rates remaining constant at 85% FY 34 onwards:

Table 173 : Year wise occupancy rate of viaduct boards on stations

2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
50%	60%	60%	60%	60%	60%	70%	70%	80%	85%

Train Wrapping and In Train Advertising – From DMRC norms, only 10% of the trains are wrapped. Based on the same, the number of trains with wrapping and in-train advertising has been capped at 1 as only 8 incremental trains are proposed.

18.2.7 ATMs/ Kiosks on Stations

There are 3 stations along the alignment. From the typical layout of the station, space for 2 ATMs/ kiosks have been identified.

Lease rental of 40 INR/ square feet / month is currently assumed. Escalation in standard commercial development of 15% every 3 years is incorporated as 5% per year. 85% occupancy is targeted only from the 10th year of operation. The occupancy rate from start of project in FY 25 is detailed below with occupancy rates remaining constant at 85% FY 34 onwards:

Table 174 :Year wise occupancy rate of ATM/Kioks on stations

2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34
50%	60%	60%	60%	60%	60%	70%	70%	80%	85%

Table 175 : Sumarry of Non farebox revenue

Financial Year	Revenue Fare Box (Cr.)	REVENUE NON FARE BOX				Total Income (Cr.)
			OTHER INCOME (Cr.)			
		Inflow from Advertising, train wrapping etc (Cr.)	Premium Levy on Development	LBT share of Registration	Development cess from PCNTDA	
FY 25	35	3	87	44	4	174
FY 26	37	4	89	45	5	179
FY 27	38	4	92	46	5	184
FY 28	47	4	94	47	5	196
FY 29	48	4	96	48	5	202
FY 30	50	5	99	49	5	207
FY 31	51	5	101	51	5	213
FY 32	61	5	104	52	5	227
FY 33	63	6	106	53	5	233
FY 34	67	6	109	55	6	242
FY 35	71	6	112	56	6	251
FY 36	87	7	114	57	6	271
FY 37	91	7	117	59	6	280
FY 38	96	8	120	60	6	290
FY 39	100	8	123	62	6	299
FY 40	121	8	126	63	6	325
FY 41	126	9	129	65	7	335
FY 42	131	9	133	66	7	346
FY 43	136	10	136	68	7	357
FY 44	161	10	139	70	7	387
FY 45	164	11	143	72	7	396
FY 46	166	11	146	73	7	404
FY 47	167	12	150	75	8	412

FY 48	196	12	154	77	8	446
FY 49	198	13	158	79	8	455
FY 50	200	13	162	81	8	464
FY 51	202	14	166	83	8	473
FY 52	237	15	170	85	9	515
FY 53	239	16	174	87	9	525
FY 54	243	16	178	89	9	536

18.3 Financial Internal Rate of Return

The **financial internal rate of return** at completion cost basis with farebox and non fare box revenue with additional revenue sources (Other Income) from improved FSI along the development corridor and cess from stamp duty works out to **10.45%.**

This is the project IRR without imposition of the capital structure. The detail is given in the Exhibit 2 at the end of chapter.

The profit and loss statement and cash flow statement are attached in the exhibit. While unabsorbed depreciation is considered while calculating tax pay-out, since deferred tax is a non cash item, we have not routed it through the balance sheet.

Additionally there is a monetary grant from PCMC generated by granting a 50 year capital lease on PCMC owned land. From an accounting treatment perspective, monetary grant is treated as other equity in the balance sheet and not as Other Income. The other equity can be treated as deferred revenue year on year and phased out from the balance sheet. However in this model, the other equity item is not phased out.

Also, Salvage value is considered as zero for ease of calculation

18.4 FIRR Sensitivity

While calculating impact of FIRR with various Capex scenarios, revised depreciation calculations and tax impact have not been effected due to small effect.

Table 176 : Capital Cost sensitivity analysis

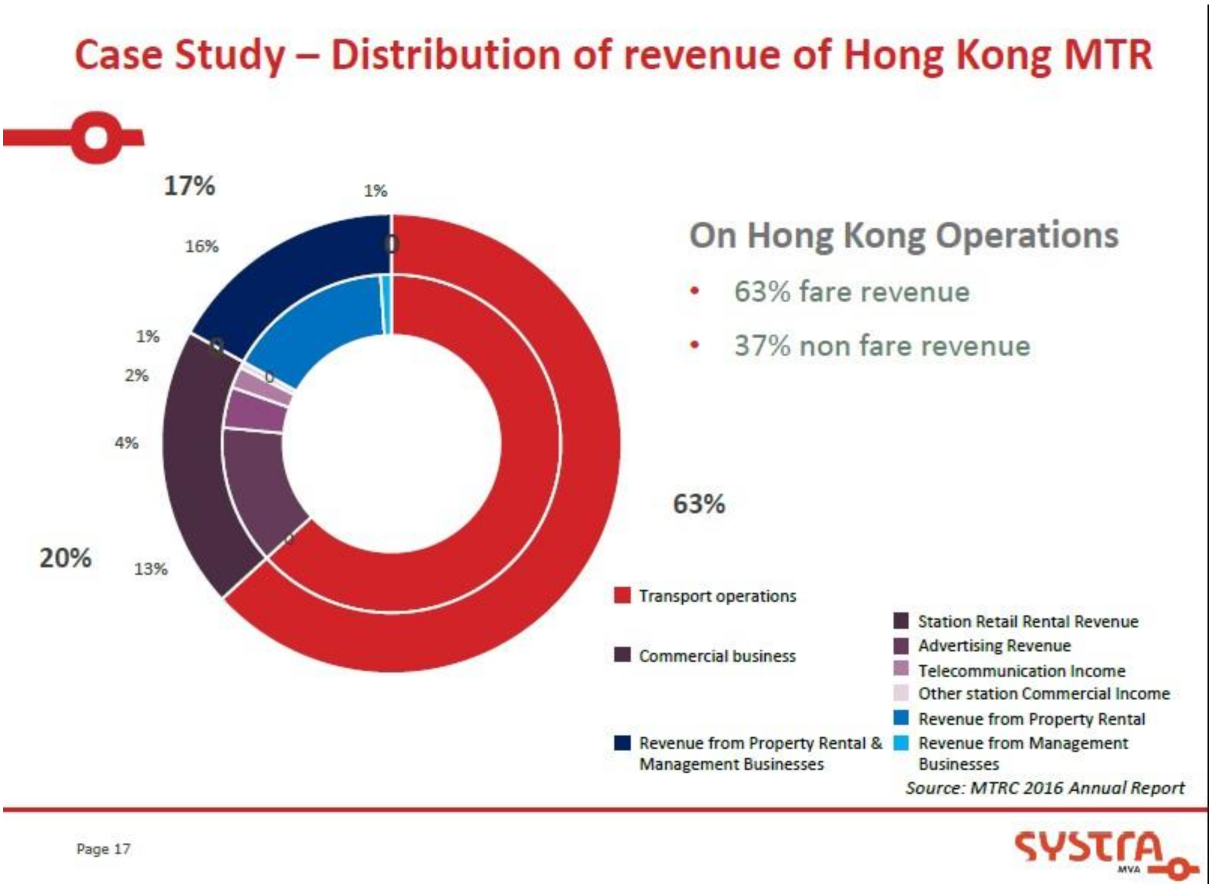
Capital cost sensitivity			
10% increase in capital cost	20% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
9.72%	9.11%	11.11%	12.15%
O & M Cost			
9.71%		11.08%	
Property Development			
With PD		Without PD	
10.45%		9.38%	

18.5 Funding Options

18.5.1 Funding Objectives

The objective of the exercise is not just financial closure but to achieve financial closure while ensuring availability of lowest cost of funds while procuring and creating sustainable systems to achieve optimal project costs. It, being a public utility service, analysis of life cycle costs – low maintenance cost and longer life spans; must be done to ensure optimal project costs. Fares must be set which minimize dependence on subsidies. Returns must accrue to both direct and indirect beneficiaries. Additionally, one must draw on experience of metro projects the world over with regard to funding patterns. Experience from successful metro projects Singapore, Hong Kong suggests between 60% to 100% government capital contribution as metro projects typically yield high economic benefits reflected in the substantially better economic IRRs of the project.

Hong Kong has one of the highest non fare box revenue collections in the world at 37% and yet 66% of the capital contribution comes from the government. This underlines the fact that government funding is required despite exploring non fare box revenue sources well.



18.6 Financing Options

The operational metro services in India have adopted a similar capital structure. This DMRC/ BMRC/ CMRL pattern of financing is discussed in detail below. Another method of financing is through a public private partnership. **However PPP mode will present several challenges the most major being:**

- **Access to low cost fund – 1.2% interest rate from multilateral funding agencies.**
- **Mode of sharing of monetary and non monetary grants by PCMC will have the lowest cost in case the asset is owned by a GoI and state controlled SPV structure**
- **This is an extension of an existing asset. The rolling stock however being added is for the entire section and not just the extended portion. Therefore there will be sharing of both capital revenue which will prove challenging of the extended portion is hived off to a private party.**

18.6.1 DMRC/BMRC/CMRL pattern of Financing

A special purpose vehicle is set up for project implementation and subsequent operation and maintenance. Equity contributions are made by:

- Government of India
- State Government
- Urban Local Bodies.

Typically Government of India makes up to 20% equity contributions at the maximum. The project cost taken for equity contribution excludes cost of land acquisition and R&R. A portion of the above will be in the form of subordinated debt which would include taxes, land etc. 20% is funded by either local bodies or state Governemnt again in the form of equity or grants. Balance 60% constitutes loans from multilateral funding agencies.

18.6.1.1 Multilateral funded loan @ 1.2% per annum

Table 177 : Loan terms

S.n.	Parameter	Value
1	Annual Interest rate for loan	1.2%
2	Front end fee	Management fee = 0.25% Commitment Fee= 0.25% p.a. on undisbursed portion
3	Repayment Period	15 Years
4	Moratorium Period	5 Years
5	Payment Schedule	Bi-annual

Table 178 : Project Capital structure – SPV Mode loan @1.2%

Particulars	Amount (Rs. Cr)	Percentage
Grant by GoI	67.02	10.00%
Grant by PCMC	121.97	18.20%
Grant by GoM	79.08	11.80%

Soft Loan from bilateral/multilateral funding agencies	402.11	60.000%
Project Cost Eligible for Grant	**670.18**	**100.0%**
SD for State Taxes, Central Taxes & Duties by GoM	90.63	
Contribution for Land, R&R, IDC, etc. by PCMC	137.87	
Total	**898.68**	
PPP Component	11.50	
Total Cost including PPP Component	**910.18**	

Conclusion and Recommendation

- FIRR for the project is 10.45%.
- SPV model with loan funded at 1.2 % per annum is proposed for implementation of the project due to highest equity IRR among all the options studied above.

EXHIBIT- 1 - Government Resolution No.PMR-3313/C.R.29/UD-7 and letter dated 29th October 2013

Sanction to the revised proposal of Pimpri- Chinchwad to Swargate and Vanaz to Ramwadi Metro Rail corridor of Pune Mahanagar Metro Rail Project.

Government of Maharashtra

Urban Development Department

Government Resolution No.PMR-3313/C.R.29/UD-7

Mantralaya, Mumbai-400032

Date: 29th October 2013.

