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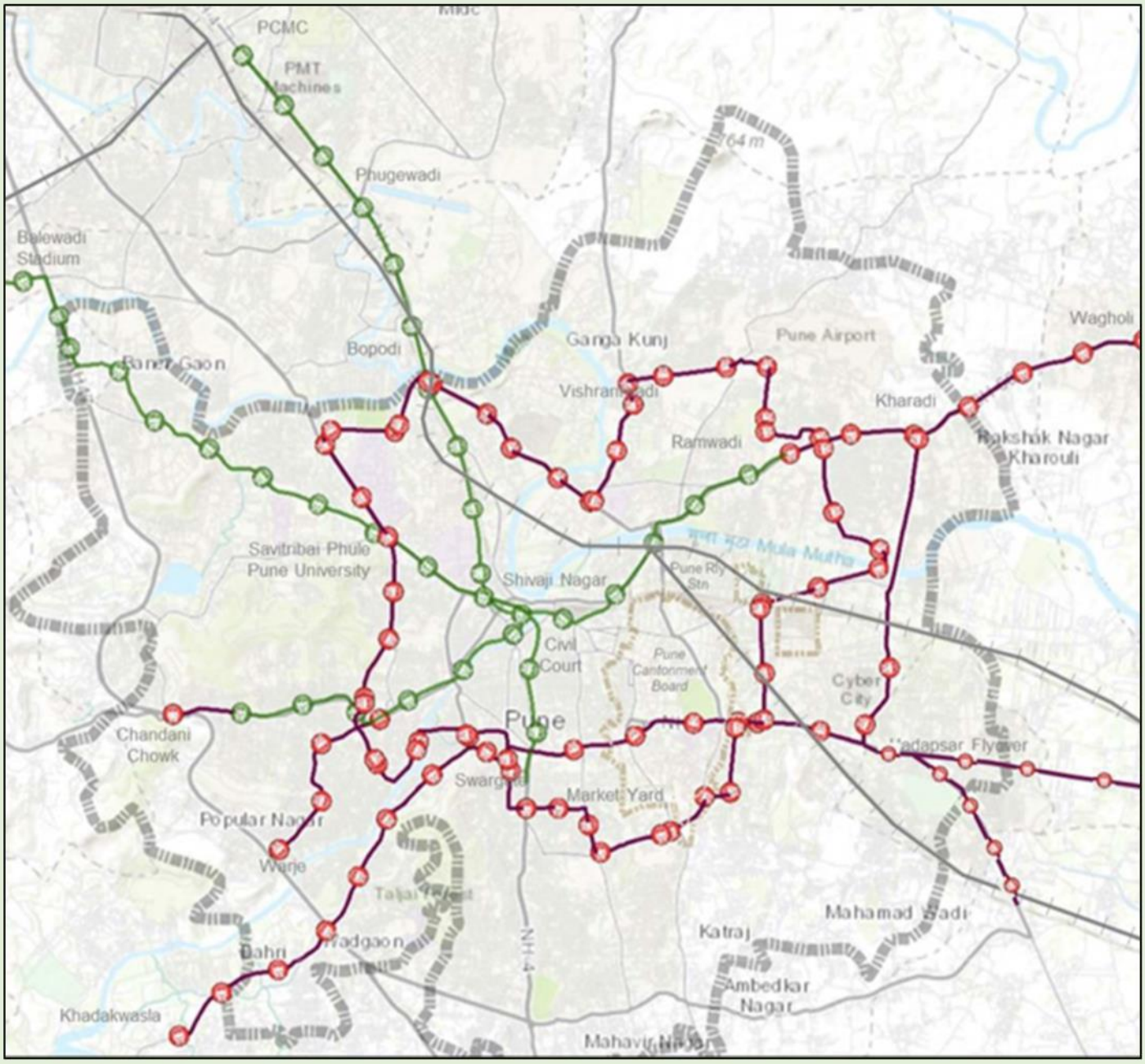
PUNE METRO

MAHARASHTRA METRO RAIL CORPORATION LIMIITED

DETAILED PROJECT REPORT



LINE 2A – VANAZ TO CHANDANI CHOWK

LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI

JULY 2024

Urban Mass Transit Company Limited

S. No	Revision	Revision Note	Submission
1	Revision 0 (R0)	First Submission	July 2022
2	Revision 1 (R1)	Revised Report incorporating changes for GST rate and project funding pattern	October 2022
3	Revision 2 (R2)	Revised Report incorporating the changes to funding pattern as suggested by PMC	December 2022
4	Revision 3 (R3)	Revised Report incorporating changes to project cost, funding pattern and associated changed on account of removal of PPP Component as per MoUHA letter dated 3rd Oct. 2023	February 2024
5	Revision 4 (R4)	Revised Report incorporating changes suggested by MoHUA (Rolling stock and Staff Quarters)	July 2024

TABLE OF CONTENTS

PREFACE I

SALIENT FEATURES I

EXECUTIVE SUMMARY I

0.1 Profile of the City I
0.2 Existing Transportation System II
0.3 Travel Demand Forecast II
0.4 System and Technology Selection IV
0.5 Civil Engineering and Alignment V
0.6 Station Planning VIII
0.7 Intermodal Integration IX
0.8 Train Operation Plan XI
0.9 Signaling and Telecommunications XIII
0.10 Fare Collection System XIV
0.11 Rolling Stocks XV
0.12 Power Supply System XV
0.13 Ventilation and Air-Conditioning System XVIII
0.14 Maintainance Depot XVIII
0.15 Environmental and Social Impact Assessment XIX
0.16 Disaster Management & Security Measures XXI
0.17 Project Cost Estimates XXII
0.18 Transit-Oriented development XXIV
0.19 Financial Analysis XXIV
0.20 Economic Analysis XXVIII
0.21 Implementation Plan XXIX
0.22 Cyber Security XXIX

CHAPTER 1: A PROFILE OF THE CITY 1-1

1.1 Introduction 1-1
1.2 Geography 1-2
1.3 Demography and Socio-Economic Profile 1-7
1.4 Urban Land Use Structure/Activity Distribution 1-13

CHAPTER 2: EXISTING TRANSPORTATION SYSTEM IN THE CITY 2-1

2.1. Introduction 2-1
2.2. Vehicular Growth and Composition 2-1
2.3. Road Network Characteristics 2-5
2.4. Major Transport Nodes 2-6
2.5. Pedestrian and NMV Facilities 2-7
2.6. Traffic Management including Parking Management 2-9
2.7. Traffic Characteristics 2-10
2.8. Traffic Safety 2-12
2.9. Intermediate Public Transit (IPT) System 2-13

2.10. Public Transportation System....2-14
2.11. Past Proposals....2-20
2.12. Interconnection with Development/Master Plans....2-40
2.13. Issues and Prospects....2-40

CHAPTER 3. TRAVEL CHARACTERISTICS & DEMAND ESTIMATES....3-1

3.1 Introduction....3-1
3.2 Methodology....3-1
3.3 Study Area and Zoning....3-3
3.4 Traffic Studies....3-4
3.5 Travel Demand Modelling....3-75
3.6 Travel Demand Forecasting....3-94
3.7 Future Year Assignments....3-102

CHAPTER 4: SYSTEM & TECHNOLOGY SELECTION....4-1

4.1. Technology....4-1
4.2. System Specifications Adopted for the Corridor....4-6

CHAPTER 5: CIVIL ENGINEERING AND ALIGNMENT....5-1

5.1 Site Appreciation and Reconnaissance Survey....5-1
5.2 Analysis of the Options....5-2
5.3 Engineering Surveys....5-7
5.4 Geotechnical Investigations....5-12
5.5 Design Norms....5-27
5.6 Route Alignment....5-37
5.7 Civil Structures....5-57
5.8 Utility Diversions....5-71
5.9 Land Requirement for Corridors....5-79

CHAPTER 6. STATION PLANNING....6-1

6.1. Station Planning....6-1
6.2. Station Area Planning for Non-Motorized Vehicle and Pedestrians Facilities: 6-57
6.3. Accessibility for Specially-Abled....6-58
6.4. Parking at Station....6-60

CHAPTER 7. INTERMODAL INTEGRATION....7-1

7.1. Intermodal Integration....7-1
7.2. Feeder Services....7-9
7.3. Infrastructure for Integration....7-17
7.4. Recommendations for Multi-Modal Integration....7-40

CHAPTER 8. TRAIN OPERATION PLAN....8-1

8.1. System Operation Approach....8-1

8.2. Existing Operation Plan for Phase - 1 8-1
8.3. Train Operation Plan for Line 2A & Line 2B 8-5

CHAPTER 9. SIGNALLING AND TELECOMMUNICATION 9-1

9.1. Signalling System 9-1
9.2. Telecommunication 9-6
9.3. Platform Screen Doors 9-19
9.4. Asset Management System 9-20

CHAPTER 10. AUTOMATIC FARE COLLECTION SYSTEM 10-1

10.1. Standards 10-3
10.2. Equipment Requirement (AFC System) 10-4
10.3. AFC Space Requirements 10-4

CHAPTER 11. ROLLING STOCK 11-1

11.1. Optimization of Coach SizE 11-1
11.2. Passenger carrying Capacity 11-1
11.3. Selection of Technology 11-4

CHAPTER 12. POWER SUPPLY AND TRACTION 12-1

12.1. Introduction 12-1
12.2. Selection of Traction System 12-1
12.3. Total Projected Power Demand 12-1
12.4. Need for High Reliability of Power Supply 12-4
12.5. Sources of Power Supply 12-5
12.6. Auxiliary Supply ArrangemeNts - Stations & Depot 12-8
12.7. Electromagnetic Interface & Compatibility 12-9
12.8. 25KV Flexible Overhead Equipment (OHE) System 12-9
12.9. Rating of Major Equipment 12-9
12.10. Standard Diesel Generator (DG) Sets 12-10
12.11. SCADA System 12-10
12.12. Solar Energy Harnessing System 12-11
12.13. Energy SAVING Measures 12-12
12.14. Electric Power Tariff 12-13

CHAPTER 13. VENTILATION & AIR CONDITIONING SYSTEM 13-1

13.1. Introduction 13-1
13.2. THE Need for Ventilation and Air-Conditioning 13-1
13.3. External Environment Conditions & Weather Data 13-2
13.4. Design Parameters for VAC System 13-2
13.5. System Brief Details 13-4

CHAPTER 14. DEPOTS 14-1

14.1. Existing Depot for EW Corridor 14-1

14.2. Approach and Maintenance 14-8
14.3. Rolling Stock Maintenance Needs 14-9
14.4. Inspection Requirement at Depot 14-10
14.5. Design of Depot 14-11
14.6. Equipment at Depot-Cum-Workshop 14-12
14.7. Design of Depot Infrastructure Facilities 14-14
14.8. Operational Features 14-17

CHAPTER 15: ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT 15-1

15.1 Objective of Environmental Impact Assessment 15-1
15.2 Applicable Legal Framework and Policies 15-1
15.3 Baseline Environment Scenario 15-6
15.4 Identified Environmental Impacts 15-41
15.5 Environmental Management Plan (EMP) 15-56
15.6 Environmental Monitoring Plan (EMoP) 15-65
15.7 EMP Budget 15-68
15.8 Social Impact Assessment (SIA) 15-71

CHAPTER 16: DISASTER MANAGEMENT & SECURITY 16-1

16.1. Introduction 16-1
16.2. The Need for Disaster Management Measures 16-1
16.3. Objectives 16-1
16.4. List of Serious Incidents 16-2
16.5. Authorities to be Contacted in Case of Disasters 16-2
16.6. Provisions at Metro Stations/Other Installations 16-4
16.7. Preparedness of Disaster Management 16-9
16.8. Security Measures in Metro 16-9

CHAPTER 17: DETAILED PROJECT COST ESTIMATES 17-1

17.1 Capital Cost Estimate 17-1
17.2 Innovations Proposed to Reduce the Cost 17-6
17.3 Detailed Project Cost Estimates 17-6
17.4 Taxes and Duties 17-13
17.5 Summary of Capital Cost 17-17
17.6 Estimations of Operation and Maintenance Costs 17-21

CHAPTER 18. TRANSIT ORIENTED DEVELOPMENT 18-1

18.1. Objectives of Transit Oriented Development 18-2
18.2. National TOD Policy 18-2
18.3. Need of Detailed Study 18-3
18.4. TOD Proposal for Pune Metro Line 2 Extensions 18-3
18.5. Statutory Regulations & Compliances 18-21
18.6. Non-Fare Box Revenue Estimation 18-23
18.7. Property Development 18-39

CHAPTER 19: FINANCIAL ANALYSIS & NON FARE BOX REVENUE 19-1

19.1 Introduction 19-1
19.2 Project Financing 19-10
19.3 Financial Internal Rate of Return 19-13
19.4 FIRR Sensitivity 19-15
19.5 Alternative Sources For Means of Finance – Exploring Private Participation 19-15

CHAPTER 20: ECONOMIC ANALYSIS 20-1

20.1. Approach & Methodology for Economic Analysis 20-1
20.2. Estimation of Economic Project Cost of MRTS 20-2
20.3. Economic Benefits of MRTS 20-5
20.4. EIRR for 30 Years 20-8
20.5. Outcome on Economic Viability 20-8
20.6. Sensitivity Analysis 20-8

CHAPTER 21: IMPLEMENTATION PLAN 21-1

21.1. Project Implementation Plan 21-1
21.2. Contracts 21-1
21.3. Legal & Institutional Framework 21-2
21.4. Roles & Responsibility of City Government 21-3

CHAPTER 22: IT/OT AND CYBER SECURITY 22-1

22.1. Background 22-1
22.2. Introduction 22-1
22.3. Metro Rail IT Infrastructure Overview 22-2
22.4. Main Constituents of Cyber Security 22-3
22.5. Network Security 22-4
22.6. Web Application Security 22-6
22.7. Identity and Access Management 22-7
22.8. Threat and Vulnerability Management 22-8
22.9. Security Monitoring 22-10
22.10. Incident Management 22-14
22.11. Cyber Security Case 22-15

LIST OF FIGURES

FIGURE 0-1: LINE 2A, LINE 2 & LINE 2B ALIGNMENT AND STATIONS....III
FIGURE 0-2: CONCEPTUAL OPERATION PLAN.... XII
FIGURE 0-3: SCHEMATIC FOR PUNE MRTS PHASE 2 CORRIDORS XVII
FIGURE 1-1: VIEW OF PUNE CITY FROM VETAL HILL 1-1
FIGURE 1-2: LOCATION AND REGIONAL SETTING OF PUNE....1-2
FIGURE 1-3: ADMINISTRATIVE BOUNDARIES OF PUNE METROPOLITAN REGION AREA....1-3
FIGURE 1-4: TOPOGRAPHIC MAP OF THE STUDY AREA....1-4
FIGURE 1-5: SHANKAR SETH ROAD & MAGARPATTA ROAD IN PUNE....1-5
FIGURE 1-6: MAJOR ROAD AND RAIL NETWORK IN THE STUDY AREA 1-6
FIGURE 1-7: POPULATION GROWTH TRENDS IN PMR....1-8
FIGURE 1-8: EXISTING LAND USE MAP OF PMC....1-15
FIGURE 1-9: EXISTING LAND USE MAP OF PCMC 1-16
FIGURE 1-10: IT & ITES ESTABLISHMENTS IN PUNE 1-18
FIGURE 1-11: PROPOSED LAND USE OF PMC 1-20
FIGURE 1-12: PROPOSED LAND USE MAP OF PCMC - 2021 1-22
FIGURE 2-1: GROWTH OF REGISTERED VEHICLES IN PUNE....2-2
FIGURE 2-2: MODE-WISE DISTRIBUTION OF REGISTERED VEHICLES IN PUNE 2-3
FIGURE 2-3: MAJOR ROAD AND RAIL NETWORK IN THE STUDY AREA 2-5
FIGURE 2-4: PUNE RAILWAY STATION 2-6
FIGURE 2-5: PUNE AIRPORT 2-7
FIGURE 2-6: DAILY TRAFFIC COMPOSITION ON MAJOR SCREEN LINE LOCATIONS 2-11
FIGURE 2-7: AUTO RICKSHAW STAND ZONES IN PMC AND PCMC 2-14
FIGURE 2-8: CITY BUS SERVICE NETWORK OF PMPML 2-15
FIGURE 2-9: OPERATIONAL BRTS CORRIDORS IN THE STUDY AREA....2-17
FIGURE 2-10: ROUTE MAP OF PUNE METRO RAIL PROJECT 2-19
FIGURE 2-11: PUNE METRO RAIL PHASE 1 ROUTE MAP 2-21
FIGURE 2-12: LINE 3 CONNECTING CIVIL COURT (SHIVAJI NAGAR) AND HINJEWADI 2-23
FIGURE 2-13: RECOMMENDED MASS TRANSIT CORRIDOR IN 2028 2-27
FIGURE 2-14: RECOMMENDED MASS TRANSIT CORRIDOR IN 2038 2-28
FIGURE 2-15: STUDY AREA FOR METRO FEEDER NETWORK – DPR FOR METRO FEEDER CONNECTIVITY.2-29
FIGURE 2-16: PROPOSED FEEDER NETWORK – DPR FOR METRO FEEDER CONNECTIVITY 2-30
FIGURE 2-17: STUDY AREA FOR NMT MASTER PLAN – DPR FOR NMT PLAN AND PBS SCHEME 2-31
FIGURE 2-18: PROPOSED NMT NETWORK – DPR FOR NMT PLAN AND PBS SCHEME 2-32
FIGURE 2-19: PROPOSED PBS DOCKING LOCATIONS – DPR FOR NMT PLAN AND PBS SCHEME 2-33
FIGURE 2-20: KEY PLAN SHOWING HCMTR CORRIDOR – FEASIBILITY STUDY FOR HCMTR ALIGNMENT .2-35
FIGURE 2-21: INTEGRATION OF HCMTR WITH OTHER INFRASTRUCTURE PROJECTS – FEASIBILITY STUDY FOR HCMTR ALIGNMENT 2-36
FIGURE 2-22: ALIGNMENT OF PROPOSED METRO NEO CORRIDOR IN PCMC 2-39
FIGURE 2-23: ISSUES & CHALLENGES W.R.T TRANSPORTATION IN PUNE CITY....2-43
FIGURE 2-24: ON-STREET PARKING NEAR KOTHRUD BUS DEPOT (TOWARDS CHANDANI CHOWK)....2-43
FIGURE 3-1: STUDY METHODOLOGY....3-2
FIGURE 3-2: TRAFFIC ANALYSIS ZONE MAP 3-3
FIGURE 3-3: ROAD NETWORK IDENTIFIED FOR THE ROAD NETWORK INVENTORY....3-9
FIGURE 3-4: DISTRIBUTION OF THE SURVEYED NETWORK BY RIGHT OF WAY....3-10
FIGURE 3-5: DISTRIBUTION OF SURVEYED NETWORK BY LANE CONFIGURATION....3-12
FIGURE 3-6: DISTRIBUTION OF SURVEYED ROAD NETWORK BY ONE-WAY MOVEMENTS 3-13
FIGURE 3-7: ROAD NETWORK IDENTIFIED FOR SPEED AND DELAY SURVEY 3-15
FIGURE 3-8: DISTRIBUTION OF SURVEYED ROADS BY RUNNING SPEED 3-18
FIGURE 3-9: DISTRIBUTION OF SURVEYED ROADS BY JOURNEY SPEED 3-19
FIGURE 3-10: LOCATION-WISE INTENSITY (PCU) AND SHARE ON OUTER CORDON LOCATIONS 3-20
FIGURE 3-11: AVERAGE TRAFFIC COMPOSITION AT OUTER CORDON LOCATIONS 3-23
FIGURE 3-12: OUTER CORDON SURVEY LOCATIONS FOR ORIGIN AND DESTINATION SURVEYS....3-25
FIGURE 3-13: SCREEN LINE SURVEY LOCATIONS....3-29
FIGURE 3-14: AVERAGE COMPOSITION OF VEHICLES AT SCREEN LINE LOCATIONS....3-34
FIGURE 3-15: MID-BLOCK SURVEY LOCATIONS....3-38

FIGURE 3-16: AVERAGE TRAFFIC COMPOSITION AT MID-BLOCK LOCATIONS....3-40
FIGURE 3-17: TURNING MOVEMENT COUNT LOCATIONS....3-42
FIGURE 3-18: AVERAGE TRAFFIC COMPOSITION AT INTERSECTIONS....3-45
FIGURE 3-19: PEDESTRIAN SURVEY LOCATIONS....3-47
FIGURE 3-20: BUS STOP BOARDING AND ALIGHTING SURVEY LOCATIONS....3-49
FIGURE 3-21: HOURLY VARIATION OF BUS STOP BOARDING AND ALIGHTING....3-50
FIGURE 3-22: AVERAGE OCCUPANCY AT SURVEYED BUS STOP LOCATIONS....3-51
FIGURE 3-23: HOURLY VARIATION OF AVERAGE BUS OCCUPANCY AT BUS STOP LOCATIONS....3-51
FIGURE 3-24: TRIP PURPOSE OF BOARDING AND ALIGHTING PASSENGERS....3-52
FIGURE 3-25: ACCESS AND DISPERSAL TRIP LENGTH OF THE BOARDING PASSENGERS AND ALIGHTING PASSENGERS....3-53
FIGURE 3-26: WILLINGNESS TO PAY FOR MRTS BY BOARDING AND ALIGHTING PASSENGERS....3-55
FIGURE 3-27: TERMINAL SURVEY LOCATIONS IN THE STUDY AREA....3-56
FIGURE 3-28: ACCESS AND EGRESS MODES OF RAIL PASSENGERS....3-59
FIGURE 3-29: ACCESS AND EGRESS MODES OF BUS PASSENGERS....3-59
FIGURE 3-30: WILLINGNESS TO PAY FOR MRTS BY RAIL PASSENGERS....3-61
FIGURE 3-31: WILLINGNESS TO PAY FOR MRTS BY BUS TERMINAL PASSENGERS....3-61
FIGURE 3-32: DISTRIBUTION OF HOUSEHOLDS BY HOUSEHOLD SIZE....3-64
FIGURE 3-33: DISTRIBUTION OF RESIDENTS BY GENDER AND AGE GROUP....3-65
FIGURE 3-34: TRIP LENGTH FREQUENCY DISTRIBUTION (TLFD)....3-69
FIGURE 3-35: FOUR-STAGE TRAVEL DEMAND MODEL....3-77
FIGURE 3-36: TRAFFIC ANALYSIS ZONE MAP....3-79
FIGURE 3-37: CODED HIGHWAY NETWORK....3-82
FIGURE 3-38: BASE YEAR PUBLIC TRANSPORT NETWORK....3-83
FIGURE 3-39: METHODOLOGY FOR THE CALIBRATION OF MATRICES....3-85
FIGURE 3-40: OBSERVED AND MODELLED TRIP LENGTH FREQUENCY DISTRIBUTION (ALL MODES)....3-87
FIGURE 3-41: TRAFFIC FLOW MAP FOR PMR_2022....3-89
FIGURE 3-42: PUBLIC TRANSPORT FLOW MAP FOR PUNE – 2022....3-90
FIGURE 3-43: GROWTH DIRECTION OF PUNE....3-95
FIGURE 3-44: LINE 2A, LINE 2 & LINE 2B ALIGNMENT AND STOPS....3-103
FIGURE 3-45: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2027....3-107
FIGURE 3-46: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2027....3-108
FIGURE 3-47: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2037....3-109
FIGURE 3-48: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2037....3-110
FIGURE 3-49: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2047....3-111
FIGURE 3-50: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2047....3-112
FIGURE 3-51: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2057....3-113
FIGURE 3-52: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2057....3-114
FIGURE 3-53: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2027 .3-117
FIGURE 3-54: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2037 .3-118
FIGURE 3-55: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2047 .3-119
FIGURE 3-56: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2057 .3-120
FIGURE 3-57: TRIP LENGTH FREQUENCY DISTRIBUTION WITH THE PROJECT FOR LINE 2....3-121
FIGURE 3-58: LINE 2 PHPDT FOR THE BASE YEAR 2027....3-123
FIGURE 3-59: LINE 2 PHPDT FOR THE BASE YEAR 2037....3-123
FIGURE 3-60: LINE 2 PHPDT FOR THE BASE YEAR 2047....3-124
FIGURE 3-61: LINE 2 PHPDT FOR THE BASE YEAR 2057....3-124
FIGURE 5-1: ALIGNMENT OF LINE 2A – VANAZ TO CHANDANI CHOWK....5-2
FIGURE 5-2: ALIGNMENT OF LINE 2B – RAMWADI TO WAGHOLI / VITTHALWADI....5-5

FIGURE 5-3: GROUND LEVEL PLUS TWO LEVELS OF FLYOVER AND MRTS ON TOP 5-6
FIGURE 5-4: PROPOSED FLYOVER AND UNDERPASS AT KHARADI JUNCTION.....5-7
FIGURE 5-5: TOPOGRAPHIC SURVEY USING TOTAL STATION IN PROGRESS.....5-11
FIGURE 5-6: TOPOGRAPHIC SURVEY IN PROGRESS.....5-11
FIGURE 5-7 LOCATION OF PUNE CITY IN SEISMIC MAP OF MAHARASHTRA.....5-14
FIGURE 5-8 SEISMIC MAP OF INDIA 5-14
FIGURE 5-9: 1 IN 9, 300MR TURNOUT (ALL DIMENSIONS IN METRE).....5-34
FIGURE 5-10: 1 IN 9, 190MR TURNOUT (ALL DIMENSIONS IN METRE).....5-34
FIGURE 5-11: 1 IN 7, 190MR TURNOUT (ALL DIMENSIONS IN METRE).....5-34
FIGURE 5-12: SCISSOR CROSSOVER – 1 IN 9, 300MR – TRACK CENTRE – 4.5M.....5-35
FIGURE 5-13: SCISSOR CROSSOVER – 1 IN 9, 300MR – TRACK CENTRE – 4.5M.....5-36
FIGURE 5-14: PROPOSED LINE 2A AND LINE 2B MRTS ROUTES FOR PUNE METRO PHASE-2 (DPR PART-1) 5-38
FIGURE 5-15: PROPOSED LINE 2A WITH STATIONS.....5-39
FIGURE 5-16: PROPOSED LINE 2B WITH STATIONS.....5-44
FIGURE 5-17: PROPOSED LINE 2B WITH RSS LOCATION 5-47
FIGURE 5-18: METRO VIADUCT ON SEGMENTAL BOX GIRDER, UNDER CONSTRUCTION 5-58
FIGURE 5-19: TYPICAL CROSS SECTION OF A DUAL TRACK METRO VIADUCT ON SEGMENTAL BOX GIRDER 5-59
FIGURE 5-20: LAUNCHING OF DOUBLE U GIRDER.....5-60
FIGURE 5-21: CONSTRUCTION OF BALANCED CANTILEVER TYPE VIADUCT 5-61
FIGURE 5-22: LAUNCHING OF SEGMENTAL BOX ON VIADUCT.....5-63
FIGURE 5-23: SEQUENCING OF ACTIVITIES- PRECAST U GIRDER. 5-63
FIGURE 5-24: CONSTRUCTION OF BALANCED CANTILEVER TYPE VIADUCT. 5-64
FIGURE 5-25: SPAN BY SPAN CONSTRUCTION OF VIADUCT 5-65
FIGURE 5-26: CASTING OF BOX SEGMENTS IN CASTING YARD.....5-66
FIGURE 5-27: TRANSPORTATION OF BOX GIRDER 5-67
FIGURE 5-28 PLACING OF I-GIRDER 5-68
FIGURE 5-29 PREPARING OF DECK-BED 5-69
FIGURE 5-30 LAUNCHING OF I-GIRDER 5-69
FIGURE 5-31: LAND IDENTIFIED FOR RSS 5-88
FIGURE 6-1: PUNE METRO LINE 2A – VANAZ TO CHANDANI CHOWK ALIGNMENT 6-3
FIGURE 6-2: PUNE METRO LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI ALIGNMENT 6-4
FIGURE 6-3 PEDESTRIAN FLOW ANALOGY 6-9
FIGURE 6-4: AFC GATES AT STATIONS 6-10
FIGURE 6-5: TICKET VENDING MACHINES 6-11
FIGURE 6-6: TICKET COUNTER.....6-12
FIGURE 6-7: TYPE A – CONCOURSE LEVEL.....6-16
FIGURE 6-8: TYPE A – PLATFORM LEVEL.....6-17
FIGURE 6-9: TYPE A – CROSS SECTION 6-18
FIGURE 6-10: TYPE B - CONCOURSE LEVEL.....6-20
FIGURE 6-11: TYPE B - PLATFORM LEVEL.....6-21
FIGURE 6-12: TYPE B - CROSS SECTION 6-22
FIGURE 6-13: TYPE C - CONCOURSE LEVEL 6-24
FIGURE 6-14: TYPE C - PLATFORM LEVEL 6-25
FIGURE 6-15: TYPE C - CROSS SECTION.....6-26
FIGURE 6-16: METRO ALIGNMENT THROUGH KOTHRUD DEPOT METRO STATION 6-29
FIGURE 6-17: METRO ALIGNMENT THROUGH CHANDANI CHOWK METRO STATION 6-32
FIGURE 6-18: METRO ALIGNMENT THROUGH VIMAN NAGAR METRO STATION 6-35
FIGURE 6-19: METRO ALIGNMENT THROUGH SOMNATH NAGAR METRO STATION.....6-38
FIGURE 6-20: METRO ALIGNMENT THROUGH KHARADI BYPASS METRO STATION 6-40
FIGURE 6-21: METRO ALIGNMENT THROUGH TULAJA BHAVANI METRO STATION 6-42
FIGURE 6-22: METRO ALIGNMENT THROUGH UBALE NAGAR METRO STATION.....6-44
FIGURE 6-23: METRO ALIGNMENT THROUGH UPPER KHARADI ROAD METRO STATION 6-46
FIGURE 6-24: METRO ALIGNMENT THROUGH WAGHESHWAR TEMPLE METRO STATION 6-48
FIGURE 6-25: METRO ALIGNMENT THROUGH WAGHOLI METRO STATION 6-50
FIGURE 6-26: METRO ALIGNMENT THROUGH SIDDHARTH NAGAR METRO STATION 6-52

FIGURE 6-27: METRO ALIGNMENT THROUGH BAKORI PHATA METRO STATION 6-54
FIGURE 6-28: METRO ALIGNMENT THROUGH VITTHALWADI METRO STATION 6-56
FIGURE 6-29: PLANNING FOR NON-MOTORIZED VEHICLE AND PEDESTRIAN FACILITIES 6-57
FIGURE 6-30: DISABLED FRIENDLY FEATURES 6-58
FIGURE 6-31: TACTILE FLOORING 6-59
FIGURE 6-32: ACCESSIBILITY FOR SPECIALLY-ABLED 6-60
FIGURE 7-1: VARIOUS LINKAGES OF MULTI-MODAL TRANSPORTATION SYSTEM 7-1
FIGURE 7-2: FIVE PILLARS OF MULTI-MODAL INTEGRATION 7-2
FIGURE 7-3: METRO MULTI-MODAL INTEGRATION IN THE CATCHMENT AREA 7-5
FIGURE 7-4: HUB AND SPOKE MODEL OF FEEDER SERVICES 7-10
FIGURE 7-5: METRO FEEDER SERVICES 7-11
FIGURE 7-6: PUNE METRO FEEDER SERVICE 7-12
FIGURE 7-7: FEEDER ROUTES METRO LINE 2A 7-14
FIGURE 7-8: FEEDER ROUTES METRO LINE 2B 7-15
FIGURE 7-9: HIERARCHY OF MULTI-MODAL INTEGRATION PLANNING 7-18
FIGURE 7-10: LEVELS OF PRIORITY 7-19
FIGURE 7-11: MMI PLANNING AT SANT TUKARAM METRO STATION (PUNE MRTS PHASE – 1) 7-20
FIGURE 7-12: EXAMPLE 1: MMI IMPLEMENTATION FOR PUNE MRTS PHASE – 1 7-21
FIGURE 7-13: EXAMPLE 2: MMI IMPLEMENTATION FOR PUNE MRTS PHASE - 1 7-21
FIGURE 7-14: EXAMPLE 3: MMI IMPLEMENTATION FOR PUNE MRTS PHASE - 1 7-22
FIGURE 7-15: EXAMPLE 4: MMI IMPLEMENTATION FOR PUNE MRTS PHASE - 1 7-22
FIGURE 7-16: PUBLIC BICYCLE SHARING SYSTEM AT PUNE METRO STATION 7-23
Figure 7-17: E-Bike Sharing Schemes 7-24
FIGURE 7-18: SIGNAGES AND WAY-FINDINGS 7-26
FIGURE 7-19; INTEGRATION – KOTHRUD BUS DEPOT STATION 7-27
FIGURE 7-20: INTEGRATION - CHANDANI CHOWK STATION 7-28
FIGURE 7-21: INTEGRATION: VIMAN NAGAR STATION 7-29
FIGURE 7-22: INTEGRATION: SOMNATH NAGAR STATION 7-30
FIGURE 7-23: INTEGRATION – KHARADI BYPASS STATION 7-31
FIGURE 7-24: INTEGRATION - TULAJA BHAVANI STATION 7-32
FIGURE 7-25: INTEGRATION - UBALE NAGAR STATION 7-33
FIGURE 7-26: INTEGRATION - UPPER KHARADI ROAD STATION 7-34
FIGURE 7-27: INTEGRATION - WAGHESHWAR TEMPLE STATION 7-35
FIGURE 7-28: INTEGRATION - WAGHOLI STATION 7-36
FIGURE 7-29: SIDDHARTH NAGAR STATION 7-37
FIGURE 7-30: INTEGRATION - BAKORI PHATA STATION 7-38
FIGURE 7-31: INTEGRATION - VITTHALWADI STATION 7-39
FIGURE 7-32: SMART CARD SYSTEM 7-41
FIGURE 8-1: TRACK PLAN OF LINE 2 – VANAZ TO RAMWADI (PHASE-1) 8-2
FIGURE 8-2: SCHEMATIC TRACK PLAN OF PUNE METRO PHASE-2 8-3
FIGURE 8-3: CONCEPTUAL OPERATION PLAN 8-11
FIGURE 8-4: KHARADI BYPASS STATION – ARRANGEMENT 8-12
FIGURE 8-5: DEMAND AND CAPACITY (2027) 8-14
FIGURE 8-6: DEMAND AND CAPACITY (2037) 8-16
FIGURE 8-7: DEMAND AND CAPACITY (2047) 8-18
FIGURE 8-8: DEMAND AND CAPACITY (2057) 8-21
FIGURE 11-1: EXAMPLE FOR INTERIOR VIEW OF THE CAR** 11-7
FIGURE 11-2: EXAMPLE FOR VIEW OF THE PASSENGER DOOR** 11-8
FIGURE 11-3: EXAMPLE VIEW OF THE DRIVING CAB 11-9
FIGURE 12-1: SCHEMATIC OF PUNE MRTS PHASE 2 CORRIDORS 12-6
FIGURE 12-2: TYPICAL HIGH VOLTAGE RECEIVING SUB-STATION 12-7
FIGURE 12-3: TYPICAL INDOOR AUXILIARY SUB-STATION 12-8
FIGURE 14-1: VANAZ DEPOT LAYOUT 14-3
FIGURE 14-2: VANAZ DEPOT WITH AUGMENTATION 14-6
FIGURE 15-1: SAMPLING LOCATIONS – LINE 2A 15-7
FIGURE 15-2: SAMPLING LOCATIONS – LINE 2B 15-8
FIGURE 15-3: DEM MAP OF THE STUDY AREA 15-9

FIGURE 15-4: SOME PHOTOGRAPHS OF SOIL SAMPLING IN THE STUDY AREA.....15-11
FIGURE 15-5: LAND USE/LAND COVER MAP OF 500M RADIUS AROUND LINE 2A.....15-14
FIGURE 15-6: LAND USE/LAND COVER MAP OF 500M RADIUS AROUND LINE 2B.....15-14
FIGURE 15-7: SATELLITE MAP OF THE STUDY AREA.....15-15
FIGURE 15-8: GSHAP SEISMIC HAZARD MAP OF MAHARASHTRA.....15-16
FIGURE 15-9: BMTPC EARTHQUAKE HAZARD MAP OF INDIA AND MAHARASHTRA WITH PROJECT SITE..15-17
FIGURE 15-10: GEOLOGY OF PUNE CITY ALONG WITH PROJECT CORRIDORS AND STUDY AREA.....15-19
FIGURE 15-11: MAJOR AQUIFER SYSTEMS IN PUNE DISTRICT.....15-20
FIGURE 15-12: HYDROGEOLOGY OF PUNE DISTRICT.....15-21
FIGURE 15-13: DRAINAGE MAP OF THE STUDY AREA.....15-24
FIGURE 15-14: SOME PHOTOGRAPHS SHOWING WATER QUALITY MONITORING.....15-26
FIGURE 15-15: MONTHLY TEMPERATURE DATA OF PUNE.....15-31
FIGURE 15-16: DIURNAL TEMPERATURE VARIATION IN PUNE.....15-32
FIGURE 15-17: MONTHLY RELATIVE HUMIDITY DATA OF PUNE.....15-32
FIGURE 15-18: DIURNAL RELATIVE HUMIDITY VARIATION IN PUNE.....15-33
FIGURE 15-19: ANNUAL WIND ROSE DIAGRAM OF PUNE.....15-34
FIGURE 15-20: SOME PHOTOGRAPHS SHOWING AMBIENT AIR QUALITY MONITORING.....15-35
FIGURE 15-21: SOME PHOTOGRAPHS OF NOISE MONITORING IN THE STUDY AREA.....15-39
FIGURE 15-22: PHOTOGRAPHS OF PUBLIC CONSULTATIONS IN PROJECT STUDY AREA.....15-75
FIGURE 18-1: TOD ZONES FOR VIMAN NAGAR TO VITTHALWADI STATIONS.....18-6
FIGURE 18-2: TOD ZONES FOR VANAZ TO CHANDANI CHOWK.....18-18
FIGURE 18-3: IDENTIFIED PLOTS FOR THE PROPERTY DEVELOPMENT UNDER TOD.....18-40
FIGURE 19-1: VARIOUS PPP MODELS.....19-16
FIGURE 20-1: FRAMEWORK FOR ECONOMIC ANALYSIS.....20-1
FIGURE 21-1: IMPLEMENTATION SCHEDULE FOR MONITORING PROJECT.....21-6
FIGURE 22-1: TYPICAL RAIL SYSTEM OVERVIEW.....22-2
FIGURE 22-2: LOGICAL ARCHITECTURE AND INFORMATION FLOW (CONCEPTUAL).....22-3
FIGURE 22-3: SECURITY MONITORING.....22-11