Ref:- Government Resolution No. PMR-3313/C.R.29/UD-7 Mantralaya, Mumbai-400032 ,dated 11 Sept,2013

PREAMBLE:

Keeping in view the traffic and transportation problems arising out of ever-increasing population and rapid increase in number of vehicles, it has become necessary to strengthen the Public Transport systems in Pune Metropolitan Region. Pune Metro Railway Project is one of the several proposals contemplated to address this traffic problem engulfing Pune and Pimpri-Chinchwad. Pune Municipal Corporation and Pimpri Chinchwad Municipal Corporation jointly appointed Delhi Metro Rail Corporation to prepare a Detailed Project Report for examining the feasibility of planning and implementation of Pune Metro Railway Project.

In the Detailed Project Report of Pune Metro Project prepared by Delhi Metro Rail Corporation (DMRC) various Metro Rail Corridors have been proposed. Phase 1 of the Project includes two corridors viz. Corridor 1- Pimpri Chinchwad to Swargate and Corridor2 – Vanaz to Ramwadi. After giving due consideration to technical issues, feasibility of implementation and financial viability, the General Body of Pune Municipal Corporation has accorded approval to Corridor 2 – Vanaz to Ramwadi, which entirely traverses through their jurisdiction, vide Resolution no. 90 dated 23/06/2010. Similarly, for Corridor 1- Pimpri Chinchwad to Swargate, the General Bodies of Pune Municipal Corporation and Pimpri Chinchwad Municipal Corporation have accorded approval vide Resolution no.577 of PMC General Body-51 dated 24/12/2012 and Resolution no.133 of PCMC General Body-8 dated 20/9/2012 respectively.

Vide the Government Resolution referred to above the Government of Maharashtra had accorded sanction to 'Corridor 2 Vanaz to Ramwadi' elevated Metro Project. But due to elapse of time leading to increase in cost a revised proposal for Corridor 2 Vanaz to Ramwadi along with a proposal for Corridor 1- Pimpri Chinchwad to Swargate is now submitted to the Government of Maharashtra seeking its sanction for the same. Pune Mahanagar Metro Railway proposal under Phase 1 comprises of Corridor-1 (Pimpri

Chinchwad to Swargate - Length 16.59 km) and Corridor- 2 (Vanaz to Ramwadi- Length 14.52km). Corridor – 1 Pimpri Chinchwad to Swargate is estimated to cost Rs.5618 Crore at January 2013 prices with a completion cost estimated at Rs 6960 Crore. Corridor- 2 Vanaz to Ramwadi is estimated to cost Rs.2663 Crore at January 2013 prices with a completion cost estimated at Rs 3223 Crore. The subject of granting sanction to the proposal of Corridor-1 and revised proposal of Corridor-2 of Pune Metro Railway Project has been under the consideration of Government of Maharashtra. After considering all the relevant aspects of the proposal, the Government of Maharashtra has taken following decision.

GOVERNMENT RESOLUTION

[I] Sanction is hereby accorded to the proposal of Corridor no 1-Pimpri Chinchwad to Swargate and revised proposal of Corridor no 2- Vanaz to Ramwadi which form Pune Mahanagar Metro Rail Project Phase 1.

1. Sanction is hereby accorded to Corridor no.1 Pimpri Chinchwad to Swargate, partly elevated and partly underground as per details attached at Annexure 1, which forms a part of Pune Mahanagar Metro Rail Project Phase 1.

2. Vide the above referred Government Resolution the Government of Maharashtra had accorded sanction to 'Corridor 2 Vanaz to Ramwadi' elevated Metro Project Sanction is now accorded to the revised proposal of Corridor 2 Vanaz to Ramwadi (as per details attached at Annexure 2), which forms a part of Pune Mahanagar Metro Rail Project Phase 1, incorporating the updated capital expenditure based on January 2013 prices and revised time line for implementation.

3. Sanction is hereby accorded to submit the proposal of Pune Mahanagar Metro Rail Project Phase 1 comprising of the above referred two corridors to the Government of India for seeking its approval.

4. Sanction is hereby accorded for the establishment of 'Pune Mahanagar Metro Rail Corporation Limited' a Special Purpose Vehicle Company (SPV) for implementation of the project comprising of the two corridors. Since in comparison to 20% equity participation of the Government of India the equity participation of Government of Maharashtra and the Local Bodies being 30%, sanction is hereby accorded to appoint six directors nominated by the Government of Maharashtra and the two Municipal Corporations on the Board of the proposed Company. Government of India needs to be requested to keep this in view. Accordingly following shall be the list of Directors :

   1) Principal Secretary (UD-1) Urban Development Dept., Govt. of Maharashtra.
   2) Principal Secretary (Finance) Finance Dept., Govt. of Maharashtra.

3) Principal Secretary (UD-2) Urban Development Dept., Govt. of Maharashtra.
4) Municipal Commissioner, Pune Municipal Corporation
5) Municipal Commissioner, Pimpri Chinchwad Municipal Corporation.
6) Principal Secretary (Industries) Industries, Energy & Labour Dept., Govt. of Maharashtra.
7) Nominated Officers from Govt. of India – 5

5. Sanction is hereby accorded to vest the 'Pune Mahanagar Rail Corporation Limited' with similar authority as is available to Delhi Metro rail Corporation (DMRC) for Implementation of the Project. Sanction is hereby accorded to appoint Pune Municipal Corporation and Pimpri Chinchwad Municipal Corporation as the Executing Agencies, until the formation of Pune Mahanagar Metro Rail Corporation Limited.

6. Sanction is hereby accorded to authorize Pune Municipal Corporation and the proposed Pune Mahanagar Metro Rail Corporation to enter into correspondence with the Government of India and the Ministry of Railways in connection with the implementation of the project and obtaining funds to the tune of 20% which is the equity participation of the Government of India. Sanction is hereby accorded to authorize the Municipal Commissioner of Pune Municipal Corporation for entering into correspondence with the Government of India until the SPV Company is established.

7. Sanction is hereby accorded to the proposed Financial Structure for the project implementation which is as follows :
   - Pune Mahanagar Metro Rail Project Phase 1 – Corridor 2 Vanaz to Ramwadi – Pune Municipal Corporation 10% Share, Govt of Maharashtra 20% Share, Govt. of India 20 % Share, Balance 50 % to be raised through borrowing or other sources.
   - Pune Mahanagar Metro Rail Project Phase 1 – Corridor 1 Pimpri Chinchwad to Swargate – Pune Municipal Corporation and Pimpri Chinchwad Municipal Corporation 10% Share, Govt of Maharashtra 20% Share, Govt. of India 20 % Share, Balance 50 % to be raised through borrowing or other sources.

8. The 10 % share of the total capital cost of Corridor no. 2 Pimpri Chinchwad to Swargate, which forms a part of Pune Mahanagar Metro Rail Project – Phase 1, shall be shared by Pune Municipal Corporation and Pimpri Chinchwad Municipal Corporation in proportion of the expenditure which will be incurred over the length falling in the jurisdiction of each of the Corporations (Pro rata basis). Pune Municipal Corporation and Pimpri Chinchwad Municipal Corporations are directed to deposit their respective

shares for Corridor no. 1 and Corridor no. 2 with the 'Pune Mahanagar Metro Rail Corporation Limited'.

9. Sanctions is hereby accorded to deposit 20% share of the State Government in the capital expenditure of the project with the 'Pune Mahanagar Metro Rail Corporation Limited'. The 20% share of the State Government shall also include the cost of State Government Land, assessed at prevalent rates, required to be acquired for the Project.

10. Sanction is hereby accorded to raise funds for implementation of the Project through various sources of revenue listed in Annexure 3 attached herewith.

11. In principal sanction is hereby accorded to implement commuter fare rates as tabulated below as the Pune Mahanagar Metro Rail Project is proposed to be implemented under the provisions of Metro Railway Act enacted by the Government of India.

Sr.No.	Distance in K.m.	Revised Rate as per Year 2009(Rs.)	Rate for Pune Metro for the Year 2018-2019(Rs.)
1	0-2	8	13
2	2-4	10	17
3	4-6	12	20
4	6-9	15	25
5	9-12	16	27
6	12-15	18	30
7	15-18	19	32
8	18-21	21	35
9	21-24	22	37
10	24-27	23	38
11	27-30	25	42
12	More than 30 K.m.	27	45

Sanction is hereby accorded to periodic revision of fares by the Fare Regulation Committee to be established as per the provisions of the Metro Railway Act.

12 Sanction is hereby accorded to declare this Project as Essential Public Project and Important Public Transport Project.

[II] In principal sanction is hereby accorded to extension of Pune Metro Project Corridor no. 1 from Pimpri to Nigdi and Swargate to Katraj (a Length of approximately 15 km). Sanction is hereby accorded to include these extensions as Phase 2 and prepare a Detailed Project Report for the same and forward it to the Government of India as a standalone proposal.

This Govt. Resolution is being forwarded after giving due considerations to the Govt. of Maharashtra's Planning Department's demy-official reference No.155/1444 dtd.13/08/2013 and Finance Department's demy-official reference No.470/ Expenditure dtd.14/08/2013

In the Name & Orders from Governor of Maharashtra.

(S.K.Salimath)
Deputy Secretary, Govt. Of Maharashtra

To,

The Secretary, Governor, Govt. of Maharashtra,

Principal Secretary of Chief Minister, Mantralaya, Mumbai 400 032

The Secretary of Vice Chief Minister, Mantralaya, Mumbai 400 032

Private Secretary of State Minister(Navi), Mantralaya, Mumbai 400 032.

Chief Secretary, Govt. of Maharashtra, Mantralaya, Mumbai 400 032

Upper Chief Secretary(Revenue)Revenue & Forest Department, Mantralaya, Mumbai 400 032

Upper Chief Secretary, Home Department, Mantralaya, Mumbai 400 032

Principal Secretary (Navi -1), Nagar Development Department, Mantralaya, Mumbai 400 032

Principal Secretary (Finance) Finance Department, Mantralaya, Mumbai 400 032

Principal Secretary ,Planning Department, Mantralaya, Mumbai 400 032

Principal Secretary(Transport),Home Department, Mantralaya, Mumbai 400 032

Principal Secretary(Navi 2),Nagar Development Department, Mantralaya, Mumbai 400 032

Secretary (Special Project),General Administration Department, Mantralaya, Mumbai 400 032

Annexure-1

Pune Mahanagar Metro Rail Phase 1, Corridor No.1

Detailed Information

Corridor No.1 Pimpri Chinchwad to Swargate	
Total Length	**16.59 K.m.**
Stations	15
Length in Pimpri Chinchwad Municipal Corporation Boundary Out of Total Length	7.15 km
Stations in Pimpri Chinchwad Municipal Corporation Boundary	6 **(**Totally Elevated**) (**elevated)
Length in Pune Municipal Corporation **(**with Khadki Cantonment Boundary)	9.44 km
Stations in Pune Municipal Corporation Boundary(with Khadki Cantonment Boundary)	Total 9 Stations, out of this 4.78 K.m. is Elevated & 3 Stations Elevated & remaining 4.66 K.m. Length route is Underground & 6 Stations are Underground.

Annexure-2

Pune Mahanagar Metro Rail Phase 1, Corridor No.2

Detailed Information

Corridor no.2 Vanaz to Ramwadi	
Total Length	14.925 km(Totally Elevated)
Stations	15 (Totally Elevated)

Annexure – 3

[I] Various sources needed to be tapped to raise funds for implementation of Pune Mahanagar Metro rail Project.

(i) Increase of FSI up to a maximum of 4 (four) in the area falling within 500 m distance on both sides of the Metro Corridors by making requisite provisions in the Development Control Rules of the respective Municipal .Corporations and recovering the surcharge collected against the additional FSI granted.

(ii) In cities and towns wherein, the Government notifies implementation of Important Public Transport Projects, making provisions in the MRTP Act 1966 for increasing the Development Charges being levied by up to 100 % and utilizing the additional revenue thus collected for implementation of such Projects.

(iii) In the limits of Municipal Corporations wherein the Government notifies implementation of Important Public Transport Projects making provisions in the Maharashtra Municipal Corporation Act to levy surcharge of 1 % on Stamp Duty on transactions such as sale, donation, lease and mortgage involving immovable property and on security deposits in connection with agreements involving transactions pertaining to immovable properties, lease and mortgages. Provisions shall be made in the Act to authorize the District Dy Registrars for recovery of the surcharge while registering the transactions involving sale, donation, lease and mortgage of land or other immovable properties and thereafter the Government releasing grants equivalent to the additional revenue thus collected to the respective Municipal Corporation or the SPV established to implement the concerned Important Public Transport Project.

(iv) Commercial utilization of land of the Metro Stations and Maintenance Depots and use of revenue thus generated for the implementation of the Project.

(v) Utilization of revenue generated from Advertising and Parking for the implementation of the Project.

[II] The revenue generated from the above sources is to be deposited in a separate 'Public Transport Fund' to be created by the Municipal Corporations and it is to be deposited with the SPV Company formed for implementation of the Project to the extent of the share of the capital cost of the project to be borne by the Municipal Corporations and for debt servicing in relation to the Project. If the fund falls short in servicing the Project as above the two Municipal Corporations shall raise the funds from other sources to mitigate the shortfall.

EXHIBIT 2 – Project IRR

	FY 18	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35
Revenue Fare Box							34	35	37	45	46	48	49	59	60	64	68	83
Revenue Non Fare Box																		
Inflow from Advertising, train wrapping etc							3.4	3.7	3.9	4.1	4.3	4.5	5.0	5.2	5.8	6.2	6.5	6.8
Other Income																		
Premium levy on development														103.6	106.2	108.9	111.6	114.4
LBT share of Registration														51.9	53.2	54.5	55.9	57.3
PCNTDA Dev Fee							4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.2	5.4	5.5	5.7	5.8
Total Income							**42**	**44**	**45**	**54**	**55**	**57**	**60**	**225**	**231**	**239**	**248**	**267**
Energy Expense							5.1	5	5	6	6	6	6	7	7	7	7	8
Employee Benefit Expense							27.9	30	33	36	39	43	47	51	56	61	66	72
O&M Expediture							8.7	9	10	11	11	12	13	14	14	15	16	17
Total Expenses							**42**	**45**	**48**	**52**	**56**	**61**	**66**	**71**	**77**	**83**	**90**	**97**
Finance costs																		
Profit/ Loss Before Tax							**0**	**-1**	**-3**	**1**	**-1**	**-3**	**-6**	**154**	**154**	**157**	**158**	**171**
Income Tax Payable																		
Profit/ Loss for the Year							**0**	**-1**	**-3**	**1**	**-1**	**-3**	**-6**	**154**	**154**	**157**	**158**	**171**
Cash Flow Statement																		
Cash Outflow																		
Capital Expenditure			0	-129	-247	-297	-215	0	0	0	0	0	0	0	0	0	0	0
Principal Repayment																		
Cash Inflow																		
PAT							0	-1	-3	1	-1	-3	-6	154	154	157	158	171
Depreciation							0	0	0	0	0	0	0	0	0	0	0	0
Interest During Construction																		
Debt Drawdown																		
Equity - Cash Flow from Property Development - Deferred Revenue							155											
Net Cash Flow to Equity			0	-129	-247	-297	-61	-1	-3	1	-1	-3	-6	154	154	157	158	171
Project IRR		**10.45%**																
Balance Sheet																		
Uses of Fund																		
Cash							-61	-62	-65	-64	-65	-68	-74	79	234	390	549	719
Fixed Asset - Gross Block							888	888	888	888	888	888	888	888	888	888	888	888
Accumulated Depreciation*							0	0	0	0	0	0	0	0	0	0	0	0
CWIP		0	0	129	375	672												
Net Block							888	888	888	888	888	888	888	888	888	888	888	888
Total Asset		**0**	**0**	**129**	**375**	**672**	**827**	**826**	**823**	**824**	**823**	**820**	**813**	**967**	**1121**	**1278**	**1436**	**1607**
Sources of Fund																		
Equity																		
Shareholder's Fund		0	0	129	375	672	672	672	672	672	672	672	672	672	672	672	672	672
Retained Earning							0	-1	-4	-3	-4	-8	-14	140	294	451	609	780
Other Equity							155	155	155	155	155	155	155	155	155	155	155	155
Non Current Liabilities																		
Term Loan		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities		**0**	**0**	**129**	**375**	**672**	**827**	**826**	**823**	**824**	**823**	**820**	**813**	**967**	**1121**	**1278**	**1436**	**1607**

	FY 36	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42	FY 43	FY 44	FY 45	FY 46	FY 47	FY 48	FY 49	FY 50	FY 51	FY 52	FY 53
Revenue Fare Box	87	92	96	116	121	126	131	155	157	159	161	188	190	192	194	227	230	233
Revenue Non Fare Box																		
Inflow from Advertising, train wrapping etc	7.2	7.5	7.9	8.3	8.7	9.1	9.6	10.1	10.6	11.1	11.6	12.2	12.8	13.5	14.2	14.9	15.6	16.4
Other Income																		
Premium levy on development	117.3	120.2	123.2	126.3	129.4	132.7	136.0	139.4	142.9	146.4	150.1	336.7	345.2	353.8	362.6	371.7	381.0	390.5
LBT share of Registration	58.7	60.2	61.7	63.2	64.8	66.4	68.1	69.8	71.6	73.3	75.2	168.6	172.9	177.2	181.6	186.2	190.8	195.6
PCNTDA Dev Fee	5.9	6.1	6.2	6.4	6.6	6.7	6.9	7.1	7.2	7.4	7.6	17.1	17.5	17.9	18.4	18.8	19.3	19.8
Total Income	**277**	**286**	**295**	**320**	**330**	**341**	**351**	**381**	**389**	**397**	**405**	**722**	**738**	**754**	**771**	**819**	**837**	**855**
Energy Expense	8	8	8	9	9	9	10	10	10	10	11	11	11	11	12	12	12	12
Employee Benefit Expense	78	85	93	101	111	121	131	143	156	170	186	202	220	240	262	285	311	339
O&M Expediture	19	20	21	23	24	26	28	30	32	34	37	39	42	45	48	52	56	60
Total Expenses	**105**	**113**	**123**	**133**	**144**	**156**	**169**	**183**	**198**	**215**	**233**	**252**	**274**	**297**	**322**	**349**	**379**	**411**
Finance costs																		
Profit/ Loss Before Tax	**172**	**172**	**172**	**187**	**186**	**185**	**183**	**198**	**191**	**182**	**172**	**470**	**465**	**458**	**449**	**470**	**458**	**444**
Income Tax Payable																		
Profit/ Loss for the Year	**172**	**172**	**172**	**187**	**186**	**185**	**183**	**198**	**191**	**182**	**172**	**470**	**465**	**458**	**449**	**470**	**458**	**444**
Cash Flow Statement																		
Cash Outflow																		
Capital Expenditure	0	-20	-72	-11	0	0	0	-310	0	0	0	0	0	0	0	0	0	-252
Principal Repayment																		
Cash Inflow																		
PAT	172	172	172	187	186	185	183	198	191	182	172	470	465	458	449	470	458	444
Depreciation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Interest During Construction																		
Debt Drawdown																		
Equity - Cash Flow from Property Development - Deferred Revenue																		
Net Cash Flow to Equity	172	153	100	176	186	185	183	-112	191	182	172	470	465	458	449	470	458	192
Project IRR																		
Balance Sheet																		
Uses of Fund																		
Cash	891	1044	1144	1320	1506	1691	1874	1762	1953	2135	2308	2778	3243	3700	4150	4619	5077	5269
Fixed Asset - Gross Block	888	907	980	991	991	991	991	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1552
Accumulated Depreciation*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CWIP																		
Net Block	888	907	980	991	991	991	991	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1552
Total Asset	**1778**	**1951**	**2123**	**2310**	**2497**	**2682**	**2864**	**3062**	**3253**	**3436**	**3608**	**4078**	**4543**	**5001**	**5450**	**5920**	**6377**	**6821**
Sources of Fund																		
Equity																		
Shareholder's Fund	672	672	672	672	672	672	672	672	672	672	672	672	672	672	672	672	672	672
Retained Earning	951	1124	1296	1483	1670	1855	2037	2235	2426	2609	2781	3251	3716	4174	4623	5093	5550	5994
Other Equity	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155
Non Current Liabilities																		
Term Loan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities	**1778**	**1951**	**2123**	**2310**	**2497**	**2682**	**2864**	**3062**	**3253**	**3436**	**3608**	**4078**	**4543**	**5001**	**5450**	**5920**	**6377**	**6821**

19. ECONOMIC ANALYSIS

19.1 Introduction

1. The current service delivery is not commensurate with the existing traffic scenario in urban areas in general. Pune City urban transport service is one such area which require more attention. Based on Comprehensive Mobility Plan Study (CMP), 2008 findings, a metro rail transport system is proposed to tackle the growing intra-urban transport demand in Pune City.

2. As a public transport system, Metro Rail Transport System (MRTS) proposed in Pune will supplement the growing intra-city travel demand, especially in the selected heavy traffic corridors. Spending public money in the construction of MRTS lines has been defended as a socially desirable public investment which produces several types of benefits such as:

- Passenger time savings,
- Increase in comfort,
- Generation of new trips,
- Reduction in congestion and delays in roads,
- Reduction in accidents, reduction in environmental externalities,
- Wider economic benefits including the development of the less developed regions

3. Many factors influence the market shares between the other modes of public transport and MRTS. According to the literature, travel time is the most important one. The MRTS has a clear advantage over the traditional bus services and the fast growing costly IPT modes. Other factors that contribute to the relative position of MRTS are ticket prices, frequency of the service, the integration of networks, accessibility , reliability and punctuality of the services and government policy.

4. The findings of this Feasibility Study will determine this intra-urban transport service through MRTS to improve accessibility so that residents of Pune City will have better access to economic and social activities.