LIST OF TABLES

TABLE 0-1: NOMENCLATURE OF THE PUNE MRTS PHASE-2 CORRIDORS FOR THE PRESENT STUDY II
TABLE 0-1: DETAILS OF LINE 2A AND LINE 2B II
TABLE 0-2: LIST OF STATIONS OF THE PROPOSED CORRIDORS III
TABLE 0-3: PHPDT ON THE PROPOSED METRO CORRIDORS IV
TABLE 0-4: DAILY RIDERSHIP (IN LAKHS) ON THE PROPOSED METRO CORRIDORS IV
TABLE 0-5: SYSTEM SPECIFICATION CHARACTERISTICS V
TABLE 0-6: GEOMETRIC PARAMETERS V
TABLE 0-7: DESIGN VALUES VI
TABLE 0-8: VERTICAL CURVE PARAMETERS VI
TABLE 0-9: ALIGNMENT SUMMARY OF LINE 2A (VANAZ TO CHANDANI CHOWK) VII
TABLE 0-10: ALIGNMENT SUMMARY OF LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI) VII
TABLE 0-11: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2A (VANAZ TO CHANDANI CHOWK) ... VII
TABLE 0-12: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI) VIII
TABLE 0-13: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2A (VANAZ TO CHANDANI CHOWK) VIII
TABLE 0-14: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI) VIII
TABLE 0-15: STATION TYPES IX
TABLE 0-16: PROPOSED STATION TYPOLOGIES FOR LINE 2A AND LINE 2B IX
TABLE 0-17: FEEDER BUSES REQUIRED XI
TABLE 0-18: CONSIDERATIONS FOR CALCULATING RAKE REQUIREMENT XII
TABLE 0-19: COACH REQUIREMENT XIII
TABLE 0-20: RAKE REQUIREMENT XIII
TABLE 0-21: BROAD FEATURES OF ROLLING STOCK XV
TABLE 0-22: POWER DEMAND (MVA) FOR LINE 2, LINE 2A AND LINE 2B XVI
TABLE 0-23: POWER DEMAND (MVA) FOR LINE 2A AND LINE 2B XVI
TABLE 0-24: SOURCES OF POWER SUPPLY XVI
TABLE 0-25: APPLICABLE CODES AND STANDARDS FOR VAC SYSTEM DESIGN XVIII
TABLE 0-26: SUMMARY OF EXISTING VANAZ DEPOT XIX
TABLE 0-27: ABSTRACT OF CAPITAL COST (RS IN CRORE) FOR LINE 2A AND LINE 2B XXII
TABLE 0-28: REVENUE FROM VCF XXIV
TABLE 0-29: PROJECT COST DETAILS (RS IN CRORE) XXIV
TABLE 0-30: O&M AND REPLACEMENT COST XXV
TABLE 0-31: FUNDING PATTERN XXVII
TABLE 0-32: LOAN TERMS XXVII
TABLE 0-33: SENSITIVITY ANALYSIS XXVII
TABLE 0-34: ECONOMIC COST OF THE PROJECT XXVIII
TABLE 0-35: SUMMARY OF ECONOMIC BENEFITS (RS IN CRORES) XXVIII
TABLE 0-36: IMPLEMENTATION SCHEDULE OF THE PROJECT XXIX
TABLE 1-1: POPULATION TRENDS IN THE STUDY AREA (IN LAKHS) 1-8
TABLE 1-2: POPULATION FORECAST FOR PMR 1-10
TABLE 1-3: WORKING POPULATION IN PMC AND PCMC 1-11
TABLE 1-4: LAND USE OF PMC 1-14
TABLE 1-5: LAND USE OF PCMC 1-16
TABLE 1-6: PROPOSED LAND USE OF PMC FOR 2027 BY DP (2007 – 2027) 1-19
TABLE 1-7: PROPOSED LAND USE FOR THE EXTENDED AREAS OF PCMC 1-21
TABLE 2-1: GROWTH OF REGISTERED VEHICLES IN PUNE 2-1
TABLE 2-2: COMPOSITION OF REGISTERED VEHICLES AND GROWTH RATE IN PMC 2-4
TABLE 2-3: LIST OF PRIMARY TRAFFIC SURVEYS 2-10
TABLE 2-4: ACCIDENT TREND OF ROAD ACCIDENTS IN PUNE (2013-17) 2-12
TABLE 2-5: TOTAL NUMBER OF BUSES PLYING WITHIN PMR 2-14
TABLE 2-6: SALIENT FEATURES OF CITY BUS SERVICES IN PUNE 2-15
TABLE 2-7: PUNE BRTS CORRIDORS 2-17
TABLE 2-8: APPROVED PUNE METRO CORRIDORS 2-19

TABLE 2-9: LIST OF PAST STUDIES/REPORTS 2-20
TABLE 2-10: DETAILS OF THE PUNE METRO CORRIDORS 2-21
TABLE 2-11: DAILY RIDERSHIP UNDER VARIOUS SCENARIOS 2-22
TABLE 2-12: PEAK HOUR PEAK DIRECTION TRAFFIC (PHPDT) UNDER VARIOUS SCENARIOS 2-22
TABLE 2-13: DETAILS OF THE LINE 3 METRO CORRIDOR 2-23
TABLE 2-14: DAILY RIDERSHIP ON LINE 3 ON VARIOUS SCENARIOS 2-24
TABLE 2-15: MAXIMUM PHPDT ON LINE 3 ON VARIOUS SCENARIOS 2-24
TABLE 2-16: RECOMMENDED PUBLIC TRANSPORT NETWORK AND SYSTEM (2028) 2-25
TABLE 2-17: RECOMMENDED PUBLIC TRANSPORT NETWORK AND SYSTEM (2038) 2-25
TABLE 2-18: CATEGORY OF VEHICLES AND FLEET SIZES – DPR FOR METRO FEEDER CONNECTIVITY 2-31
TABLE 2-19: NUMBER OF PBS DOCKING LOCATIONS – DPR FOR NMT PLAN AND PBS SCHEME 2-33
TABLE 2-20: PT RIDERSHIP DEMAND ON THE HCMTR CORRIDOR 2-34
TABLE 2-21: DETAILS OF THE METRO CORRIDOR – DPR 2019 2-37
TABLE 2-22: TRAVEL DEMAND FORECAST FOR PUNE METRO PHASE 1 EXTENSIONS (NO. OF PASSENGERS) 2-37
TABLE 2-23: DETAILS OF THE METRO CORRIDOR 2-37
TABLE 2-24: TRAVEL DEMAND FORECAST FOR PUNE METRO PHASE 1 EXTENSIONS 2-37
TABLE 2-25: DETAILS OF THE METRO CORRIDOR 2-38
TABLE 2-26: DETAILS OF THE METRO CORRIDOR 2-39
TABLE 3-1: LIST OF PRIMARY TRAFFIC SURVEYS 3-5
TABLE 3-2: DISTRIBUTION OF ROAD LENGTH BY RIGHT OF WAY 3-11
TABLE 3-3: DISTRIBUTION OF ROAD LENGTH BY CARRIAGEWAY 3-11
TABLE 3-4: DISTRIBUTION OF ROAD LENGTH BY TYPE OF CARRIAGEWAY 3-11
TABLE 3-5: DISTRIBUTION OF AVAILABILITY OF SERVICE LANE 3-12
TABLE 3-6: DISTRIBUTION OF ROADS BY ABUTTING LAND USE 3-13
TABLE 3-7: DISTRIBUTION OF ROADS BY AVAILABILITY OF FOOTPATH WIDTH 3-14
TABLE 3-8: DISTRIBUTION OF ROADS BY AVAILABILITY OF FOOTPATH 3-14
TABLE 3-9: AVERAGE JOURNEY AND RUNNING SPEED ON MAJOR ROAD NETWORKS 3-15
TABLE 3-10: DISTRIBUTION OF ROAD LENGTH AS PER RUNNING AND JOURNEY SPEED 3-17
TABLE 3-11: DAILY TRAFFIC AT OUTER CORDON LOCATIONS 3-20
TABLE 3-12: MODE-WISE TRAFFIC VOLUME AT OUTER CORDON LOCATIONS 3-22
TABLE 3-13: COMPOSITION OF VEHICLES (IN %AGE) AT OUTER CORDON LOCATIONS 3-23
TABLE 3-14: HOURLY VARIATION OF TRAFFIC AT OUTER CORDON LOCATIONS 3-24
TABLE 3-15: TRAVEL PATTERN OF PASSENGER VEHICLE AT OUTER CORDON LOCATIONS 3-26
TABLE 3-16: TRIP PURPOSE BY MODE AT OUTER CORDON LOCATIONS 3-26
TABLE 3-17: MODE-WISE DISTRIBUTION OF TRIP FREQUENCY FOR PASSENGER VEHICLES AT CORDON LOCATIONS 3-27
TABLE 3-18: OCCUPANCY FACTOR OBTAINED AT EACH CORDON LOCATION 3-27
TABLE 3-19: VEHICULAR AND PASSENGER FLOW AT OUTER CORDON LOCATIONS 3-28
TABLE 3-20: LOCATION-WISE TRAFFIC AT SCREEN LINE LOCATIONS 3-30
TABLE 3-21: MODE-WISE TRAFFIC VOLUME AT SCREEN LINE LOCATIONS 3-31
TABLE 3-22: MODE-WISE COMPOSITION OF TRAFFIC AT SCREEN LINE LOCATIONS 3-32
TABLE 3-23: PEAK HOUR TRAFFIC AT SCREEN LINE LOCATIONS 3-34
TABLE 3-24: OCCUPANCY FACTORS AT SCREEN LINES IN PEAK PERIOD 3-35
TABLE 3-25: TOTAL PASSENGER VEHICLES AND PASSENGERS AT SCREEN LINES 3-36
TABLE 3-26: LOCATION-WISE TRAFFIC AT MID-BLOCK LOCATIONS 3-39
TABLE 3-27: MODE-WISE COMPOSITION OF TRAFFIC AT MID-BLOCK LOCATIONS 3-39
TABLE 3-28: PEAK HOUR TRAFFIC AT MID-BLOCK LOCATIONS 3-40
TABLE 3-29: PASSENGER FLOW AT MID-BLOCK LOCATIONS 3-41
TABLE 3-30: LOCATION-WISE TRAFFIC AT INTERSECTIONS 3-42
TABLE 3-31: MODE-WISE COMPOSITION OF TRAFFIC AT INTERSECTIONS 3-43
TABLE 3-32: PERCENTAGE OF MODE-WISE COMPOSITION OF TRAFFIC AT INTERSECTIONS 3-44
TABLE 3-33: PEAK HOUR TRAFFIC AT INTERSECTIONS 3-46
TABLE 3-34: DAILY AND PEAK HOUR PEDESTRIAN TRAFFIC AT SURVEY LOCATIONS 3-48
TABLE 3-35: BUS STOP BOARDING AND ALIGHTING COUNTS 3-49
TABLE 3-36: BUS PASSENGER ACCESS AND DISPERSAL MODES OF BOARDING AND ALIGHTING BUS PASSENGERS 3-53

TABLE 3-37: RAILWAY TERMINAL ENTRY AND EXIT COUNTS 3-56
TABLE 3-38: INTER-CITY BUS TERMINAL ENTRY AND EXIT COUNTS 3-57
TABLE 3-39: HOURLY VARIATION OF PASSENGER FLOWS AT RAILWAY TERMINALS 3-57
TABLE 3-40: HOURLY VARIATION OF PASSENGER FLOWS AT BUS TERMINALS 3-58
TABLE 3-41: DISTRIBUTION OF RAIL AND BUS PASSENGERS BY TRIP PURPOSE 3-60
TABLE 3-42: EQUIVALENT CAR SPACE (ECS) UNITS FOR VARIOUS MODES OF VEHICLES 3-62
TABLE 3-43: PARKING ACCUMULATION AT VARIOUS ON-STREET PARKING LOCATIONS 3-62
TABLE 3-44: PARKING DURATION AT VARIOUS ON-STREET PARKING LOCATIONS 3-63
TABLE 3-45: HH DETAILS 3-65
TABLE 3-46: DISTRIBUTION OF HOUSEHOLDS BY MONTHLY HOUSEHOLD INCOME 3-66
TABLE 3-47: DISTRIBUTION OF HOUSEHOLDS BY MONTHLY EXPENDITURE ON TRANSPORT 3-66
TABLE 3-48: DISTRIBUTION OF HOUSEHOLDS BY VEHICLE OWNERSHIP 3-66
TABLE 3-49: DISTRIBUTION OF HOUSEHOLDS BY EDUCATION LEVEL 3-67
TABLE 3-50: DISTRIBUTION OF HOUSEHOLDS BY OCCUPATION PROFILE 3-68
TABLE 3-51: MODE-WISE DISTRIBUTION OF TRIPS 3-68
TABLE 3-52: DISTRIBUTION OF TRIPS BY PURPOSE 3-69
TABLE 3-53 MODE-WISE TRIP LENGTH (KM) DETAILS 3-70
TABLE 3-54: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT OUTER CORDON LOCATIONS 3-71
TABLE 3-55: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT SCREEN LINE LOCATIONS 3-72
TABLE 3-56: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT MID-BLOCK LOCATIONS 3-73
TABLE 3-57: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT INTERSECTIONS 3-73
TABLE 3-58: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT TERMINALS 3-74
TABLE 3-59: PARAMETERS CONSIDERED FOR TRAVEL DEMAND MODEL 3-78
TABLE 3-60: SALIENT FEATURES OF CODED HIGHWAY NETWORK 3-80
TABLE 3-61: STUDY AREA POPULATION AND EMPLOYMENT FOR THE BASE YEAR 3-84
TABLE 3-62: SUMMARY OF BASE YEAR DAILY TRAVEL DEMAND 3-84
TABLE 3-63: TRIP GENERATION MODELS 3-86
TABLE 3-64: CALIBRATED DETERRENCE FUNCTION 3-87
TABLE 3-65: BASE YEAR OBSERVED AND MODELLED MODE SHARES (MOTORIZED MODES) 3-88
TABLE 3-66: COMPARISON OF OBSERVED AND MODELLED TRIPS 3-91
TABLE 3-67: COMPARISON OF OBSERVED AND MODELLED PASSENGERS AT BUS STOPS 3-93
TABLE 3-68: GROWTH DIRECTION BASED ON REAL ESTATE ACTIVITY 3-94
TABLE 3-69: POPULATION FORECAST 3-98
TABLE 3-70: EMPLOYMENT FORECAST 3-98
TABLE 3-71: GENERALIZED COST PARAMETERS 3-100
TABLE 3-72: UTILITY EQUATION FOR ALTERNATIVE MODES 3-100
TABLE 3-73: MODE-WISE PROJECTED TRAVEL DEMAND IN THE HORIZON YEARS (PEAK HOUR) 3-101
TABLE 3-74: PASSENGERS SHIFTED TO MASS TRANSIT 3-101
TABLE 3-75: DETAILS OF LINE 2A AND LINE 2B 3-102
TABLE 3-76: LIST OF STATIONS OF THE PROPOSED CORRIDORS 3-103
TABLE 3-77: MAX PHPDT ON LINE 2 IN HORIZON YEARS IN WITH AND WITHOUT PROJECT SCENARIOS 3-104
TABLE 3-78: DAILY RIDERSHIP ON LINE 2 IN HORIZON YEARS IN WITH AND WITHOUT PROJECT SCENARIOS 3-104
TABLE 3-79: PEAK HOUR SECTION LOADS ON THE PROPOSED CORRIDORS 3-105
TABLE 3-80: STATION-WISE DAILY BOARDINGS AND ALIGHTINGS ON THE PROPOSED CORRIDORS 3-115
TABLE 3-81: AVERAGE TRIP LENGTH ON THE PROPOSED CORRIDORS 3-121
TABLE 3-82: SUMMARY OF DAILY RIDERSHIP AND PHPDT ON LINE 2 3-122
TABLE 4-1: SELECTION CRITERIA OF MASS RAPID TRANSIT MODES 4-2
TABLE 4-2: BROAD PARAMETERS OF VARIOUS MASS TRANSIT SYSTEMS 4-5
TABLE 4-3: MAX PHPDT ON LINE 2 IN HORIZON YEARS 4-5
TABLE 4-4: SYSTEM SPECIFICATION CHARACTERISTICS 4-6
TABLE 5-1: ALIGNMENT OPTIONS FOR VANAZ TO CHANDANI CHOWK 5-3
TABLE 5-2: LIST OF GPS ALONG LINE 2A: VANAZ TO CHANDANI CHOWK 5-8
TABLE 5-3: LIST OF GPS ALONG LINE 2B: RAMWADI – WAGHOLI/VITTHALWADI 5-8
TABLE 5-4: LIST OF TBMS ALONG CORRIDOR 2B: RAMWADI – WAGHOLI/VITTHALWADI 5-9
TABLE 5-5: BOREHOLE LOCATIONS 5-15

TABLE 5-6: SUMMARY OF FIELD INVESTIGATION 5-17
TABLE 5-7: FOUNDATION PARAMETERS 5-19
TABLE 5-8: VALUES OF Ø FOR GRANULAR SOIL 5-21
TABLE 5-9: SAFE BEARING CAPACITY BASED ON ROCK MASS RATING (RMR) 5-21
TABLE 5-10: RECOMMENDATION FOR BEARING CAPACITY 5-24
TABLE 5-11: RECOMMENDATION FOR PILE CAPACITIES 5-25
TABLE 5-12: DESIGN CRITERIA 5-27
TABLE 5-13 DESIGN VALUES 5-28
TABLE 5-14: PROPOSED MRTS CORRIDORS FOR DPR PART-1 5-38
TABLE 5-15: PROPOSED STATIONS ON VANAZ – CHANDANI CHOWK CORRIDOR 5-40
TABLE 5-16: VERTICAL PROFILE (GRADE TABLE) – PROPOSED LINE 2A 5-40
TABLE 5-17: ABSTRACT OF VERTICAL GRADIENTS 5-41
TABLE 5-18: HORIZONTAL REPORT (CURVE SUMMARY) OF LINE 2A 5-42
TABLE 5-19: THE ABSTRACT AND DETAILS OF CURVES 5-43
TABLE 5-20: MAJOR ROADS ALONG LINE 2A 5-43
TABLE 5-21: MAJOR ROADS ACROSS LINE 2A 5-44
TABLE 5-22: PROPOSED STATIONS ON LINE 2B RAMWADI - WAGHOLI/VITTHALWADI CORRIDOR 5-49
TABLE 5-23: VERTICAL PROFILE OF RAMWADI - WAGHOLI/VITTHALWADI CORRIDOR 5-50
TABLE 5-24: ABSTRACT OF VERTICAL GRADIENTS 5-52
TABLE 5-25: DETAILS OF HORIZONTAL CURVES (CURVE SUMMARY) – LINE 2B 5-53
TABLE 5-26: ABSTRACT OF HORIZONTAL CURVES 5-56
TABLE 5-27: MAJOR ROADS ALONG LINE 2B 5-56
TABLE 5-28: MAJOR ROADS ACROSS LINE 2B 5-57
TABLE 5-29: ORGANISATIONS / DEPARTMENTS WITH CONCERNED UTILITY SERVICES IN PUNE 5-72
TABLE 5-30: DETAILS OF AFFECTED STORM WATER PIPE LINES IN LINE 2A (VANAZ – CHANDANI CHOWK) 5-73
TABLE 5-31: DETAILS OF AFFECTED STORM WATER PIPE LINES IN LINE 2B (RAMWADI-WAGHOLI/VITTHALWADI) 5-73
TABLE 5-32: DETAILS OF AFFECTED WATER PIPE LINES IN LINE 2A (VANAZ – CHANDANI CHOWK) 5-74
TABLE 5-33: DETAILS OF AFFECTED WATER PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI) 5-74
TABLE 5-34: DETAILS OF AFFECTED SEWER LINES IN LINE 2A (VANAZ – CHANDANI CHOWK) 5-75
TABLE 5-35 : DETAILS OF AFFECTED SEWER PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI) 5-75
TABLE 5-36: DETAILS OF AFFECTED GAS PIPE LINES IN LINE 2A (VANAZ – CHANDANI CHOWK) 5-77
TABLE 5-37: DETAILS OF AFFECTED GAS PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI) 5-77
TABLE 5-38: DETAILS OF AFFECTED OPTICAL FIBRES CABLE IN LINE 2A (VANAZ – CHANDANI CHOWK) ...5-77
TABLE 5-39: DETAILS OF AFFECTED OPTICAL FIBRES CABLE IN 2B (RAMWADI- WAGHOLI/VITTHALWADI) .5-78
TABLE 5-40: DETAILS OF AFFECTED HT LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI) 5-78
TABLE 5-41: SUMMARY OF AFFECTED UTILITIES 5-79
TABLE 5-42: DETAILS OF LAND TO BE ACQUIRED AT STATION LOCATIONS ON CORRIDOR 2A- VANAZ TO CHANDANI CHOWK 5-81
TABLE 5-43: DETAILS TEMPORARILY LAND REQUIREMENT AT STATION LOCATIONS ON CORRIDOR 2A- VANAZ TO CHANDANI CHOWK 5-81
TABLE 5-44: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2A (VANAZ TO CHANDANI CHOWK) 5-82
TABLE 5-45: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2A (VANAZ TO CHANDANI CHOWK) 5-83
TABLE 5-46: DETAILS OF LAND TO BE ACQUIRED AT STATION LOCATIONS ON CORRIDOR 2B- RAMWADI TO WAGHOLI/VITTHALWADI 5-84
TABLE 5-47: DETAILS TEMPORARILY LAND REQUIREMENT AT STATION LOCATIONS ON CORRIDOR 2B-RAMWADI- WAGHOLI/VITTHALWADI 5-85
TABLE 5-48: LAND REQUIREMENT FOR THE RSS 5-87
TABLE 5-49: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI) 5-89
TABLE 5-50: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI) 5-89
TABLE 5-51: AGENCY WISE LAND REQUIREMENT 5-90
TABLE 5-52: ESCALATED LAND COST FOR PROJECT 5-90
TABLE 6-1: LIST OF STATIONS FOR LINE 2A AND LINE 2B 6-1

TABLE 6-2: CORRIDOR DESCRIPTION....6-2
TABLE 6-3: LOS GUIDELINES FOR THE PEDESTRIANS....6-9
TABLE 6-4: STATION TYPES....6-15
TABLE 6-5: ROOM SCHEDULE FOR STATION TYPE A – CONCOURSE LEVEL....6-15
TABLE 6-6: ROOM SCHEDULE FOR TYPE B STATION....6-19
TABLE 6-7: ROOM SCHEDULE FOR TYPE C STATION....6-23
TABLE 6-8: PROPOSED STATION TYPOLOGIES FOR LINE 2A AND LINE 2B....6-27
TABLE 6-9: DETAILS OF KOTHRUD BUS DEPOT METRO STATION....6-28
TABLE 6-10: DETAILS OF CHANDANI CHOWK METRO STATION....6-30
TABLE 6-11: DETAILS OF VIMAN NAGAR METRO STATION....6-33
TABLE 6-12: DETAILS OF SOMNATH NAGAR METRO STATION....6-36
TABLE 6-13: DETAILS OF KHARADI BYPASS METRO STATION....6-39
TABLE 6-14: DETAILS OF TULAJA BHAVANI METRO STATION....6-41
TABLE 6-15: DETAILS OF UBALE NAGAR METRO STATION....6-43
TABLE 6-16: DETAILS OF UPPER KHARADI ROAD METRO STATION....6-45
TABLE 6-17: DETAILS OF WAGHESHWAR TEMPLE METRO STATION....6-47
TABLE 6-18: DETAILS OF WAGHOLI METRO STATION....6-49
TABLE 6-19: DETAILS OF SIDDHARTH NAGAR METRO STATION....6-51
TABLE 6-20: DETAILS OF BAKORI PHATA METRO STATION....6-53
TABLE 6-21: DETAILS OF VITTHALWADI METRO STATION....6-55
TABLE 6-22: DETAILS OF LAND IDENTIFIED FOR THE TOD....6-61
TABLE 7-1: COMPONENTS FOR MULTI-MODAL INTEGRATION....7-3
TABLE 7-2: INTEGRATION OF METRO STATION WITH OTHER MODES OF TRANSPORT....7-7
TABLE 7-3: FEEDER ROUTES....7-12
TABLE 7-4: FEEDER BUSES REQUIRED....7-16
TABLE 8-1: LINE 2 DETAILS (PHASE - 1)....8-4
TABLE 8-2: SUMMARY OF RIDERSHIP AND PHPDT....8-5
TABLE 8-3: DETAILS OF STATION BOARDING AND ALIGHTING....8-6
TABLE 8-4: SECTIONAL TRAFFIC DEMAND FOR HORIZON YEARS....8-8
TABLE 8-5: CAPACITY OF 3 CAR TRAIN AND 6 CAR TRAIN....8-10
TABLE 8-6: SUMMARY – PROPOSED CORRIDORS (2027)....8-13
TABLE 8-7: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2027)....8-13
TABLE 8-8: SUMMARY – PROPOSED CORRIDORS (2037)....8-15
TABLE 8-9: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2037)....8-15
TABLE 8-10: SUMMARY – PROPOSED CORRIDORS (2047)....8-17
TABLE 8-11: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2047)....8-17
TABLE 8-12: SUMMARY – PROPOSED CORRIDORS (2057)....8-19
TABLE 8-13: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2057)....8-19
TABLE 8-14: SECTION WISE PROPOSED HEADWAY....8-21
TABLE 8-15: HOURLY TRAIN OPERATION PLAN – 2027....8-23
TABLE 8-16: HOURLY TRAIN OPERATION PLAN – 2037....8-24
TABLE 8-17: HOURLY TRAIN OPERATION PLAN – 2047....8-25
TABLE 8-18: HOURLY TRAIN OPERATION PLAN - 2057....8-26
TABLE 8-19: VEHICLE KILOMETRE FOR THE PROPOSED CORRIDORS....8-27
TABLE 8-20: CONSIDERATIONS FOR CALCULATING RAKE REQUIREMENT....8-28
TABLE 8-21: COACH REQUIREMENT....8-28
TABLE 8-22: RAKE REQUIREMENT....8-29
TABLE 9-1: STANDARDS FOR SIGNALLING SYSTEM....9-4
TABLE 9-2: STANDARDS OF TELECOMMUNICATION SYSTEM....9-17
TABLE 10-1: STANDARDS TO BE ADOPTED FOR AFC SYSTEM....10-3
TABLE 10-2: STATION EQUIPMENT REQUIREMENT....10-5
TABLE 11-1: SIZE OF THE COACH....11-1
TABLE 11-2: CARRYING CAPACITY OF MEDIUM RAIL VEHICLES....11-1
TABLE 11-3: WEIGHT OF METRO RAIL VEHICLES (TONS) – 3 CAR TRAIN....11-2
TABLE 11-4: WEIGHT OF METRO RAIL VEHICLES (TONS) – 6 CAR TRAIN....11-2
TABLE 11-5: SALIENT FEATURES OF ROLLING STOCK FOR MRT'S PARAMETER DETAIL....11-11
TABLE 12-1: POWER DEMAND (MVA) FOR LINE 2, LINE 2A AND LINE 2B....12-2

TABLE 12-2: POWER DEMAND (MVA) FOR LINE 2A AND LINE 2B 12-2
TABLE 12-3: DETAILED POWER ESTIMATION FOR LINE 2A, LINE 2A AND LINE 2B 12-2
TABLE 12-4: SOURCES OF POWER SUPPLY 12-5
TABLE 13-1: CLASSES OF ENVIRONMENT 13-2
TABLE 13-2: REQUIREMENTS FOR CLASS A 13-2
TABLE 13-3: REQUIREMENTS FOR CLASS B 13-3
TABLE 13-4: REQUIREMENTS FOR CLASS C 13-3
TABLE 13-5: REQUIREMENTS FOR CLASS D 13-3
TABLE 13-6: APPLICABLE CODES AND STANDARDS FOR VAC SYSTEM DESIGN 13-4
TABLE 14-1: VANAZ DEPOT FACILITIES 14-1
TABLE 14-2: RAKE REQUIREMENT 14-4
TABLE 14-3: SUMMARY OF EXISTING VANAZ DEPOT 14-4
TABLE 14-4: MAINTENANCE SCHEDULE 14-9
TABLE 14-5: TRAIN CLEANING SCHEDULE 14-10
TABLE 14-6: LIST OF EQUIPMENT AT DEPOT-CUM-WORKSHOP 14-12
TABLE 15-1: DETAILS OF PROPOSED METRO CORRIDORS 15-1
TABLE 15-2: SUMMARY OF ENVIRONMENTAL LEGISLATION APPLICABLE FOR THIS PROJECT 15-4
TABLE 15-3: SCOPING MATRIX 15-6
TABLE 15-4: SOIL TYPES FOUND IN PUNE DISTRICT 15-10
TABLE 15-5: SOIL SAMPLING LOCATIONS 15-11
TABLE 15-6: RESULTS OF SOIL SAMPLING IN STUDY AREA 15-12
TABLE 15-7: GENERALISED STRATIGRAPHY OF PUNE DISTRICT 15-18
TABLE 15-8: SURFACE WATER FLOW CHARACTERISTICS IN PUNE DISTRICT 15-23
TABLE 15-9: MONITORING STATIONS FOR SURFACE WATER QUALITY ASSESSMENT 15-25
TABLE 15-10: MONITORING STATIONS FOR GROUND WATER QUALITY ASSESSMENT 15-26
TABLE 15-11: WATER QUALITY RESULTS FOR SURFACE WATER SAMPLES COLLECTED 15-26
TABLE 15-12: WATER QUALITY RESULTS FOR GROUNDWATER SAMPLES COLLECTED 15-28
TABLE 15-13: METEOROLOGICAL PARAMETERS MONITORED AT PROJECT SITE 15-30
TABLE 15-14: AVERAGE OF METEOROLOGICAL DATA FROM IMD PUNE (CLIMATOLOGICAL TABLES) 15-30
TABLE 15-15: AMBIENT AIR QUALITY MONITORING LOCATIONS FOR PHASE 1 EXTENSIONS 15-35
TABLE 15-16: TECHNIQUES USED FOR THE ANALYSIS OF AMBIENT AIR QUALITY PARAMETERS 15-36
TABLE 15-17: RESULTS OF ANALYSIS OF AMBIENT AIR MONITORING 15-37
TABLE 15-18: NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) 15-37
TABLE 15-19: NOISE MONITORING LOCATIONS 15-38
TABLE 15-20: TEST METHOD USED FOR AMBIENT NOISE LEVEL MONITORING 15-38
TABLE 15-21: RESULTS OF ANALYSIS OF AMBIENT NOISE LEVEL DATA AT VARIOUS LOCATIONS 15-38
TABLE 15-22: NATIONAL AMBIENT AIR QUALITY STANDARDS IN RESPECT OF NOISE 15-40
TABLE 15-23: GIRTH-WISE SUMMARY OF TREES LIKELY TO BE AFFECTED ALONG LINE 2A 15-41
TABLE 15-24: GIRTH-WISE SUMMARY OF TREES LIKELY TO BE AFFECTED ALONG LINE 2B 15-41
TABLE 15-25: REDUCTION IN DAILY VEHICLE KM (IN LAKHS) 15-42
TABLE 15-26: DAILY REDUCTION IN FUEL CONSUMPTION (DAILY LTS IN LAKHS) 15-43
TABLE 15-27: DAILY NET SAVINGS ON FUEL EXPENDITURE (IN RS. MILLION) 15-43
TABLE 15-28: POLLUTION REDUCTION (IN TONS/YEAR) 15-43
TABLE 15-29: GUIDELINE VIBRATION DAMAGE THRESHOLD CRITERIA 15-47
TABLE 15-30: VIBRATION SOURCE LEVELS FOR CONSTRUCTION EQUIPMENT 15-48
TABLE 15-31: SCREENING DISTANCES (IN METERS) FOR VIBRATION ASSESSMENT 15-48
TABLE 15-32: NOISE LEVELS (LDN) IN DB(A) AT DIFFERENT DISTANCES 15-49
TABLE 15-33: WATER REQUIREMENT 15-50
TABLE 15-34: POTENTIAL ENVIRONMENTAL IMPACT OF PROJECT 15-51
TABLE 15-35: ENVIRONMENTAL ASSESSMENT CHECKLIST FOR ENVIRONMENTAL & SOCIAL SENSITIVITY OF PROJECT 15-52
TABLE 15-36: ENVIRONMENTAL ASSESSMENT CHECKLIST FOR CLIMATE CHANGE & DISASTER RISK OF PROJECT 15-55
TABLE 15-37: SUMMARY OF ENVIRONMENTAL MANAGEMENT PLAN (EMP) INCLUDING MITIGATION MEASURES PROPOSED 15-59
TABLE 15-38: SUGGESTED ENVIRONMENTAL MONITORING PROGRAM (EMOP) 15-65
TABLE 15-39: DETAILS OF TENTATIVE EMP COSTING FOR LINE 2A 15-68

TABLE 15-40: DETAILS OF TENTATIVE EMP COSTING FOR LINE 2B 15-70
TABLE 15-41: DETAILS OF PERMANENT ACQUISITION SQ MTS FOR LINE 2A 15-73
TABLE 15-42: DETAILS OF PERMANENT ACQUISITION SQ MTS FOR LINE 2B 15-73
TABLE 15-43: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2A 15-73
TABLE 15-44: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2B 15-73
TABLE 15-45: AFFECTED STRUCTURES 15-74
TABLE 15-46: SOCIO-DEMOGRAPHICS OF PUNE DISTRICT 15-76
TABLE 15-47: LAND AND R&R COST 15-80
TABLE 17-1: DETAILS OF LINE 2A AND LINE 2B 17-2
TABLE 17-2: BASIS OF RATES 17-2
TABLE 17-3: DETAILED COST ESTIMATE FOR LINE 2A – VANAZ TO CHANDANI CHOWK 17-6
TABLE 17-4: DETAILED COST ESTIMATE FOR LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI 17-10
TABLE 17-5: TAXES AND DUTIES COMPONENTS 17-13
TABLE 17-6: SUMMARY OF TAXES AND DUTIES FOR LINE 2A AND LINE 2B 17-14
TABLE 17-7: DETAILS OF TAXES AND DUTIES FOR LINE 2A – VANAZ TO CHANDANI CHOWK 17-15
TABLE 17-8: DETAILS OF TAXES AND DUTIES FOR LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI 17-16
TABLE 17-9: ABSTRACT OF CAPITAL COST FOR LINE 2A AND LINE 2B 17-17
TABLE 17-10: COMPONENT WISE ESCALATION FOR LINE 2A 17-19
TABLE 17-11: COMPONENT WISE ESCALATION FOR LINE 2B 17-20
TABLE 17-12: STAFF COSTS 17-21
TABLE 17-13: MAINTENANCE COSTS 17-21
TABLE 17-14: ESTIMATED POWER CONSUMPTION (IN CR KWH) ON LINE 2A AND LINE 2B 17-22
TABLE 17-15:ADDITIONAL INVESTMENT AND REPLACEMENT COST 17-23
TABLE 17-16: SUMMARY OF THE O & M COSTS (RS IN CRORES) 17-23
TABLE 18-1: MAXIMUM PERMISSIBLE FSI - REGULATIONS 18-21
TABLE 18-2: CIRCLE RATES IN THE TOD ZONE 18-23
TABLE 18-3: IDENTIFIED VACANT LAND PARCELS 18-25
TABLE 18-4: POTENTIAL FOR PREMIUM FSI 18-27
TABLE 18-5: REVENUE CALCULATION FROM PREMIUM FSI 18-29
TABLE 18-6: REVENUE THROUGH ADDITIONAL PREMIUM FSI 18-30
TABLE 18-7: TOTAL REVENUE THROUGH ADDITIONAL STAMP DUTY IN THE CITY (RS CRORE) 18-31
TABLE 18-8: SHARE RATIO OF REVENUE FROM ADDITIONAL STAMP DUTY BETWEEN MAHA METRO AND PMRDA 18-33
TABLE 18-9: REVENUE COLLECTED FROM ADDITIONAL STAMP DUTY FOR MAHA METRO 18-35
TABLE 18-10: REVENUE COLLECTED FOR LINE 2A AND LINE 2B THROUGH STAMP DUTY 18-36
TABLE 18-11: CONSOLIDATED REVENUE FROM PREMIUM FSI AND STAMP DUTY FOR THE LINE 2 EXTENSIONS FROM THE YEAR 2023 TO YEAR 2057 18-37
TABLE 18-12: NON-FARE REVENUE ESTIMATION FOR THE PROJECT YEAR (RS. IN CRORE) 18-39
TABLE 18-13: PLOTS IDENTIFIED FOR PROPERTY DEVELOPMENT 18-41
TABLE 18-14: ESTIMATED BUILT UP FOR IDENTIFIED LAND PARCELS 18-41
TABLE 18-15: LAND VALUE 18-42
TABLE 19-1: PROJECT COST DETAILS (RS IN CRORE) 19-1
TABLE 19-2: ADDITIONAL INVESTMENT AND REPLACEMENT COST (RS IN CRORE) 19-2
TABLE 19-3: SUMMARY OF OPERATION AND MAINTENANCE EXPENSES(RS. IN CR.) 19-2
TABLE 19-4: RIDERSHIP (IN LAKHS) OF LINE 2A AND LINE 2B 19-4
TABLE 19-5: TRIP LENGTH DISTRIBUTION 19-4
TABLE 19-6: FARE STRUCTURE 19-4
TABLE 19-7: FARE REVENUE (RS IN CRORE) 19-5
TABLE 19-8: CASH FLOW FROM TOD 19-6
TABLE 19-9: NON FARE BOX REVENUE 19-7
TABLE 19-10: ADVERTISING AREA 19-7
TABLE 19-11: SUMMARY OF REVENUES (RS IN CRORES) 19-8
TABLE 19-12: ADVANTAGES AND LIMITATIONS - JOINT VENTURE MODEL BETWEEN GOI AND STATE GOVERNMENT 19-10
TABLE 19-13: FUNDING PATTERN 19-11