19.2 Scope and Objectives

1. The objective of this feasibility study (FS) to evaluate the potential for the identified MRTS services in Pune City and to assess strategically the overall need and potential for development.
2. The scope of the study is divided into two stages, further divided into several phases:
3. Stage 1
    a. Phase 0 – Inception
    b. Phase 1 – Transport demand assessment
    c. Phase 2 – Corridor definition and Techno-economic feasibility
4. Stage 2
    a. Phase 3 – Detailed Project Report

5. Corridor 1A (PCMC-Nigdi Section) is considered separately for economic analysis. Thus, the present report had considered Corridor 1A (PCMC-Nigdi Section) for the study include:

Corridor 1A:	Nigdi - PCMC	Km	4.413

6. The objective of the economic analysis in the FS is to identify and quantify the benefits and costs associated with the investment proposal in order to select the optimum solution along with the economic viability in terms of its likely investment return potential. This is carried out in order to assess the economic feasibility and prioritize the identified transport investment proposal and assist the governments in Maharastra State in making the right decision.

19.3 Approach and Methodology for the Analysis

1. The economic analysis contained in this chapter has been undertaken in accordance with the available guidelines including '*Appraisal Guidelines for Metro Rail Projects Proposals*' (2017) and '*Metro Rail Policy 2017*' by the Ministry of Housing & Urban Affairs, Govt. of India; and '*Manual on Economic Evaluation of Highway Projects in India*' IRC-SP30, 2009 by the Indian Roads Congress, '*Guidelines for the Economic Analysis of Projects, and Framework for the Economic and Financial Appraisal of Urban Development Sector Projects'1994* by Asian Development Bank (ADB). Economic analysis involve comparing 'with project' and 'without project' alternatives. By comparing the above alternatives, the net agency costs and net user costs and finally net project benefits associated with the project during its analysis period were calculated for the proposed improvement options separately in order to arrive at their internal rate of return (IRR) and net present value (NPV) both for economic and financial analysis.

19.3.1 Methodolody for Economic Analysis

1. In accordance with the guidelines, economic feasibility analysis was carried out for 30 years analysis period for Life Cycle Cost Analysis (LCCA):

- Base Year (2019)
- Construction period (2021 - 2025)
- Project opening for traffic (2025)
- Project operating period (2025 - 2050)
- End of the analysis period (2050)

2. Thus a period of 30 years of operation is considered for the evaluation. All the cost were at 2019 (Base Year) level and also the results including NPV, IRR were estimated for the base year level.

3. Considering the component wise opportunity cost (estimated for Maharastra State

conditions), the financial cost was converted into economic cost in accordance with the available guidelines from international funding agencies like Asian Development Bank (ADB).

4. The conventional economic model like HDM (which is used for highway improvement project analysis) may not be relevant for most of the rapid urban transport projects etc. Hence appropriate excel based models are developed, to quantify the relevant project benefits; life cycle costing; project net benefits and finally economic feasibility criteria like EIRR and ENPV.

5. Updated inputs available from the guidelines explained abobe, available secondary sources and the input data from the Comprehensive Mobility Plan (2008) with suitable updates pertaining to the unit rates of VOC and travel time for different vehicle categories etc were used for the excel based models developed for this study.

6. The cost – benefit analysis was carried out by using the discounted cash flow (DCF) technique to obtain the economic internal rate of return (EIRR) and economic net present value (ENPV) for the proposed investments and the likely quantified project benefits linked with the project during the project analysis period

7. *Economic Opportunity Cost of Capital (EOCC)*: Given the complexity of estimating country-specific economic opportunity cost of capital (EOCC), a discount rate of 14% in constant economic prices is used. The EIRR must be compared with the EOCC, for interpretation purpose of project feasibility.

19.4 Estimation of Economic Project Cost of MRTS

19.4.1 Capital Cost

For economic analysis, only the cost estimates of the MRTS (excluding the cost of property development[6]) estimated in the cost section is adopted. Adding the preoperative expenses, physical contingency, applicable taxes, price contingency etc, the total financial cost for all the proposed three corridors were estimated for the base year (2019).
The economic costs of capital works and annual operation and maintenance are calculated from the financial cost estimates on the following basis:

(i) Price contingencies are excluded but physical contingencies are included because they represent real consumption of resources;
(ii) Import duties and taxes are excluded because they represent transfer payments. For this the shadow exchange rate factor (SERF) worked out below (1.03)[7] was used;

[6] Property development being a commercial activity, it is not considered for economic analysis.

[7]

Shadow Exchange Rate Factor (SERF) — INR in Billion

Details	2015-16	2014-15	2013-14	2012-13	2011-12	Average
Exports (INR Billion)	17,146	18,963	18,942	16,353	14,660	17,213
Imports (INR Billion)	24,880	27,371	27,142	26,732	23,455	25,916
Customs Duties (INR Billion)	2,083	1,887	1,231	1,155	1,056	1,482
Shadow Conversion Factor (SCF)	0.953	0.961	0.974	0.974	0.973	0.967
Shadow Exchange Rate Factor (SERF)	**1.05**	**1.04**	**1.03**	**1.03**	**1.03**	**1.03**

Source: Hand Book of Statistics on Indian Economy, 2015-16, 2014-15 & 2013-14, Reserve Bank of India

Note: Calculation Method based on ERD Technical Note Series No. 11, February 2004, 'Shadow Exchange Rate for Project Economic Analys

(iii) The existence of unemployment and under-employment for unskilled workers within the Indian economy means that the opportunity cost of unskilled labour can be lower than its wage rate – a conversion factor (SWRF) of 0.81[8] of the market wage rate for construction labour is used to estimate the shadow wage rate;

(iv) The market wage rate for skilled labour and the acquisition cost of land are considered to represent opportunity costs, as both factors are in demand;

(v) All costs are valued using the domestic price numeraire, to enable an easier comparison with the information used to measure benefits (e.g. a significant component of benefit is the savings in resources, which would be used in the without project situation).

Table 179 : Details of project cost

Details	Total
Length Km	4.413
Project Cost Rs Crore	780.81
Project Cost Rs Crore/Km	176.93
Economic Cost Rs Crore	575.13
Economic Cost Rs Crore /Km	130.32

19.4.2 Capital Replacement

25% of electrical and mechanical equipments, 50% of signalling and telecommonucation equipment need replacement in 15 years, Rolling stock will be added in 20 years.

Table 180 : Estimated Replacement Cost (Rs Crore)

Year	Total
2038	32.19
2043	92.97

Source: Consultant Estimate

19.4.3 O&M Cost

Annual operating costs of this investment proposal at constant prices has been broken down into different items of this investment proposal and used for analysis purposes. This annual operation and maintenance (O&M) for the proposed project include staff cost, maintenance cost and power charges as estimated in the financial analysis chapter, is considered for analysis.

Table 181 : Maintenance Cost

1. Staff cost - Rs Crore	27.9
2. Maintenance cost @1.364 Crore/km - Rs Crore	10.8

8

Shadow Wage-rate Factor (Y)	
Unskilled labor cost (Rs. per day)* (L)	400
Minimum Wages in Maharastra w.e.f January 1, 2018 (Rs. per day	495
Shadow Wage-rate Factor (Y); Y = L/M	0.81

*Wages practiced in Maharastra state in the construction industry in 2018.

** Minimum Wage in Maharastra w.e.f January 1, 2018 to March 31, 2018; https://www.labourlawreporter.com/wp-content/uploads/2017/04/Minimum-wages-maharashtra-01-01-18-a.pdf

Note: Calculated using the 'Guidelines for the Economic Analysis of Projects, 1997, ADB

3. Power charges - Rs Crore	5.1
Total - Rs Crore	**43.8**

Source: Consultant Estimate

19.5 Economic Benefits of MRTS

Proposed MRTS is expected to divert passengers from the existing modes like car, bus, two wheelers and auto with better comfort and improved speed. These improvements will benefit the users in terms of better speed with service quality and reduced travel time. In addition, the proposed MRTS will reduce the carbon emission from the diverted traffic and also will reduce stress on the existing road corridors. Reduction in the congestion on the existing road corridors will result in reduction of road accidents. Accordingly, the economic benefits considered in the present analysis for the subprojects in transport component in this investment proposal include:

i) Value of Travel Time Savings
    a. For the diverted passengers by using the proposed HSR system;
    b. For the non-diverted passengers in the form of reduced congestion due to the diverted HSR traffic
ii) Value of vehicle operating cost (VOC) savings
    a. For the diverted passengers by using the proposed HSR system;
    b. For the non-diverted passengers in the form of reduced congestion due to the diverted HSR traffic
iii) Savings in Reduction of Accidents
iv) Pollution Reduction Benefits in terms of reduction in carbon emission from the vehicles due to the diversion to MRTS
v) Reduced Road Infrstructure Costs
    a. Reduction in annual maintenance cost
    b. Reduction in the road capacity improvement cost

Above project economic benefits are estimated on annual basis for the selected alignment corridors proposed in the technical section. Projected MRTS traffic for the selected option, in terms of daily passengers and passenger km, upon which the benefits are estimated is presented below in Table 182. Average trip length by MRTS is estimated to be 7.7km. Considering the assigned traffic to MRTS, its trip length, the modes from which these MRTS trips were diverted etc., the travel scenario under (i) without project and (ii) with project scenario including distribution by different modes were developed. This was used as the inputs for estimating all the project benefits discussed above.

Table 182 : Projected MRTS Daily Traffic Diverted from Different Modes

Year	Corridor 1A – PCMC to Nigdi	
	No. of daily passengers	Daily Passenger km (Lakh)
2021	26,000	2.2
2022	27,500	2.4
2023	29,000	2.5

2024	30,125	2.6
2025	31,250	2.7
2026	32,375	2.8
2027	33,500	2.9
2028	34,625	3
2029	35,750	3.1
2030	36,875	3.2
2031	38,000	3.3
2032	40,500	3.6
2033	43,000	3.8
2034	45,375	4
2035	47,750	4.2
2036	50,125	4.5
2037	52,500	4.7
2038	54,875	4.9
2039	57,250	5.1
2040	59,625	5.4
2041	62,000	5.6
2042	63,000	5.7
2043	64,000	5.8
2044	64,750	5.9
2045	65,500	5.9
2046	66,250	6
2047	67,000	6.1
2048	67,750	6.2
2049	68,500	6.3
2050	69,250	6.3
2051	70,000	6.4

8. Additional assumptions followed for estimating the project benefits are given below.

Table 183 : Details of Road User Cost adopted for the Study

Vehicle Category	VOC (Rs. / Vehicle Km)	
	2008 [1,3]	2019 [2]
Car - New Technology (Maruti 800)	4.07	6.95
Bus	16.37	27.96
TW	1.40	2.39
Auto rickshaw	3.98	6.80
Share-Auto	4.49	7.67
Taxi	4.70	8.03
2-Axle Truck	14.77	25.23
LCV	10.96	18.72
Goods Tempo	4.61	7.87

Goods Auto	3.59	6.13

1 Approach for Economic and Operation Assessment for Identified Urban Roads and Transportation Sub-projects, Working Paper No. : WP-05, Comprehensive Transportation Study for Chennai Metropolitan Area, May 2008

2. Escalated to 2019 with 5.5% annual growth based on inflation.

3. Includes fuel cost

Table 184 : Vehicle Category wise Passenger Travel Time (2019) - Urban Condition

Vehicle Type	Time value (Rs / Hour), 2019		
	Work	Non work	Combined
Bus	81.99	24.60	59.03
Mini Bus	81.33	24.40	58.56
TW	94.88	28.46	68.31
Car - Old Tech	142.31	42.69	102.47
Car - New Tech	213.47	64.04	153.70