TABLE 19-14: REPAYMENT PHASING 19-11
TABLE 19-15: YEAR WISE BREAKUP OF PROJECT COST (RS. IN CR.) 19-12
TABLE 19-16: PROJECT FIRR.....19-13
TABLE 19-17: SENSITIVITY ANALYSIS 19-15
TABLE 19-18: RISK BASED COMPARISON OF PPP MODELS 19-20
TABLE 19-19: RISK BASED COMPARISON OF PPP MODELS 19-21
TABLE 20-1: ESTIMATED MODE WISE TRIPS IN 'WITH' AND 'WITHOUT' SCENARIO (PEAK HOUR TRIPS IN LAKHS) 20-2
TABLE 20-2: ESTIMATED MODE WISE TRIPS IN 'WITH' AND 'WITHOUT' SCENARIO (PERCENTAGE).....20-2
TABLE 20-3: FACTORS USED FOR ECONOMIC COSTS.....20-3
TABLE 20-4: ECONOMIC COST OF THE PROJECT.....20-3
TABLE 20-5: PHASING OF PROJECT COST 20-3
TABLE 20-6: ECONOMIC O & M COST 20-4
TABLE 20-7: ECONOMIC CAPITAL REPLACEMENT COST AND ADDITIONAL INVESTMENT (RS IN CRORES) ...20-4
TABLE 20-8: FACTORS USED FOR CONVERTING PROJECT BENEFITS IN TERMS OF ECONOMIC COST 20-6
TABLE 20-9: ASSUMPTIONS FOR VEHICLE OPERATING COST AND VALUE OF TIME 20-6
TABLE 20-10: MODE WISE OPERATIONAL PARAMETERS 20-6
TABLE 20-11: MODE WISE EMISSION FACTORS (GRAM/KM).....20-7
TABLE 20-12: COST OF ACCIDENTS 20-7
TABLE 20-13: SUMMARY OF ECONOMIC BENEFITS (RS IN CRORES).....20-8
TABLE 20-14: OUTCOMES OF ECONOMIC VIABILITY.....20-8
TABLE 20-15: SUMMARY OF SENSITIVITY ANALYSIS 20-9
TABLE 20-16: EIRR ANALYSIS (RS IN CRORE).....20-10
TABLE 21-1: IMPLEMENTATION SCHEDULE OF THE PROJECT.....21-1

ABBREVIATIONS

2W	Two-Wheeler
3W	Three-Wheeler
4W	Four-Wheeler
AAI	Airports Authority of India
AAR	Alternative Analysis Report
BAU	Business As Usual
BRTS	Bus Rapid Transit System
CAGR	Compound Annual Growth Rate
CGWB	Central Ground Water Board
CMP	Comprehensive Mobility Plan
DCB	Dehu Cantonment Board
DMIC	Delhi Mumbai Industrial Corridor
DPR	Detailed Project Report
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicle
G. O	Government Order
GDP	Gross Domestic Product
GoI	Government of India
GoM	Government of Maharashtra
HCMTR	High-Capacity Mass Transit Route
IT	Information Technology
KCB	Khadki Cantonment Board
Kms	Kilometres
LoA	Letter of Award
MA&UD	Municipal Administration and Urban Development
MAHA-METRO	Maharashtra Metro Rail Corporation Limited
MEMU	Main Line Electric Multiple Unit
MoHUA	Ministry of Housing and Urban Affairs
MRTS	Mass Rail Transit Systems
MSRTC	Maharashtra State Road Transport Corporation
NH	National Highway
PCB	Pune Cantonment Board

PMC	Pune Municipal Corporation
PCMC	Pimpri Chinchwad Municipal Corporation
PCTR	Per Capita Trip Rate
PMPML	Pune Mahanagar Parivahan Mahamandal Limited
PMR	Pune Metropolitan Region
PMRDA	Pune Metropolitan Region Development Authority
PPH	Persons Per Hectare
PPP	Public Private Partnership
RfP	Request for Proposal
SH	State Highway
TP Scheme	Town Planning Scheme
UA	Urban Agglomeration
UMTC	Urban Mass Transit Company
URDPFI	Urban and Regional Development Plans Formulation & Implementation
V/C	Volume/Capacity

PREFACE

As the largest urban conglomerates in Maharashtra, Pune and Pimpri Chinchwad Metropolitan Region (PMR) is second only to Mumbai Metropolitan Region (MMR). The two cities together are widely regarded as India's IT, education hub and also as the top automobile and manufacturing hub.

Pune and Pimpri Chinchwad have experienced rapid and tremendous growth in economic activities over the last two decades due to favourable socio-economic conditions and investment opportunities. Over these years, the jurisdiction of the two cities has been extended constantly to accommodate the urban agglomeration needs. The urbanization of this region is expected to receive further impetus in the next 30 years due to the region's ambitious development plan. Therefore, the region must get an appropriate urban transport infrastructure as a backbone to support such rapid growth and developments in new areas.

The Government of Maharashtra (GoM) is well aware of the urgent need to have in place a safe, reliable, efficient, affordable, commuter-friendly, and environmentally sustainable rapid public transport system covering, to the extent possible, the entire Pune Metropolitan Region.

At present, besides the city bus services, the conventional mode of public transport and the Bus Rapid Transit Systems (developed by PMC and PCMC) are operated by PMPML. Some suburban rail services connect Pune and Pimpri Chinchwad with Lonavala. Further, intra city and regional commute is being provided by MSRTC.

To address the increased travel demand of the urban theatre and to provide a high-capacity public transport system to its residents, the GoM, through the Maharashtra Metro Rail Corporation Limited (Maha-Metro), explored the options of high-capacity mass transit systems for major cities such as Pune, Nagpur, and Nashik.

For Pune Metro, the Phase-1 of the Metro project was approved by GoM in the year 2016 and construction is underway on three (03) Metro lines:

Line 1: Running from North to South from **PCMC to Swargate**. It is **17.8 km** long having **14 stations,** including 5 underground & 9 elevated stations.

Line 2: Running from West to East from **Vanaz to Ramwadi**. It is **15.7 km** long having **16 elevated stations.**

Line 3: Running from the North-West to the centre of the city, i.e., **from Hinjewadi to Civil Court**. It is **23.3 km** long having **23 elevated stations.**

Line 1 and Line 2 are being implemented by Maha-Metro. Line 3 is planned to be implemented as a PPP project under the aegis of PMRDA.

After experiencing fast growth, particularly in the out-growth areas of PMC and PCMC and the Chakan and Katraj areas, GoM has further entrusted Maha-Metro to develop extensions of Pune Metro Phase-1. It is noteworthy that part sections of the Pune Metro Line 1 and Line 2, which have been completed in all aspects, are operational for passenger traffic since March 2022.

Two corridors are planned as part of Pune Metro Phase-1 extension:

- **Corridor 1** extension from **PCMC to Nigdi in the North of Line 1 (~4.4 km)**
- **Corridor 2** extension from **Swargate to Katraj in the South of Line 1 (~5.5 km)**

Besides these extensions, the CMP–2018 has identified the need for mass transit systems on various other corridors. The expansion of Pune MRTS as Phase-2 was also deliberated upon in the meeting of PUMTA held on 19th December 2020. GoM, vide letter in the month of October 2021, instructed Maha-Metro to undertake an Alternative Analysis Study and Detailed Project Report for 82.5 kms corridors. Based on the existing metro corridor alignments and existing site conditions, the nomenclature for the above-mentioned mass transit corridors has been summarised in the Table below.

TABLE 0-1: NOMENCLATURE OF THE PUNE MRTS PHASE-2 CORRIDORS FOR THE PRESENT STUDY

DPR	Corridor Details	Approx. Length (km)	Status of the Draft DPR
DPR Phase-2 Part 1	Vanaz to Chandani Chowk (Line 2A)	01.50	DPR Approved by GoM (March 2024)
	Ramwadi to Wagholi/Vitthalwadi (Line 2B)	12.00	
DPR Phase-2 Part 2	Khadakwasla to Swargate	20.00	DPR Approved by PMC (August 2023) And Submitted to GoM
	Swargate to Hadapsar		
	Hadapsar to Kharadi		
	SNDT to Warje to Manik Baug	13.00	
DPR Phase-2 Part 3	PMC - High Capacity Mass Transit Route (HCMTR)	36.00	Draft DPR Submitted to PMC (September 2022)
	Total	**82.50**	

It is to note here that the Part 1, Part 2 and Part 3 of the DPR has been prepared and is at various stages of approval. Over and above DPR Part 4 has been prepared for Proposed Extensions of 17 km (Hadapsar to Loni Kalbhor and Hadapsar to Saswad Road) and submitted to PMC.

This DPR for Line 2A and Line 2B, has been finalised based on the comments/inputs received from Maha-Metro team, and the local administrative stakeholders and State Government. It would be pertinent to state that Maha-Metro appreciates the inputs and assistance received from PMC, PMRDA, and the Cantonment Boards for the preparation of this DPR. Maha-Metro has attempted to assess best possible integrated, seamless, forward looking transport infrastructure and solutions in the present exercise. Maha-Metro looks forward to an early response and comments from the stakeholders.

SALIENT FEATURES

Gauge (Standard) - 1435 mm

Maximum Operating Speed - 85 kmph

Route Length - Fully Elevated

S. N.	Name of the Corridor	Length (km)	No. of Stations
1	Line 2A – Vanaz to Chandani Chowk – Western Extension	1.12	2
2	Line 2B – Ramwadi to Wagholi/Vitthalwadi – Eastern Extension	11.63	11
	Total Length (km)	**12.75**	**13**

Peak Hour Peak Direction Traffic (PHPDT)

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Line 2 – With Project Scenario, i.e., Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	11,200	17,001	24,255	29,554
2	Line 2 – Without Project Scenario, i.e., Vanaz to Ramwadi	8,737	12,184	17,360	21,131

Daily Ridership (in Lakhs)

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Line 2 – With Project Scenario, i.e., Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	3.59	5.77	8.19	9.93
2	Line 2 – Without Project Scenario, i.e., Vanaz to Ramwadi	2.63	3.76	5.32	6.44

System Specification and Technology

Parameters		System Specifications
Gauge		1435 mm
Rolling Stock	Coach	Width – 2.9 m Height – 3.9 m Length - 20 to 22 m
	Train Composition	3-Car: DMC+TC+DMC 6-Car: DMC+TC+MC+MC+TC+DMC
	Coach Construction	Aluminium/Stainless Steel
	Axle Load	≤16T
	Max. Design Speed	95 kmph
	Max. Operating Speed	85 kmph

Parameters		System Specifications
	Max. Acceleration	1.0 m/s^2
	Max. Deceleration	1.1 m/s^2 (Service Brake) 1.3 m/s^2 (Emergency Brake)
	Jerk Limitation	0.75 m/s^3
	Braking System	Regenerative Braking
Traction System		25 kV ac OHE traction system
Propulsion System		3 phase drive system with VVVF control
Signalling System		Communication-Based Train Control System GoA 2 Level
Telecommunication System		IP based min 10G Wide Area Network
Fare Collection System		Computer-based AFC System – Contactless Smart Card & QR Ticket Type 1. EMV (Euro MasterCard Visa & RuPay) 2. PCI-DSS (Payment Card Industry/Data Security Standard) 3. ISO-IEC 14443

Permanent Land Requirement

Line 2A									
S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	**GoM (Govt)**	**PVT**	**Total**	**PMC**	**GoM (Govt)**	**PVT**	**Total**
1	Running Section				0.00				0.00
2	Stations	0.00	0.00	106.26	106.26	0.00	0.00	2.18	2.18
3	Depot				0.00				0.00
4	RSS/TSS				0.00				0.00
Total		**0.00**	**0.00**	**106.26**	**106.26**	**0.00**	**0.00**	**2.18**	**2.18**
Line 2B									
1	Running Section				0.00				0.00
2	Stations	190.35	0.00	520.99	711.34	0.19	0.00	8.54	8.73
3	Depot				0.00				0.00
4	RSS/TSS		5000.00		5000.00		5.27		5.27
Total		**190.35**	**5000.00**	**520.99**	**5711.34**	**0.19**	**5.27**	**8.54**	**14.00**

Temporary Land Requirement

Line 2A									
S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	**GoM (Govt)**	**PVT**	**Total**	**PMC**	**GoM (Govt)**	**PVT**	**Total**
1	Stations	0.00	0.00	115.98	115.98	0.00	0.00	0.10	0.10
2	Casting Yard		25000.00		25000.00		2.64		2.64
		0.00	**25000.00**	**115.98**	**25115.98**	**0.00**	**2.64**	**0.10**	**2.74**

Line 2B									
S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Stations	132.43	0.00	948.84	1081.27	0.02	0.00	0.57	0.59
2	Casting Yard		25000.00		25000.00		2.64		2.64
Total		**132.43**	**25000.00**	**948.84**	**26081.27**	**0.02**	**2.64**	**0.57**	**3.23**

Coach Requirement

Train Operation / Route	Time horizon Year	Headway (minutes)	Section / route length (km)	Train turnaround time (minutes)	Rake required (3-car)	Total Coaches Req.	With Traffic + Maint. Spare @10% and rounded up
Chandani Chowk - Vitthalwadi Route	2027	9.00	28.0	113.0	12.6	37.7	42
	2037	6.67	28.0	113.0	17.0	50.9	56
	2047	4.50	28.0	113.0	25.1	75.4	83
	2057	3.90	28.0	113.0	29.0	87.0	96
Vanaz - Vitthalwadi Route	2027	27.00	26.3	106.5	3.9	11.8	14
	2037	20.00	26.3	106.5	5.3	16.0	18
	2047	13.50	26.3	106.5	7.9	23.7	27
	2057	11.70	26.3	106.5	9.1	27.3	31
Vanaz - Ramwadi Route	2027	13.50	14.5	62.4	4.6	13.9	16
	2037	10.00	14.5	62.4	6.2	18.7	21
	2047	6.75	14.5	62.4	9.2	27.7	31
	2057	5.85	14.5	62.4	10.7	32.0	36

Rake Requirement

SN	Horizon Year	Total coaches	Total coaches req. (multiple of 3 to form 3-car train)	Coaches as per original EW Corr DPR	Coaches for Line 2A, 2B	Additional coaches for Line 2A, 2B in later years
1	2027	72	72	27*	45	
2	2037	95	96	48#	48	3
3	2047	141	141	48#	93	45
4	2057	163	165	48#	117	24

**This number is taken from DPR of Phase 1 and it also reflects the current procurement status for Phase 1 – Line 2 Corridor*

#There is no provision of rolling stock requirements in years beyond 2031 in DPR of Phase 1, therefore, the latest number of coaches are kept in later horizon years.

Signalling and Telecommunication

a) Type of Signalling – 'Continuous Automatic Train Control System' (CATC) based on 'Communication Based Train Control System' (CBTC) which includes Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS).

b) Telecommunication System Proposed –
- Optical Fiber Transmission System
- Telephone Exchange System
- Centralized Digital Recording System (CDRS)
- Mobile Radio Communication System (TETRA)
- Public Address System
- Centralized Master Clock System
- Passenger Information Display System
- Wi-Fi & CCTV Surveillance System
- Access Control and Intrusion Detection System
- Close Circuit Television
- Central Voice Recording System (CVRS)
- Supervisory Control and Data Acquisition (SCADA) System

Automatic Fare Collection

The AFC system proposed is a Computer based Automated fare collection System with AFC Gates and the system shall conform to the following standards as a minimum:

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

Power Supply and Traction

a) Voltage – 25 kV AC
b) Current Collection – Overhead Traction System

Corridor		Year Wise Power Demand (MvA)			
		2027	2037	2047	2057
Line 2A	Traction	0.35	0.47	0.70	0.81
	Auxiliary	0.8	0.8	0.8	0.8
Total		**1.15**	**1.27**	**1.50**	**1.61**
Line 2B	Traction	3.12	4.22	6.25	7.21
	Auxiliary	4.4	4.4	4.4	4.4
Total		**7.52**	**8.62**	**10.65**	**11.61**

Maintenance Facilities

The existing Vanaz depot is proposed to be suitably augmented to cater to Line 2A and Line 2B requirements to the extent possible. In future years (around 2047), a satellite depot is proposed to be built on the east extension side of the corridor.

Project Cost

Description	Estimated Cost (Rs. In Cr.)					
	Cost Excluding Land and R&R	Cost Including Land and R&R	Taxes & Duties	Cost with Taxes and without Land and R&R	Cost with Taxes and Land and R&R	Completion Cost
Line 2A	270.51	275.47	50.42	320.93	325.89	396.62
Line 2B	2167.83	2242.66	411.72	2579.55	2654.38	3229.62
Total	2438.34	2518.13	462.14	2900.48	2980.27	3626.24

Financial Indices

a) FIRR – 8.67%
b) EIRR – 17.93%

EXECUTIVE SUMMARY

0.1 PROFILE OF THE CITY

The study area considered for the current study is PMR. It is about 2,172 sq. km in area, covering the administrative areas of Pune Municipal Corporation (PMC), Pimpri Chinchwad Municipal Corporation (PCMC), Pune Cantonment Board (PCB), Khadki Cantonment Board (KCB), Dehu Cantonment Board (DCB), Municipal Councils, MIDC Areas, and Adjacent Villages.

The Pune and Pimpri Chinchwad Metropolitan Region (PMR) is widely regarded as the IT and education hub of India and counted as the top automobile and manufacturing hub in the country. Based on the 2011 Census of India, the population of the study area was 59.91 lakh. Based on the CMP for PMC and PCMC in PMR 2018, the same was estimated to be 77.5 lakh. Of the 77.5 lakh population, PMC contributes 37.13 lakh (i.e., ~47% of the total population of the study area), PCMC contributes 22.73 lakh (i.e. ~29%), the cantonment areas of Pune, Khadki and Dehu account for 2 lakhs, and the rest of PMR accounts for 15.62 lakh.

The growth of Pune and Pimpri Chinchwad in recent years has resulted in a rapid increase in commuter demands and a steep rise in the ownership and use of private vehicles. The number of registered vehicles in Pune has increased from 28.99 lakh in 2011 to 49.05 lakh in March 2017 to 64.72 lakh in March 2021. The average CAGR observed is 9.16%, which is 2.5 times higher than the annual population growth in the city and its surroundings.

Transportation infrastructure, however, has not kept pace with this increase in demand and is therefore highly inadequate. At present, the public transport system in Pune and Pimpri Chinchwad consists mainly of buses, a few services of the Bus Rapid Transit (BRT) system and, partial operation of the Pune Metro Phase 1 lines (i.e., five stations - PCMC to Phugewadi on Line 1 and five stations - Vanaz to Garware College on Line 2) and suburban rail. In a nutshell, in the absence of the augmentation of mass transit services, Pune may head towards an unsustainable urban transport scenario.

A Detailed Project Report for Phase 1, including Line 01 – PCMC to Swargate and Line 02 – Vanaz to Ramwadi, of the Pune Metro Rail Project had been prepared in 2015 by DMRC. The Detailed Project Report for Line 3, running from the north-west to the centre of the city, i.e., from Hinjewadi to Civil Court, which is 23.3-km long and has 23 stations, was prepared in 2016 by DMRC. Line 1 and Line 2 are being implemented by Maha-Metro. Line 3 is being implemented as a PPP project under the aegis of PMRDA. After experiencing fast growth, particularly in the out-growth areas of PMC and PCMC and the Chakan and Katraj areas, GoM has further entrusted Maha-Metro with developing extensions to Phase-1. The extension corridors, as part of Pune Metro Phase-2, includes

Corridor 1A, an extension from PCMC to Nigdi in the North of Line 1 (~4.4 km), and Corridor 2A, an extension from Swargate to Katraj in the South of Line 1 (~5.5 km)

0.2 EXISTING TRANSPORTATION SYSTEM

City-level transportation demand is catered predominantly by the city bus service, i.e., Pune Mahanagar Parivahan Mahamandal Limited (PMPML), the BRT system, a suburban railway between Pune and Lonavala, partial operation of the Pune Metro Phase-1 lines (i.e., five stations - PCMC to Phugewadi on Line 1 and five stations - Vanaz to Garware College on Line 2) and Intermediate Public Transport (IPT) modes like auto-rickshaws, shared autos, taxi services, and app-based taxi aggregators like Ola and Uber.

The fleet size of PMPML is about 1,500. The average life of the fleet is about eight years. On an average, 1,382 buses operate on 371 routes and 17,000 trips are made per day. PMPML carries around 10.65 lakh trip passengers daily (January 2017). The average number of passengers per bus per day is about 770.

Pune's BRTS is the first one in India. It is named as the "Rainbow BRT". The BRTS covers both PMC and PCMC. At present, five corridors spanning 61 km are operational. Rainbow BRT caters to 51 routes through 319 buses plying across the five corridors.

The Pune Suburban Railway between Pune and Lonavala is operated by Central Railways (CR). It runs on a double line electrified broad gauge section of 63.84 km. In a day, 18 trains are operated from Pune to Lonavala and five trains between Pune and Talegaon, with a minimum headway of 30 minutes.

0.3 TRAVEL DEMAND FORECAST

Line 2A and Line 2B, which are extensions to Line 2, i.e., Vanaz to Ramwadi of Phase-1, are coded in the travel demand model. The alignment, along with the location of stations, headways, and fare structure, were considered in estimating the ridership.

The details of Line 2A and Line 2B along with the list of Station are presented in the Table 0-1 below. The alignment and station locations are represented in Figure 0-1.

TABLE 0-1: DETAILS OF LINE 2A AND LINE 2B

S. N.	Name of the Corridor	Length (km)	No. of Stations
1	Line 2A – Vanaz to Chandani Chowk – Western Extension	1.12	2
2	Line 2B – Ramwadi to Wagholi/Vitthalwadi – Eastern Extension	11.63	11
	Total Length (km)	**12.75**	**13**

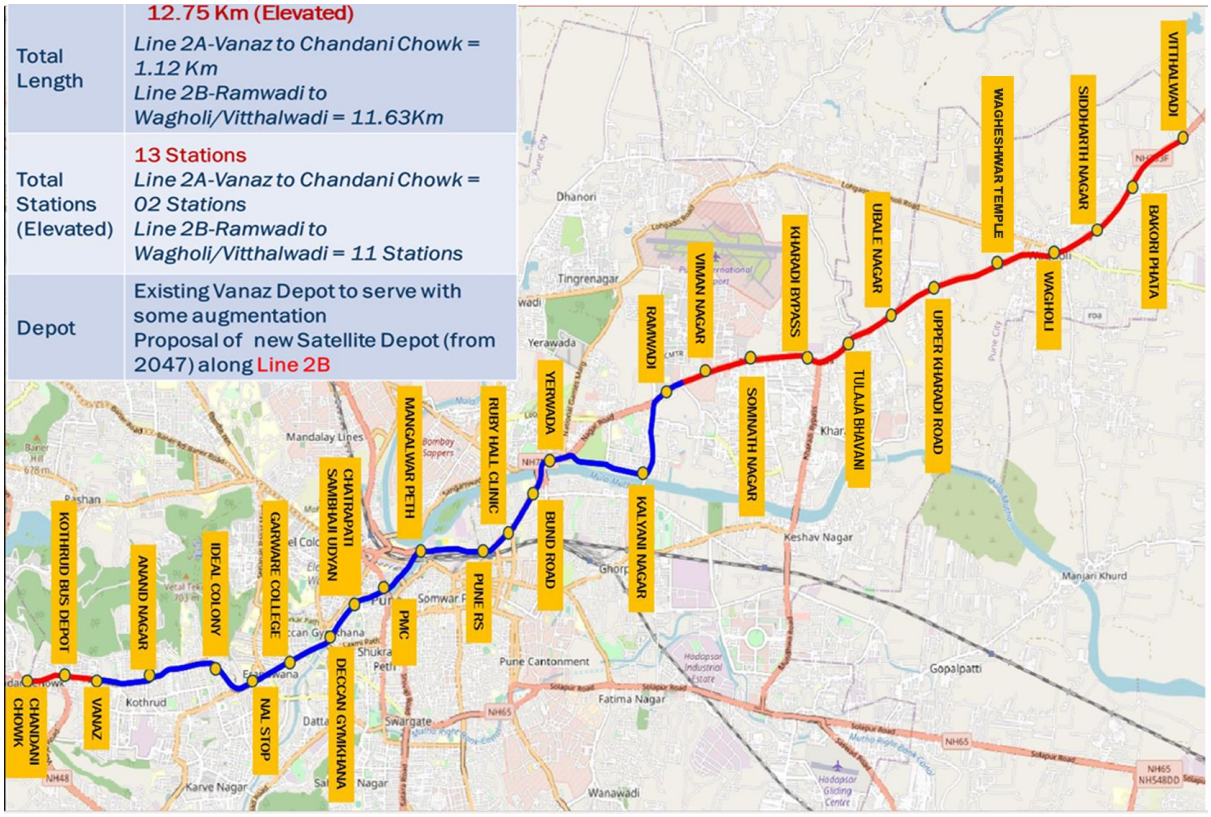


FIGURE 0-1: LINE 2A, LINE 2 & LINE 2B ALIGNMENT AND STATIONS

For the ridership estimations for the extension corridors under the scenarios mentioned in previous sections, the TAZs which were within a 1.5-km radius of the Line 2 corridor were connected to the system directly. The rest were assumed to be accessing the system via some sort of mode interchange.

TABLE 0-2: LIST OF STATIONS OF THE PROPOSED CORRIDORS

S.N.	Station Name	Phase	Chainage from Phase-1	Inter-station Distance (m)
Line 2A Vanaz to Chandani Chowk Corridor – Western Extension				
	Vanaz Station	Phase 1	-22	
	End of Phase 1	Phase 1	-757.929	
1	Kothrud Bus Depot Station	Phase 2	-964.048	942.048
2	Chandani Chowk Station	Phase 2	-1779.227	815.179
	Dead End	Phase 2	-1880	100.773
	Corridor Length (m)		**1122.071**	
Line 2B Ramwadi to Wagholi/Vitthalwadi Corridor – Eastern Extension				
	Ramwadi Station	Phase 1	14484.469	
	End of Phase 1	Phase 1	14991.719	
1	Viman Nagar Station	Phase 2	15464.618	980.149
2	Somnath Nagar Station	Phase 2	16700.889	1236.271
3	Kharadi Bypass Station	Phase 2	17601.929	901.04
4	Tulaja Bhavani Station	Phase 2	18843.676	1241.747
5	Ubale Nagar Station	Phase 2	19888.269	1044.593

S.N.	Station Name	Phase	Chainage from Phase-1	Inter-station Distance (m)
6	Upper Kharadi Road Station	Phase 2	20930.634	1042.365
7	Wagheshwar Temple Station	Phase 2	22312.06	1381.426
8	Wagholi Station	Phase 2	23269.317	957.257
9	Siddharth Nagar Station	Phase 2	24087.658	818.341
10	Bakori Phata Station	Phase 2	24948.286	860.628
11	Vitthalwadi Station	Phase 2	26232.966	1284.68
	Dead End	Phase 2	26625.00	392.034
	Corridor Length (m)		**11633.281**	

The travel demand model has been prepared for the project using PTV VISUM 2022 (software). The calibrated/validated travel demand model has been used to forecast the horizon year demand forecast on all the proposed MRTS corridors for the horizon years under the planned growth scenarios. Data from various secondary sources and primary surveys has been used to build the travel demand model for the project.

The Peak Hour Peak Direction Traffic (PHPDT) and daily ridership for the proposed metro corridors with and without extensions (Line 2A and Line 2B) for the horizon years 2027, 2037, 2047 and 2057 have been estimated and presented in Table 0-3 and Table 0-4.

TABLE 0-3: PHPDT ON THE PROPOSED METRO CORRIDORS

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Line 2 – With Project Scenario, i.e., Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	11,200	17,001	24,255	29,554
2	Line 2 – Without Project Scenario, i.e., Vanaz to Ramwadi	8,737	12,184	17,360	21,131

TABLE 0-4: DAILY RIDERSHIP (IN LAKHS) ON THE PROPOSED METRO CORRIDORS

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Line 2 – With Project Scenario, i.e., Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	3.59	5.77	8.19	9.93
2	Line 2 – Without Project Scenario, i.e., Vanaz to Ramwadi	2.63	3.76	5.32	6.44

0.4 SYSTEM AND TECHNOLOGY SELECTION

The system specification parameters for the proposed metro corridors are as mentioned in Table 0-5.

TABLE 0-5: SYSTEM SPECIFICATION CHARACTERISTICS

Parameters		System Specifications
Gauge		1435 mm
Rolling Stock	Coach	Width – 2.9 m Height – 3.9 m Length - 20 to 22 m
	Train Composition	3-Car: DMC+TC+DMC 6-Car: DMC+TC+MC+MC+TC+DMC
	Coach Construction	Aluminium/Stainless Steel
	Axle Load	≤16T
	Max. Design Speed	95 kmph
	Max. Operating Speed	85 kmph
	Max. Acceleration	1.0 m/s^2
	Max. Deceleration	1.1 m/s^2 (Service Brake) 1.3 m/s^2 (Emergency Brake)
	Jerk Limitation	0.75 m/s^3
	Braking System	Regenerative Braking
Traction System		25 kV ac OHE traction system
Propulsion System		3 phase drive system with VVVF control
Signalling System		Communication-Based Train Control System GoA 2 Level
Telecommunication System		IP based min 10G Wide Area Network
Fare Collection System		Computer-based AFC System – Contactless Smart Card & QR Ticket Type 1. EMV (Euro MasterCard Visa & RuPay) 2. PCI-DSS (Payment Card Industry/Data Security Standard) 3. ISO-IEC 14443

0.5 CIVIL ENGINEERING AND ALIGNMENT

0.5.1 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.

TABLE 0-6: GEOMETRIC PARAMETERS

S.N.	Criteria	Dimension
1	Gauge	1435 mm
2	Maximum Design Speed	95 kmph
3	Maximum Operating Speed	85 kmph
4	Maximum Axle Load	16T
5	Traction System	25 kV AC (OHE)

HORIZONTAL CURVES

TABLE 0-7: DESIGN VALUES

S.No	Design Values	Desirable Limit	Exceptional Limit
1	Maximum permissible cant (Ca)	110 mm	NA
2	Maximum permissible cant deficiency (Cd)	85 mm	NA
3	Cant Gradient	≤1:750	≤1:440
4	Rate of change of cant	35 mm/s	56mm/s
5	Rate of change of cant deficiency	35 mm/s	56mm/s
6	Minimum horizontal curve radius on mainline (elevated)	190 m	120 m
7	Minimum horizontal curve radius on mainline (underground)	300 m	200m
8	Minimum length of element (circular curve, tangent, transition curve)	20m or 0m	NA

VERTICAL CURVE

TABLE 0-8: VERTICAL CURVE PARAMETERS

Parameter	Vertical Curve
Desirable Radius on Mainline	2500 m
Absolute Minimum Radius on Mainline	1500 m
Desirable Minimum Length of Vertical Curve	50 m
Absolute Minimum Length of Vertical Curve	25 m

0.5.2 ENGINEERING SURVEY

Topographical Survey

Topographical surveys for the Pune Metro Phase-2 Corridors were done with DGPS and Total Station.

Geotechnical Investigations

In total, 13 Bore Holes (BHs) have been drilled, between 5-15 m in depth, all along the length of the proposed Metro alignment for Line 2A and Line 2B. For all viaduct locations, since heavy loads are expected, shallow foundations are ruled out; either driven or bored cast in-situ piles, preferably bored ones, will have to be provided.

Since the proposed site is situated in Seismic Zone III of the Seismic Zone Map of India, suitable seismic coefficient commensurate to Seismic Zone III (IS: 1893) should be adopted in the design of the structures.

0.5.3 ROUTE ALIGNMENT

Line 2A: Vanaz – Chandani Chowk

The proposed alignment of Line 2A starts from the dead end of Phase 1, Vanaz and heads in the west up to Chandani Chowk. The total length of the corridor is 1122.07m. Two (02) stations have been proposed in this Corridor.

TABLE 0-9: ALIGNMENT SUMMARY OF LINE 2A (VANAZ TO CHANDANI CHOWK)

Alignment Type	From (m)	To (m)	Length (m)
Elevated	-757.929	-1880	1122.071

Line 2B: Ramwadi – Wagholi/Vitthalwadi

The proposed alignment of Line 2B starts from the dead end of Phase 1, Ramwadi and heads in the east up to Wagholi/Vitthalwadi. The total length of the corridor is 11633.281m. Eleven (11) stations have been proposed in Line 2B.

TABLE 0-10: ALIGNMENT SUMMARY OF LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI)

Alignment Type	From (m)	To (m)	Length (m)
Elevated	14991.719	26625.00	11633.281

0.5.4 LAND REQUIREMENT

The summary of land requirement for the project is presented below.

Permanent Land Requirement

TABLE 0-11: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2A (VANAZ TO CHANDANI CHOWK)

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Running Section								
2	Stations			106.26	106.26			2.18	2.18
3	Depot								
4	RSS/TSS								
Total				**106.26**	**106.26**			**2.18**	**2.18**

TABLE 0-12: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI)

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Running Section				0.00				0.00
2	Stations	190.35	0.00	520.99	711.34	0.19	0.00	8.54	8.73
3	Depot				0.00				0.00
4	RSS/TSS		5000.00		5000.00		5.27		5.27
Total		**190.35**	**5000.00**	**520.99**	**5711.34**	**0.19**	**5.27**	**8.54**	**14.00**

Temporary Land Requirement

TABLE 0-13: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2A (VANAZ TO CHANDANI CHOWK)

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Stations	0.00	0.00	115.98	115.98	0.00	0.00	0.10	0.10
2	Casting Yard		25000.00		25000.00		2.64		2.64
		0.00	**25000.00**	**115.98**	**25115.98**	**0.00**	**2.64**	**0.10**	**2.74**

TABLE 0-14: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI)

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Stations	132.43	0.00	948.84	1081.27	0.02	0.00	0.57	0.59
2	Casting Yard		25000.00		25000.00		2.64		2.64
		132.43	**25000.00**	**948.84**	**26081.27**	**0.02**	**2.64**	**0.57**	**3.23**

0.6 STATION PLANNING

The stations have been planned based on the following parameters:

A. Peak hour traffic load for each station
B. 6-car trains
C. The total evacuation time for the movement of all passengers in an emergency from the platform level to the landing at the point of safety not exceeding 5.5 minutes for an open station (as per NBC 2016)
D. Compliance with 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 (revised in 2013 by Ministry of Home and Urban Affairs) and IRC SP 117-2018.

Three station typologies have been planned for the stations in Line 2A and Line 2B. Details of these typologies have been presented in Table 0-15.

TABLE 0-15: STATION TYPES

Station Type	Platform Type	Concourse	Platform
Type A Station	Island Platform with Short Concourse	62.7 X 17 m	140 x 17 m
Type B Station	Side Platform (Full Concourse)	140 x 21 m	140 x 21 m
Type C Station	Interchange Station	140 X 26 m	140 X 26 m

The typology proposed for each station is presented in Table 0-16.

TABLE 0-16: PROPOSED STATION TYPOLOGIES FOR LINE 2A AND LINE 2B

S.No	Station Name	Chainage	Interstation Distance (m)	No. of Entry/Exit	Station Typology#
Pune Metro Line 2A (Vanaz to Chandani Chowk)					
1	Kothrud Bus Depot	-964.048	942.048*	4	Type B
2	Chandani Chowk•	-1779.227	815.179	5	Type B
Pune Metro Line 2B (Ramwadi to Wagholi/Vitthalwadi)					
1	Viman Nagar	15464.618	980.149**	4	Type B
2	Somnath Nagar	16700.889	1236.271	2	Type A
3	Kharadi Bypass•	17601.929	901.04	5	Type C
4	Tulaja Bhavani	18843.676	1241.747	2	Type A
5	Ubale Nagar	19888.269	1044.593	2	Type A
6	Upper Kharadi Road	20930.634	1042.365	2	Type A
7	Wagheshwar Temple	22312.06	1381.426	4	Type B
8	Wagholi	23269.317	957.257	4	Type B
9	Siddharth Nagar	24087.658	818.341	2	Type A
10	Bakori Phata	24948.286	860.628	2	Type A
11	Vitthalwadi	26232.966	1284.68	4	Type B

*From Vanaz Metro Station of Phase 1
**From Ramwadi Metro Station of Phase 1
Type A- Island Platform Short Concourse
Type B- Side Platform full concourse
Type C- Interchange Station
• Includes Entry-Exit structures of FOB Connected to Station Concourse. Two (02) for Chandani Chowk and One (01) for Kharadi Bypass

0.7 INTERMODAL INTEGRATION

The Metro Rail Policy was formulated by Ministry of Housing and Urban Affairs (MoHUA) in 2017, emphasises on provision infrastructure for integration of all Public Transport (PT), Intermediate Public Transport (IPT) and private modes in DPR's for the metro systems. This connectivity would provide better accessibility to the Metro Station by walk, cycle,

Auto-rickshaws and bus services. Multimodal integration is planned to provide first and last mile connectivity for commuters.

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

- Minimizing pedestrian/vehicle conflicts and effective passenger interchange with feeder modes. Proper design of circulation area adjoining the station building to ensure rapid/ efficient dispersal of the passengers and avoiding conflicts between pedestrian and vehicular traffic.
- Pedestrians require a convenient and safe access to the proposed metro station. For smooth movement of pedestrians, the footpaths in the metro station primary influence zone/ catchment area will be considered to be upgraded to desired level of comfort and also proposed new footpaths in the stations vicinity areas.
- High quality pedestrian access will be accomplished through design factors such as directness and connectivity, ease of movement, safety and security. The vendors if any on the footpaths shall be removed and desired accessibility to metro stations will be provided. The facilities (footpaths/ walkways) will be directly integrated with the metro system.
- Facilitating passenger interchange with other transit systems: Dedicated linkages proposed like skywalks, covered walkways etc. which will reduce the passenger travel time and pedestrian load on the roads.
- Circulating area with adequate parking space, designated space for embarking and disembarking for vehicular-traffic (pick-drop zones) and feeder modes like Buses, IPT's and NMT.
- Availability of total carriageway and footpath widths required to cater to the proposed traffic volumes to be augmented through strengthening of road shoulder areas and relocation of vendors/hawkers, on-street parking and all encroachments from the service/access roads.

The planning of seamless transport integration facilities at the influence zones of various metro stations is of utmost importance. Feeder services to the proposed metro network will be essential to provide convenient and quick transfer of passengers from one mode of transport to another.

Various modes of transportation like feeder buses, auto rickshaw/taxi and bicycles can provide first mile as well as last mile connectivity other than walking to the metro station. For catchment area of about 0.5-1 km from the proposed network, commuter can easily access it by walk. People residing in the next 1 km can reach the station by cycles, 2-Wheeler and auto-rickshaws. Areas beyond the 2 km catchment will require regular feeder bus services to reach the Metro station.

TABLE 0-17: FEEDER BUSES REQUIRED

S.N.	Total No. of Feeder Routes	Length (km)	Fleet Required			
			2027	2037	2047	2057
Feeder Buses	11	58.5	72	94	122	150

In addition to the feeder buses, first- and last-mile connectivity is proposed through the bike sharing schemes that are being implemented under Phase-1 of Pune Metro.

0.8 TRAIN OPERATION PLAN

The salient features of the train operation plan are as given below;

- Running of services for 19 hours in a day (05:00 hrs to 24:00 hrs) with a maximum station dwell time of 30 seconds, which may be further optimized as per ridership
- Make up time of 5-10% with 8-12% coasting
- Adequate operational speed - 32 km/hr for end-to-end running on the proposed corridor

To meet the projected traffic demand, the possibility of running trains with different headways has been examined.

Accordingly, for Line 2A and Line 2B, 3 Car trains are proposed initially and as the traffic demand increase beyond 20000-25000 PHPDT, 6 Car trains can be deployed.

The trains are proposed to run on the following routes of the proposed corridors:

- **Route 1 (Chandani Chowk to Vitthalwadi):** This constitutes Line 2, Line 2A and Line 2B. 50% of trains services are proposed to be operated on this route.
- **Route 2 (Vanaz to Vitthalwadi):** This constitutes Line 2 and Line 2A. 17% of trains services are proposed to be operated on this route.
- **Route 3 (Vanaz to Ramwadi):** This comprises Line 2 of Phase-1. 33% of train services are proposed to be operated on this route.

The above proposition will achieve 100% train services in Vanaz to Ramwadi section, 67% train services in Ramwadi to Vitthalwadi section and 50% train services in Chandani Chowk to Vanaz section. This approach will optimize rolling stock requirement as well as operation cost savings, and yet meeting the traffic demand well.

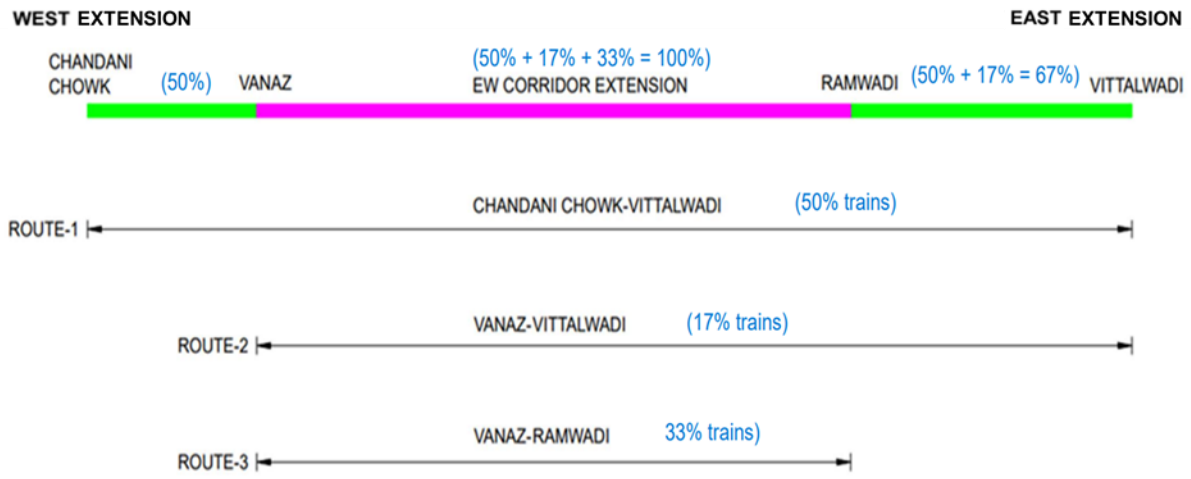


FIGURE 0-2: CONCEPTUAL OPERATION PLAN

The rake requirement is calculated based on the train formation and headway and the details are provided in Table 0-18.

TABLE 0-18: CONSIDERATIONS FOR CALCULATING RAKE REQUIREMENT

Route Description	Length (km)	No of stations	Avg speed (kmph)	Round trip length (km) [2 x section length]	Reversal Time (both ends) (minutes)	Train turnaround time (minutes)
Chandani Chowk – Vitthalwadi	28.0	29	32	56.0	8	113.0
Vanaz – Vitthalwadi	26.3	27	32	52.5	8	106.5
Vanaz – Ramwadi	14.5	16	32	29.0	8	62.4

Note: Reversal time of 4 minutes at end considered in view of availability of front crossover at terminal/intermediate reversal stations. The requirement of coaches is calculated based on the following assumptions:

- Coach requirement has been calculated based on headway during peak hours;
- 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;

TABLE 0-19: COACH REQUIREMENT

Train Operation / Route	Time horizon Year	Headway (minutes)	Section / route length (km)	Train turnaround time (minutes)	Rake required (3-car)	Total Coaches Req.	With Traffic + Maint. Spare @10% and rounded up
Chandani Chowk - Vitthalwadi Route	2027	9.00	28.0	113.0	12.6	37.7	42
	2037	6.67	28.0	113.0	17.0	50.9	56
	2047	4.50	28.0	113.0	25.1	75.4	83
	2057	3.90	28.0	113.0	29.0	87.0	96
Vanaz - Vitthalwadi Route	2027	27.00	26.3	106.5	3.9	11.8	14
	2037	20.00	26.3	106.5	5.3	16.0	18
	2047	13.50	26.3	106.5	7.9	23.7	27
	2057	11.70	26.3	106.5	9.1	27.3	31
Vanaz - Ramwadi Route	2027	13.50	14.5	62.4	4.6	13.9	16
	2037	10.00	14.5	62.4	6.2	18.7	21
	2047	6.75	14.5	62.4	9.2	27.7	31
	2057	5.85	14.5	62.4	10.7	32.0	36

TABLE 0-20: RAKE REQUIREMENT

SN	Horizon Year	Total coaches	Total coaches req. (multiple of 3 to form 3-car train)	Coaches as per original EW Corr DPR	Coaches for Line 2A, 2B	Additional coaches for Line 2A, 2B in later years
1	2027	72	72	27*	45	
2	2037	95	96	48#	48	3
3	2047	141	141	48#	93	45
4	2057	163	165	48#	117	24

**This number is taken from DPR of Phase 1 and it also reflects the current procurement status for Phase 1 – Line 2 Corridor*

#There is no provision of rolling stock requirements in years beyond 2031 in DPR of Phase 1, therefore, the latest number of coaches are kept in later horizon years.

0.9 SIGNALING AND TELECOMMUNICATIONS

0.9.1 SIGNALING SYSTEM

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

Since the existing metro corridor of Phase-1 is equipped with the CBTC system, the extension of this line will necessarily require the same system.

Considering the above, the CBTC system is recommended for Line 2A and Line 2B of the Pune Metro Rail Project.

0.9.2 TELECOMMUNICATION SYSTEM

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

- Optical Fiber Transmission System
- Telephone Exchange System
- Centralized Digital Recording System (CDRS)
- Mobile Radio Communication System (TETRA)
- Public Address System
- Centralized Master Clock System
- Passenger Information Display System
- Wi-Fi
- CCTV Surveillance System
- Access Control and Intrusion Detection System
- Close Circuit Television
- Central Voice Recording System (CVRS)
- Supervisory Control and Data Acquisition (SCADA) System

0.9.3 PLATFORM SCREEN DOORS

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

0.10 FARE COLLECTION SYSTEM

It is proposed to provide a computer-based automatic fare collection system (AFC) with contactless smart token/card type ticketing which offers lower lifecycle costs. The objective is also to ensure easy integration and interoperability of the new system with the one already proposed/implemented.

The system shall be capable of open loop transactions as well to further integrate the mobility solution with the advancements in technology and allow for a 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) and RuPay
2. PCI-DSS (Payment card Industry/Data Security Standard)
3. ISO-IEC 14443

The AFC system for the proposed metro corridors shall be of contactless smart card and QR ticket type. For multiple journeys, stored value smart cards shall be available, and for single journeys, QR tickets shall be available, which can be tapped at the exit gates at the time of exit validation. Not only smart card, National Common Mobility Card, QR code on phone, and paper QR ticket, even the mobile-based Near Field Connectivity (NFC) wallet/card linked payments would have to be catered for Automatic Fare Collection at metro stations.

0.11 ROLLING STOCKS

The rolling stock proposed for the Line 2A and Line 2B corridors will be similar to that of the Phase-1. The broad features are presented in Table 0-21.

TABLE 0-21: BROAD FEATURES OF ROLLING STOCK

S.N.	Parameter	Rolling Stock
1	Basic Unit	3-Car basic unit: 2 DMC and 1 TC. Every coach should be fully interchangeable with any other coach of the same type.
2	Train Composition	3-Car: DMC +TC +DMC 6-Car: DMC +TC +MC +MC +TC +DMC
3	Coach Dimensions	L=21.64 m,W=2.9 m,H=3.9 m
4	Coach Construction	Light-weight stainless steel/aluminium body
5	Axle Load	≤16T
6	Braking System	Regenerative Braking
7	Propulsion System	3-phase drive system with VVVF control
8	Type of Traction Supply	25 kV AC OHE system

0.12 POWER SUPPLY SYSTEM

Phase-1 of the Pune Metro has been operational with 25 kV AC overhead traction. Thus, in order to maintain the uniformity of the system, it is proposed that 25 kV AC traction shall be adopted for the proposed corridors. The 25 kV AC traction system offers several advantages like lower line losses and more regeneration.

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 2027, 2037, 2047 and 2057 – 400 kVA load is considered;
- Underground station load – not applicable;
- Depot auxiliary load – only some augmentation is needed.

Keeping in view the train operation plan, the demand of auxiliary and traction power requirements projected for the years 2027, 2037, 2047 and 2057 are summarized in the Table 0-22.

TABLE 0-22: POWER DEMAND (MVA) FOR LINE 2, LINE 2A AND LINE 2B

Corridor		Year Wise Demand			
		2027	2037	2047	2057
Line 2, Line 2A and Line 2B	Traction	9.3	12.5	18.5	21.4
	Auxiliary	14.0	14.0	15.1	15.1
Total		**23.2**	**26.4**	**33.6**	**36.5**

The apportioned demand for Line 2A and Line 2B is given in Table 0-23.

TABLE 0-23: POWER DEMAND (MVA) FOR LINE 2A AND LINE 2B

Corridor		Year Wise Demand			
		2027	2037	2047	2057
Line 2A	Traction	0.35	0.47	0.70	0.81
	Auxiliary	0.8	0.8	0.8	0.8
Total		**1.15**	**1.27**	**1.50**	**1.61**
Line 2B	Traction	3.12	4.22	6.25	7.21
	Auxiliary	4.4	4.4	4.4	4.4
Total		**7.52**	**8.62**	**10.65**	**11.61**

0.12.1 SOURCES OF POWER SUPPLY

The high voltage power supply network of Pune city has only 220 kV and 132 kV network on the periphery of the city to cater to various types of power supply demand in the vicinity of the proposed corridor. 220/132 kV substations are generally away from the alignment and, therefore, it involves substantial cable length and laying costs.

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, one new RSS near Kharadi bypass along Line 2B is proposed. Thus, there will be two RSSs for the proposed corridors viz. (1) Vanaz RSS at depot; and (2) along Line 2B.

A Neutral Section will have to be provided at/near Ramwadi to segregate traction power supplies of the two TSSs. The sources of power supply near the Phase 2 corridors of Pune MRTS, which include the proposed corridor is given in Table 0-24.

TABLE 0-24: SOURCES OF POWER SUPPLY

Corridor	GSS Name	Corridor start from	Distance in meter – along the corridor	Distance in meter – from the alignment
Ramwadi – Wagholi	132kV Kharadi GSS	Ramwadi	2700	470

Corridor	GSS Name	Corridor start from	Distance in meter – along the corridor	Distance in meter – from the alignment
Swargate – Khadakwasla	220kV Nanded city GSS	Swargate	8650	760
	220kV Parvati GSS	Swargate	2900	200
Hadapsar – Kharadi	220kV Magarpatta GSS	Kharadi	4400	450
Swargate - Hadapsar	132kV Rasta Peth GSS	Swargate	1300	2100

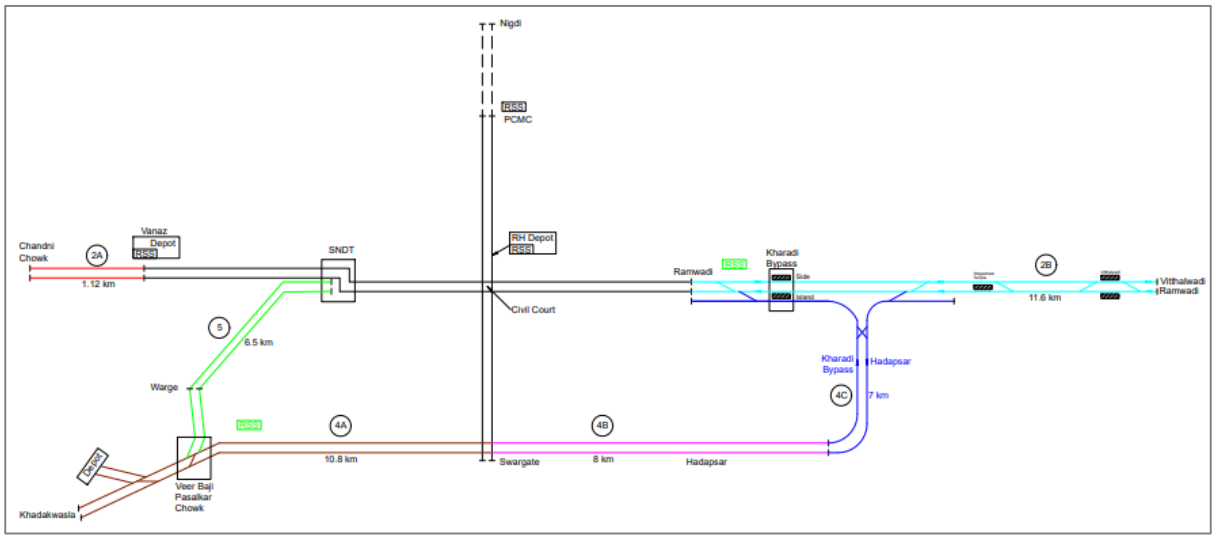


FIGURE 0-3: SCHEMATIC FOR PUNE MRTS PHASE 2 CORRIDORS

From the above GSSs, the following is the obvious choice for East Extension:

- Kharadi GSS feeding RSS for Ramwadi – Wagholi/Vitthalwadi corridor (11.63 km)

SPs (Neutral Sections) will be required:

- Between Kharadi RSS and Swargate RSS

Normal feeding zone of the Kharadi TSSs would be Line 2A Extension as well as part of the Hadapsar-Kharadi line.

0.12.2 AUXILIARY SUPPLY ARRANGEMENTS AND STANDBY POWER SUPPLY

The existing power supply arrangement at the 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 the depot for the extension line as the existing depot ASS can cater to the 2.5 MW load in the year 2057.

The station ASSs will be located inside a room at the mezzanine or platform level. The auxiliary load requirements have been assessed to increase up to 500 kW in the year 2057. 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 transformers of 2.5 MVA at the depot ASS. For property development within the footprints of the station, a provision to add a third transformer at a later date may be kept at an elevated station.

0.13 VENTILATION AND AIR-CONDITIONING SYSTEM

Concept VAC design is guided by the following codes and standards:

TABLE 0-25: APPLICABLE CODES AND STANDARDS FOR VAC SYSTEM DESIGN

IS: 655	Specification for Metal Air Ducts
IS: 277	Specification for Galvanized Steel Sheet
IS: 737	Specification for Wrought Aluminium and Aluminium Alloy sheet and Strips.
UL: 555	Fire Damper
UL: 181	Safety of Air Ducts
SMACNA	HVAC Duct Construction Standards Metal and Flexible.
AMCA Standard 210	Laboratory Methods of Testing Fans for Rating
BS 848	Fans for General Purposes
IS/IS/IEC 60034	design, performance and efficiency of motors
ISO 5801	Industrial Fans – Performance Testing using Standardized Airways
IS 3588, ISO 10816-1, IS 1940 Gr-63	Axial Fans

Multi-split air-conditioning systems are proposed for Station Control Room (SCR), Signalling Equipment Room (SER), Telecom Equipment Room (TER), etc., in n+1 configuration as these occupancies require 24-hour air-conditioning. Industrial-type exhaust fans are proposed for ventilation in all the substations.

0.14 MAINTAINANCE DEPOT

The existing Vanaz depot is proposed to be suitably augmented to cater to Line 2A and Line 2B requirements to the extent possible. In future years (around 2047), a satellite depot is proposed to be built on the east extension side of the corridor

The Vanaz Depot is planned with stabling of twenty-five (25) 3-car trains, two (02) inspection lines (currently for 3-car train and extendible for 6-car train) and two (02) heavy repair lines (currently for 3-car train and extendible for 6-car train).

Four (04) trains can be stabled at other available lines viz. inspection line, repair line or at stations.

Thus, a total holding of about 90 cars (30 trains of 3-car) can be catered to from the Vanaz depot with the development of 'Ultimate Phase' facilities. However, because of land constraints, few facilities cannot be augmented.

The total stabling capacity available in the Vanaz depot and wayside is as mentioned in Table 0-26.

TABLE 0-26: SUMMARY OF EXISTING VANAZ DEPOT

S.N.	Description	3-car Train Nos.
1	Stabling lines	25 nos.
2	Inspection lines	4 nos.
3	Internal cleaning line	1 no.
4	Pit wheel lathe line	2 nos.
5	Chandani Chowk Termination Station	4 nos.
6	Wagholi Wagholi/Vitthalwadi Terminal Station	4 nos.
7	Pocket track Mangalwar Peth	2 nos.
	Total	**42 nos.**

This satellite depot needs to be planned for about 20 (3-car trains) or 10 (6-car trains).

0.15 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

0.15.1 ENVIRONMENTAL IMPACT ASSESSMENT

Based on project particulars and existing environmental conditions, positive potential impacts have been identified that are likely to result from the proposed metro project and where feasible within the scope of this report these are quantified. The positive environmental impacts are listed below:

- Employment Opportunities
- Benefits to Economy,
- Traffic Congestion Reduction, Quick Service and Safety,
- Traffic Noise Reduction,
- Reduction of Traffic on Road,
- Less Fuel consumption,
- Reduced air pollution.

Negative impacts are listed under the following headings:

- Impacts due to project location;
- Impacts due to project design and construction;
- Impacts due to project operation

Thus total cost of EMP in construction as well as operation Phases of the project works out to be:

For Line 2A = **Rs. 0.67 Cr.**

For Line 2B = **Rs. 2.14 Cr.**

Total EMP budget for both Line 2A and Line 2B= Rs. 2.81 Cr.

0.15.2 SOCIAL IMPACT ASSESSMENT

The project shall require the acquisition / transfer of 106.26 sqm of land in Line 2A and 5711.34 Sqm for Line 2B (including stations, running section, RSS+TSS). About, 25115.98 sqm. of land is to be acquired on temporary basis for construction activities of Line 2A and 26081.27 Sqm for Line 2B. No land is required in the running section.

As per the observation received from Maha Metro, following guidelines and circulars of Government of Maharashtra are applicable for land acquisition, rehabilitation and resettlement compensation.

- Government Circular No. Misc.-03/2015/C. N34/A-2 dated 12th May 2015, 30th September, 2015 and LQN-01/2017/CN 12/A-2 dated 25th January, 2017, Revenue Forest Department, Government of Maharashtra, in the context of acquiring land of private sector by method of direct purchase through private negotiation for irrigation and other projects.
- Direct purchase method ensures that the property owners are negotiated directly for purchase of land by giving them an amount amicably accepted by the affected person which is 250% of the market value. In the process the concerned person is getting better price for the involved land and structure. This has been adopted for this DPR.

Maha-Metro shall be responsible for the implementation of the proposed corridors of the metro rail project. The Managing Director (MD) will be the in-charge of the overall project activities and will facilitate land acquisition, capacity building, and implementation of RAP.

The alignment and station entries are planned such that minimum land acquisition is required and no civil structures/buildings are hampered. The BRTS alignment on Nagar road however will be affected. About 4.5km of BRTS corridor will have to be restored after the construction. Additionally, 375m of compound wall will be affected at the station entry structures.

The Cost of the dismantling and restoration has been considered in the R&R cost.

- Cost for Restoration of BRTS – 57.26 Cr
- Cost of Restoration of Compound Wall – 0.38 Cr

0.16 DISASTER MANAGEMENT & SECURITY MEASURES

The main objectives of the disaster management measures are as follows:

- To save life and alleviate suffering
- Provide help to stranded passengers and arrange their prompt evacuation
- Instil a sense of security amongst all concerned by providing accurate information
- Protect Metro Rail property
- Expedite restoration of train operations
- Lay down the actions required to be taken by staff in the event of a disaster to ensure handling the crisis situation in a well-coordinated manner
- Ensure that all officials who are responsible for dealing 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.

To prevent emergency situations and to handle such emergency situations effectively, should it arise, there need to be the following provisions for a system that can detect the threats timely and help suppress/mitigate the same.

i. Fire detection and suppression system
ii. Smoke management
iii. Environmental control system (ECS)
iv. Track-way exhaust system (TES)
v. Station power supply system
vi. DG sets and UPS
vii. Lighting system
viii. Station area lights
ix. Seepage system
x. Water supply and drainage system
xi. Sewage system
xii. Cyber security system
xiii. 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.

The three phases of the 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 the station security system.

0.17 PROJECT COST ESTIMATES

0.17.1 CAPITAL COST

The cost estimate for the Pune Metro Phase-2 Corridors has been undertaken covering civil, electrical, signalling and telecommunication works, rolling stock, environmental

protection, rehabilitation, etc., considering 25 kV AC Overhead Traction System at July 2022 price levels.

The total completion cost of the project with July 2022 prices is estimated to be Rs. 3626.24 crore, with Rs. 396.62 crore for Line 2A and Rs. 3229.62 crore for Line 2B. The cost of land is estimated to be Rs. 22.15 crore and R&R is estimated at Rs. 57.64 crore for both extensions. The Central and State taxes and duties amount to Rs. 462.14 crore. The abstract of the capital cost is presented in Table 0-27.

TABLE 0-27: ABSTRACT OF CAPITAL COST (RS IN CRORE) FOR LINE 2A AND LINE 2B

Sl. No.	Components	Rs. In Crore		
		Line 2A	Line 2B	Total
		RL - 1.122 Kms	RL – 11.633 Kms	RL – 12.755
1	**Alignment and Formation**	**49.44**	**535.70**	**585.14**
2	**Stations**	**80.97**	**455.50**	**536.47**
2a	Stations_Civil	61.92	348.32	**410.24**
2b	Stations_E & M	19.05	107.18	**126.23**
3	**Permanent Way**	**8.82**	**95.21**	**104.03**
4	**Traction and Power Supply**	**10.02**	**161.13**	**171.15**
5	**Signaling and Telecommunication**	**18.62**	**155.09**	**173.71**
6	**Automatic Fare Collection System**	**8.34**	**47.93**	**56.27**
7	**Platform Screen Door (Half Height)**	**5.36**	**30.82**	**36.18**
8	**Shifting of Utilities**	**8.02**	**83.12**	**91.14**
9	**Multi Modal Integration & Last Mile Connectivity**	**32.60**	**46.94**	**79.54**
10	**Augmentation of Vanaz Depot**	**0.00**	**25.05**	**25.05**
11	**Staff Quarters**	**2.24**	**23.27**	**25.51**
12	**Security**	**0.88**	**4.85**	**5.73**
13	**Cyber Security**	**0.50**	**4.5**	**5.00**
14	**Rolling Stock**	**24.00**	**336**	**360.00**
15	**Land**	**4.92**	**17.23**	**22.15**
15a	Government Land (GoM) - Permanent	0.00	5.27	**5.27**
	Government Land (PMC) - Permanent	0.00	0.19	**0.19**
15b	Private Land - Permanent	2.18	8.54	**10.72**
	Government Land (GoM)- Temporary	2.64	2.64	**5.28**
15c	Government Land (PMC)- Temporary	0.00	0.02	**0.02**
15d	Private Land - Temporary	0.10	0.57	**0.67**
16	**R & R**	**0.04**	**57.60**	**57.64**
16a	R & R including hutments	0.04	0.34	**0.38**
16b	BRT Dismantling and Restoration of Works	0.00	57.26	**57.26**

Sl. No.	Components	Rs. In Crore		
		Line 2A	Line 2B	Total
		RL - 1.122 Kms	RL – 11.633 Kms	RL – 12.755
17	**Environmental Management Plan**	**0.67**	**2.14**	**2.81**
18	**Total on all items except Land and R&R (except Item No 15 & 16)**	**250.48**	**2007.25**	**2257.73**
19	**General Charges incld. Design Charges @ 5% on all items except Land and R&R (i.e. on Item No 18)**	**12.52**	**100.36**	**112.88**
20	**Contingencies @3% on all items except Land and R & R (i.e. on Item. No. 18)**	**7.51**	**60.22**	**67.73**
21	**Total including Contingencies & excluding Land and R&R (Sum of Item No. 18, Item No. 19, & Item No. 20)**	**270.51**	**2167.83**	**2438.34**
22	**Total including Contingencies & including Land and R&R (Sum Item No 21 ,Item No. 15 and Item No. 16)**	**275.47**	**2242.66**	**2518.13**
23	**Central and State Taxes (at July 2022 Price Level)**	**50.42**	**411.72**	**462.14**
24	**Total Cost Including Taxes and Duties with Land and R&R (sum of Item No. 22 & Item No. 23)**	**325.89**	**2654.38**	**2980.27**
25	**Escalation @5% per annum on the above (Item No. 24)**	**51.74**	**420.60**	**472.34**
26	**Total Completion Cost incld. Land and R & R Costs (sum of Item No. 24 and 25)**	**377.63**	**3074.98**	**3452.61**
27	**Interest During Construction (IDC)**	**18.99**	**154.64**	**173.63**
28	**Total Completion Cost incld. IDC (sum of Item No. 26 and Item No.27)**	**396.62**	**3229.62**	**3626.24**

0.18 TRANSIT-ORIENTED DEVELOPMENT

TOD focuses on the creation of high-density mixed land use development in the influence zone of transit stations. This will increase accessibility by creating pedestrian and non-motorized transport (NMT) friendly infrastructure that benefits a large number of people, thereby increasing the ridership of the transit facility and improving the economic and financial viability of the system. Along with this, TOD creates additional value for land, property and businesses, leading to agglomeration benefits. Moreover, value capturing financing (VCF) mechanisms create an opportunity to capture the value of these benefits from the beneficiaries.

In the present TOD study, the potential for revenue generation is considered in two aspects – **value capture financing** which considers revenue through premium FSI and stamp duty collection, and **property development.** For revenue estimation, the total built-

up, according to the use – residential or commercial – is calculated as per the Development Plan and the applicable TOD policy. The land rates have been taken from the ready reckoner, and duly escalated. The applicable rates and shares have been referred from various notifications by the Dept. of Urban Development, Govt. of Maharashtra. Table 0-28 shows the revenue from VCF.

TABLE 0-28: REVENUE FROM VCF

Value Capture Finance Mechanism	Estimated Revenue (Rs. in Crore)
Premium FSI	1804.4
Stamp Duty	2605.1
Total	4409.5

The potential revenue expected from the PD development is 60% of the Total Land Value (1957.58 Cr) which works out to be 1174.55 Crores.This amount is expected to be realized in FY 29-30 when the metro becomes operational.

0.19 FINANCIAL ANALYSIS

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 Vanaz to Chandani Chowk on the western side and Ramwadi to Wagholi/Vitthalwadi on the eastern end.

TABLE 0-29: PROJECT COST DETAILS (RS IN CRORE)

Sr No	Particulars	FY2022 2023 July 22 Price level	Completion Cost
1	Without Land, R&R and taxes	2438.34	2826.48
2	With Land, R&R and taxes	2980.27	3452.61

Construction period start is assumed in the month June 2023 and period of construction is assumed as four (04) years. Start of operations is assumed as June 2027.

0.19.1 OPERATING AND MAINTENANCE COST OF METRO RAIL SYSTEM

The O&M cost includes the staff cost, routine maintenance cost, and energy cost as represented in Table 0-30

TABLE 0-30: O&M AND REPLACEMENT COST

Financial Year	(Rs. in Crore)				
	Staff Cost (Esc. @9%)	Maintenance Cost (Esc. @5%)	Energy Cost (Esc @5%)	Total O & M Cost	Additional Cost & Replacement Costs[1]
2027-28	45.9	40.2	12.88	98.98	
2028-29	60.04	50.66	16.46	127.16	
2029-30	65.44	53.19	16.71	135.34	

[1] Refer Chapter 17 section 17.6.4

Financial Year	(Rs. in Crore)				
	Staff Cost (Esc. @9%)	Maintenance Cost (Esc. @5%)	Energy Cost (Esc @5%)	Total O & M Cost	Additional Cost & Replacement Costs[1]
2030-31	71.33	55.85	16.96	144.14	
2031-32	77.75	58.64	18.08	154.47	
2032-33	84.75	61.57	18.35	164.67	
2033-34	92.38	64.65	18.62	175.65	
2034-35	100.69	67.88	19.85	188.42	
2035-36	109.76	71.28	20.14	201.18	
2036-37	119.63	75.49	20.45	215.57	
2037-38	130.4	79.27	21.79	231.46	60.81
2038-39	142.14	83.23	22.3	247.67	
2039-40	154.93	87.39	22.81	265.13	
2040-41	168.87	91.76	24.51	285.14	
2041-42	184.07	96.35	25.07	305.49	
2042-43	200.64	101.17	25.65	327.46	344
2043-44	218.7	106.23	27.56	352.49	
2044-45	238.38	111.54	28.19	378.11	
2045-46	259.83	117.12	28.85	405.8	
2046-47	283.22	138.94	30.99	453.15	501.96
2047-48	308.71	145.88	31.71	486.3	1826.43
2048-49	336.49	153.18	32	521.67	
2049-50	366.77	160.84	33.91	561.52	
2050-51	399.78	168.88	34.22	602.88	
2051-52	435.76	177.32	34.54	647.62	
2052-53	474.98	186.19	36.6	697.77	
2053-54	517.73	195.5	36.94	750.17	
2054-55	564.33	205.27	37.28	806.88	
2055-56	615.12	215.54	39.51	870.17	
2056-57	670.48	240.18	39.88	950.54	
2057-58	121.8	42.03	6.71	170.54	2006.12

0.19.2 REVENUE

The revenue streams for the project are detailed as under:

- Fare Box Revenue
- Non-Fare Box Revenue
  - Value Capture Finance (VCF) Tools
  - Property Development
  - Other sources like Advertisement etc.,

0.19.2.1. FARE BOX REVENUE

The fare box revenue has been calculated based on ridership in the full Chandani Chowk to Vitthalwadi corridor, subtracting the farebox from Vanaz to Ramwadi.

The escalation in Fare Revenue is considered at 15% after every 3 years for each fare slab, which is rounded off to nearest zero. The change in travel behaviour is a gradual phenomenon. As a result, ridership on any new system takes time to stabilize and reach to the predicted level.

The fare box revenue estimation considers 75% of the projected ridership in first year of operation and then the ridership increases gradually to reach the projected level by FY 2031-32.

As the O&M period starts from June 2027 and ends on May 2057, Revenue for FY 2027-28 is considered for 10 months.

0.19.2.2. NON-FARE BOX REVENUE

The sources of non-fare box revenue identified in the study are divided into three heads:

1. Value Capture Finance (VCF) tools, including levying a premium on additional Floor Space Index (FSI) and an additional 1% cess on the stamp duty
2. Property development (cash flow from TOD)
3. Other sources like revenue from retail kiosks and ATMs at metro stations, co-branding/naming rights, metro coach/train wrapping, outdoor advertisement at the median, etc.

0.19.3 PROJECT FINANCING

0.19.3.1. EQUITY SHARING MODEL (SPV MODEL)

In the case of this project, Maha-Metro is already functioning as an SPV for metro projects in Maharashtra. In Pune, Maha-Metro is implementing Line 1 and Line 2 on the SPV model. The proposed corridors, i.e., Line 2A and 2B are extensions of the existing Line 2. So, it is proposed to consider the same SPV model for the implementation of this project. Accordingly, financial analysis has been carried out for the **SPV model**.

TABLE 0-31: FUNDING PATTERN

Particulars	Project Cost with Taxes and Duties (Rs. in Cr.)	
	Amount	% of Contribution
Equity By Govt. of India (GoI)	479.71	15.42%
Equity By Govt. of Maharashtra (GoM)	479.71	15.42%
Subordinate Debt for Central Taxes by GoI (50%)	142.64	4.58%
Subordinate Debt for Central Taxes by GoM (50%)	142.64	4.58%
Bilateral/Multilateral Loan from Funding Agencies	1867.06	60.00%
Sub-Total	**3111.76**	**100.00%**
Subordinate Debt for State Taxes by GoM	250.41	
Subordinate Debt for Land by GoM	24.86	
Subordinate Debt for R&R by GoM	65.34	
Contribution for Land by Pune Municipal Corporation (PMC)	0.24	
Total Cost	**3452.61**	
Subordinate Debt for Interest during Construction (IDC) by GoM	173.63	
Total Project Completion Cost	**3626.24**	

TABLE 0-32: LOAN TERMS

S.N.	Parameter	Value
1	Annual interest rate for loan	4.5%
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

0.19.3.2. FINANCIAL INTERNAL RATE OF RETURN

The financial internal rate of return at completion cost basis with fare box and non-fare box revenue works out to be **8.67%.**

0.19.3.3. FIRR SENSITIVITY

A sensitivity analysis of economic analysis is being carried out based on critical factors such as project cost and ridership.

TABLE 0-33: SENSITIVITY ANALYSIS

Particulars	FIRR based on Project Cost	FIRR based on Ridership
Base	8.67%	8.67%
5% Lower	8.74%	8.20%
10% Lower	8.82%	7.69%
5% Higher	8.59%	9.11%
10% Higher	8.52%	9.52%

0.20 ECONOMIC ANALYSIS

The project horizon is 30 years, with the construction period of 4 years, starting from June 2023, and the operation and maintenance period of 30 years, starting from June 2027.