Note:

1. Approach for Economic and Operation Assessment for Identified Urban Roads and Transportation Sub-projects, Working Paper No.: WP-05, Comprehensive Transportation Study for Chennai Metropolitan Area, May 2008

2. Escalated to 2019 with 10% annual growth.

Table 185 : Assumptions for Carbon Emission Estimation

Treatment cost of CO2 Rs/Ton	500

Source: Appraisal Guidelines for Metro Rail Projects Proposals, 2017, MOH&UA, GOI

Carbon (CO_2) Emission - Ton /litre	0.0023

Source: *GHG Analysis Road Improvement, Guidance Note, World Bank Group, February 2016*)

Table 186 : : Unit Cost of Accidents

Details	2004 (in INR)	2019 (in INR)
Cost of Fatal Accident	437342	9,01,194
Cost of person injury	64256	1,32,407
Cost of damage to vehicles	29,911	61,636

Source: Appraisal Guidelines for Metro Rail Projects Proposals, 2017, MOH&UA, GOI

Note: 2004 costs are updated using average 5.5% inflation rate

Table 187 : Estimation of Savings in Road Stress Reduction

Reduction in Maint. Cost Rs Crore/Year

Major impacted roads length - Km	0.585
Average annual maintenance Rs Crore /Km	0.093
Total annual maintenance Rs Crore	0.546
Reduction in Maint. Cost Rs Crore/Year	**0.055**

Reduction in Widening Cost Rs Crore/Year

Major impacted roads length - Km	0.585
Average widening cost Rs Crore/Km	1.5
Total widening cost Rs Crore	8.775
Reduction in widening Cost Rs Crore/Year	**0.293**

19.6 Economic Analysis – EIRR & NPV for 30 Years

As part of the economic feasibility analysis, the feasibility parameters developed are shown in Table 188. A more detailed economic feasibility analysis is given in Table 188.

- Economic Internal Rate of Return (EIRR)
- Economic Net Present Value (ENPV)

Table 188 : Economic Cost-Benefit Analysis

Details	Present Value (Rs. Crore) a/, b/
Costs	
Capital costs	414.1
O&M costs	184.8
Total costs	598.9
Benefits	
Savings in Travel Time Cost	840.2
Savings in VOC	112.4
Savings in Reduction of Accidents	1.2
Pollution Reduction Benefits	1.8
Reduced Road Infrastructure Costs	1.4
Total benefits	957.0
Economic Return Measures	
Net present value (Rs. Crore)	358.1
EIRR (%)	23.55 %

a/ In 2019 prices; b/ Discounted at 14% EOCC

19.7 Sensitivity Analysis

Sensitivity analysis was carried out to their economic feasibility results for the following scenarios is presented in Table 189:

- Capital cost increase by 20%
- O&M costs increased by 20%
- Target beneficiaries reduced by 20%

- Delay in accrual of benefit by 1 year
- Combined adverse condition

Table 189 : Results of Sensitivity Analysis

Details	EIRR (%)	ENPV @14% (Rs Crore)	MIRR (%)	SV	Benefit - Cost Ratio (2018 Price)	Benefit - Cost Ratio (Current Price)
Main Evaluation (Base Case)	23.55%	358.1	14.99%		1.60	3.57
20% Capital Cost Overrun	20.34%	275.2	14.11%	86.5%	1.40	3.34
20% O&M Cost Overrun	22.62%	321.1	14.75%	193.8%	1.51	3.16
20% Decrease in Project Benefits	18.68%	166.7	13.64%	37.4%	1.28	2.86
One Year Delay in Implementation	23.52%	309.0	14.94%		1.59	3.51
All Four Tests Combined	15.07%	37.6	12.47%		1.06	2.34

SV = Switching Value; MIRR = Modified Internal Rate of Return; ENPV = Economic Net Present Value; EIRR = Economic Internal Rate of Return

Note:
1. Calculated as the percentage change in a variable required for EIRR to reduce to 14%.
2. Discounted at 14% of EOCC.
3. MIRR, is the internal rate of return of an investment that is modified to account for the difference between re-investment rate and investment return.

19.8 Outcome on Economic Viability

1. The evaluation has indicated that the proposed MRTS extension in Pune City in Corridor 1A, with a length of 4.413 km**,** considered under the investment proposals is found to be economically viable, with the calculated EIRR value exceeding the economic opportunity cost of capital. With the EIRR of 23.55% and ENPV of Rs. 358.1 Crore @ 14% discount rate, the proposed MRTS is found to be economically viable. In most of the sensitivity analysis scenarios, EIRRs were found to be marginally lesser to the minimum required rate.
2. Furthermore, for this investment proposed, the calculated EIRR value is considered minimum estimates of economic return, as there are a number of economic benefits like travel comfort, tourism benefits, employment generation and environment improvement that have not been quantified.

Exhibit 1 : Economic Analysis of Pune MRTS

Year	Economic Cost			Economic Project Benefits						Net Benefit	Base Case	Construction Cost (20% Cost Increase Scenario)	O&M Cost (20% O&M Cost Increase Scenario)	Net Benefits (20% Benefits Reduction Scenario)	One year Delay	Combined Effect (Worst Scenario)
	Capital Cost	O&M Cost	Total	VOC Savings	Time savings	Savings in Reduction of Accidents	Pollution Reduction Benefits	Reduced Road Infrstructure Costs	Total							
2,021	863	-	863	-	-	-	-	-	-	(863)	-863	-1,035.24	(863)	-862.70	-	-
2,022	1,438	-	1,438	-	-	-	-	-	-	(1,438)	-1438	-1,725.40	(1,438)	-1,437.84	(863)	(1,035)
2,023	1,921	-	1,921	-	-	-	-	-	-	(1,921)	-1921	-2,305.14	(1,921)	-1,920.95	(1,438)	(1,725)
2,024	1,530	322	1,852	181	1,365	2	3	3	1,555	(297)	-297	-602.63	(361)	-607.68	(1,921)	(2,305)
2,025	-	332	332	189	1,418	2	3	3	1,615	1,284	1284	1,283.79	1,217	960.72	(297)	(978)
2,026	-	342	342	196	1,471	2	3	3	1,676	1,334	1334	1,334.14	1,266	999.01	1,284	894
2,027	-	352	352	203	1,524	2	3	3	1,736	1,384	1384	1,384.24	1,314	1,037.04	1,334	931
2,028	-	362	362	210	1,577	2	3	3	1,796	1,434	1434	1,434.07	1,362	1,074.80	1,384	967
2,029	-	373	373	217	1,630	2	4	3	1,857	1,484	1484	1,483.64	1,409	1,112.28	1,434	1,002
2,030	-	384	384	225	1,683	2	4	3	1,917	1,533	1533	1,532.92	1,456	1,149.47	1,484	1,038
2,031	-	396	396	232	1,736	3	4	3	1,978	1,582	1582	1,581.92	1,503	1,186.36	1,533	1,073
2,032	-	408	408	240	1,789	3	4	3	2,038	1,631	1631	1,630.62	1,549	1,222.94	1,582	1,107
2,033	-	420	420	257	1,907	3	4	3	2,174	1,754	1754	1,753.63	1,670	1,318.90	1,631	1,141
2,034	-	433	433	274	2,025	3	4	3	2,309	1,876	1876	1,876.47	1,790	1,414.65	1,754	1,235
2,035	-	446	446	290	2,137	3	5	3	2,437	1,991	1991	1,991.13	1,902	1,503.79	1,876	1,328
2,036	-	459	459	305	2,248	3	5	3	2,564	2,105	2105	2,105.50	2,014	1,592.61	1,991	1,415
2,037	-	473	473	321	2,360	3	5	3	2,692	2,220	2220	2,219.54	2,125	1,681.09	2,105	1,501
2,038	322	487	809	337	2,472	3	5	3	2,820	2,011	2011	1,947.01	1,914	1,447.35	2,220	1,587
2,039	-	502	502	353	2,584	3	6	3	2,948	2,447	2447	2,446.64	2,346	1,857.01	2,011	1,286
2,040	-	517	517	369	2,696	3	6	3	3,076	2,560	2560	2,559.67	2,456	1,944.42	2,447	1,757
2,041	-	532	532	385	2,807	3	6	3	3,204	2,672	2672	2,672.33	2,566	2,031.45	2,560	1,841
2,042	-	548	548	401	2,919	3	6	3	3,333	2,785	2785	2,784.61	2,675	2,118.09	2,672	1,925
2,043	926	564	1,490	403	2,966	3	7	3	3,382	1,892	1892	1,706.64	1,779	1,215.39	2,785	2,008
2,044	-	581	581	405	3,013	3	7	3	3,431	2,850	2850	2,849.89	2,734	2,163.63	1,892	917
2,045	-	599	599	404	3,049	3	7	3	3,466	2,867	2867	2,867.00	2,747	2,173.83	2,850	2,047
2,046	-	617	617	403	3,084	3	7	3	3,500	2,883	2883	2,883.17	2,760	2,183.18	2,867	2,054
2,047	-	635	635	401	3,119	3	7	3	3,534	2,898	2898	2,898.36	2,771	2,191.63	2,883	2,060
2,048	-	654	654	399	3,155	4	7	3	3,567	2,913	2913	2,912.54	2,782	2,199.16	2,898	2,065
2,049	-	674	674	396	3,190	4	7	3	3,600	2,926	2926	2,925.65	2,791	2,205.73	2,913	2,068
2,050	-	694	694	393	3,225	4	7	3	3,632	2,938	2938	2,937.67	2,799	2,211.29	2,926	2,071
									Total	51,734	51,734	50,334	49,113	37,367	48,797	31,273
									ENPV	3,581	3,581	2,752	3,211	1,667	3,090	376
									EIRR	23.55%	23.55%	20.34%	22.62%	18.68%	23.52%	15.07%
									MIRR	14.99%	14.99%	14.11%	14.75%	13.64%	14.94%	12.47%
									SV			86.5%	193.8%	37.4%		
									B C Ratio	1.60	1.60	1.40	1.51	1.28	1.59	1.06

20. IMPLEMENTATION PLAN

On receipt of the Detailed Project Report, following actions will be required for implementing the Pune Metro Phase 1A:

- Approval to the Detailed Project Report to be taken from Maharastra State Government (Cabinet approval).
- The DPR to be forwarded to the Ministry of Urban Development (GOI), Planning Commission and Finance Ministry with the request for approving the Metro project and for financial participation through equity contribution in the Pune Metro Corridor 1A.
- Signing of an MOU between Maharastra State Government, Government of India and PCMC 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, operational subsidy, if any, etc.
- The present Special Purpose Vehicle (SPV) a 50:50 jointly owned company of GoI and GoM is responsible for implementation of all metro projects in the state of Maharashtra outside Mumbai Metropolitian region including Pune Metro Rail project phase 1 and the current extension from PCMC to Nigdi.
- PCMC as a major equity shareholder will form a part of the SPV with a seat in Board of Directors of Maha Metro. The State Government should arrange the funding of subordinated debt required for executing this project and get the whole funding plan approved by the Government of India. The loan portion of the funding will have to be tied up by State Government in consultation with the Government of India.
- An act needs to be passed for collection of 1% cess on property registrations (Earlier covered as LBT) allowing for collection of the cess in PCMC and sharing of 25% of this amount with the SPV.
- Implementation of TOD Policy allowing incremental FAR of 4, 500m on either side of alignment, Premium collection for the same and sharing of proceeds with Maha Metro to the tune of 75% by PCMC.
- The Government should freeze all developments along the corridors suggested. For any constructions within 50 m. of the proposed alignment, a system of No Objection Certificate should be introduced so that infructuous expenditure at a later stage is avoided.