TABLE 0-34: ECONOMIC COST OF THE PROJECT

Particulars	Amount (Rs. Cr)
Project Cost at July 2022 price level Excluding Price Contingencies, Import duties & taxes, Sunk costs, Interest payment, principal payment and interest during construction period etc.	2518.13
Conversion Factor	0.83
Economic Cost of Project	**2090.05**

0.20.1 QUANTIFIABLE ECONOMIC BENEFITS ACCRUED TO SOCIETY

The quantifiable benefits for the society owing to the implementation of the metro rail project are as follows:

- Travel time savings
- Savings in vehicle operating cost
- Savings from accident reduction
- Savings from pollution reduction
- Savings due to reduced road stress

TABLE 0-35: SUMMARY OF ECONOMIC BENEFITS (RS IN CRORES)

Particular	2028-29	2037-38	2047-48	2057-58
Travel Time Saving	91.58	634.34	2728.95	1333.49
Saving in Vehicle Operating Cost	99.46	269.74	610.49	172.93
Saving from Accident Reduction	0.39	2.41	8.90	4.79
Saving from Pollution Reduction	3.26	7.12	10.47	1.87
Saving due to Reduced Road Stress	4.97	10.42	15.47	2.77
Total	**199.66**	**924.03**	**3374.28**	**1515.85**

0.20.2 EIRR FOR 30 YEARS

Considering the economic lifecycle cost and economic benefit, the economic internal rate of return (EIRR) for the corridor from Line 2A and Line 2B comes out to be **17.93%** for the

duration of 30 years of the project period, which is above the established cut-off criterion of 14% as per the Appraisal Guidelines for Metro Rail Project Proposals by MoHUA, GoI.

This implies that the economic benefits accruing due to this project are substantial and will yield high savings for the economy as a whole.

0.20.3 SENSITIVITY ANALYSIS

A sensitivity analysis of economic analysis is being carried out based on the critical factors such as:

1. Cost overruns due to delay or other factors
2. Increase in maintenance cost
3. Reduction in ridership
4. Reduction in benefits
5. Combination of reduction in benefits and increase in cost

0.21 IMPLEMENTATION PLAN

Based on the important milestones given in Table 0-36, as soon as the approval is accorded from State Government, the appointment of General Consultants (GC) and Detailed Design Consultants (DDC) may be initiated for the preparation of tender documents as well as project management. As the land acquisition is a time consuming activity, the process to acquire the land for the Project may also start simultaneously.

TABLE 0-36: IMPLEMENTATION SCHEDULE OF THE PROJECT

SN	Tasks	Anticipated Timelines
1	Submission of the DPR	July 2022
2	Approval of DPR by PMC	September 2022
3	Approval of DPR by GoM	October 2022
4	Final Approval by GoI	January 2023
5	Packaging and invitation of bids	April 2023
6	Commencement of civil works	June 2023
7	Commencement of operation	June 2027

Line 1 and Line 2 of Pune MRTS Phase-1 are being implemented on SPV Model by Maha-Metro. The proposed metro corridors (i.e. Line 2A-Vanaz to Chandani Chowk and Line 2B-Ramwadi to Wagholi/Vitthalwadi), may also be implemented on SPV model The commercial operation of these corridors may start from June 2027 after about 4 years of construction including land acquisition.

0.22 CYBER SECURITY

Metro railways are deploying automation technologies/systems both for core rail systems and other systems. However, the increasing use of digital technologies in rail systems is creating new vulnerabilities in the physical domain, making the IT/OT systems susceptible to cyber-attacks. These vulnerabilities can be exploited by threat actors to disrupt

operations. Therefore, safeguards are required to be built in at the preparatory stage of the metro rail project.

Multiple digital technologies are deployed in metro rail:

- Train control system
- Train control management system (TCMS) in rolling stock
- Telecommunication systems
- Traction and power SCADA system
- Facilities SCADA system
- Tunnel ventilation SCADA system (for UG)
- Automatic Fare Collection system
- Platform Screen Door system
- Building management system
- Fire control and alarm system

Additionally, office automation/IT system is deployed in metro offices and depots.

A new standard TS 50701 (Railway Cyber Security) has been published in recent times in view of the increasing use of digital technologies in rail operation and administration and the importance of cyber security in this context. Therefore, comprehensive cyber security is proposed for the Pune Metro Phase 2 network.

The following are the main constituents of cyber security implementation in a metro rail organization:

- Initial risk assessment
- Security service and infrastructure
    - Authorization
    - Identification
    - Authorization and access control
    - Network security
    - Firewalls
    - Data security administration
    - Network devices
    - Server, host and end-point security
    - Application security
    - System availability and continuity
    - Technological means to security
    - Equipment security
- Elaboration of security requirements for each network
    - Signalling communication network
    - Operational communication network
    - Administrative communication network
    - Fire and emergency network
    - Traffic light communication network
- Security system specific requirements
    - Railway scheduling system
    - Rolling stock on-board system

  - ATS and SCADA interface
  - Interface between cellular network and Metro CBN
- Security requirements for testbed and pre-production (staging) environment
  - Staging
  - Testbed and model
- Cyber risk assessment and penetration testing
- Periodic cyber risk assessment
- Penetration testing

CHAPTER 1: A PROFILE OF THE CITY

1.1 INTRODUCTION

Pune is known as 'The Queen of the Deccan' due to its scenic beauty and rich natural resources. It is located along the banks of the Mula and Mutha rivers, 150 km south-east of Mumbai on the leeward side of the Sahayadri, i.e., the Western Ghats. Pune is the second-largest city in the state of Maharashtra, and the seventh-most populous city in India, with an estimated population of 77.53 lakh as of 2018[1]. Apart from being a major IT, educational, automobile, and manufacturing hub, the city is the administrative headquarters of the Pune district. In fact, the city is often referred as the 'Oxford of the East' due to the presence of several well-known educational institutions.

Pune was the centre of the Maratha Empire established by Chatrapati Shivaji Maharaj in the early 17th century. Over a century, the city administration changed hands, from the Ahmednagar Sultanate to the Adel Shah Dynasty, and then the Mughals. During the 18th century, the city became the seat of the Peshwas, the prime ministers of the Maratha Empire. They established Maratha supremacy over northern India, making Pune an important political center in the Indian subcontinent.

The city was also associated prominently with India's struggle for independence and major social reforms in the late 19th and early 20th centuries. After the country gained independence, Pune witnessed enormous growth, transforming into a modern metropolis.

FIGURE 1-1: VIEW OF PUNE CITY FROM VETAL HILL[2]

Along with the municipal corporations of Pune and Pimpri Chinchwad, the three (03) cantonment towns of Pune, Khadki and Dehu Road form the urban core of the Pune Metropolitan Region (PMR). As per the 2011 - Census of India, the population of the Pune

1Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018
2Source: smartnet.niua.org

city was 3.12 million and the population of the metropolitan region was estimated as 5.99 million (refer to Table 1-1).

PMR is one of the fastest-growing metropolitan areas in India and is witnessing rapid growth in economic activities, rapid urbanization and urban sprawl. Over time, Pune has evolved from a cultural hub in the state to an industrial hub of India. This evolution has triggered enormous economic growth in the City since the early 2000s. Due to this, the City's jurisdictional boundaries have been extended twice over the past decade.

1.2 GEOGRAPHY

1.2.1 LOCATION

Pune is located at approximately 18° 32" North latitude and 73° 51" East longitude. It is situated 560 meters above sea level on the Deccan Plateau on banks of the Mula and Mutha rivers. The city is surrounded by hills on the east and the south. The Sinhagad-Katraj-Dive Ghat range is the southern boundary of the urban area. Pune and Pimpri Chinchwad are twin cities that are broadly separated by the Mula and Mutha rivers. Pimpri Chinchwad is located on the north and north-west side of Pune. The centers of the twin cities are approximately 15 km apart. The geographical location of Pune is shown in Figure 1-2.

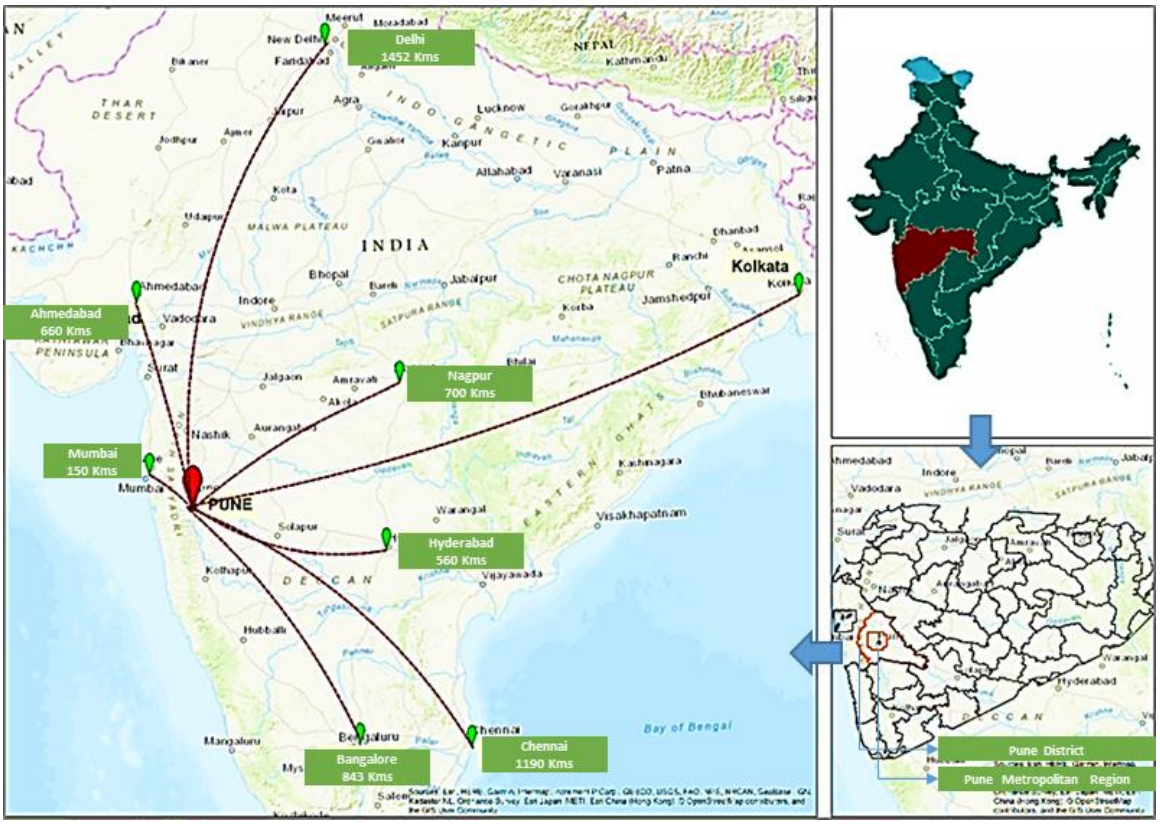


FIGURE 1-2: LOCATION AND REGIONAL SETTING OF PUNE

1.2.2 ADMINISTRATIVE BOUNDARIES

The study area considered for the current study is about 2,172 sq. km, covering Pune, Pimpri Chinchwad Municipal Corporation, and surrounding urban/industrial areas (the rest of PMR). The study area map is represented in Figure 1-3.

The study area comprises of Pune Municipal Corporation (PMC), Pimpri Chinchwad Municipal Corporation (PCMC), Pune Cantonment Board (PCB), Khadki Cantonment Board (KCB), Dehu Cantonment Board (DCB), Municipal Councils, MIDC Areas and adjacent Villages.

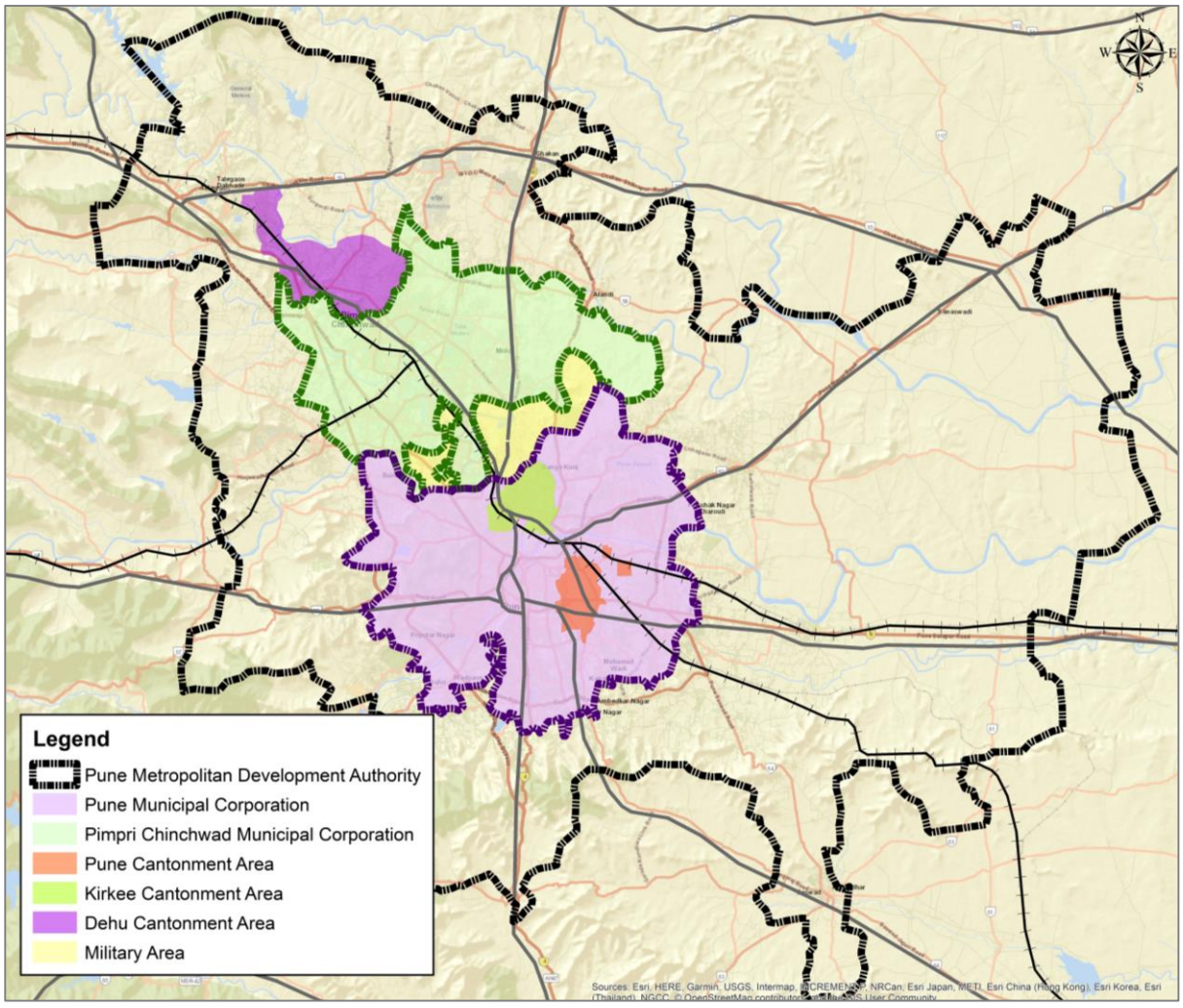


FIGURE 1-3: ADMINISTRATIVE BOUNDARIES OF PUNE METROPOLITAN REGION AREA

1.2.3 CLIMATE

Pune has a moderate climate. The average temperature in the city ranges from 11°C to 44°C. The south-west monsoons bring rain from June to October. The average rainfall in this period varies from 600 mm to 700 mm. The area adjacent to the Western Ghats

receives more rain than the areas further east. Some salient features of Pune's climate are described as under:

- Pune has a tropical wet and dry climate, with the characteristics of a hot semi-arid climate.
- The maximum temperature typically reaches 42°C in the summer months (mid-March to mid-June).
- During the monsoons, the temperature ranges between 22°C to 28°C.
- The average annual rainfall in the city is 722 mm.
- July is the wettest month of the year.

1.2.4 PHYSICAL SETTING

1.2.4.1. TOPOGRAPHY

As described in Section 1.1, the city of Pune is situated on the leeward side of the Western Ghats and lies between 18° 32" North latitude and 73° 51" East longitude. Based on the topographical conditions, the highest point within the region is the Vetal Hill (800 m) whereas the highest point of the urban area is the Sinhagad Fort (1400 m).

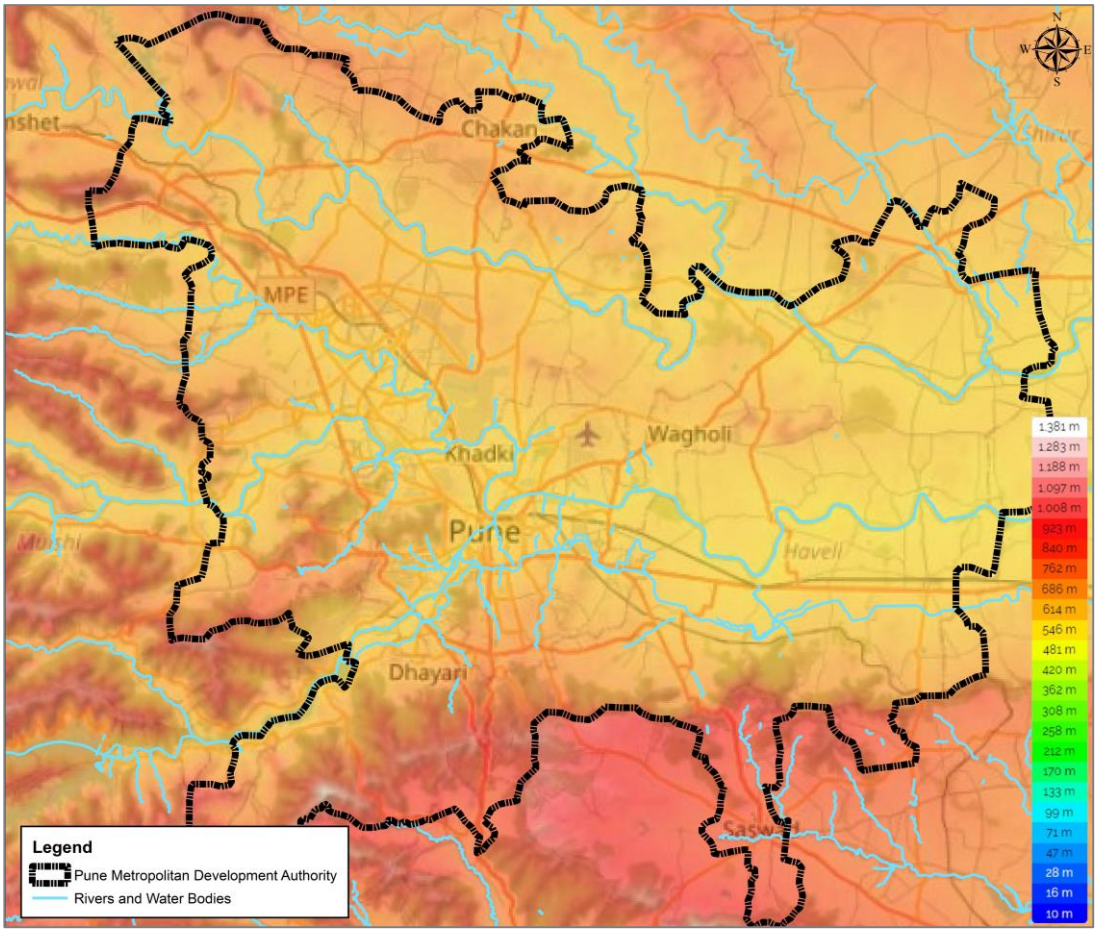


FIGURE 1-4: TOPOGRAPHIC MAP OF THE STUDY AREA

1.2.4.2. HYDROLOGY

The city is served by the Mutha and Mula rivers, which drain into the Bhima river, to the east of Pune. Hydrologically, Pune is located in the North Bhima River Basin. The rivers have dams located in the upstream of the watershed.

The Mutha River has Khadakwasla Dam**,** located approximately 10 km south from centre of the city. This is the major source of water supply to Pune city and the cantonment areas. Mula originates from the Mulshi Dam, which is located approximately 50 km upstream of the region.[3]

1.2.4.3. SEISMICITY

Pune lies very close to the seismically active zone around Koyna Dam, about 100 km south of the city. The city has been categorized in Zone 3 by the India Meteorological Department and has an intensity up to 7 on the Richter scale. The probability of earthquake occurrence is Indeterminate[4].

1.2.5 REGIONAL LINKAGES

1.2.5.1. ROAD

Pune is located to the south-east of Mumbai at a distance of about 150 kms. It is well connected with all the major cities in India by both National and State Highways. Figure 1-5 shows typical roads in Pune (Shankar Seth Road and Magarpatta Road).

FIGURE 1-5: SHANKAR SETH ROAD & MAGARPATTA ROAD IN PUNE

3Source: Revised City Development Plan for Pune - 2041
4Source: Integrated Regional Disaster Management Plan for Pune Municipal Corporation

1.2.5.2. RAIL

The Pune Railway Station is administered by the Pune Railway Division of the Central Railways. All the railway lines to Pune are broad gauge. The city is well connected with all the major cities in India through the railways. Local trains (EMUs) connect Pune to the industrial town of Pimpri Chinchwad and the hill station of Lonavala. Figure 1-6 represents the major road and rail networks within the study area.

The regional and local road network of the study area are discussed in detail in Section 2.3 of Chapter 2.

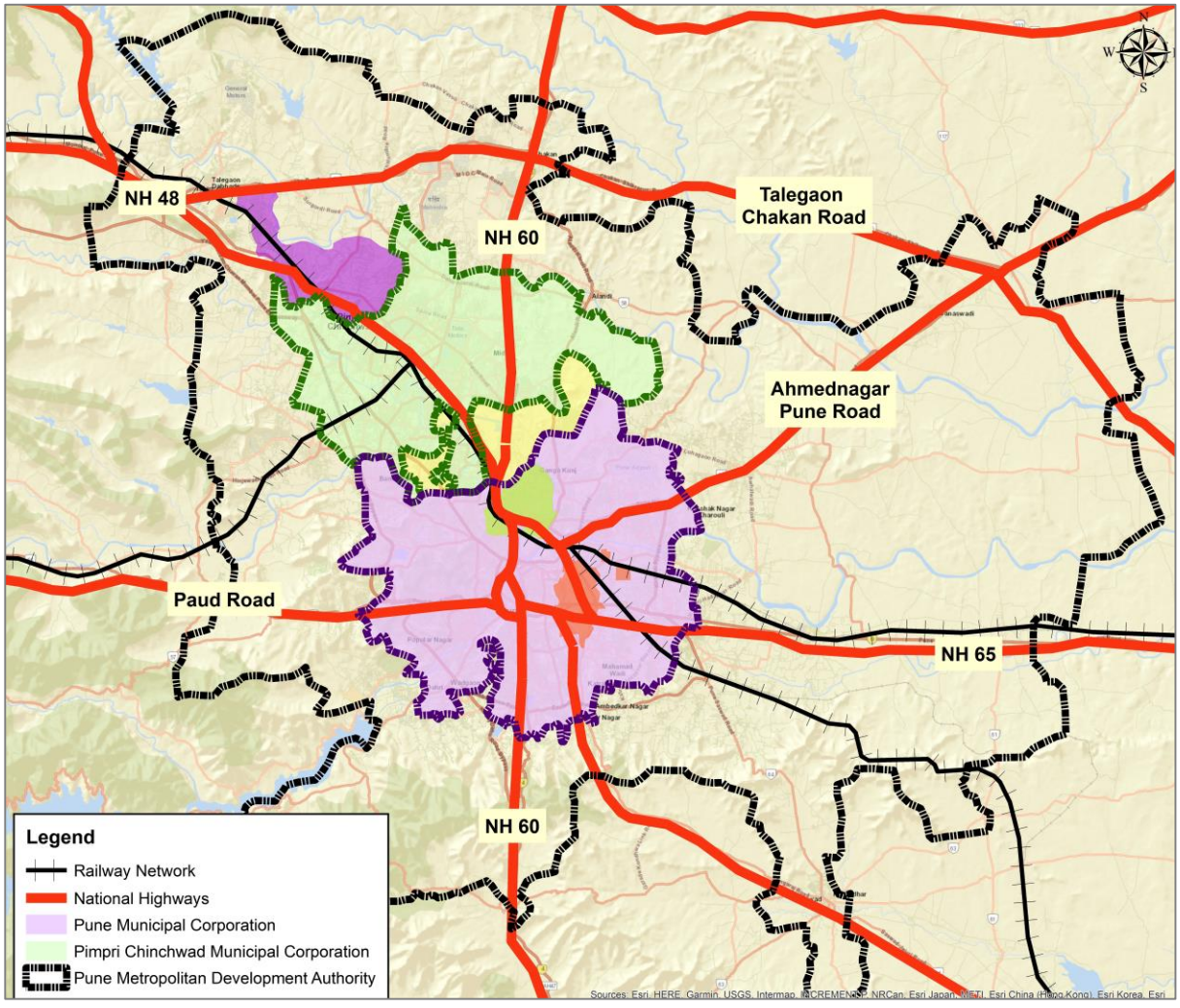


FIGURE 1-6: MAJOR ROAD AND RAIL NETWORK IN THE STUDY AREA

1.2.5.3. AIRPORT

Pune Airport is an international airport located at defence land in Lohagaon (about 10 kms away from Pune city). The airport connects the city to all the major cities in the country

like Delhi, Mumbai, Hyderabad, Chennai, Bangalore, Kolkata, etc. Direct international flights to Dubai and Frankfurt also operate from here.

As the current airport is saturated, the Government of Maharashtra (GoM) is planning to construct a new greenfield airport near Saswad and Jejuri in Purandar Taluka, to the south-east of Pune city.

1.2.5.4. INTER-CITY BUS TRANSPORT

Inter-city, intra-state, and inter-state services are provided by the state-run bus service, i.e., Maharashtra State Road Transport Corporation (MSRTC) and PMPML. With a fleet of 18,000 buses and a staff of 1.07 lakh employees, MSRTC operates 1,05,000 bus trips daily, covering 5.8 million km. Various services are operated by the MSRTC catering to the needs of intra-state and inter-state passengers. Over 7 million passengers avail these services daily.

MSRTC operates buses from Pune to all major parts of the state from four (04) bus terminals: Swargate, Shivaji Nagar, Pune Railway Station and Vallabh Nagar. The two major bus terminals that cater to the majority of the inter-city traffic are Swargate and Pune Railway Station.

Apart from the MSRTC, the following also operate to and from Pune:

- State transport corporations of neighbouring states such as Gujarat, Karnataka and Telangana.
- Private bus operators providing connectivity to all the major cities within the state and the neighbouring states of Gujarat, Karnataka and Telangana. Private bus services are operated majorly from the Sangamwadi and Akrudi bus terminals.

1.3 DEMOGRAPHY AND SOCIO-ECONOMIC PROFILE

1.3.1 POPULATION

The delineated study area (refer to Figure 1-3) spread over 2,172 sq. km, covering Pune Municipal Corporation (PMC), Pimpri Chinchwad Municipal Corporation (PCMC), and the

rest of the Pune Metropolitan Region (PMR). It has been witnessing a high population growth over the years, which can be attributed to a high natural growth, change in the administrative boundaries, and migration of people from adjacent towns and rural areas who seek better education, employment and livelihood opportunities.

Based on the 2011 Census of India, the population of the study area was 59.91 lakh. Based on the CMP for PMC and PCMC in PMR 2018, the same is estimated to be 77.5 lakh in 2018. Of the 77.5 lakh population, PMC contributes 37.13 lakh (i.e., ~47% of the total population of the study area), PCMC contributes 22.73 lakh (i.e. ~29%), the cantonment areas of Pune, Khadki and Dehu account for 2 lakhs, and the rest of PMR accounts for 15.62 lakh.

Table 1-1 represents the population trends in the study area. It can be observed from the table that the population growth rate in the study area in the last decade, i.e., 2001 – 2011, is 42%. The decadal growth rate of PMC and PCMC is observed to be 23% and 72%, respectively.

TABLE 1-1: POPULATION TRENDS IN THE STUDY AREA (IN LAKHS)[5]

Year	1961	1971	1981	1991	2001	2011	2018
Pune Municipal Corporation (PMC)	6.07	8.56	12.03	15.67	25.38	31.24	37.14
Pimpri Chinchwad Municipal Corporation (PCMC)	0.40	0.99	2.52	5.21	10.16	17.28	22.74
Pune Cantonment (PC)	0.66	0.78	0.86	0.82	0.80	0.72	0.72
Khadki Cantonment (KC)	0.58	0.65	0.81	0.78	0.77	0.79	0.79
Dehu Cantonment (DC)	-	0.25	0.33	0.41	0.47	0.49	0.52
Rest of Pune Metropolitan Region (PMR)	1.01	1.11	2.01	3.55	4.57	9.39	15.62
Pune Metropolitan Region (PMR)	8.72	12.34	18.56	26.44	42.16	59.91	77.53
Growth Rate (%)		41%	50%	42%	59%	42%	29%

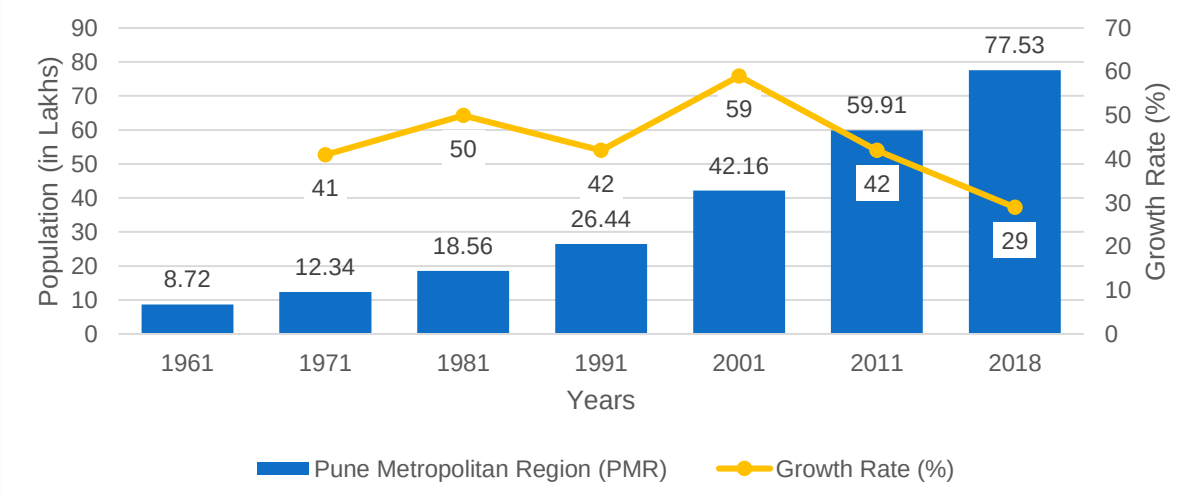


FIGURE 1-7: POPULATION GROWTH TRENDS IN PMR

5Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

POPULATION DENSITY

Based on the CMP for PMC and PCMC in PMR 2018, the population density of PMC and PCMC is 152 PPH and 134 PPH, respectively. The average population density of Pune city is on the lower side of the permissible limit of the URDPFI guidelines for metropolitan cities. This is mainly due to the large extent of vacant spaces available in the peripheral, undeveloped areas of the city.

SEX RATIO

As per the District Census Handbook – Maharashtra, Census of India 2011, the sex ratio (number of females per 1000 males) for PMC and PCMC is 948 and 833, respectively.

HOUSEHOLD SIZE

As per the District Census Handbook the recorded number of households in PMC and PCMC is 7,42,602 and 4,27,356, respectively. The average household size in PMC and PCMC is 4.2 and 4.0 respectively.

1.3.2 MIGRATION PATTERNS

1.3.2.1. PUNE

The city of Pune has developed as the counter magnet of Mumbai, the administrative capital of Maharashtra State and the business capital of India. Due to the high cost of living in Mumbai and its overcrowded state, Pune has emerged as a better place for people aspiring for better opportunities in all spheres of life from all over the country. It is now one of the most preferred destinations in India for jobs, education, healthcare, real estate investment, etc. This has led to increased migration. This growth has been supplemented by multiple factors like its natural growth and extension of jurisdiction.

As per a study conducted by the Gokhale Institute of Politics and Economics, the in-migrated population of the Pune urban agglomeration has increased from 3.1 lakh in 1991 to 7.4 lakh in 2001, accounting for 13% and 20% of the total population, of which the composition of state migrants is 73% and 65% percent, respectively. The migrant population in Pune city has increased from 3.7 lakh in 2001 to 6.6 lakh in 2011 (the projected in-migration of 2011 as per the Gokhale Demographic Study) accounting for 14% and 21% of the total population.

1.3.2.2. PIMPRI CHINCHWAD

In Pimpri Chinchwad, about 57% of the population growth has been on account of migration. Migration into the PCMC region is essentially from within Maharashtra. Approximately 31% of the sampled population is from the Pune district, 12% from other districts of Maharashtra, 14% from outside Maharashtra, and the remaining 43% of the

population are original inhabitants of the region. The main reason for migration has been economic, i.e., for employment. The large number of industries and service sectors located in the area has attracted a large population.

1.3.3 POPULATION PROJECTIONS

As mentioned in Section 1.3.1, the population of the study area is 59.91 lakh, as per the 2011 Census, and the estimated population in the 2018 CMP is about 77.5 lakh. Based on past trends, it can be observed that in the last decade the population grew by 5.76 lakh and 7.22 lakh in PMC and PCMC, respectively. The corresponding decadal growth of the population has been 23% and 72%, respectively, while the overall population growth rate in the study area in the last decade was 42%.

This high growth rate seen in the past decades due to migration and the addition of new areas has started to show a downward trend. However, it is anticipated that it would still be on the higher side for the next three decades due to the all-round economic development of the Pune and its surroundings. Population projections are based on the several considerations:

- Development plan, past growth trends, existing and proposed land use
- Major transport infrastructure projects such as Metro, BRTS, Ring Road, Airport and TP schemes, etc.
- Growth direction and transport infrastructure likely to be developed
- Density already achieved & scope for further densification on developable land.

Based on the above, a population forecast for the next 20 years has been made as part of the CMP for PMC and PCMC in PMR in 2018, which is presented in Table 1-2.

TABLE 1-2: POPULATION FORECAST FOR PMR[6]

Year	2018	2028	2038
Pune Municipal Corporation (PMC)	37.14	45.27	52.54
Pimpri Chinchwad Municipal Corporation (PCMC)	22.74	30.55	39.11
Pune Cantonment (PC)	0.72	0.72	0.72
Khadki Cantonment (KC)	0.79	0.79	0.79
Dehu Cantonment (DC)	0.52	0.55	0.56
Rest of Pune Metropolitan Region (PMR)	15.62	23.11	32.59
Total Pune Metropolitan Region (PMR)	77.53	101.00	123.32

As part of the current study, the following documents have been referred to for the forecast of the population in the study area beyond 2038, the same is discussed in detail in Chapter 3 of this report;

- The Population Forecast for the PMR as per the CMP-2018.

6Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

- The Population Forecast for PMRDA as per the Draft DP (2021 – 2041).

1.3.4 ECONOMIC PROFILE

The employment data as per the Census of India 2011 for PMC and PCMC is summarized in Table 1-3. One of the important parameters indicating the economic activity of the area is Work Force Participation Rate (WFPR).

TABLE 1-3: WORKING POPULATION IN PMC AND PCMC[7]

Parameters	Year	PMC	PCMC
Population	1991	15,66,651	5,20,639
	2001	25,38,473	10,15,598
	2011	31,24,458	17,27,692
Employment	1991	5,31,493	1,66,833
	2001	8,65,150	3,50,260
	2011	11,98,602	5,96,184
WFPR	1991	33.9%	32.0%
	2001	34.1%	34.5%
	2011	38.3%	34.5%

1.3.4.1. INDUSTRIES

The city of Pune has developed as the counter magnet of Mumbai and is the second-largest city in Maharashtra. It is a center for economic activities, with an estimated GDP of $69 billion, and is fast emerging as one of the 'Investment Hubs of Maharashtra'.

Pune has had well-established manufacturing, glass, sugar, and forging industries since the 1950-60s. It also has a growing hinterland, with many information technology and automotive companies setting up their establishments in the Pune district. Some of these activities are detailed below:

- The IT/ITES sector is located in Hadapsar, Talwade, and Hinjewadi IT Park (Rajiv Gandhi IT Park).
- The automotive sector is located majorly in PCMC.
- It is home to the Automotive Research Association of India (ARAI), which is responsible for the homologation of all vehicles available in India.
- All sectors of the automotive industry are represented in Pune, from 2-wheelers and auto-rickshaws to cars, tractors, tempos, excavators, and trucks.
- Automotive companies such as Bajaj Auto, Tata Motors, Mahindra & Mahindra, Mercedes Benz, Force Motors (Firodia Group), Kinetic Motors, General Motors, Land Rover, Jaguar, Renault, Volkswagen, and Fiat have set up their manufacturing units in Pune.

7Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

- Some major industrial areas surrounding Pune are Talegaon, Ranjangaon, Chakan, Shikarpur, etc.
- Serum Institute of India, the world's fifth-largest vaccine producer by volume, has a manufacturing unit in Pune.
- Pune is the largest hub of German companies in India, with over 225 German companies setting up their businesses here.
- The Pune Food Cluster Development Project, funded by the World Bank, is being implemented by SIDBI to facilitate the development of fruit and vegetable processing industries in and around Pune.
- Many industrial areas developed by Maharashtra Industrial Development Corporation (MIDC) and private industrial areas are located in the Pune Metropolitan Region, which employs a large number of people.
- Some major industrial areas within the study area are Chakan, Hadapsar, Hinjewadi, Jejuri, Kharadi, Pimpri Chinchwad, Pirangut, Rajangaon, Talewadi Software Park, Talegaon, Talegaon Floriculture Park, Sanaswadi, and Uruli Kanchan.

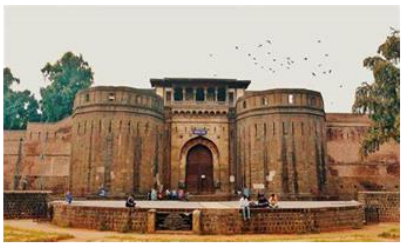
1.3.4.2. EDUCATION AND RESEARCH CENTERS

Pune is known as the 'Oxford of the East' due to the presence of several well-known educational institutions. The city has emerged as a major educational hub in recent decades, with nearly half of the total international students in the country studying in Pune.

Apart from the Savitribai Phule Pune University (Formally University of Pune ,the second-largest university in the country), the city has over a hundred educational institutes and more than nine deemed universities. Some institutes of national importance in Pune are Fergusson College, Bharti Vidyapeeth, College of Engineering Pune (third-oldest engineering college in Asia) and the Symbiosis Group of Institutions.

1.3.4.3. TOURISM

Pune, the 'Queen of the Deccan', is surrounded by green hills and placid lakes, and enjoys a pleasant climate. The cultural capital of Maharashtra is also among the greenest urban areas in India.



The Pune Metropolitan Region is home to various kinds of tourist spots like historical locations, spiritual and religious destinations, hill stations, trekking spots, museums, amusement parks, waterfalls, etc. This is why Pune is visited by a large number of domestic and international tourists every year.

Some prominent tourist locations in Pune are Shaniwarwada, Aga Khan Palace, Sinhagad, Bund Garden, Lal Mahal, Parvati Hill, National War Memorial Southern Command, Saras Baug Wada, Tulsi Baug, Ohel David Synagogue, Khadakwasla Dam, etc.

1.4 URBAN LAND USE STRUCTURE/ACTIVITY DISTRIBUTION

1.4.1 PLANNING STUDY AREAS AND EXISTING PLANS

1.4.1.1. PUNE

Pune has established itself as a prominent hub for manufacturing industries, the IT sector and educational institutions. The rapid growth of Pune has also transformed its character from a pensioner's city to a prosperous economic centre and bustling cultural capital. In addition to this, it is a tourist magnet due to its rich history and natural beauty.

1.4.1.2. PIMPRI CHINCHWAD

The city of Pimpri-Chinchwad is predominantly an industrial area, which has developed largely over the last four decades. Thus, it can be called a relatively newly developed urban agglomeration area of Pune.

Pimpri was established as a center for refugees from Pakistan. Industrialization in the 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 led further 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 same excellent connectivity that Pune has.

1.4.2 EXISTING LAND USE DISTRIBUTION

1.4.2.1. PUNE

The Central Business District (CBD) of Pune is a high-density zone with major land use for residential and commercial activities. The old city is congested, with narrow roads and a lack of open spaces. The majority of the middle- and high-income groups inhabit the peripheral areas, i.e., the first belt area. Industrial developments are found mostly in pockets and belts along the radial roads entering the city.

In 2001, a couple of fringe areas peripheral to the city were merged with PMC. Between 1987 and 2001, PMC also observed spatial growth towards employment nodes, and as a result, the fringe areas that were closer to these nodes and offered immediate connectivity to them witnessed rapid growth in an unorganized manner. Due to strong economic activity nodes in the city and region, these employment nodes have been attracting a significant share of the migrant population looking for better employment opportunities, thus increasing the demand for housing.

Since it was anticipated that the future growth of Pune shall be governed by transport corridors connecting these employment nodes, the Development Plan 2001, made especially for the newly added fringe areas, increased residential use by 14%, favouring the housing demand.

As represented in Table 1-4, around 42% of the overall area is under the residential zone, 2% is under the commercial zone, 4% under the industrial zone, and 16% under public/semi-public and recreational use. The area under transport has reduced to 13%, which is low in comparison to other metropolitan cities where it ranges from 16% to 25%.

TABLE 1-4: LAND USE OF PMC[8]

S. N.	Land Use	Area in Sq. Km		Total	Area in %
		1987 DP	Newly Merged Area		
1	Residential	50.58	53.16	103.74	42.53
2	Commercial	2.35	1.57	3.92	1.61
3	Industrial	7.26	2.62	9.88	4.05
4	Public and Semi-Public	15.22	1.45	16.67	6.83
5	Public Utilities	1.38	0.00	1.38	0.57
6	Transport	22.00	9.81	31.81	13.04
7	Reserved, Forest & Agri.	2.35	26.70	29.05	11.91
8	Water Bodies	12.04	2.48	14.52	5.95
9	Hills and Hill Slopes	12.45	0.00	12.45	5.10
10	Recreational	12.73	7.79	20.52	8.41
	Total	**138.36**	**105.58**	**243.94**	**100**

8Source: City Sanitation Plan 2001, PMC

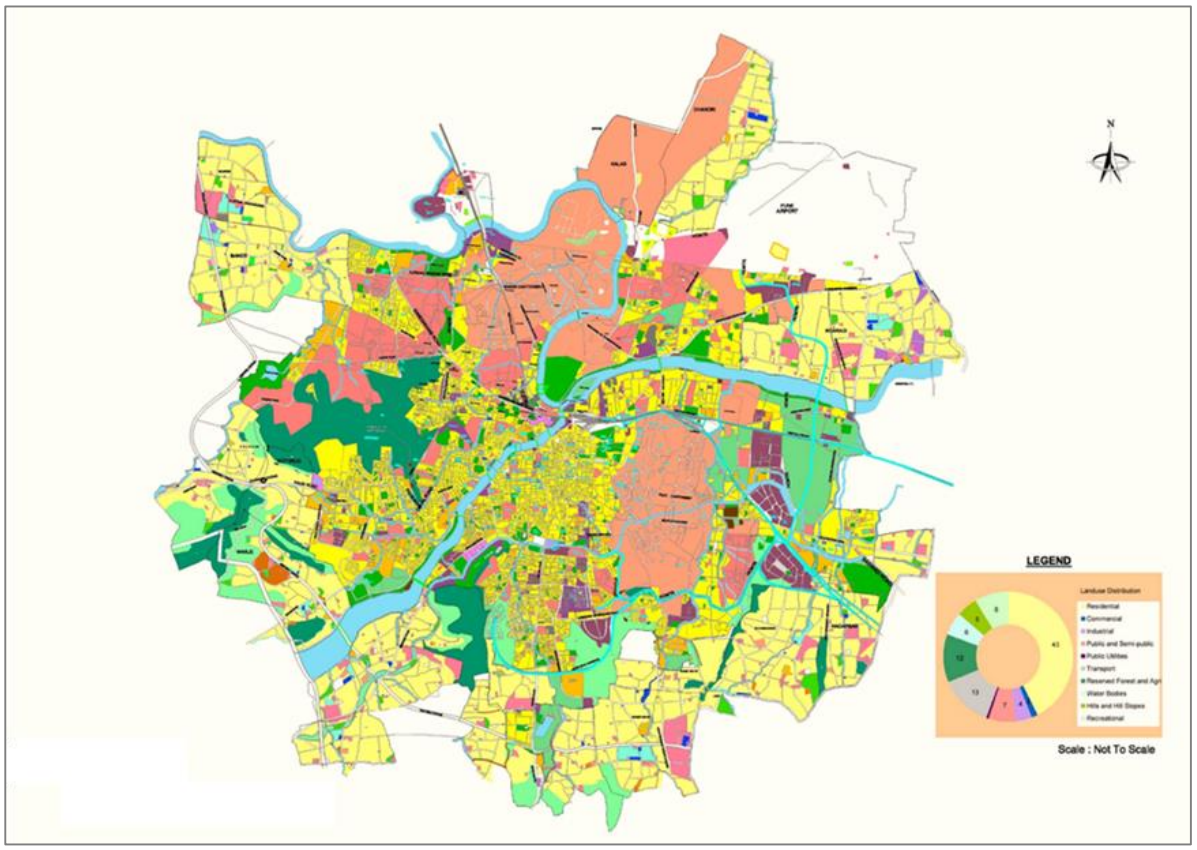


FIGURE 1-8: EXISTING LAND USE MAP OF PMC[9]

Urban growth in Pune city has followed a radial pattern with organic development along the highways. While radials have been well-developed, the circular road development is lagging behind, resulting in detours and congestion in central areas. there is a lack of ring roads or even partial ring roads in Pune.

1.4.2.2. PIMPRI CHINCHWAD

Out of the total area, residential land use constitutes about 19%. Figure 1-9 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. The area under transport is less than 4%, which is very low in comparison to the other cities.

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

9 Source: Draft Revised CDP for Pune-2041 – Volume 1 &CMP for PMC and PCMC in PMR - 2018

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 NH-4.

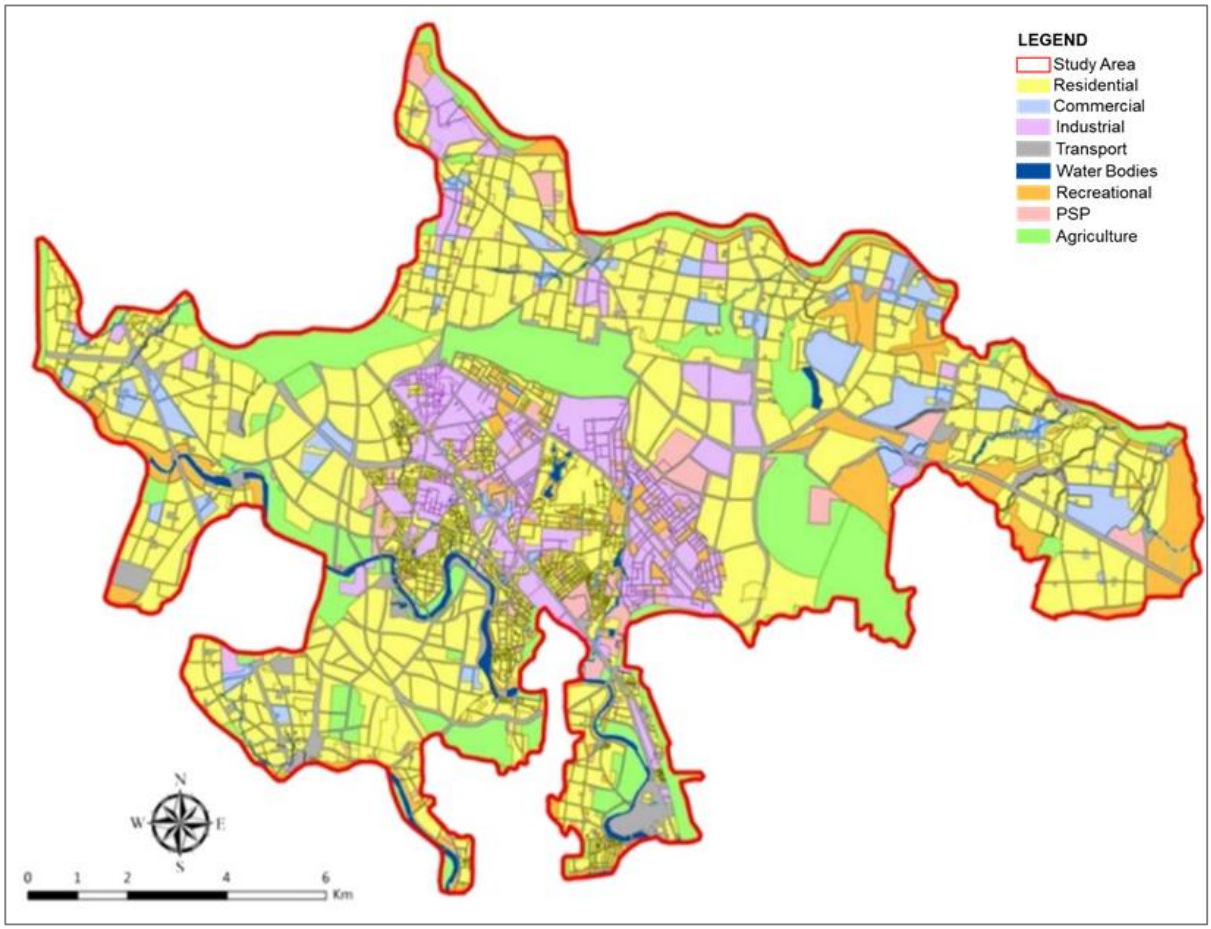


FIGURE 1-9: EXISTING LAND USE MAP OF PCMC[10]

TABLE 1-5: LAND USE OF PCMC[11]

S. N.	Land Use	Area in Sq. Km		Total	Area in %
		1987 DP	Newly Merged Area		
1	Residential	10.16	22.26	32.42	19.01
2	Commercial	0.40	0.19	0.59	0.35
3	Industrial	10.85	1.48	12.33	7.23
4	Public and Semi-Public	0.84	0.82	1.66	0.97
5	Public Utilities	0.42	0.39	0.81	0.48
6	Transport	4.26	2.38	6.64	3.89
7	Reserved, Forest &Agri.	26.27	33.27	59.54	34.92
8	Water Bodies	1.89	0.95	2.84	1.67
9	Quarry	0.22	2.46	2.68	1.57
10	Recreational	0.69	0.01	0.70	0.41

10Source: Draft Development Plan – 1997, PCMC&CMP for PMC & PCMC in PMR - 2018
11Source: Draft Development Plan – 1997, PCMC

S. N.	Land Use	Area in Sq. Km		Total	Area in %
		1987 DP	Newly Merged Area		
11	Barren/Vacant Lands	30.01	20.29	50.30	29.50
	Total	**86.01**	**84.50**	**170.51**	**100**

1.4.3 REVIEW OF ZONING REGULATIONS

1.4.3.1. PUNE

The permissible FSI is 1.5 for purely residential buildings and 2.00 for building with a mixed residential and commercial use subject to a maximum tenement density of 250 tenements per hectare, provided in a building with the mixed residential and commercial uses, the commercial use will be permitted only on the ground floor and the residential use and commercial use shall not exceed FSI 1.5 and 0.5, respectively.

1.4.3.2. PIMPRI CHINCHWAD

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

1.4.4 ACTIVITY LOCATIONS

1.4.4.1. PUNE

The growth of PMC is being driven by various industry segments. Except for the Kharadi Knowledge Park, which is located within PMC limits, all other industries are located outside PMC in PMR or close to PMR towards the north-west, north and north-east. PCMC houses a majority of the industrial development.

A large proportion of the city's population thrives on wholesale and retail trade and commerce. The city serves as the regional wholesale market for food grains and other commodities. It also serves as the market center for agricultural products, such as green peas, wheat, rice, pulses, oilseeds, maize, etc., which are cultivated in the rural hinterland. Pune also functions as a distributing centre for agricultural implements, fertilizers, drugs and medicines, iron and steel, cement and minerals, petroleum products, forest products such as timber, and readymade garments and textiles.

Currently, the CBD comprises the areas of Camp (MG Road, East Road), Swargate, Laxmi Road (Tilak Road, Bajirao Road), Kalyani Nagar, Shivajinagar, Wakad Wadi, Deccan, FC Road, JM Road, and Ahmednagar Road.

The main commercial activities observed in these areas are corporate offices, headquarters for manufacturing and service units, business process outsourcing centers, call centers, banking, insurance, retail trading, shopping malls, entertainment, cinema theatres, health services, educational institutions, hotels and restaurants, etc.

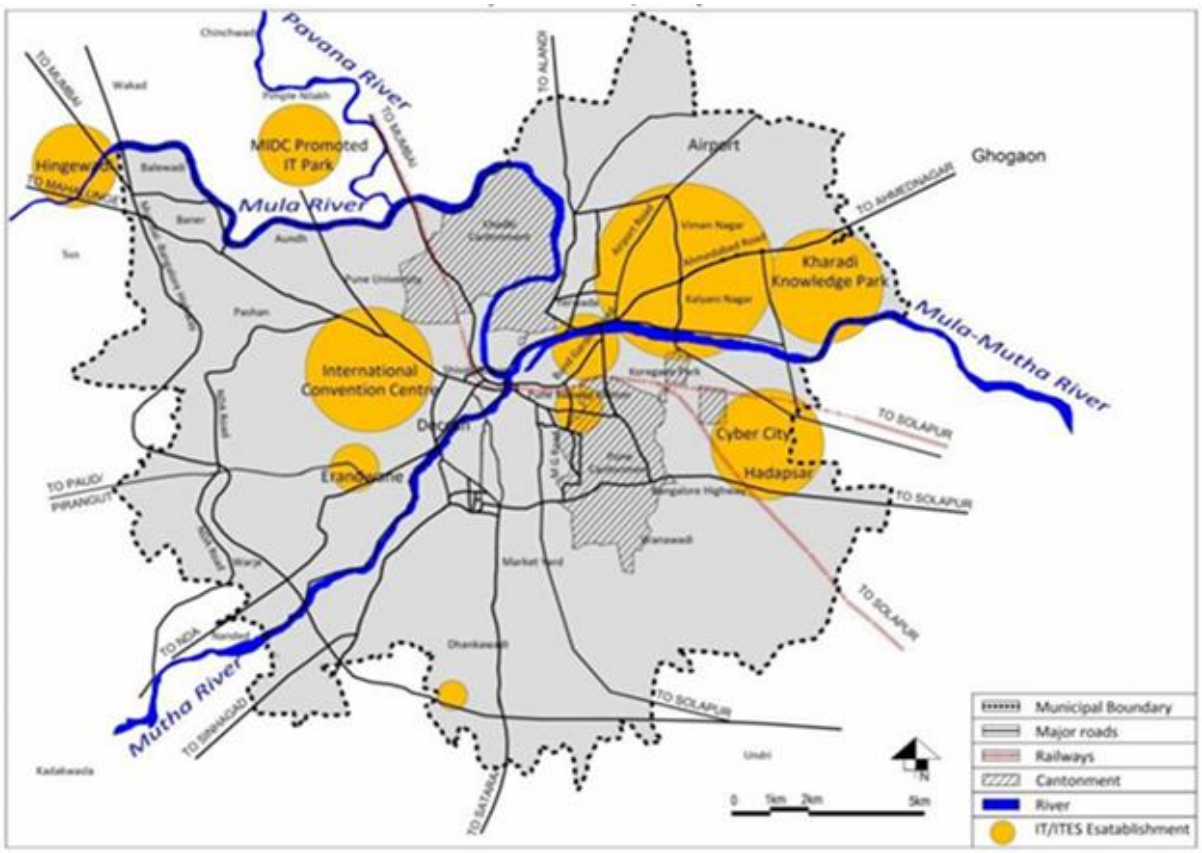


FIGURE 1-10: IT & ITES ESTABLISHMENTS IN PUNE

1.4.4.2. PIMPRI CHINCHWAD

The city's central 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 areas along the industrial belt on the old Mumbai-Pune highway and at the junction of NH-4 and NH-50. Small-format commercial development is also seen spread through the neighbourhood as the development control rules allow for mixed use on roads with ROW of 18 m or more. This is advantageous in reducing some of the shopping trips.

There are few recreational areas in the city despite the presence of large water bodies. Some of the neighbourhood chowks serve as recreational spaces with informal markets and eateries.

1.4.5 LAND USE PROPOSALS

1.4.5.1. PUNE

The proposed land use of PMC for 2027 by DP (2007 – 2027) is given in Table 1-6. The proposed Land use map of PMC is shown in Figure 1-11.

TABLE 1-6: PROPOSED LAND USE OF PMC FOR 2027 BY DP (2007 – 2027)

S. N.	Land Use	Area in Sq. Km	Area in %
1	Residential	104.60	35.44%
2	Commercial	4.08	1.38%
3	Industrial	5.58	1.89%
4	Public and Semi-Public	39.07	13.24%
5	Public Utilities	3.21	1.09%
6	Transport	45.03	15.26%
7	Reserved, Forest & Agriculture	42.48	14.39%
8	Water Bodies	13.92	4.72%
9	Hills and Hill Slopes	16.86	5.71%
10	Recreational	20.34	6.89%
	Total	**295.17**	**100%**

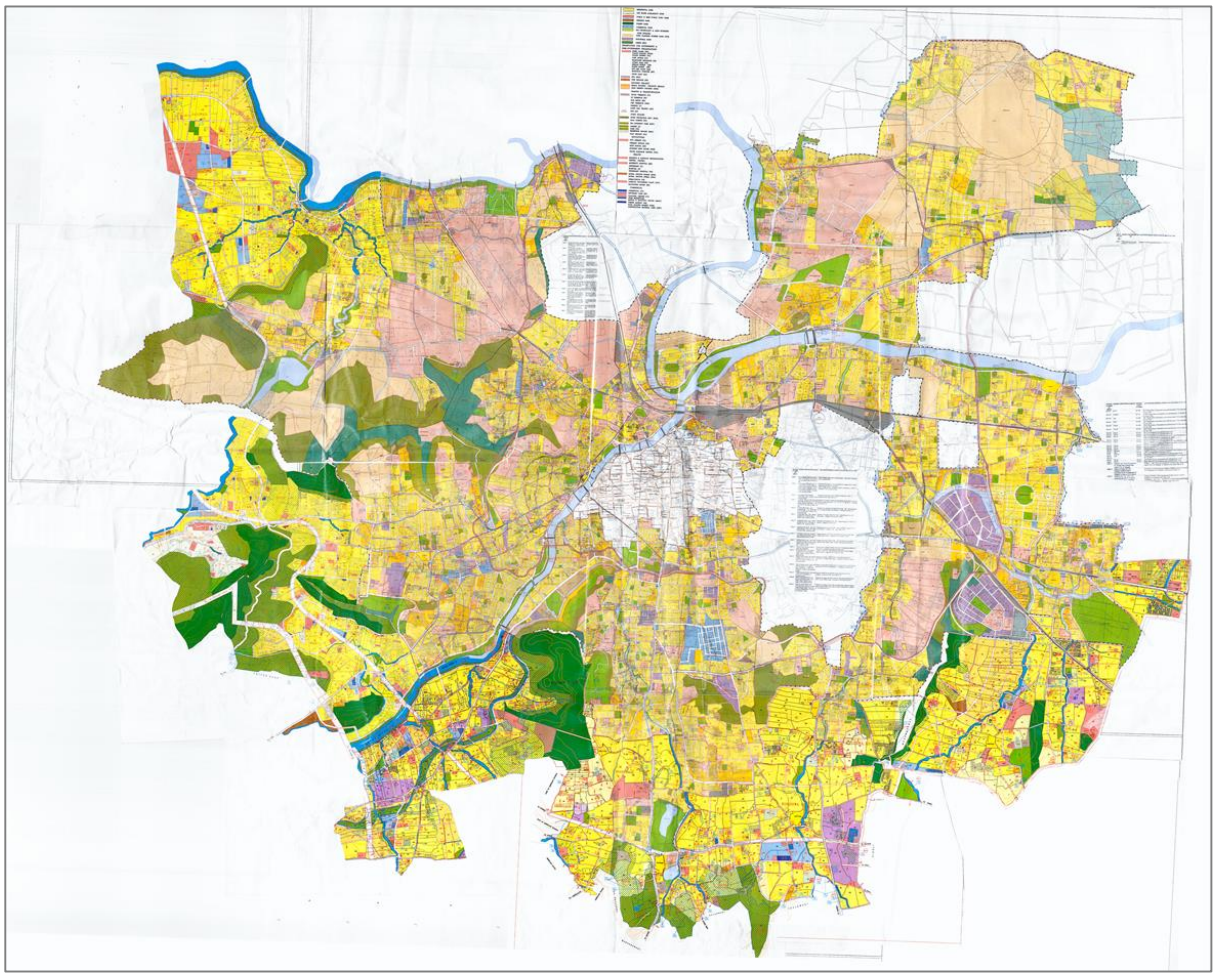


FIGURE 1-11: PROPOSED LAND USE OF PMC

The growth direction envisaged by the Development Plan is as follows:

- The growth direction of PMC as envisaged in the Development Plan is towards Hinjewadi, PCMC and Hadapsar. The growth is triggered mainly by the IT industry in Hinjewadi, automobile industry in PCMC, and BPO, IT and manufacturing industries in Hadapsar.
- The growth corridors mainly pass through the north, west and east. The southern side of PMC contains hilly areas where growth is not favourable. Growth is restricted considerably in the north-east direction too due to the presence of the airport funnel area.

However, some major proposals may result in the deviation of the growth direction of PMC as envisaged in the Development Plan. The proposed road from Charoli- Lohagaon is likely to intensify development in the surrounding areas of the airport. Several Town Planning schemes have been proposed along the Ring Road, which is also going to redefine the growth direction.

The proposed airport at Purandar near Saswad Town is likely to trigger development in available developable areas in the southern direction. Undri, Pisoli, Mohammedwadi along the Eastern Bypass and Viman Nagar, Baner, and Balewadi are developing areas with the potential to develop further.

1.4.5.2. PIMPRI CHINCHWAD

The proposed land use of PCMC is shown in Table 1-7. The proposed Land use map of PCMC is shown in Figure 1-12.

TABLE 1-7: PROPOSED LAND USE FOR THE EXTENDED AREAS OF PCMC[12]

Land Use	Area in Sq. Km			% to Total Area
	Land as per Development Plan 1987	Proposed Land of Newly Merged Areas	Total	
Residential	10.2	47.3	57.5	33.7
Commercial	0.4	2.7	3.1	1.8
Industrial	10.9	3.1	14	8.2
Public Utilities	0.4	1.0	1.4	0.8
Public and Semi-Public	0.8	2.7	3.5	2.1
Transportation	4.3	10.9	15.2	8.9
Open Spaces/Recreational	0.7	2.6	3.3	1.9
Water Bodies	1.9	1.3	3.2	1.9
Quarry	0.2	-	0.2	0.1
Barren/Vacant Land	30.0	-	30.0	17.6
Agriculture & Reserve Forest	26.3	12.9	39.2	23.0
Total Developed Area	**86.0**	**84.5**	**170.6**	**100**

Based on the DP of PCMC, the following has been observed:

- Residential areas have been proposed in the extended areas to absorb the future population.
- Commercial uses have been distributed at the vantage locations mainly along the intersection of major roads in the proposed residential uses.
- Mixed land use development.
- Large developable lands in Wakad, Punawale and Kiwale to be developed, i.e., the western side of the PCMC.
- On the eastern side, areas like Charoli, Moshi, Chimbali and Talwade are likely to be developed.

12Source: Development Plan – 1997, PCMC

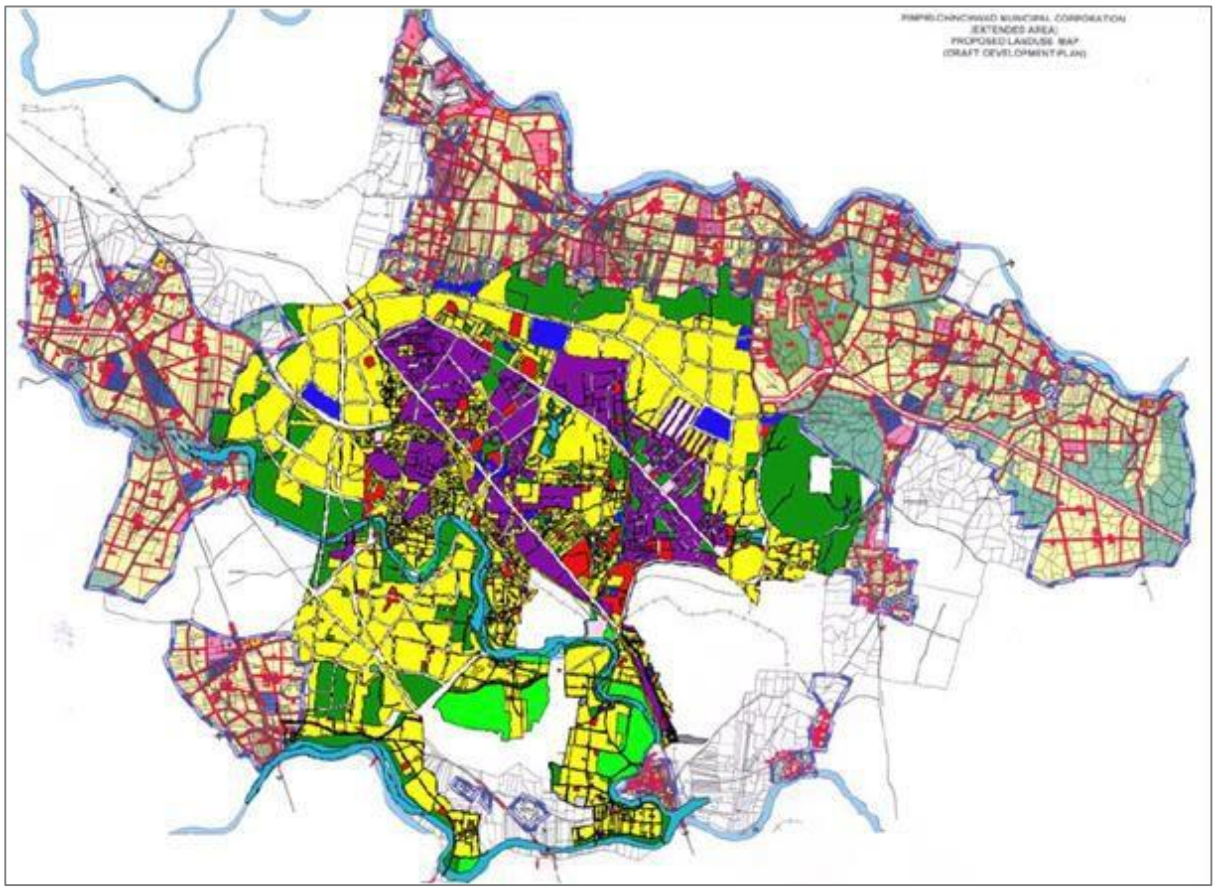


FIGURE 1-12: PROPOSED LAND USE MAP OF PCMC - 2021[13]

From Table 1-7, it is observed that ~33% of the total area of PCMC is for residential against the earlier 11.8%. Landuse share for Commercial, Industrial, Public Utilities, Public and Semi Public Landuse is 12.7%. Hence, even after an increased allocation, the transportation sector will have a share of only 9% of the total area, underlying the need for optimized and efficient public transport systems.

13 Source: Draft Development Plan-2021 Final Report, 2000

CHAPTER 2: EXISTING TRANSPORTATION SYSTEM IN THE CITY

2.1. INTRODUCTION

The growth of Pune and Pimpri Chinchwad in recent years has resulted in rapidly increasing commuter demands and a steep rise in ownership & use of private vehicles. Transportation infrastructure, however, has not kept pace with this increase in demand and is therefore highly inadequate. With the number of registered vehicles rising, roads and parking spaces in the city are chocked, especially during peak hours.

The public transport share has been overthrown completely by the tremendous growth in private vehicles. This vicious increase in private vehicle ownership (mostly 2-wheelers and 4-wheelers) has become uncontrollable due to the increased transport demand and the lack of convenient public transport options.

It is to be noted that, at present, the public transport system in Pune and Pimpri Chinchwad consists mainly of buses, a few services of the Bus Rapid Transit (BRT) system, partial operation of the Pune Metro Phase 1 lines (i.e., five stations - PCMC to Phugewadi on Line 1 and five stations - Vanaz to Garware College on Line 2) and Suburban Rail. In a nutshell, in the absence of the augmentation of mass transit services, Pune may head towards an unsustainable urban transport scenario.

The urban transport infrastructure of Pune and Pimpri Chinchwad requires significant upgradation in terms of adequacy/capacity, as well as an integrated approach in providing this infrastructure, to meet the existing and future transit demands.

This chapter intends to understand the existing transport scenario in the study area through a series of secondary data related to its transport modes and demand.

2.2. VEHICULAR GROWTH AND COMPOSITION

Table 2-1 and Figure 2-1 represent the growth of registered vehicles in Pune.

TABLE 2-1: GROWTH OF REGISTERED VEHICLES IN PUNE[1]

S. N.	Year	Registered Vehicles (in Lakhs)	CAGR (%)
1	March 2011	28,99,492	9.68%
2	March 2012	31,80,055	9.83%
3	March 2013	34,92,678	8.92%
4	March 2014	38,04,064	8.83%
5	March 2015	41,39,977	8.73%
6	March 2016	45,01,504	8.97%

1Source: RTO, Pune

S. N.	Year	Registered Vehicles (in Lakhs)	CAGR (%)
7	March 2017	49,05,100	5.36%
8	March 2018	53,23,394	8.53%
9	March 2019	57,81,524	8.61%
9	March 2020	62,08,200	7.38%
10	March 2021	64,72,048	4.25%[2]
	Average CAGR (%)		8.05%

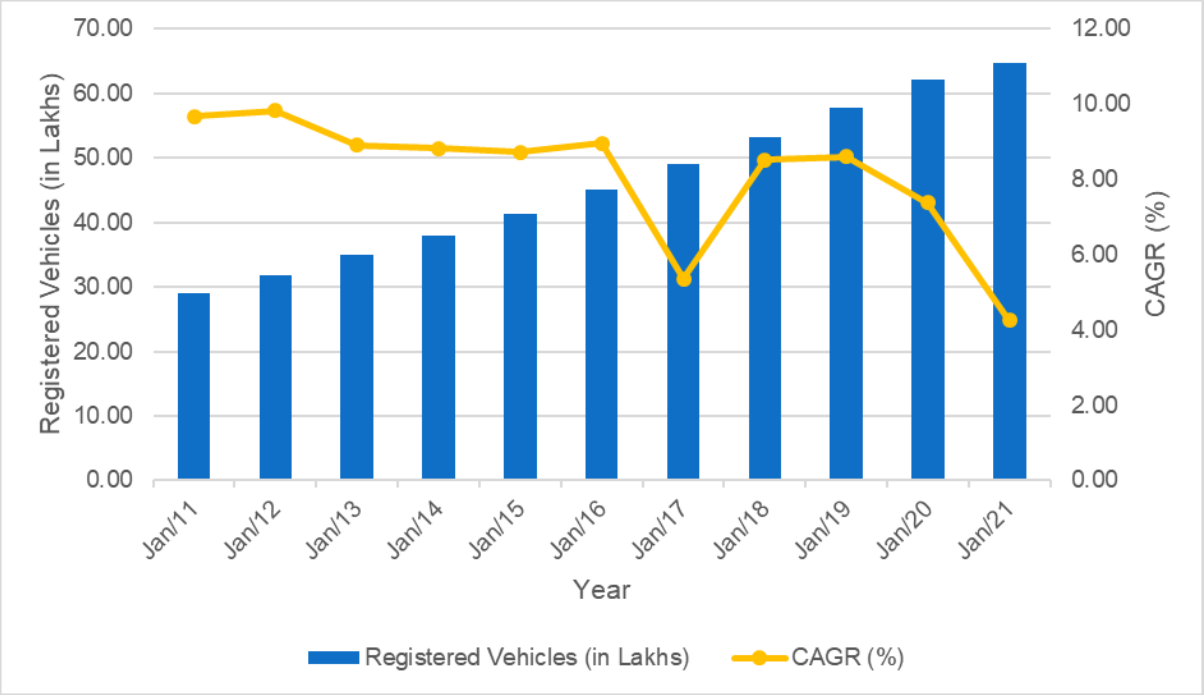


FIGURE 2-1: GROWTH OF REGISTERED VEHICLES IN PUNE[3]

As per the data collected from the RTO, Pune, the number of registered vehicles has increased from 28.99 lakh in 2011 to 49.05 lakh in March 2017 to 64.72 lakh in March 2021. The average CAGR observed is 9.16%, which is higher by 2.5 times of the annual population growth in the city and its surroundings. The density of growth of vehicles in the city has affected the existing transport situation to a significant extent.

Table 2-2 and Figure 2-2 represent the mode-wise composition of registered vehicles in Pune. It can be observed that of the total registered vehicles in Pune and Pimpri Chinchwad, 75% share is of 2-wheelers and 18% share is of 4-wheelers and taxis.