20.1 Implementation on Delhi Metro Model

Maha Metro has to take action for appointment of General Consultants for project management including preparation of tender documents. Till the General Consultants are in position, Maha Metro should appoint an interim Consultant for all preliminary and enabling jobs such as land acquisition, detailed design of civil structures, utility diversions, etc. The proposed date of commissioning of the corridor with suggested dates of important milestones is given below :

Table 190 : Implementation Schedule of the project

S. No	Tasks	Anticipated Timelines
1	Approval of DPR by GoM	September 2021
2	Final Approval by GoI	November 2021
3	Packaging & Invitation of Bids	January 2022
4	Commencement of Civil Works	February 2022
5	Commencement of Operation	April 2025

20.2 ORGANISATIONAL SET-UP OF SPV

Maha Metro is the SPV responsible for the implementation of the project, which has already been set up for the implementation of Pune Metro Phase 1 as well as its extension from PCMC to Nigdi. PCMC.

The board comprises of 13 directors of whom, 5 directors are nominees of GoI, five directors are nominees of GoM, and three are functional directors. The chairman is secretary MOHUA – a Nominee of GoI and the Managing directo is a nominee of GoM. Since, PCMC is a major equity shareholder, the organisational setup of the Maha Metro board would be extented to include a representative of the Pimpri Chinchwad Muncipal Corporation.

The Directors will be Implementing a metro project in a congested metropolis. In sheer size, magnitude and technical complexity there are no parallels to metro projects. Further, these projects are to be carried out in difficult urban environment without dislocating city life, while at the same time preserving the environment. The project involves integration of a number of complex technical systems some of these technologies used in these systems are totally new to the country each one of which is a major project by itself. Interfacing various system contracts is a difficult and highly skilled exercise. Side by side, timely and adequate funds have to be assured for implementation and lands, without encumbrances, have to be taken possession of in time. Clearances from the local authorities have to be taken which includes permission to cut trees, diversion of utilities, management of road traffic, etc., all of which will call for an efficient and competent project implementing agency.

20.3 Contracts

20.3.1 Civil Works

It is proposed to carry out the civil works through following construction contracts:

(a) Viaduct Construction-It is suggested that each contract can be limited to about 5 to 6 kms in length.

(b) Station Contracts- It is proposed that each station contract comprises of 3 to 6 stations.

Architectural finishes, fire fighting arrangements and general electrification, will form part of civil contracts.

20.3.2 Systems Contract

- Design, construct and installation for Traction and Power Supply.
- Design, construct and installation of Signal and Telecommunication works.
- Design, construct and installation of lifts.
- Design, construct and installation of escalators.
- Design, construct and commissioning of Automatic Fare Collection System.

- Design and supply of rolling stock.
- Installation of track in Depot and on main line.
- Design and installation of Signages.

20.3.3 High Power Committee

During the implementation of the project several problems with regard to acquisition of land, diversion of utilities, shifting of structures falling on the project alignment, rehabilitation of project affected persons, etc. are likely to arise. For expeditious resolution of these problems, an institutional mechanism needs to be set up at the State Government level. Towards this end, it is recommended that a High Power Committee under the chairmanship of Chief Secretary, Maharashtra should be set up. Other members of this Committee should be Secretaries of the concerned Departments of the State Government and Heads of civic bodies who will be connected in one way or the other with the implementation of the project. Commissioner of Pune Urban Development Authority and Chief Executive Officer of PCMC should also be the member of this committee. This Committee should meet once a month and sort out all problems brought before it by Maha Metro.

For Delhi Metro also such a High Power Committee was set up and it proved very useful in smooth implementation of the Delhi Metro rail project.

20.4 Empowered Committee

At the Central Government level an Empowered Committee, under the chairmanship of Cabinet Secretary, is presently functioning for Delhi Metro project. Other members of this Committee are Secretaries of Planning Commission, Ministry of Home Affairs, Ministry of Urban Development, Ministry of Surface Transport, Ministry of Environment and Forests, Department of Expenditure, Chief Secretary of Delhi Government and a representative from the PMO. The Empowered Committee meets regularly and takes decisions on matters connected with inter-departmental coordination and overall planning, financing and implementation of the Delhi Metro project. It is suggested that the role of this Empowered Committee should be enlarged to include Pune Metro project extension also and the Chief Secretary, Maharastra should be inducted as a member of this Committee.

20.5 Empowered Group of Ministers (EGOM)

Union Cabinet had set up a Empowered Group of Ministers (EGoM) to take decisions on behalf of the Cabinet on policy matters concerning Delhi Metro project. The Group of Ministers is chaired by the Home Minister. Other members of the GOM are Minister of Urban Development and Poverty Alleviation, Minister of Railways, Minister of Finance and Company Affairs and Deputy Chairman Planning Commission. Chief Minister, Delhi and Lt. Governor, Delhi, are permanent invitees to all meetings of the GOM. The GOM meets whenever any problem requiring decision on behalf of the Union Cabinet is to be taken. It is suggested that the role of this GOM should be enlarged to include Pune Metro Extension. The Chief Minister, Maharastra should be inducted as a member and should attend the meetings of GOM whenever any issue concerning Pune Metro is to be deliberated upon.

20.6 Concessions from Government

Metro rail projects need very heavy investment. Loans have invariably to be taken to fund a part of the capital cost of the projects. These projects yield low financial internal rate of return. With reasonable fare level, servicing of these loans often pose problems. To make the project financially viable, therefore, the fares need to be substantially increased to socially un-acceptable levels. This results in the ridership coming down significantly, as it is sensitive to increases in the fare level. Thus the very objective of constructing the metro rail system to provide an affordable mode of mass travel for public is defeated. It, therefore, becomes necessary to keep the initial capital cost of a metro project as low as possible so that the fare level of the metro system can be kept at reasonable level.

Thus, Government should exempt the following: -

- Tax on electricity required for operation and maintenance of the metro system.
- Basic Custom Duty at concessional rate of 5%.

20.7 Need for dedicated fund for metro projects

We also strongly recommend that the State Government and PCMC start building up funds for the project through dedicated levies as has been done by other State Governments.

To enable the State Governments to provide their share of equity in the Special Purpose Vehicles set up for such projects, it would be necessary to constitute a Special Metro Fund at the State Government level. The State Government should resort to imposition of dedicated levies for raising resources for these Funds. Areas where such dedicated levies are possible via State government and Urban local body are given below:

Annual Grant by PCMC:

- An act needs to be passed for collection of 1% cess on property registrations (Earlier covered as LBT) allowing for collection of the cess in PCMC and sharing of 25% of this amount with the SPV.
- Implementation of TOD Policy allowing incremental FAR of 4, 500m on either side of alignment, Premium collection for the same and sharing of proceeds with Maha Metro to the tune of 75% by PCMC.
- Developemnt cess in PCNTDA

21. LIST OF APPROVALS REQUIRED FOR PROJECT IMPLEMENTATION

The details of the comprehensive checklist for approval of large scale projects

21.1 Project Feasibility / Pre-Sanction Stage

21.1.1 APPROVALS FROM LOCAL BODY

- Land use plan approval
- Approval for change in land use
- NOC for construction / augmentation
- Relaxation in respect of density/ ground coverage/ FAR/ setbacks/ height

21.1.2 APPROVAL FROM AIRPORT AUTHORITY

- No objection certificate (legal document) is required for height clearance
- NOC from coastal zone management authority

21.2 Sanction Stage - Lay Out Plan/ Local Area Plan/ Urban Design Plan

- Local body approvals
- Approval from national monument authority
- Approval from tree authority committee
- Approval from Maharashtra heritage conservation committee
- Approval from railway authority/port
- Approval from road owning agency
- Approval from traffic & coordination dept. (municipal)
- Approval from chief fire officer
- Approval from chief controller of explosives
- Approval is required from the chief inspector of factories, in case of industrial building.
- Environment clearance is required from ministry of environment and forests (MOEF)

21.3 Sanction / Building Permit Stage

- Approval from local body
- Approval from licensing

- Approval is required from the power distributing / supply agency
- Approval / NOC /assurance is required from the water supply agency
- Approval / NOC is required from the storm water & drain department/sewerage department
- Approval is required from the storm water & drain dept. / sewerage dept. for drainage & sewerage connection before start of construction

21.4 Construction Stage

- Permission is required from the central ground water authority
- Intimation to the local authority
- Plinth level notice

21.5 Completion Cum Occupancy Certificate Stage

- MRT Rail / Rail Safety Clearance
- Completion-cum-occupancy certificate from local body
- Approval from the lift inspector
- Approval for handicapped accessibility & amenity

22. RISK ASSESSMENT

Pune MRT Line corridor project is a complex project in a transport infrastructure pristine environment. In order to mitigate most of the risks identified at this stage of the project, it becomes essential the selected contractors demonstrate adequate experience and a General Consultant is introduced in order to control and monitor the performance of the contractor. Possible Risk & Mitigation measures are listed below.

22.1 Before Construction

22.1.1 Land Acquisition – Temporary & Permanent

Land pocket identifications for temporary & permanent works should be accurately assessed during planning and design stages and land should be acquired ahead of the construction acitivties. Any delay in land acquisition will have immediate impact on the schedule of the project. Local authorities shall be proactive in this as delay in land acquisition affects project time frame & budget adversely.

The General Consultant would work hand in hand with the State Government and Maharashtra Metro Rail Corporation Limited to pass these obstacles standing along the way.

22.1.2 Utility Identification & Relocations

Utility Identification survey shall be done, before start of the construction, through GPRS/ Equivalent survey. Proper & timely shifting of utilities are essential in order to avoid delay in construction.

22.1.3 Energy providers

Utilities may also be directly connected to the existing and newly implemented Pune MRT system. This is particularly true for the energy providers. Power supply design will have to be prepared in collaboration with the local energy providers in order to ensure the power requirement can actually be met by the provider and under which conditions.

Once the power supply scheme has been agreed upon and implemented, the system will require to be highly reliable to ensure continuous operation at the defined time of operation. An audit of the power provider shall be conducted before construction so that adequate measures are taken ahead of operations.

22.1.4 Monitoring of the project

Since Maharashtra Metro Rail Corporation Limited have the required expertise and few experienced manpower to check and monitor the contractors' work, it may be necessary to engage a General Consultants from the very start of the Pune MRTproject, who will do this job on behalf of Maharashtra Metro Rail Corporation Limited.

22.2 During Construction

22.2.1 Construction schedule

Planned construction schedule envisages 3 years for construction and commissioning of first approx. 4.413 km which is very challenging and it is important the contractor in charge has a clear understanding of the works to be accomplished and the construction methods to be followed.