2In March 2021 – The growth in vehicle registration is reduced due to the COVID-19 pandemic and the lockdown.
3Source: RTO, Pune

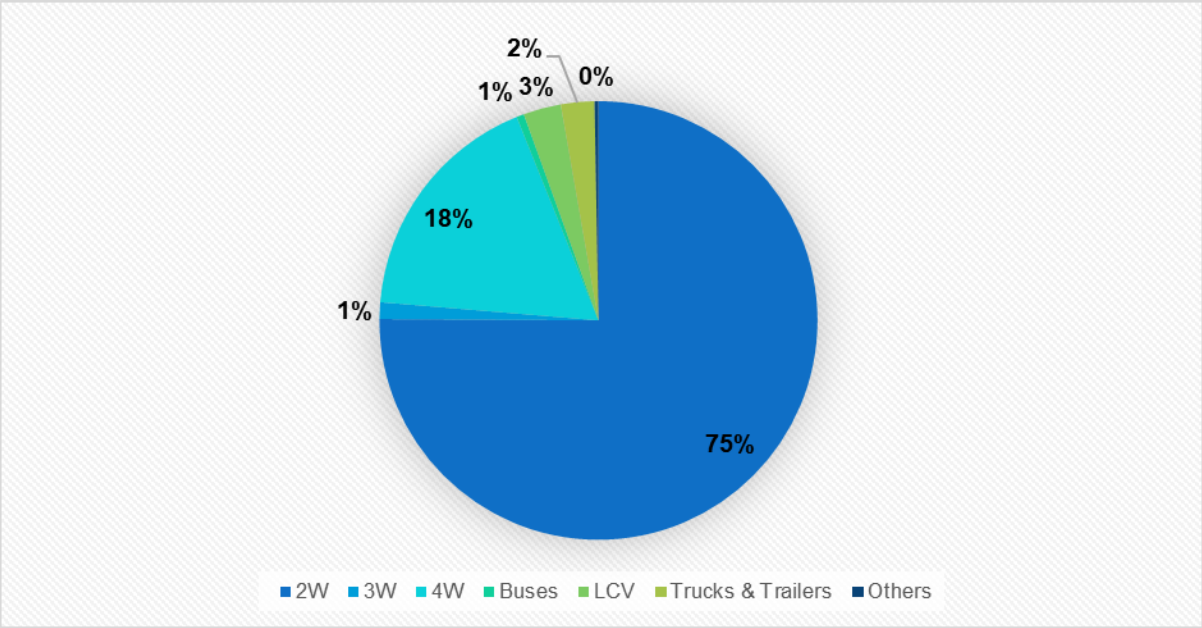


FIGURE 2-2: MODE-WISE DISTRIBUTION OF REGISTERED VEHICLES IN PUNE[4]

It is observed that, there is an average of 634 two-wheelers per 1000 number of residents (population) and 155 cars per 1000 number of residents (population) in PMC and PCMC areas. Since the existing public transport system is unable to cater to the increasing travel needs of residents, private vehicles numbers seem to be increasing drastically.

It is also observed that PMPML, State Transport and Private Buses have increased in total numbers significantly from 2011 to 2021. However, the enormous growth of private vehicles and the inadequate augmentation of transport related civil infrastructure and services has overshadowed the growth and increased presence of buses for public transport.

Therefore, the city may have to plan more of line haulage based mass public transport network and services in order to have a sustainable transport scenario in near and long term future.

4Source: RTO, Pune

TABLE 2-2: COMPOSITION OF REGISTERED VEHICLES AND GROWTH RATE IN PMC[5]

Type of Vehicles		Mar-11	Mar-12	Mar-13	Mar-14	Mar-15	Mar-16	Mar-17	Mar-18	Mar-19	Mar-20	Mar-21	CAGR % (Mar-11 to Mar-17)
Motor Bikes	Nos	21,64,434	24,00,882	26,29,516	28,55,901	31,12,469	33,85,371	36,67,177	39,97,869	43,46,054	46,63,879	48,60,471	8.43%
	%age	74.60%	75.50%	75.30%	75.10%	75.20%	75.20%	74.80%	75.10%	75.17%	75.12%	75.10%	
Cars/Jeeps	Nos	4,37,336	5,07,706	5,78,605	6,45,306	7,04,733	7,67,389	8,44,215	8,81,402	9,69,290	10,47,611	10,94,674	9.61%
	%age	15.10%	16.00%	16.60%	17.00%	17.00%	17.00%	17.20%	16.56%	16.77%	16.87%	16.91%	
Taxi	Nos	20,414	17,793	19,565	20,987	22,753	30,761	46,511	34,982	37,639	40,869	43,145	7.77%
	%age	0.70%	0.60%	0.60%	0.60%	0.50%	0.70%	0.90%	0.66%	0.65%	0.66%	0.67%	
Auto Rickshaws	Nos	69,473	50,692	49,686	50,392	51,224	50,892	50,892	76,048	74,570	77,322	79,179	1.32%
	%age	2.40%	1.60%	1.40%	1.30%	1.20%	1.10%	1.00%	1.43%	1.29%	1.25%	1.22%	
PMPML+ST Buses +Pvt. Buses	Nos	15,663	10,477	11,650	14,065	15,331	18,606	24,122	21,294	22,300	24,706	26,662	5.46%
	%age	0.50%	0.30%	0.30%	0.40%	0.40%	0.40%	0.50%	0.40%	0.39%	0.40%	0.41%	
School Buses	Nos	960	1,354	1,711	1,842	1,969	2,499	2,660	1,521	1,888	2,317	2,760	11.14%
	%age	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.10%	0.03%	0.03%	0.04%	0.04%	
Pvt. Services Vehicles	Nos	1,114	1,641	1,652	1,750	1,817	1,861	1,924	760	944	271	323	-11.63%
	%age	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.00%	0.00%	
Ambulances	Nos	1,583	1,525	1,613	2,038	2,627	2,730	2,844	3,802	3,894	4,778	5,693	13.65%
	%age	0.10%	0.00%	0.00%	0.10%	0.10%	0.10%	0.10%	0.07%	0.07%	0.08%	0.09%	
Articulated & Multi Axle Vehicles	Nos	53	885	914	1,145	2,464	4,003	7,044	2,281	2,832	3,475	4,140	54.62%
	%age	0.00%	0.00%	0.00%	0.00%	0.10%	0.10%	0.10%	0.04%	0.05%	0.06%	0.06%	
Trucks & Lorries	Nos	47,150	35,573	36,985	39,901	41,104	43,524	51,268	59,318	60,411	64,381	66,535	3.50%
	%age	1.60%	1.10%	1.10%	1.00%	1.00%	1.00%	1.00%	1.11%	1.04%	1.04%	1.03%	
Tankers	Nos	5,219	3,740	3,751	4,622	4,909	4,632	4,714	6,084	5,900	6,353	6,645	2.44%
	%age	0.20%	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%	0.11%	0.10%	0.10%	0.10%	
Delivery Van 4W	Nos	41,439	48,610	54,181	57,117	62,652	67,386	73,900	79,851	87,549	94,137	97,364	8.92%
	%age	1.40%	1.50%	1.60%	1.50%	1.50%	1.50%	1.50%	1.50%	1.51%	1.52%	1.50%	
Delivery Van 3W	Nos	46,192	45,866	47,832	50,641	53,140	55,233	58,276	71,486	75,514	80,254	82,673	5.99%
	%age	1.60%	1.40%	1.40%	1.30%	1.30%	1.20%	1.20%	1.34%	1.31%	1.29%	1.28%	
Tractors	Nos	28,423	29,920	31,214	34,059	37,084	39,545	41,509	47,911	51,208	54,860	57,041	7.21%
	%age	1.00%	0.90%	0.90%	0.90%	0.90%	0.90%	0.80%	0.90%	0.89%	0.88%	0.88%	
Trailers	Nos	13,994	15,735	15,803	15,738	16,334	16,678	16,868	22,815	24,188	25,249	25,460	6.17%
	%age	0.50%	0.50%	0.50%	0.40%	0.40%	0.40%	0.30%	0.43%	0.42%	0.41%	0.39%	
Others	Nos	6,045	7,656	8,000	8,560	9,367	10,394	11,176	10,647	11,563	12,416	12,944	7.91%
	%age	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%	
Total		28,99,492	31,80,055	34,92,678	38,04,064	41,39,977	45,01,504	49,05,100	53,23,394	57,81,524	62,08,200	64,72,048	8.05%

5Source: RTO, Pune

2.3. ROAD NETWORK CHARACTERISTICS

Pune is one of the most important administrative center as well as educational and cultural capitals. The city is well-connected with the state capital and surrounding district headquarters through roads and railway networks. Some of the major national and state highways passing through the study area are:

1. National Highways
    a. Mumbai Bengaluru National Highway (NH 48),
    b. Pune Hyderabad National Highway (NH 65),
    c. Pune Nashik National Highway (NH 60),
    d. Mumbai Pune Expressway (MPEW),
    e. Pune Saswad Pandharpur National Highway (NH 965)
    f. Jalgaon Ahmednagar Pune Paud Mulshi Dighi Port (NH 753F)
2. State Highways
    a. Pune Alandi State Highway
    b. Pune Paud Road State Highway
    c. Talegaon Chakan State Highway

The Mumbai-Pune Expressway connects Mumbai and Pune. It starts at Kalamboli in Navi Mumbai and ends at Kiwale in Pune. The Mumbai-Pune Expressway is the 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[6].

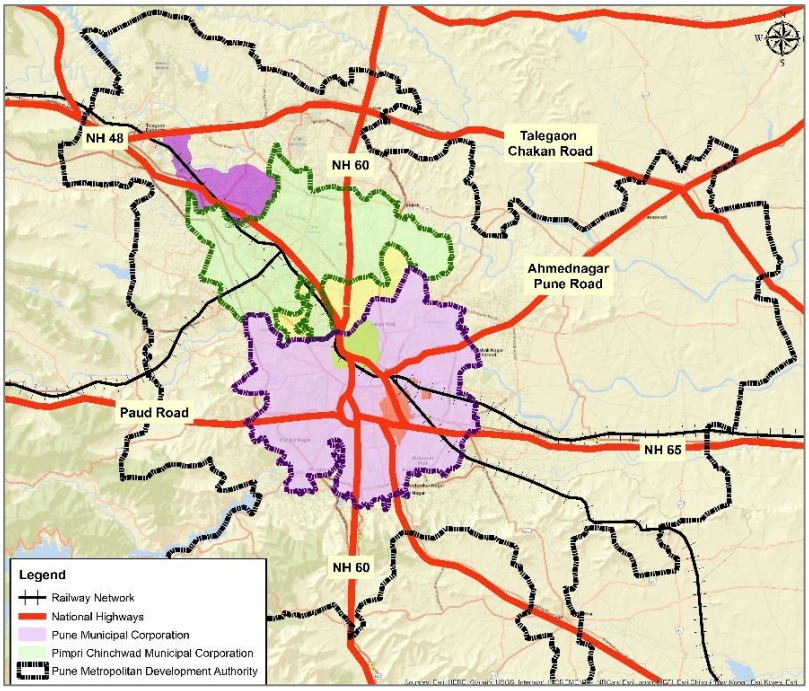


FIGURE 2-3: MAJOR ROAD AND RAIL NETWORK IN THE STUDY AREA

6Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

As per the CMP for PMC and PCMC in PMR, the following characteristics of the road network are observed:

- 13.04% of the land in PMC is under transportation and 3.89% of land in Pimpri Chinchwad is under transportation, which represents a gross inadequacy of transport infrastructure.
- About 24% of the road network has three (03) more than three (03) lane carriageway.
- About 82% of the roads are divided roads.
- About 28% of the roads are encroached on and its major causes are shops, on-street parking, auto/taxi stands and utilities.
- About 80% of the roads in the study area are bituminous in nature.
- Pavement condition of roads is good in the study area.
- Street lighting is present on 84% of the road network.
- About 65% of the roads within the study area do not have any form of footpath/pedestrian facilities.

2.4. MAJOR TRANSPORT NODES

The Pune Railway Station is one of the major transport nodes in the city. The railway station is administered by the Pune Railway Division of the Central Railways. It is a major railway junction in the country and is connected to

- Mumbai-Pune-Solapur
- Pune-Miraj
- Daund-Baramati

FIGURE 2-4: PUNE RAILWAY STATION

The station serves as a stop for north-bound trains from Mumbai, Gujarat and Madhya Pradesh. It also serves as a stop for south-bound trains from Goa and Karnataka. The station is also a major hub for freight transportation. Maldhakka is the freight depot of the Pune Railway Station.

MSRTC operates inter-city buses from four (04) bus terminals, i.e., Swargate, Shivaji Nagar, Pune Railway Station and Vallabh Nagar. PMPML operates buses from thirteen (13) depots, which are located at Swargate, Shivaji Nagar, Kothrud, Katraj, Hadapsar, Market Yard, Upper Depot, Pune Railway Station, Nigdi, Pimpri, Bhosari, Wagholi and Bhekrai Nagar. Apart from these, the 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.

Of all the above-mentioned major bus transport nodes in the city, the Pune Railway Station in the northern part of the city and the Swargate Bus Stand in the southern part of the city are serve as major bus stands, catering to the inter-city traffic with origin and destination other than Pune.

The Pune International Airport is located at Lohagaon, approximately 10 km from Pune city. The airport is operated by the Airports Authority of India (AAI). The airport caters to ~5 to 15 million passengers annually and connects all the major cities in the country. The Government of Maharashtra is planning to construct a new greenfield airport near Saswad and Jejuri in Purandar Taluka. The proposed airport will be spread over 2,400 hectares.

FIGURE 2-5: PUNE AIRPORT

2.5. PEDESTRIAN AND NMV FACILITIES

Non-motorized transport (also known as active transport and human-powered transport) includes walking, cycling, etc. Walking and cycling are the most sustainable modes of transport. Moreover, they have health benefits. Thus, the economic rate of return for creating NMT is very high as the benefits of creating NMT infrastructure outweigh the cost incurred.

As per the CMP Study – 2018, the share of NMT (i.e., pedestrian and NMV) in the PMR is 27.6%, i.e., the trips made by walking and cycling. Further, ~70% to 80% of public transport trips start and end with walk trips.

As per the Road Inventory Survey conducted as part of the CMP, it was found that 23% of the roads have footpaths on both sides and 12% have footpaths on one side only. Overall, 65% of the roads whose minimum ROW is 7 m, do not have any footpaths. It was also noticed that 25% of the footpaths are encroached upon by utilities, shops, hawkers, and parking.

Based on various assessments, the following was concluded with regard to pedestrian and NMV facilities:

- The city has pedestrian facilities which need considerable improvement. The pedestrian facilities at intersections, the availability of footpath, etc. need improvement too as many parts of the city are not served by them.
- The city has NMT facilities that may need considerable improvement as many parts of the city are not served by them.

EFFORTS BY PMC TO IMPROVE NMT INFRASTRUCTURE

NMT improvements are often one of the most effective ways of encouraging the use of public transport. The quality of the pedestrian environment is important for community liveability and social cohesion. Making streets pleasant and safe for walking allows residents to interact and children to play.

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:

- Formulated Pedestrian Policy
- 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 ABB Area)

A Non-Motorized Transport (NMT) Cell was set up in 2008 by PMC to look at issues related to pedestrians and cyclists, and the provision of footpath and bicycle track infrastructures. Its objective is to plan and maintain consistent, high-quality pedestrian infrastructure with an equitable allocation of road space. At present, the length of bicycle tracks in PMC is around 40 km. The Cell has planned to develop 75 km of footpaths along BRT corridors and complementary 15 km of bicycle tracks on the following roads:

- Sancheti-Aundh Road
- Wakdewadi-Harris Bridge
- Alandi Road
- Nagar Road
- Nehru-Market Yard Road
- Upper Indiranagar Road
- Satara Road
- Sinhagad Road
- Karve Road
- Paud Road
- University Chowk to Wakad Phata

The Bicycle Master Plan for Pune has recommended the formulation and implementation of the following:

- City-wide bicycle network
- Bicycle design guidelines
- Public bicycle system
- Bicycle parking
- Integration with transit
- Regulation and enforcement
- Outreach and promotion

- Monitoring and evaluation
- Implementation schedule

The plan 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 Rs.150 crores in 2016-2020.

EFFORTS BY PCMC TO IMPROVE NMT INFRASTRUCTURE

PCMC has developed bicycle tracks along several roads and along the BRT routes. But most of the tracks are being used to park vehicles. There is also a need to ensure that the bicycle tracks are free of encroachments.

The length of bicycle tracks in PCMC is around 10 km. PCMC is now exploring the idea of implementing the PBS.

PROPOSALS AS PER THE CMP

Some key proposals for improving pedestrian and NMV facilities are described below:

1. ~47 km of roads have been identified in PMC and PCMC for the development of footpaths, with a minimum footpath width of 1.8 m, as per the IRC 103:2012.
2. Development of pedestrian grade separated facilities
3. Development of pedestrian cross walks
4. Development of zebra crossings with rumble strips and pedestrian signal
5. Pedestrian priority streets
6. Pedestrianization
7. Development of bicycle tracks on key corridors in Pune and PCMC with 2 m for one-way movement and 3 m for two-way movement and a recommended buffer of 0.5 m between motor vehicle or parking lanes and bicycle tracks.
8. Introduction of a Public Bike Sharing Scheme in the city – Pune already has bicycle sharing schemes. Launched in 2017 by Zoom car (PEDL) and the Chinese firm OFO in association with PMC in central parts of the city, they are popular among residents for making short trips. The same is recommended for extensions in various parts of the city.

2.6. TRAFFIC MANAGEMENT INCLUDING PARKING MANAGEMENT

The main aim of traffic management is to provide for the safe, orderly, and economical movement of persons and goods, and to enhance the standard of the native atmosphere on and adjacent to traffic facilities. This results in more efficient use of transportation resources, as opposed to increasing the transportation system supply, by expanding the roads, parking facilities, and facilities for private vehicles.

The traffic police have set up traffic management and traffic regulation teams at the control room. The traffic management team coordinates continuously with the traffic police to manage and smoothen the traffic in Pune and Pimpri Chinchwad.

As per the CMP Study – 2018, 27% of the roads have on-street parking, which effectively reduces the carriageway utilization and affects the smooth movement of traffic. This is a point of concern, especially in the central business district and market area. At present, there is no penalty for unauthorized on-street parking. Inadequate off-street parking facilities and widespread on-street parking have been observed, which is free except on MG Road and in the Cantonment area.

2.7. TRAFFIC CHARACTERISTICS

Traffic and transportation characteristics help in appreciating the spatial and temporal characteristics of travel within the study area, transport network capacity, utilization, and the prevailing level of service. To understand the traffic and transportation characteristics of the study area, a wide range of traffic surveys were carried out within the study area between November 2021 and January 2022 for the present study.

The broad details of the various surveys carried out for the present study are presented in the table below.

TABLE 2-3: LIST OF PRIMARY TRAFFIC SURVEYS[7]

S. N.	Type of Survey	Quantity /Details	Duration of the Survey
1	Classified Traffic Volume Counts at OC Locations	19	24 Hours
2	Classified Traffic Volume Counts at Screen Lines	31	16 Hours
3	Classified Traffic Volume Counts at MB	13	16 Hours
4	Origin and Destination Survey at OC	07	24 Hours
5	Turning Volume Counts at Intersections	27	16 Hours
6	Passenger Terminal Counts (Rail and Bus)	13	16 Hours
7	Passenger Terminal OD Surveys (Rail & Bus)	3500 Samples	16 Hours
8	Bus Stop Boarding and Alighting Surveys	30	16 Hours
9	Bus Stop OD Surveys	5000 Samples	16 Hours
10	Household Interview Surveys (0.5 % of the households in the Study Area)	9693 Samples	----
11	Road Network Inventory Surveys	~ 610 km	----
12	Speed and Delay Surveys (Private and Public Transport)	350 km	----
13	Pedestrian Surveys	21	16 Hours
14	On-Street and Off-Street Parking Surveys	24	16 Hours

All the above-mentioned surveys were undertaken on a non-event working day through videographic and interview surveys.

7 OC – Outer Cordon Locations; MB – Mid Block Locations; OD – Origin and Destination

The assessment of these surveys shall cover the following aspects:

- Peak Hour Traffic
- Traffic Composition
- Mode-Wise Hourly Variation in Traffic
- Variation in Flow during Peak and Off Peak Hours
- Traffic Movement Pattern
- Trips by Purpose
- Trip Frequency and Modes
- Origin and Destination Pairs
- Speed and Delay – Journey Speeds on City Road Network
- Road Network Characteristics, etc.

The outcomes of the traffic surveys are mentioned in detail in Section 3.4.1. Traffic Survey Data Assessment in Chapter 3.

TRAFFIC VOLUME AND COMPOSITION

The total daily traffic volumes in terms of the number of vehicles and Passenger Car Units (PCUs) have been compared at the mid-block/screen line locations.

The count observed at different locations along the screen line locations varies between 18,665 PCUs (19,252 vehicles) on the Dhanori Alandi Road to 1,66,781 PCUs (1,61,615 Vehicles) on the Westernly Bypass on Bangalore Highway throughout a non-event working day.

The daily composition at these locations is represented in Figure 2-6.

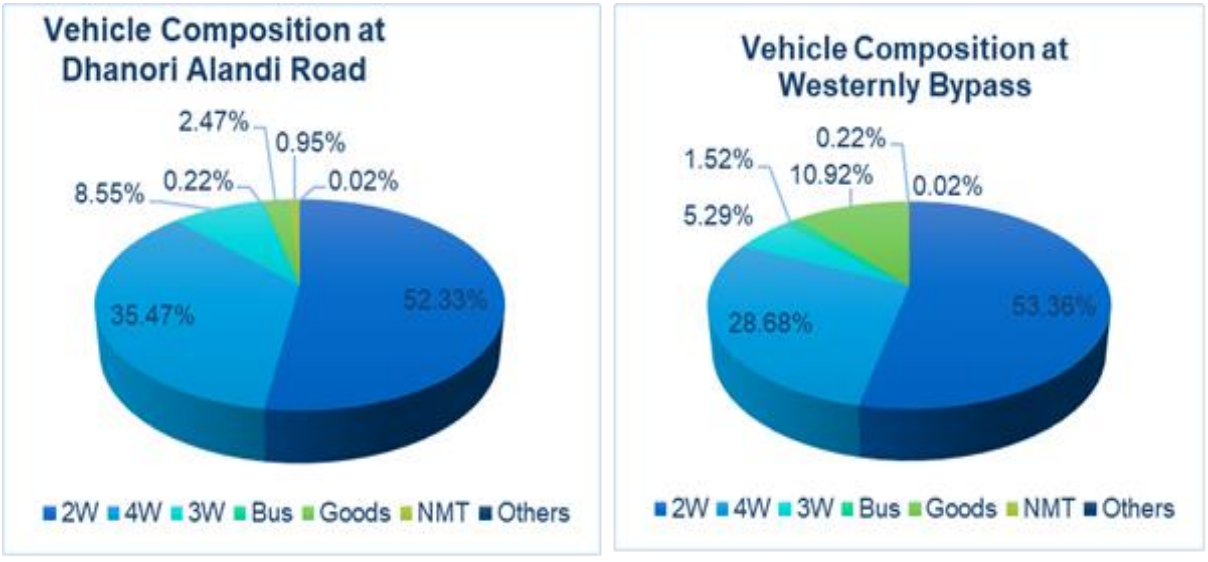


FIGURE 2-6: DAILY TRAFFIC COMPOSITION ON MAJOR SCREEN LINE LOCATIONS

SPEED AND DELAY

The average journey speeds indicate that about 33% of the surveyed roads have average journey speeds below 15 kmph and 20% of the surveyed roads have average journey speeds above 30 kmph.

The average running speeds indicate that about 23% of the surveyed roads have average running speeds below 15 kmph and 34% of the surveyed roads have average running speeds above 30 kmph.

The majority (about 70%) of the delays along the surveyed roads were caused by congestion at the signalized/non-signalized intersections, whereas the remaining 30% is due to congestion along the roads caused by on-street and off-street parking, loading and unloading of vehicles on the main roads, encroachment of the road space by hawkers, and ad-hoc pedestrian movements.

2.8. TRAFFIC SAFETY

Road safety becomes a cause of prime concern with the increasing number of transport modes. Inadequate facilities for pedestrians and NMVs and lack of segregation from fast-moving traffic are also main causes of road fatalities. Table 2-4 shows the trends of road accidents in Pune between 2013 and 2017.

TABLE 2-4: ACCIDENT TREND OF ROAD ACCIDENTS IN PUNE (2013-17)[8]

S. N.	Year	Fatal		Grievous		Minor		Non-Injured	Total Victims
		Accident	No. of Death	Accident	No. of Injured	Accident	No. of Injured		
1	2013	388	399	518	618	659	885	122	1902
2	2014	378	399	495	629	580	773	119	1801
3	2015	419	438	568	698	367	507	89	1643
4	2016	397	410	595	676	306	360	78	1446
5	2017	360	373	607	710	358	441	182	1524

As discussed in the previous section, the city of Pune has been witnessing an increase in vehicle ownership and population. Consequently, there has been an increase in the fatality rate and road accidents. Upon closely examining the data for the period between 2013 and 2017, the following has been observed:

- The trends show that there has been a gradual decrease in the number of total crashes in the city. It has reduced from 388 in 2013 to 360 in 2017, i.e., a 7.8% decline over the five years between 2013 and 2017.
- 1325 road accidents occurred in the year 2017, of which 1524 victims were involved in road crashes. As per police records, 360 were fatal accidents and the rest were major/minor injuries. 182 incidents (non-injured) also occurred in the same year.

8Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

- On reviewing the data pertaining to the gender-wise involvement of road users in the road accidents, the following is observed;
    - 75.42% of the road accidents involved males and 24.58% females across various categories of road accidents in the year 2017.
    - During 2013-2017, a total of 8334 road accidents occurred, of which 2019 accidents were fatal and 3330 accidents were grievous. Also, 76.90% males and 23.10% females were involved in these road accidents.
    - 2-wheelers and cars were involved in around 60% of the road accidents each year.
    - Most victims were two-wheeler riders (57%) and pedestrians (28%).

From vehicular population data (refer to Section 2.1) and road crash data (refer to Section 2.8), it was found that the rate of traffic deaths per 1,00,000 vehicles is 7.2 and the rate of traffic deaths per 1,00,000 people is 5.

According to the World Health Organization, the average annual rate was 17.4 per 100,000 people. Low-income countries now have the highest annual road traffic fatality rates, at 24.1 per 100,000, while the rate in high-income countries is the lowest, at 9.2 per 100,000. For India, the average rate of traffic deaths is 16.6 per 1,00,000 people (WHO, 2013). The study area has shown a considerably lower rate of traffic deaths per 1,00,000 people in Pune.

As per the CMP - Road Design and Road Infrastructure, traffic management needs to be improved considerably to reduce road accidents in the study area.

2.9. INTERMEDIATE PUBLIC TRANSIT (IPT) SYSTEM

The various IPT modes in Pune are auto-rickshaws, shared autos, and taxi services, which include app-based taxi aggregators like Ola and Uber. Auto-rickshaws are the main IPT modes in Pune. There are no specific route restrictions for the auto-rickshaws.

A total of 922 designated auto rickshaw stands have been provided in Pune, Pimpri Chinchwad and the Cantonment Area, which are represented in the Figure 2-7.

Auto rickshaws provide connectivity to the city core areas which has a narrow road network. Many people prefer them over the local bus service due to shorter wait times and point-to-point service. A total of 79,179 auto-rickshaws, 43,145 taxis and 12,944 other passenger vehicular permits had been issued in Pune and Pimpri-Chinchwad in 2021.

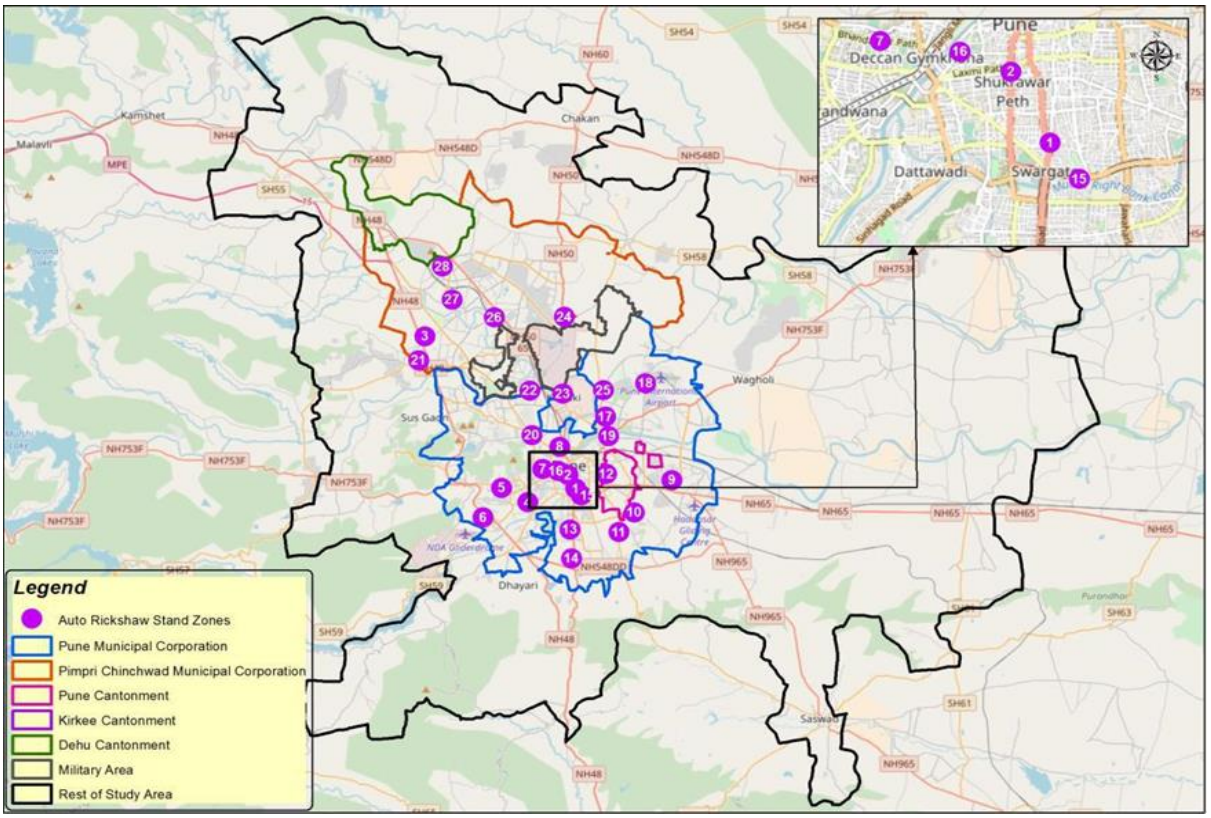


FIGURE 2-7: AUTO RICKSHAW STAND ZONES IN PMC AND PCMC

2.10. PUBLIC TRANSPORTATION SYSTEM

2.10.1. CITY BUS SERVICES

The city bus public transport system in the study area is operated by Pune Mahanagar Parivahan Mahamandal Limited (PMPML). The fleet size of PMPML is about 1,500. The average life of the fleet is about eight years. On an average, 1,382 buses operate on 371 routes and 17,000 trips are made per day. PMPML carries around 10.65 lakh trip passengers daily (January 2017). The average number of passengers per bus per day is about 770. PMPML operates various services like Regular Service, Rainbow Buses, Night Buses, Pune Darshan, Ladies Special and Airport Buses.

TABLE 2-5: TOTAL NUMBER OF BUSES PLYING WITHIN PMR[9]

Year	Total No. of Buses Plying within the City
2015-16	1447
2016-17	1382
2017-18	1425
2018-19	1373
2019-20	1383
2020-21	1598

9Source: Pune Municipal Corporation – Open Source Data

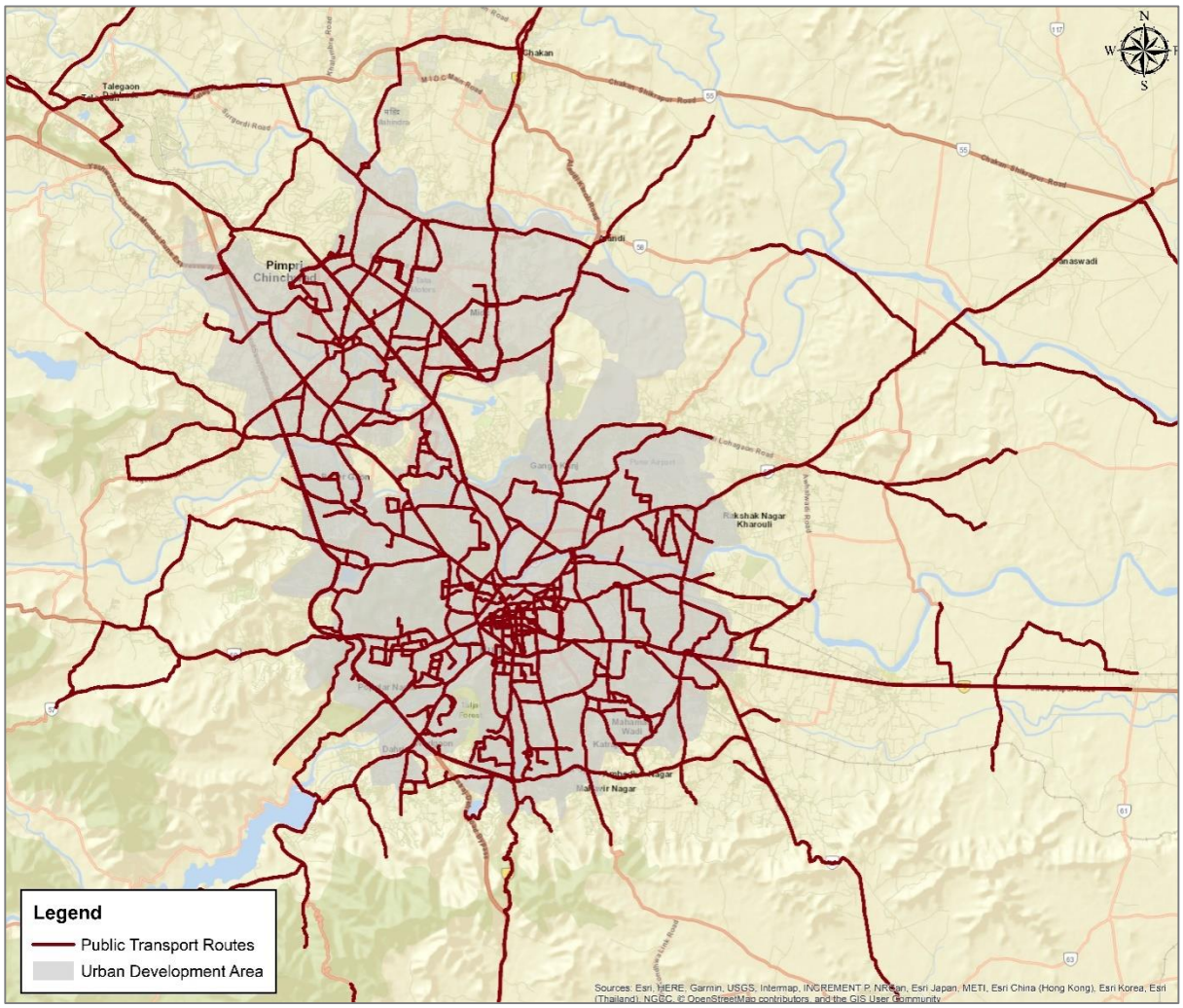


FIGURE 2-8: CITY BUS SERVICE NETWORK OF PMPML[10]

Table 2-6 presents the salient features of the city bus services in Pune. It clearly shows that ridership on buses is declining due to an increased preference for personal vehicles.

TABLE 2-6: SALIENT FEATURES OF CITY BUS SERVICES IN PUNE[11]

Year	Mode Share - Total No. of Trips	Average No. of Daily Trips	Average No. of Passengers (in Lakhs)	Average Trip Length in km (Daily)	Average cost per km (daily)	Revenue per km
2015-16	20.41%	17642	11.24	17.75	81.01	67.77
2016-17	19.14%	17073	10.79	17.78	85.19	65.94
2017-18	18.81%	17789	10.89	21.72	76.98	58.73
2018-19	16.47%	16473	10.34	21.20	83.51	59.69

10Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018
11Source: opendata.punecorporation.org

Year	Mode Share - Total No. of Trips	Average No. of Daily Trips	Average No. of Passengers (in Lakhs)	Average Trip Length in km (Daily)	Average cost per km (daily)	Revenue per km
2019-20	16.22%	16791	10.47	21.37	90.50	60.75
2020-21[12]	15.22%	19,019	10.04	NA	NA	NA

At present, PMPML has 13 bus depots and 2392 bus stops. PMPML has recently introduced e-buses (a fleet of 220, of 12 m and 9 m buses) operating on a Gross Cost Model (km-based). 500 more e-buses are being procured on the same lines from FAME-II and through State Government funding. Two dedicated e-bus depots have also been developed.

2.10.2. BUS RAPID TRANSIT SYSTEM (BRTS)

Pune's BRTS is the first Bus Rapid Transit System in India. It is named the 'Rainbow BRT'. The BRTS covers both PMC and PCMC. At present, five corridors of 61 km are operational. Rainbow BRT caters to 51 routes through 319 buses plying across the five corridors. The BRTS route from Dapodi-Nigdi on the Pune-Mumbai highway is expected to be operational soon. The details of the BRTS corridors operational in Pune are presented in Table 2-7 and Figure 2-9.

However, the system is not fully segregated or closed. The BRTS has several issues like the 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, lack of multi-modal integration facilities, etc. Due to these issues, the system is yet to attract good ridership. For the success of BRTS, strict enforcement and traffic discipline are required.