Adequate monitoring of project construction and schedule should also be implemented to identify an issue appearing and avoid any slippage. The nomination of a General Consutlant would serve that purpose.

22.2.2 Cost management

Along with schedule risks, project such as MRT project are often exposed to costs risk.

22.2.3 Interface management

While it needs to be anticipated before construction starts, interface management becomes critical during construction if not performed adequately resulting in mistake at site and delay.

22.2.4 Setting up of working site

It is paramount the working site areas are clearly delineated and properly barricaded and guarded to avoid unattended intrusion of non authorized personnel or vehicle.

When setting up the working areas, traffic management plan shall be implemented to provide adequate traffic diversion and lessen disruptions to the road users.

22.2.5 Concurrent activities with other departmental construction works

In order to avoid conflicting works activities, proper liasoning is required between different Government departments working on the same perimeter.

22.2.6 Safety, Health & Environment

The Contractor is required to comply with all the precautions as required for the safety of the workmen as per the national Labour Organisation (ILO) as far as those are applicable to this contract. The contractor shall supply all necessary safety appliances such as safety goggles, helmets, masks, etc., to the workers and staff. The contractor has to comply with all regulation regarding.

The Contractor shall also ensure they fulfill their contract requirements for minimizing construction noise by developing mitigation measures to tackle the noise problem for at-grade or elevated tracks, e.g. by prescribing noise barriers or noise enclosures, either complete enclosure or partial.

22.2.7 Approvals from statutory bodies

The approval required for such project are listed in Chapter 21. Delay in statutory bodies' approval will create delay in construction timeline.

22.3 During Operation

22.3.1 Security

Security is a relatively new challenge in the context of public transport. It addresses problems caused intentionally. Security problems or threats are caused by people whose actions aim at undermining or disturbing the public transport system and/or to harm passengers or staff. These threats range from daily operational security problems such as disorder or vandalism. Operating MRT stations and running trains also become a soft target in time of any insurgencies or terrorist activities.

22.3.2 Energy providers

In case the energy provider is not found reliable enough, operations of the system is at risk.

23. SAFETY

Ensuring safety along the newly implemented transport corridor is paramount for the success of the project. Given the configuration of the Metro line corridor, the following items shall be implemented.

23.1 Ensuring safety during construction

Construction methods deployed at site shall not endanger the life of workers. It is advised that method used are largely tried and tested and do not present any kind of risk for the safety of workers.

Implementation of the MRT corridor on elevated stretch should ideally happen in a non-built area and located at enough distance from any built-up land wherever practicable.

Traffic diversion shall be adequately planned to avoid any conflict between construction related activities and associated traffic flow on one hand and regular road traffic on the other hand.

Implementation of MRT stations shall be planned in coherence with the urban fabric and local development also planned to support safety requirements generated due to new development.

23.2 Ensuring safety during operation

23.2.1.1 Station operations

Facilities required at any station for emergency evacuation as per NFPA 130 Guidelines has been adopted. The stations have been planned in accordance with 'Guidelines for Pedestrian Facilities, and 'National Building Code-2016', for Disabled friendly and other and Indian best practices/standards which ensure adequate sizing of station and comfort of passengers. The regulations are tailored to avoid any injury or casualty in case

Electrical installations shall be confined in "authorized personnel only" area.

Specific safety rules and procedures shall be followed by MRT staff during both operation in station and in depot area.

23.2.1.2 Train operations

However, signalling system ensures the safety of running trains during operations through an efficient train control, ensuring safety in train movements.

Rolling stock running on the system is tailored to ensure safety of the passengers and shall comprises the following characteristics: continuous automatic train protection, fire-proofing, emergency door control, crashworthiness design protecting passengers in case of accident

23.2.1.3 Passenger awareness

Wide publicity shall be given to all commuters and general public for awareness on safety in Metro systems. General Do's & Don'ts shall be circulated and displayed in station areas for users and workers in the metro system to ensure safety.

Passengers shall be particularly made aware of risks associated with 25KV OHE and unauthorized access to track or prohibited areas in stations.

24. CONCLUSION AND RECOMMENDATION

Pune has witnessed enormous growth during the last 10 years. The growth is mainly the result of immigration as the city provided better employment opportunities. Pune and surrounding areas are experiencing tremendous economic growth supported by favourable socio-economic conditions and investment climate. Rapid urbanization in the recent past has put the city's travel infrastructure to stress. Being densely populated area, Pune's traffic needs cannot be met by only road-based system. Road-based, has already come under stress leading to longer travel time, increased air pollution and rise in number of road accidents. However BRTS has offered some respite in this context, but it may not be sustainable and cater travel demand in longer horizon. With projected increase in the population of the city, strengthening and augmenting of transport infrastructure has assumed urgency. For this purpose provision of rail-based Metro system in the city has been considered.

Studies have brought out that a Light Capacity Metro with carrying capacity of about 15,000 to 25,000 PHPDT will be adequate to meet not only the traffic needs for the present but for the future 30 to 40 years also. The extension of a Metro System of PCMC to Swargate in corridor 1A is at an estimated completion cost of Rs. 910.18 Crores (with Central taxes & duties) to be made operational as recommended in implementation chapter.

A detailed Environmental Impact Assessment Study has been carried out for the project. As a part of this Study, comprehensive environmental baseline data was collected, and both positive and negative impacts of the project were assessed in detail. The project has many positive environmental impacts like reduction in traffic congestion, sa10.ving in travel time, reduction in air and noise pollution, lesser fuel consumption, lesser road accidents etc, with a few negative impacts (especially during implementation phase of the project) for which Environmental Management Plan has been suggested.

After examining the various options for execution of the extension of Pune Metro Project, it has been recommended that the project should get executed through the existing SPV on DMRC funding pattern.

The fare structure is as per the Government Resolution No. PMR-3313/C.R.29/UD-7 dated 11 Sept. 2013. Subsequently, for the purpose of assessing returns from the project, the fares have been revised every third year with an escalation of 15% every three years.

Pune Metro shall get following exemptions:

- Tax on electricity required for operation and maintenance of the metro system.
- Basic Custom duty is taken at concessional rate of 5%

As per the present policy 50% of the Central Taxes will be paid by GOI as subordinate Debt and balance 50% will be paid by the concerned State Government. Maharastra State Government may pursue the Central Government to extend the same benefit to Pune Metro.

While the Financial Internal Rate of Return (FIRR) for the project has been assessed as 10.45% with central taxes with property development of 5.4 Ha land and the Economic Internal Rate of Return (EIRR) works out 23.55%.

The project has already received in principle approval from Government of Maharastra in october 2013.

For implementation of the project, an act needs to be passed for collection of 1% cess on property registrations (Earlier covered as LBT) allowing for collection of the cess in PCMC and sharing of 25% of this amount with the SPV. Also, implementation of TOD Policy allowing incremental FAR of 4, 500m on either side of alignment needs to be done, premium collection for the same and sharing of proceeds with Maha Metro to the tune of 75% by PCMC.

Meanwhile, the State Government should freeze all future developments along the proposed route of extention of Pune Metro to avoid infructuous expenditure.

Land required for PD if the additional PD income is considered. PCMC has provided 5.4 Ha of land, which shall be auctioned out to a developer with maximum allowable FAR of 4, for a 50 year capital lease period after implementation of project in order to maximize the benefit. Accordingly, the corridor is recommended for implementation.

25. CHECKLIST

S.No.	Items	Yes/No
	CMP/ Master Plan	
1.	Does the city have a Master Plan for the horizon year?	Yes
2.	Does the city have a Comprehensive Urban Mobility Plan/Integrated Mobility Plan (IMP); and have the recommendations of the same been incorporated in the City Master Plan/Development Plan?	Yes
3.	Has the Comprehensive Urban Mobility Plan been notified as per the State Town and Country Planning Act, if not, will it be notified in next six months?	Yes
	Alternatives Analysis	
4.	Has the Alternatives Analysis Report been prepared as per the framework issued by MoHUA and with justifications for the construction of a Metro Rail?	Yes
	Detailed Project Report	
5.	As part of the DPR, has Techno Economic Feasibility of the Metro System been examined or not?	Yes
6.	Does the proposal include Economic cost and benefit analysis?	Yes
7.	Does the proposal contain the status report on prevailing pre-metro urban transport infrastructure in the city?	Yes
8.	Is the DPR prepared strictly in accordance with the standards and specifications of Metro rail system issued by MoHUA from time to time?	Yes
	Public Transport System	
9.	Does the city have an existing Public Transport System? (please tick)	
	a) Upto 50 buses	
	b) 50 to 100 buses	
	c) 100 to 200 buses	
	d) More than 200 buses	Yes
10.	Does the proposal include a report on how the Metro Rail will integrate with the existing transportation systems/proposed transit	Yes

11.	Does the proposal include a status report on the existing status and financial viability or socio- economic benefits of an existing Metro Rail System, if any in the city and the support being extended by the State Government to improve its financial viability?	
12.	Does the proposal contain a report on making a feeder system integrated with the proposed Metro Rail project?	Yes
13.	Does the report ensure last mile connectivity/NMT infrastructure?	Yes
	Transit Oriented Development (TOD) and Non Fare Box Revenue	
14.	Does the proposal contain distinct proposal for development of commercial property at and around stations to supplement fare-box revenue?	Yes
15.	Are the recommendations of the Transit Oriented Development Plan incorporated in the Master Plan?	Yes
16.	Has TOD plan and Value capture financing framework been prepared as per guidelines issued by MoHUA?	Yes
17.	Does the proposal include expanding utility capacity to densify areas around metro station as per notified TOD policy?	Yes
18.	Does the proposal include measures that will be taken for maximization of non-fare box non-property revenue?	Yes
19.	Does the proposal contain a detailed Environmental and Social Impact Analysis?	Yes
	Economic Analysis	
20.	Does the proposal contain measures for optimization of O&M costs?	Yes
21.	Does the proposal contain an Economic Analysis of the project along with the calculated values of EIRR and ENPV as per approved framework of MoHUA?	Yes
	Implementation Framework	
22.	Does the proposal include the exploration of PPP models for implementing the project? Does proposal contain implementation of at least one component of Metro Rail Project through PPP?	Yes
23	Does the proposal include the exploration of PPP models for Operations and/or maintenance of the project?	Yes (For AFC, PPP Mode is recommended)

24	Does the project clearly bring out key performance indicators and robust monitoring mechanism?	Yes
25.	Is the methodology devised for integrating fares of all available modes with Metro system planned (including National Common Mobility Card)?	Yes
26.	Does the proposal contain an MOU in between various service providers to provide seamless integration between the various modes?	No, will be developed at later stage
27.	Does the proposal include any monitoring mechanism to monitor the project during construction & implementation?	Yes
28.	In case the project is for a metropolitan region, is there an MOU between the participating states?	Not applicable , participating state is only Maharashtra
29.	Is there an involvement of municipal corporation/city development authority in implementing and/or operating the project?	Yes
	Role of State Government and UMTA	
30.	Has State Government committed in maintaining the financial viability of metro line?	Yes
31.	Has the State Government committed for providing & financing security provision for Metro System?	Yes
32.	Has the State Government firmed up funding of the project, with exploration of various methods?	Yes
33.	Has the State Government committed financial support to the project including O&M to ensure financial sustainability during the project life cycle including the operations stage?	Yes
34.	Has the State Government set up or firmed up the plan for setting up of UMTA for the city?	Yes
35.	Is the UMTA notified?	Yes
36.	If UMTA is not notified, is there a commitment for notifying it within a year?	Not applicable

37.	Is there a role, responsibility and involvement (including financial stake) of the city government in the Metro Rail project, both during construction and the operations phase	Yes
38.	Has the State Government committed for enabling policy & regulatory framework required for enhancing non fare box revenue	Yes
39.	Has the StateGovernment devised any option to enable metro rail implementing agencies to issue corporate bonds	No

26. ANNEXURE 1 – GEOTECHNICAL REPORT

26.1 INTRODUCTION:

It is proposed to construct metro station buildings and metro for Pune metro rail phase II. To assess the subsoil strata from safe bearing capacity point of view, soil investigation work was entrusted to Monarch Surveyors & Engineering Consultants Pvt. Ltd, by Systra MVA Consulting (India) Pvt. Ltd.

26.2 SITE LOCATION:

The project area is located PCMC to Nigdi stretch.

26.3 PROPOSED CONSTRUCTION:

It is proposed to construct metro station building and metro rail. It is anticipated that the structures will be constructed mainly from reinforced concrete.

26.4 SCOPE OF SERVICES:

The limited scope of services as defined in work order consists of drilling and sampling in boreholes and carrying out relevant laboratory tests on representative soil and rock samples. Borehole depth was agreed with client's representative.

26.5 FIELD WORK:

Drilling and sampling in soil and rock was carried out using rotary drilling rig. Borehole in soil was advanced using rotary drilling method, while NX size core barrel with Tungsten carbide/ diamond bit was used to drill in rock. Water was circulated to cool the drilling bit. Ground water table was recorded after 24 hours of completion of drilling. On completion of drilling, soil samples were packed in plastic containers with proper identification tags. Rock cores were numbered and kept in core boxes. Field work was performed during March - April 2018.Co-ordinates and elevation data provided by client is tabulated below

Bore Hole no	Location
BH1	Ginger Hotel Gate

BH2	Near Ranka Jewellers Chinchwad
BH3	In front of Tech Mahindra
BH4	Opposite Sai Baba TVS
BH5	Near Balaji Auto gate
BH6	In front of Nigdi Police station

26.6 SUB SOIL PROFILE

Sub-soil conditions described below are based on sampling in boreholes. Generalized sub-soil profile for the area investigated can be classified in different layers as detailed below. The layers encountered in field may not be in the same order as mentioned below. In the following table thickness of various layers (in mts) and SPT range or RQD range (as the case may be) is described.

Layer I: Silty sand

Layer II: Disintegrated rock (completely weathered rock)

Layer III Moderately weathered moderately fractured amygdaloidal/compact Basalt

Bore Hole no	Layer I	Layer II		Layer III	
	Thick	Thick	RQD	Thick	RQD
BH1	1.5	-	-	29.5	12-98
BH2	2.0	-	-	28.0	0-97
BH3	2.0	-	-	28.0	57-99
BH4	2.0	1.0	0	27.0	41-99
BH5	2.0	1.0	0	27.0	0-94
BH6	2.0	4.0	0-7	10.5	10-95

26.7 GROUND WATER LEVEL:

Water level was encountered in the boreholes as tabulated below. Correct method to determine ground water table is to install standpipe piezometer and monitor over long period of time.

Bore Hole no	Depth m
BH1	6.5
BH2	4.5
BH3	3.0
BH4	7.0
BH5	6.5
BH6	7.5

26.8 LABORATORY TESTING:

On completion of drilling samples were sent to the laboratory for further testing. Samples were classified in the laboratory and representative samples were selected for testing. Following tests were performed.

- Dry Density
- Soaked unconfined Compression Test
- Percentage absorption and porosity
- Specific gravity

26.9 ENGINEERING ANALYSIS:

Engineering analysis of the substratum was performed to determine net safe bearing capacity. Parameters obtained are based on various field and laboratory tests. Foundations shall be placed on rock.

Safe baring capacity for foundations placed on rock is determined as per procedure given in IS12070 "Code of practice for Design and Construction of Shallow Foundations on Rock. The procedure is based on RMR (Rock Mass Rating) concept. RMR is calculated as per the method given in IS 13365 (Part 1) "Quantitative Classification System of Rock Mass". Determination of RMR takes into consideration following properties of rock stratum

- Strength of Intact rock material
- Rock Quality Designation
- Spacing of Discontinuities
- Condition of Discontinuities
- Ground water condition
- Orientation of Discontinuities
- Joint Orientation

It is mentioned in IS 12070 that if net allowable bearing capacity is determined based on RMR "settlement of raft foundation up to 6m thickness to be less than 12mm".

Average parameters up to 5m below the foundation depth are considered for calculations.

26.10 CONCLUSIONS & RECOMMENDATIONS:

Conclusions and Recommendations are based on following accepted norms.

Foundations should not fail in shear.

Allowable settlement should be within tolerable limit.

Net safe bearing capacity (SBC) recommendations for pad foundations placed at different depths below the ground surface existing at the time of investigation is tabulated below.

It is recommended to adopt net safe bearing capacity as described below in the tabulated form:

Bore hole No.	Depth	Net Safe Bearing Capacity
BH1	2.5	45T/m^2
	3.0	45T/m^2
	4.5	50T/m^2
BH2	2.5	45T/m^2
	3.0	55T/m^2
	4.5	60T/m^2
BH3	2.5	55T/m^2
	3.5	60T/m^2
BH4	3.0	50T/m^2
	4.5	65T/m^2
BH5	3.0	55T/m^2
	4.5	55T/m^2
	6.0	215T/m^2
BH6	3.0	55T/m^2
	4.5	55T/m^2
	6.0	65T/m^2
	7.5	95T/m^2

Whenever foundations are placed on rock, it is essential to ensure that there are no loose pockets on rock surface. In case of loose pockets or over excavation, it shall be filled by plain cement concrete.

26.11 MODULUS OF SUBGRADE REACTION:

Modulus of sub grade reaction is determined from plate load test data. In the absence of such data empirical co-relation may be used. One such correlation is listed below:

Modulus of sub grade reaction Ks = 40 F x qa KN/m^3 (Bowles)
F = Factor of safety

qa = Allowable bearing capacity KN/m2

Notes:

1. This report is issued based on the subsoil condition revealed at the location of boreholes and laboratory tests performed on recovered samples. If during construction of foundations it is observed that sub soil conditions vary from those revealed during investigation it is essential that Monarch Surveyors & Engineering Consultants Private limited Pune shall be contacted so that on confirmation supplementary report shall be issued.

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M. Tech. (Geotech). FIIB, FIGS, FIIE
Geotechnical Consultant

Calculations for Safe Bearing Capacity

Foundations placed on rock

IS 13365 considers five parameters for determining RMR

BH 1 Depth 4.5m

Parameter	Value	Rating
Strength of intact rock (MPa)	4.5-5.4	1
Rock quality Designation %	17-78	13
Spacing of discontinuities	Moderate to wide	15
Conditions of discontinuities	-	20
Ground water condition	Wet	7
Adjustment for joint orientation	Fair	-7
Total		49

According to IS 12070 (table 3) classification of rock is III and safe bearing pressure will vary from 141 to 280T/m^2. By linear interpolation safe bearing capacity will be 200T/m^2.

Average unconfined compression strength is 49.5 Kg/cm^2. Applying correction (Nj) of 0.1 gross safe bearing pressure will be 49.5T/m^2. Recommended value is 50T/m^2.

BH 2 Depth 4.5m

Parameter	Value	Rating
Strength of intact rock (MPa)	3.6-8.9	1
Rock quality Designation %	71-89	13
Spacing of discontinuities	Wide	15
Conditions of discontinuities	-	20
Ground water condition	Wet	7
Adjustment for joint orientation	Fair	-7
Total		49

According to IS 12070 (table 3) classification of rock is III and safe bearing pressure will vary from 141 to 280T/m2. By linear interpolation safe bearing capacity will be 200T/m2.

Average unconfined compression strength is 62.5 Kg/cm^2. Applying correction (Nj) of 0.1 gross safe bearing pressure will be 62.5T/m2.

Recommended value is 60T/m^2.

BH 3 Depth 2.5m

Parameter	Value	Rating
Strength of intact rock (MPa)	5.3-6.2	1
Rock quality Designation %	57-87	13
Spacing of discontinuities	Wide	15
Conditions of discontinuities	-	20
Ground water condition	Wet	7
Adjustment for joint orientation	Fair	-7
Total		49

According to IS 12070 (table 3) classification of rock is III and safe bearing pressure will vary from 141 to 280T/m2. By linear interpolation safe bearing capacity will be 200T/m2.

Average unconfined compression strength is 57.5 Kg/cm^2. Applying correction (Nj) of 0.1 gross safe bearing pressure will be 57.5T/m^2. Recommended value is 55T/m^2.

BH 4 Depth 4.5m

Parameter	Value	Rating
Strength of intact rock (MPa)	6.2-8.0	1
Rock quality Designation %	61-77	13
Spacing of discontinuities	Wide	15
Conditions of discontinuities	-	20
Ground water condition	Wet	7
Adjustment for joint orientation	Fair	-7
Total		49

According to IS 12070 (table 3) classification of rock is III and safe bearing pressure will vary from 141 to 280T/m2. By linear interpolation safe bearing capacity will be 200T/m2.

Average unconfined compression strength is 71 Kg/cm^2. Applying correction (Nj) of 0.1 gross safe bearing pressure will be 71T/m^2. Recommended value is 65T/m2.

BH 5 Depth 6.0m

Parameter	Value	Rating
Strength of intact rock (MPa)	7.1-49.1	4
Rock quality Designation %	57-89	13
Spacing of discontinuities	Moderate to wide	15
Conditions of discontinuities	-	20
Ground water condition	Wet	7
Adjustment for joint orientation	Fair	-7
Total		52

According to IS 12070 (table 3) classification of rock is III and safe bearing pressure will vary from 141 to 280T/m2. By linear interpolation safe bearing capacity will be 221T/m2.

Average unconfined compression strength is 281 Kg/cm^2. Applying correction (Nj) of 0.1 gross safe bearing pressure will be 281T/m^2. Recommended value is 215T/m^2.

BH 6 Depth 7.5m

Parameter	Value	Rating
Strength of intact rock (MPa)	7.2-12.5	1
Rock quality Designation %	40-95	13
Spacing of discontinuities	Moderate to wide	15
Conditions of discontinuities	-	20
Ground water condition	Wet	7
Adjustment for joint orientation	Fair	-7
Total		49

According to IS 12070 (table 3) classification of rock is III and safe bearing pressure will vary from 141 to 280T/m2. By linear interpolation safe bearing capacity will be 200T/m2.

Average unconfined compression strength is 98.5 Kg/cm^2. Applying correction (Nj) of 0.1 gross safe bearing pressure will be 98.5T/m^2. Recommended value is 95T/m2.