12 Source: PMPML Website & ESR 2020-21

TABLE 2-7: PUNE BRTS CORRIDORS[13]

Corridor Name	Length (km)	Stations	Region
Nagar Road	14	13	Pune
Sangamwadi-Vishrantwadi	08	09	Pune
Sangvi Phata-Kiwale	14	21	Pimpri Chinchwad
Nashik Phata-Wakad	08	15	Pimpri Chinchwad
Total (Rainbow BRT)	**44**		
Pilot BRT	17	Upgradation of Corridor in Progress	
Grand Total	**61**		

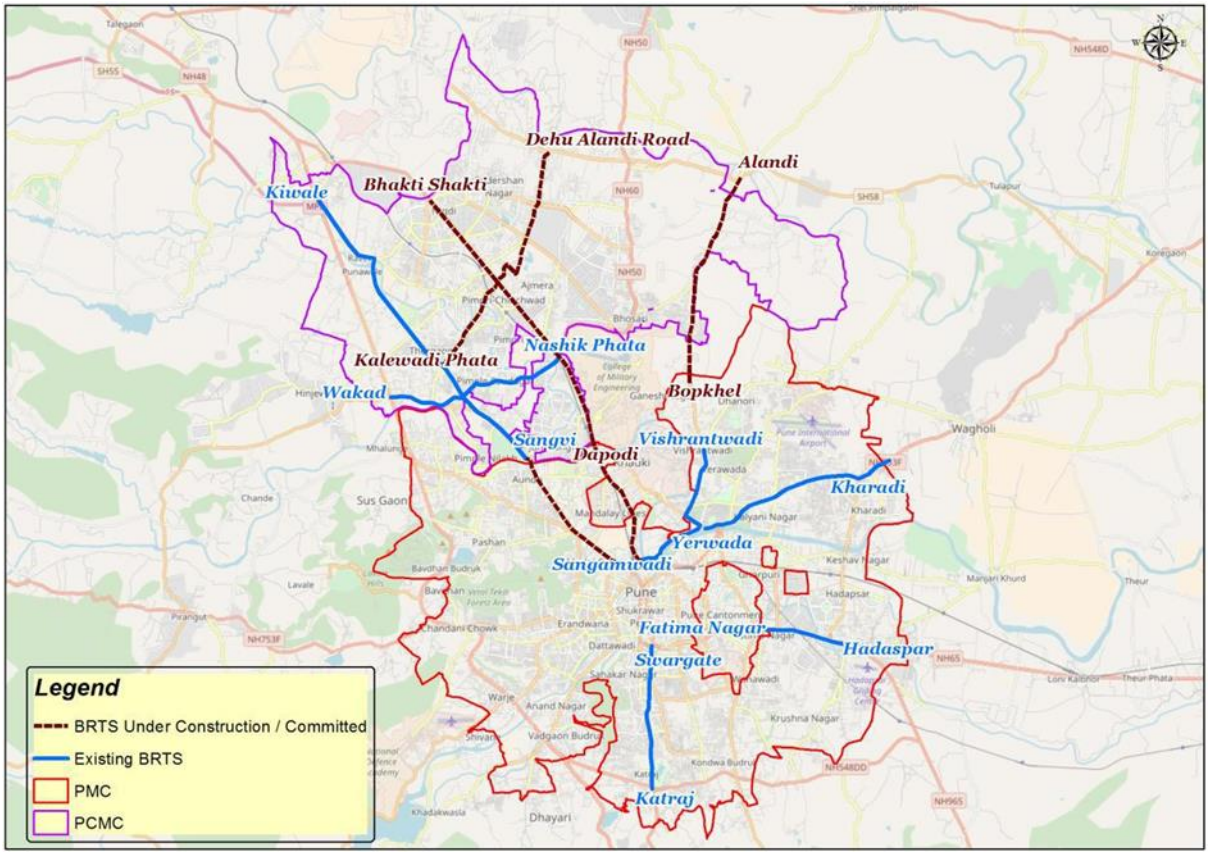


FIGURE 2-9: OPERATIONAL BRTS CORRIDORS IN THE STUDY AREA[14]

2.10.3. SUBURBAN RAILWAY

The Pune Suburban Railway between Pune and Lonavala is operated by Central Railways (CR). It runs on a double line electrified broad gauge section of 63.84 km. In a day, 18 trains are operated from Pune to Lonavala and five trains between Pune and Talegaon.

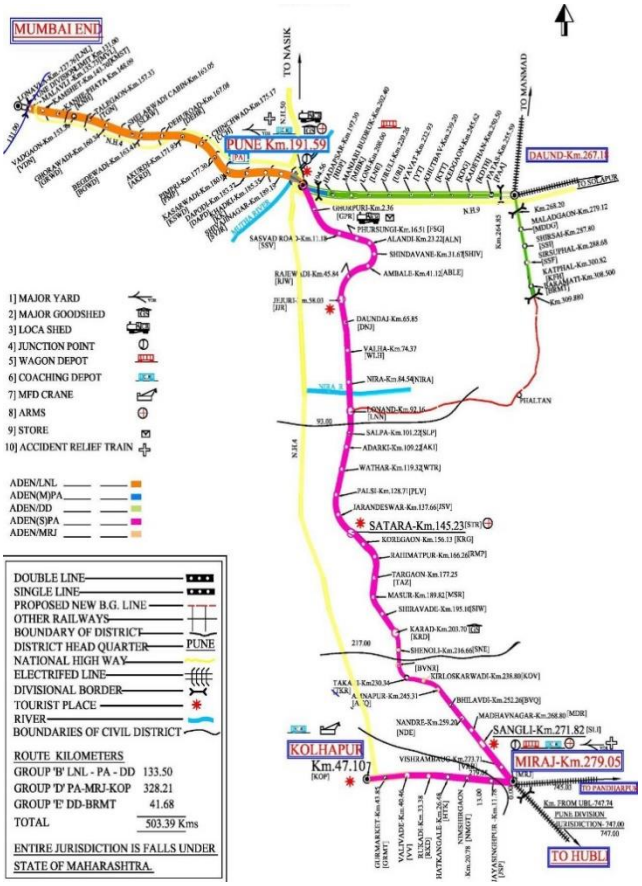
13Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018
14Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

The minimum headway of the trains is 30 minutes and the frequency is observed to be low, which makes the system heavily crowded during peak hours.

A large number of students, employees, and industrial workers travel by the suburban train.

Mumbai Rail Vikas Corporation (MRVC) is planning for a third and fourth line between Pune and Lonavala, exclusively for suburban rail operations.

Based on the rail passenger statistics, it has been observed that in 2016-17, about 1.15 lakh passengers were carried daily, while in 2017-18, about 1.11 lakh passengers were carried daily by the suburban services.



Stations along the Pune-Lonavala railway line are the Shivajinagar Station, Khadki Station, Pimpri Station, Chinchwad Station, Akurdi Station, Dehu Road Station, Talegaon Station and Lonavala Station.

There are eight passenger trains between Pune Junction and Daund section. These trains operate as suburban trains on this route. The Pune to Daund section becomes the third route for suburban trains. The important halts on this route are Loni Station and Urali Station.

2.10.4. METRO

The metro system was approved for two corridors – PCMC-Swargate and Vanaz-Ramwadi – in December 2016.

The survey and design work of Pune Metro began in June 2017. It is being implemented by Maha-Metro, a Special Purpose Vehicle (SPV) of the Government of India and Government of Maharashtra.

The metro corridors are a combination of elevated and underground sections.

As of March 2022, the Phase-1 Metro has started partial operations, i.e., five stations on Line 1, i.e., from PCMC to Phugewadi, and five stations on Line 2, i.e., Vanaz to Garware College.

TABLE 2-8: APPROVED PUNE METRO CORRIDORS

Alignment	Corridor	Rail Length (km)	Stations		
			Underground	Elevated	Total
Line 1	PCMC – Swargate	17.52	05	09	14
Line 2	Vanaz – Ramwadi	15.75	-	16	16
Line 3	Shivaji Nagar – Hinjewadi	23.3	-	23	23

The approved route map of the Pune Metro corridors is represented in Figure 2-10.

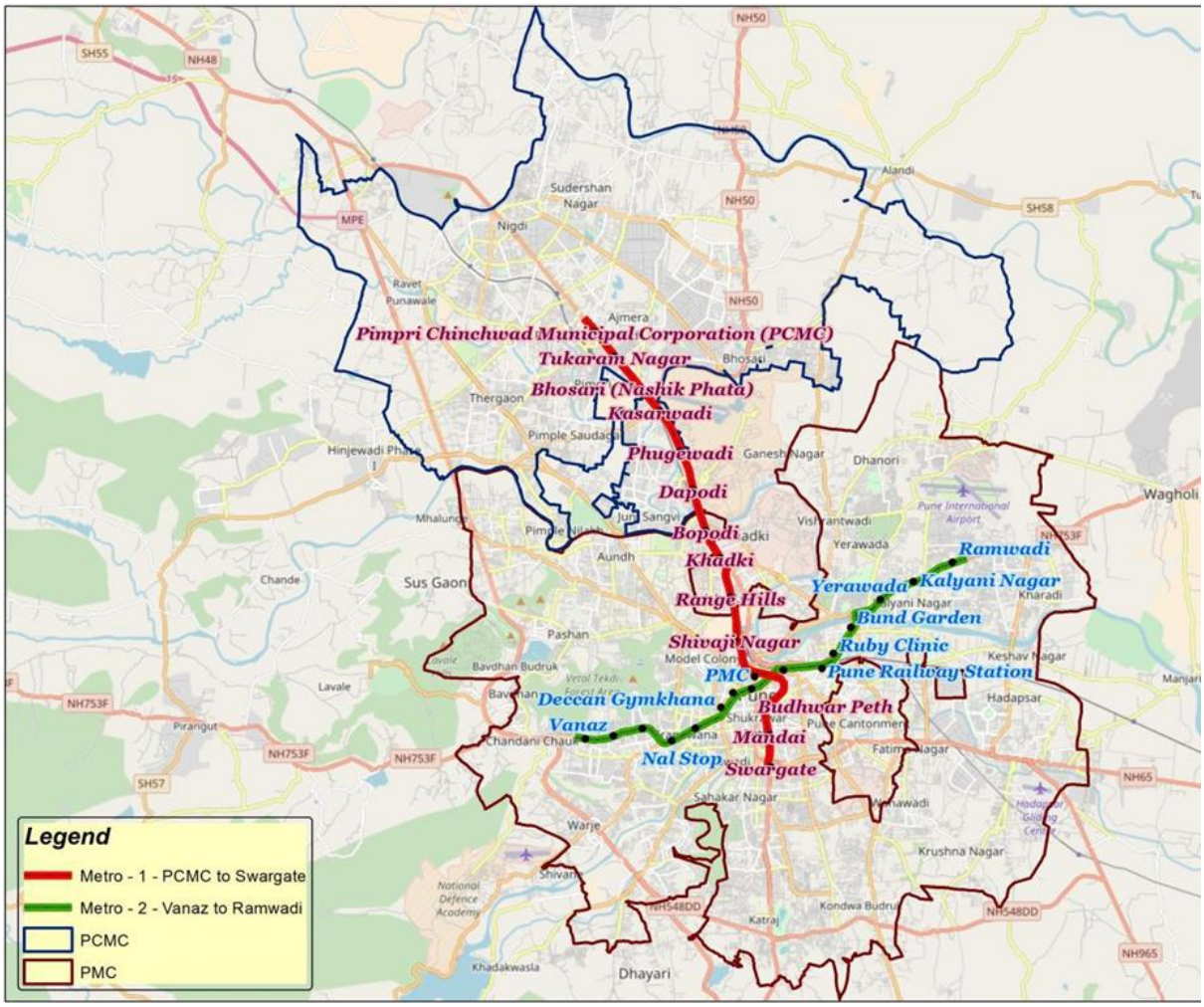


FIGURE 2-10: ROUTE MAP OF PUNE METRO RAIL PROJECT[15]

15Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

2.11. PAST PROPOSALS

Various past studies have been reviewed for the purpose of understanding the past transport scenario and proposals in the study area. A list of the studies reviewed is presented in the following table.

TABLE 2-9: LIST OF PAST STUDIES/REPORTS

S.N.	Name of the Study	Year
1	Final Detailed Project Report for Pune Metro Rail Project, DMRC	2015
2	Final Detailed Project Report for Pune Metro Rail Project, DMRC (Line 3)	2016
3	Comprehensive Mobility Plan for PMC and PCMC in PMR	2018
4	DPR - MMI Plan & PBS Scheme for 30 Metro Rail Stations	2019
5	Feasibility Study Elevated/At Grade Corridor - HCMTR	2019
6	Detailed Project Report for Swargate to Katraj	2019
7	Detailed Project Report for PCMC to Nigdi	2019
8	Detailed Project Report for HCMTR Pimpri Chinchwad	2020

Note: Some of the project Reports are under various stages of approvals by the State and the Central Govt.

2.11.1. FINAL DPR PUNE METRO RAIL PROJECT (LINE 01 & 02) - 2015

A Detailed Project Report for Line 01 – PCMC to Swargate and Line 02 – Vanaz to Ramwadi for the Pune Metro Rail Project was prepared in 2015 by DMRC. The details of the corridors are given in Table 2-10.

Figure 2-11 represents the mass transit corridors (Line 1 and Line 2) considered for this study.

FIGURE 2-11: PUNE METRO RAIL PHASE 1 ROUTE MAP [16]

Based on the traffic and demand assessments, two (02) corridors were finalized in the DPR as Phase-1of Pune Metro in 2015. The details of the same are presented in Table 2-10

TABLE 2-10: DETAILS OF THE PUNE METRO CORRIDORS[17]

S.N.	Corridor Name	Length	No. of Stations
1	PCMC to Swargate Corridor	16.59 Km	15 (Underground – 06 and Elevated – 09)
2	Vanaz to Ramwadi Corridor	14.67 Km	16

The estimated Daily Ridership and Peak Hour Peak Direction Traffic (PHPDT) under two (02) scenarios (i.e., Optimistic Projections and Most Likely Projections) are represented in Table 2-11 and Table 2-12.

16Source: https://www.punemetrorail.org/
17Detailed Project Report for Pune Metro - 2015

TABLE 2-11: DAILY RIDERSHIP UNDER VARIOUS SCENARIOS[18]

S.N.	Corridor	2011	2018	2021	2031
Optimistic Projections					
1	PCMC to Swargate	4,80,860	5,16,855	5,32,281	6,13,442
2	Vanaz to Ramwadi	2,89,813	4,21,123	4,77,399	5,92,168
Most Likely Traffic Projections					
1	PCMC to Swargate	-	3,82,577	3,97,229	4,43,849
2	Vanaz to Ramwadi	-	1,89,306	2,12,019	2,90,515

TABLE 2-12: PEAK HOUR PEAK DIRECTION TRAFFIC (PHPDT) UNDER VARIOUS SCENARIOS[19]

S.N.	Corridor	2018	2021	2031
Optimistic Projections				
1	PCMC to Swargate	19,488	19,693	23,387
2	Vanaz to Ramwadi	15,760	18,244	22,414
Most Likely Traffic Projections				
1	PCMC to Swargate	17,905	18,961	20,035
2	Vanaz to Ramwadi	6,203	8,519	10,982

As per the DPR, the planning of metro infrastructure for two (02) corridors in Pune is based on the Most Likely Projections**.** Salient features of the scenario are as under:

Daily Ridership

- PCMC to Swargate – The daily ridership is estimated to increase from 3.82 lakh in 2018 to 4.43 lakh in 2031.
- Vanaz to Ramwadi – The daily ridership is estimated to increase from 1.89 lakh in 2018 to 2.90 lakh in 2031.

PHPDT

- PCMC to Swargate – The PHPDT is estimated to increase from 17,905 in 2018 to 20,035 in 2031.
- Vanaz to Ramwadi – The PHPDT is estimated to increase from 6,203 in 2018 to 10,982 in 2031.

Considering the ridership and PHPDT under the Most Likely Projections as mentioned above, a Medium Capacity Metro System with a range of 30,000 to 50,000 PHPDT has been recommended for Phase-1 of the Pune Metro.

18 Extracted from the Detailed Project Report (DPR) for Pune Metro 2015
19 Extracted from the Detailed Project Report (DPR) for Pune Metro 2015

2.11.2. DPR FOR PUNE METRO RAIL PROJECT (LINE 03) - 2016

Pune Metropolitan Regional Development Authority (PMRDA) was mandated by the Government of Maharashtra (GoM) to develop a metro rail link between the downtown area at Shivaji Nagar and the Information Technology Industry Zone at Hinjewadi on the outskirts of the city.

The details of the corridor are presented in Table 2-13.

TABLE 2-13: DETAILS OF THE LINE 3 METRO CORRIDOR

S.N.	Corridor Name	Length	No. of Stations
1	Shivaji Nagar to Hinjewadi	23.33 km	23

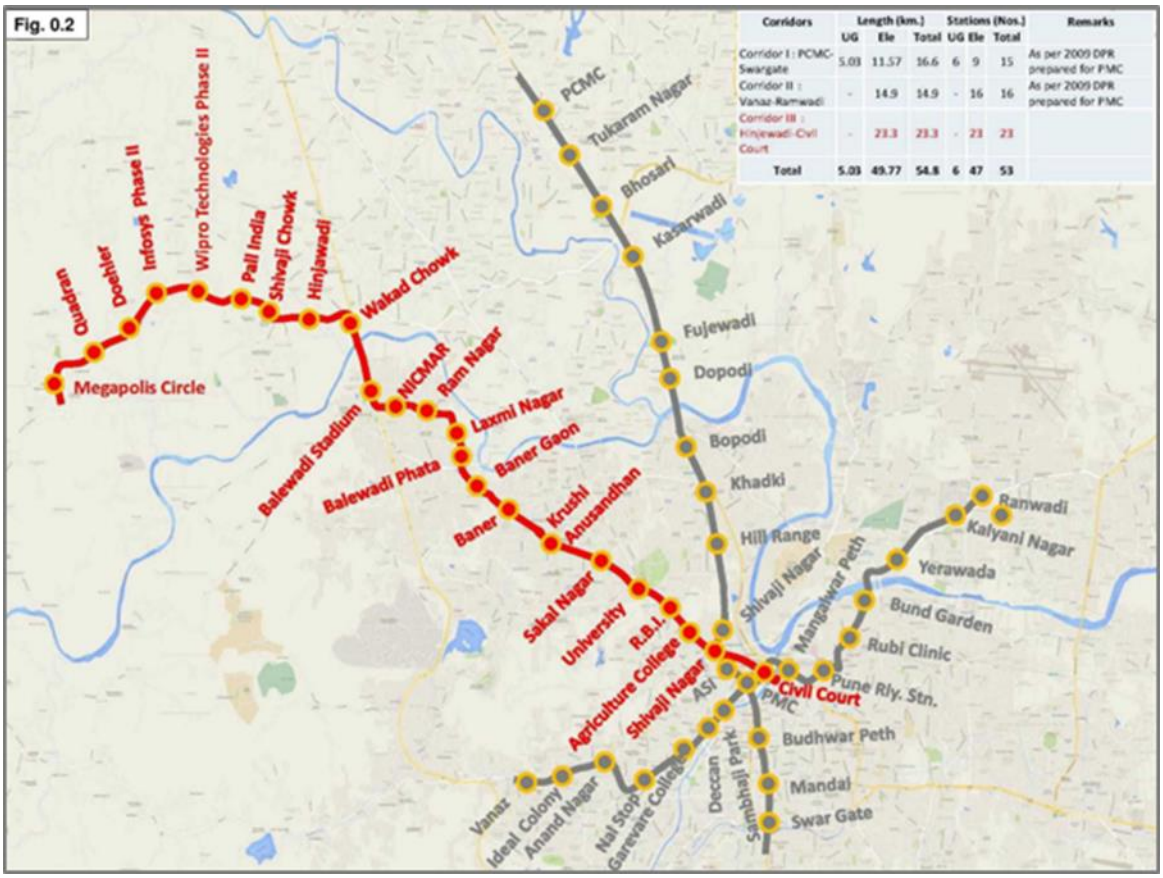


FIGURE 2-12: LINE 3 CONNECTING CIVIL COURT (SHIVAJI NAGAR) AND HINJEWADI

Table 2-14 and Table 2-15 represent the Daily Ridership and Peak Hour Peak Direction Traffic (PHPDT) under Optimistic Projections and Most Likely Projections scenarios.

TABLE 2-14: DAILY RIDERSHIP ON LINE 3 ON VARIOUS SCENARIOS[20]

Horizon Year	Most Likely Scenario	Optimistic Scenario
2019	192,270	359,664
2021	261,915	482,835
2025	351,724	633,728
2031	478,299	825,717
2041	574,156	991,240
2051	664,258	1,126,870

TABLE 2-15: MAXIMUM PHPDT ON LINE 3 ON VARIOUS SCENARIOS

Horizon Year	Most Likely Scenario	Optimistic Scenario
2019	3524	7701
2021	8143	14895
2025	11888	21022
2031	15872	27040
2041	19089	32528
2051	22125	37712

Based on the Alternative System Assessment, it is observed that road-based systems can optimally carry a maximum of 8,000 PHPDT. The average trip length on the corridor is observed to be 9.06 km in the year 2021.

With an aim of reducing traffic and with a PHPDT of more than 8000 on the corridor, two (02) alternative systems have been evaluated, i.e., Mono Rail and Light Capacity Metro. Monorail can carry the PHPDT projected but it has some demerits over the Light Capacity Metro. Accordingly, it has been recommended to adopt a stable, tested and reliable metro technology, i.e., a Light Capacity Metro System.

2.11.3. COMPREHENSIVE MOBILITY PLAN FOR PUNE CITY – 2018

To cater to the increased mobility needs of the twin cities of Pune and Pimpri Chinchwad through sustainable modes and improve the quality of life of residents and aid in the economic growth of the region, Pune Metropolitan Region Development Authority engaged L&T Infrastructure Engineering Limited to prepare the Comprehensive Mobility Plan (CMP) for PMC and PCMC in PMR.

A CMP is a city's long-term blueprint for improving accessibility and mobility. The aim of the plan is to develop an adequate, safe, environmentally friendly, affordable, equitable,

20Source: Final Detailed Project Report (DPR) for Line 03 Pune Metro - 2016

comfortable, efficient, and integrated transport system within the framework of a progressive and competitive market economy.

It advocates planning the mobility of people rather than vehicles by providing sustainable mobility plan options and accessibility for all citizens to jobs, education, social services and recreation facilities at an affordable cost and within reasonable time.

As part of the CMP study, major mobility corridors have been identified and classified as Metro, Light Metro and BRTS. The recommended mobility corridors in 2028 are presented in Table 2-16 and Figure 2-13 and those in 2038 are presented in Table 2-17 and Figure 2-14.

TABLE 2-16: RECOMMENDED PUBLIC TRANSPORT NETWORK AND SYSTEM (2028)

S.N.	Proposed Public Transport Corridor	Length in km	PHPDT 2028
Metro Corridors			
1	Nigdi – Katraj	33.63	15,500
2	Chandani Chowk – Wagholi	25.99	13,000
3	Hinjewadi – Shivaji Nagar	23.33	15,000
4	Shivaji Nagar - Hadapsar	11.74	13,000
5	Hinjewadi - Chakan	30.08	13,000
Light Metro Corridors			
6	Sinhagad Road (Veer Baji Pasalkar Chowk to Pune Cantonment)	9.08	7,500
Total		**133.85**	
BRTS Corridors			
1	Yerwada – Airport	5.05	1,600
2	Kaspate Wasti – Kalewadi Phata	1.80	950
3	HCMTR PMC	38.45	1,500
4	HCMTR PCMC	31.40	2,200
5	Chinchwad - Talwade	12.00	1,400
Total		**98.93**	

TABLE 2-17: RECOMMENDED PUBLIC TRANSPORT NETWORK AND SYSTEM (2038)

S.N.	Proposed Public Transport Corridor	Length in km	PHPDT 2028	PHPDT 2038
Metro Corridors				
1	Nigdi – Katraj	33.63	15,500	19,000
2	Chandani Chowk – Wagholi	25.99	13,000	17,500
3	Hinjewadi – Shivaji Nagar	23.33	15,000	23,000
4	Shivaji Nagar - Hadapsar	11.74	13,000	21,000
5	Hinjewadi - Chakan	30.08	13,000	21,000
Light Metro Corridors				

S.N.	Proposed Public Transport Corridor	Length in km	PHPDT 2028	PHPDT 2038
6	Sinhagad Road (Veer Baji Pasalkar Chowk to Pune Cant.)	9.08	7,500	13,500
7	Warje - Swargate	8.87	7,000	9,500
8	Wagholi – Pawar Wasti – Hinjewadi	35.23	-	12,000
10	Chandani Chowk - Hinjewadi	17.81	-	5,000
Total		**195.76**		
BRTS Corridors				
1	Yerwada – Airport	5.05	1,600	3,000
2	Kaspate Wasti – Kalewadi Phata	1.80	950	2,500
3	HCMTR PMC	38.45	1,500	3,500
4	HCMTR PCMC	31.40	2,200	4,500
5	Chinchwad - Talwade	12.00	1,400	2,000
6	BRTS along the Westernly Bypass	49.00	900	1500
7	Ring Road BRTS	134.00	1,400	3,500
Total		**147.93**		

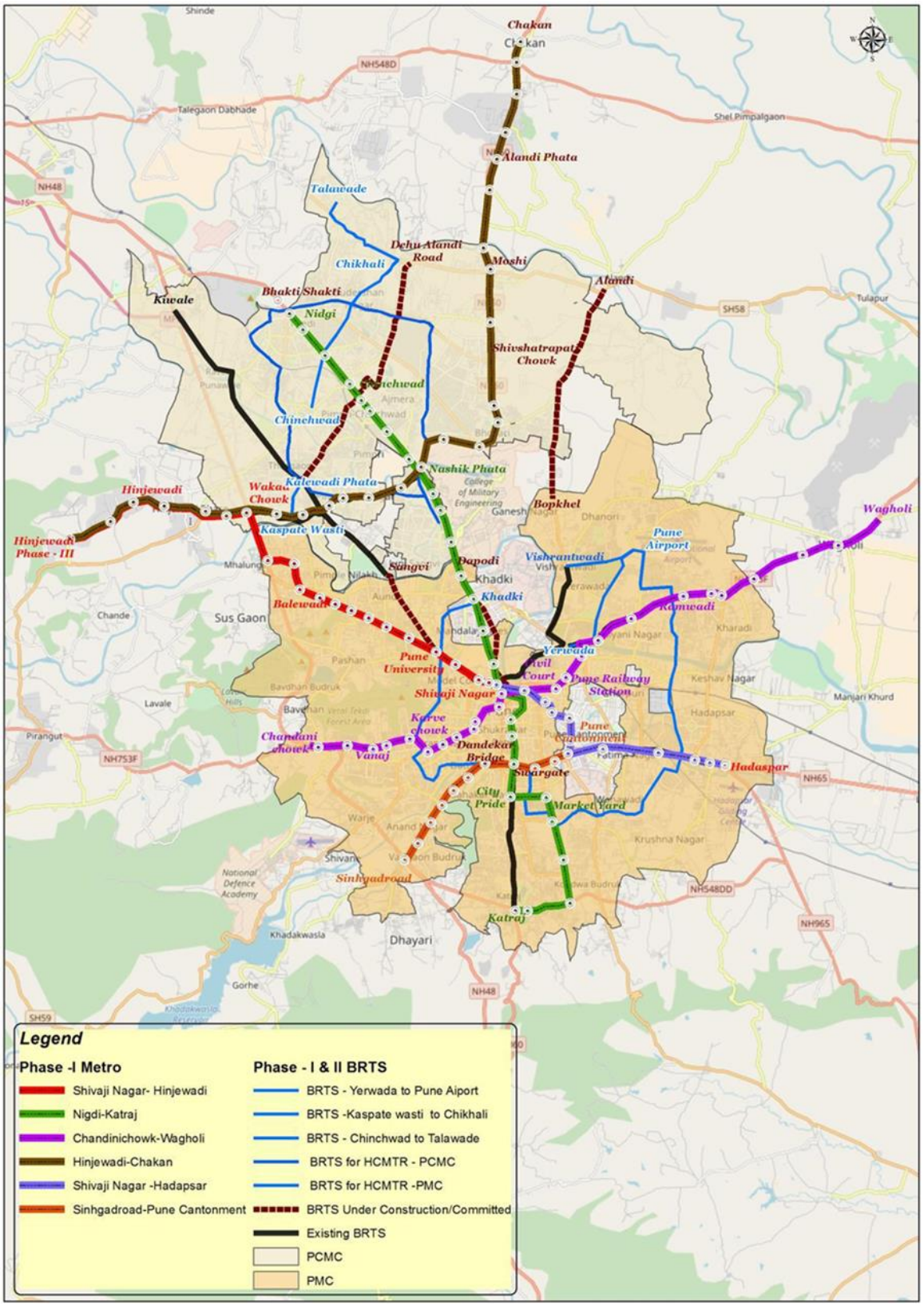


FIGURE 2-13: RECOMMENDED MASS TRANSIT CORRIDOR IN 2028[21]

21 Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

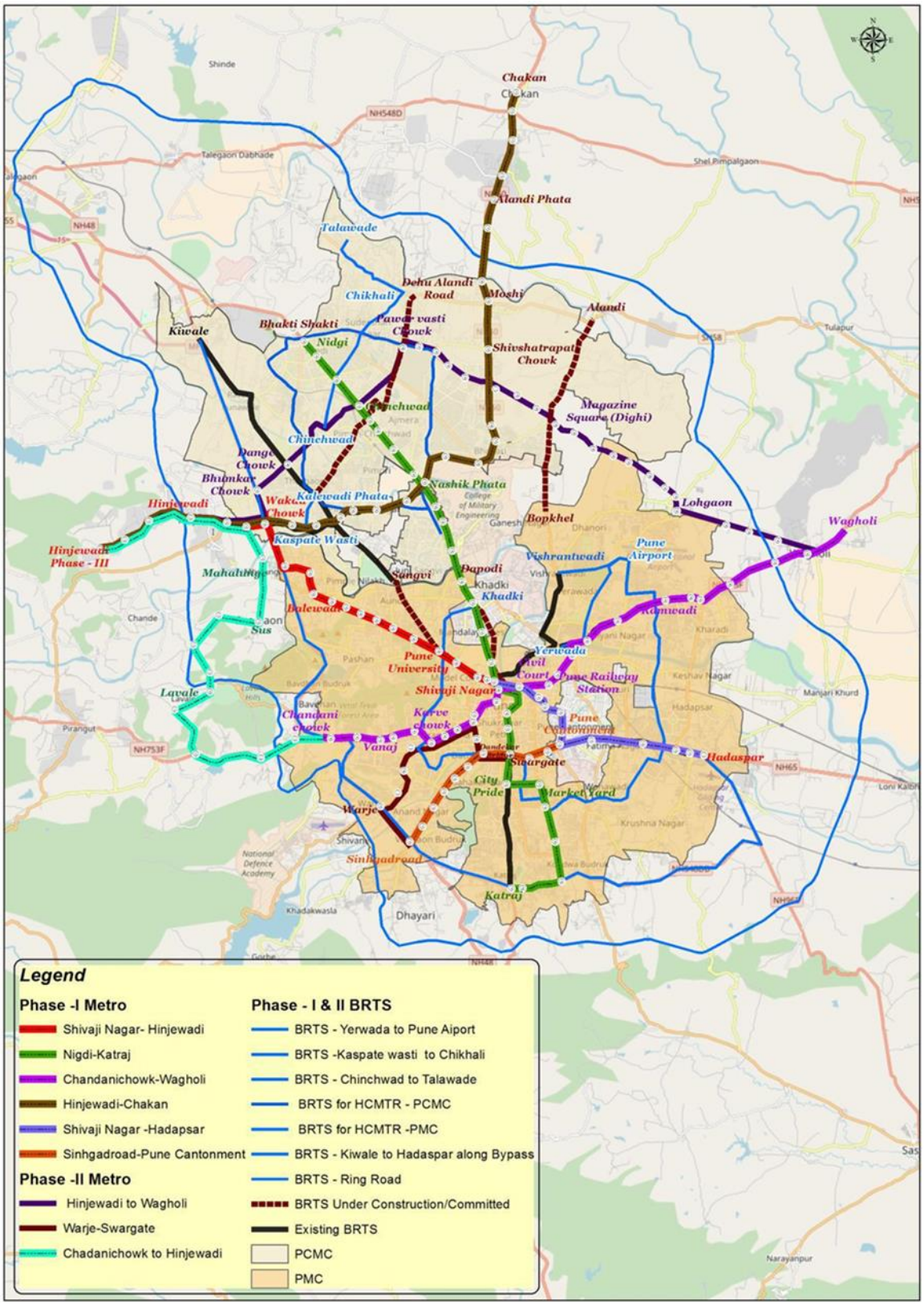


FIGURE 2-14: RECOMMENDED MASS TRANSIT CORRIDOR IN 2038[22]

22 Source: Comprehensive Mobility Plan for PMC and PCMC in PMR - 2018

2.11.4. DPR - MMI PLAN & PBS SCHEME - 30 METRO RAIL STATIONS - 2019

The DPR for the MMI Plan and PBS Scheme for 30 Metro Rail Stations in Pune Project was divided into two (02) modules.

- Module 1 – DPR for Metro Feeder Bus Connectivity
- Module 2 – DPR for NMT Plan and PBS Scheme.

The outcomes of both the modules are described in the section below.

Module 1 – DPR for Metro Feeder Bus Connectivity

The DPR for Metro Feeder Bus Connectivity has been prepared in 2019. It deals with the metro feeder bus connectivity for a catchment area of 2.5 km buffer on either side of the metro stations. The main aim of the DPR is to provide an organized feeder system to support the major mass transit systems in Pune city and enhance the ridership.

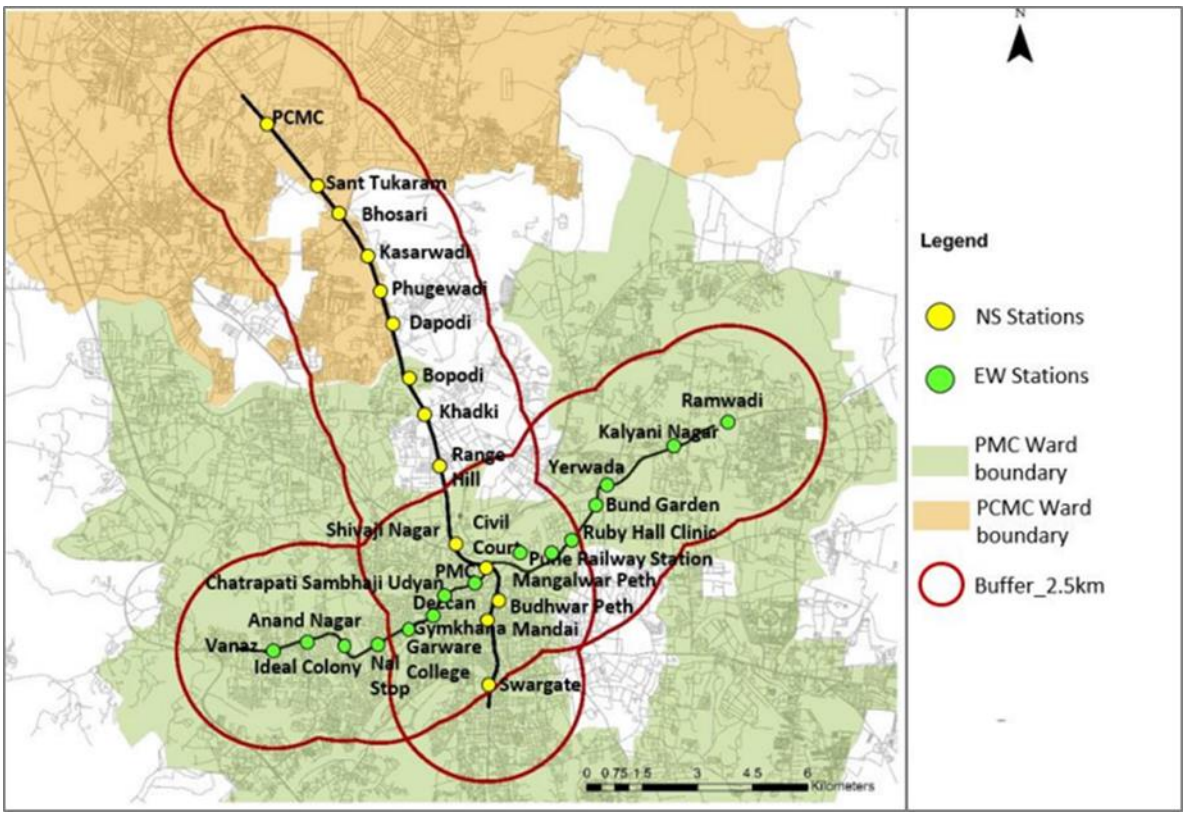


FIGURE 2-15: STUDY AREA FOR METRO FEEDER NETWORK – DPR FOR METRO FEEDER CONNECTIVITY

Various surveys like origin-destination survey, bus frequency survey, and stated preference surveys were conducted within the study area to capture the demand and determine the feeder requirements. Major observations from the primary survey analysis are:

- The cyclist and pedestrian opinion survey revealed that only 44.5% of the users are satisfied with the current NMT facilities provided.
- Only 40.6% of the current PT users said that they are satisfied with the PT facilities, indicating a need for improvement in PT facilities. The problems stated included low frequency, lack of adequate signage, infrastructure facilities, etc.
- About 36% of the PT users walk for more than 500 m to reach their nearest bus stops. This in turn results in increased travel time, which needs to be dealt with by introducing an effective feeder system in Pune city.
- The survey results showed that 4.84% of the people are willing to use feeder services to and from metro stations. Thus, feeder buses can be provided to give better first- and last-mile connectivity.
- From the bus boarding and alighting surveys, it was found that connectivity needs to be established through feeder services along various sub-arterial and collector roads where the PMPML services are lacking currently.

Based on the inferences drawn from the data analysis and surveys, 31 feeder routes were identified for 30 metro stations. Figure 2-16 shows the overall feeder network proposed as part of the study.

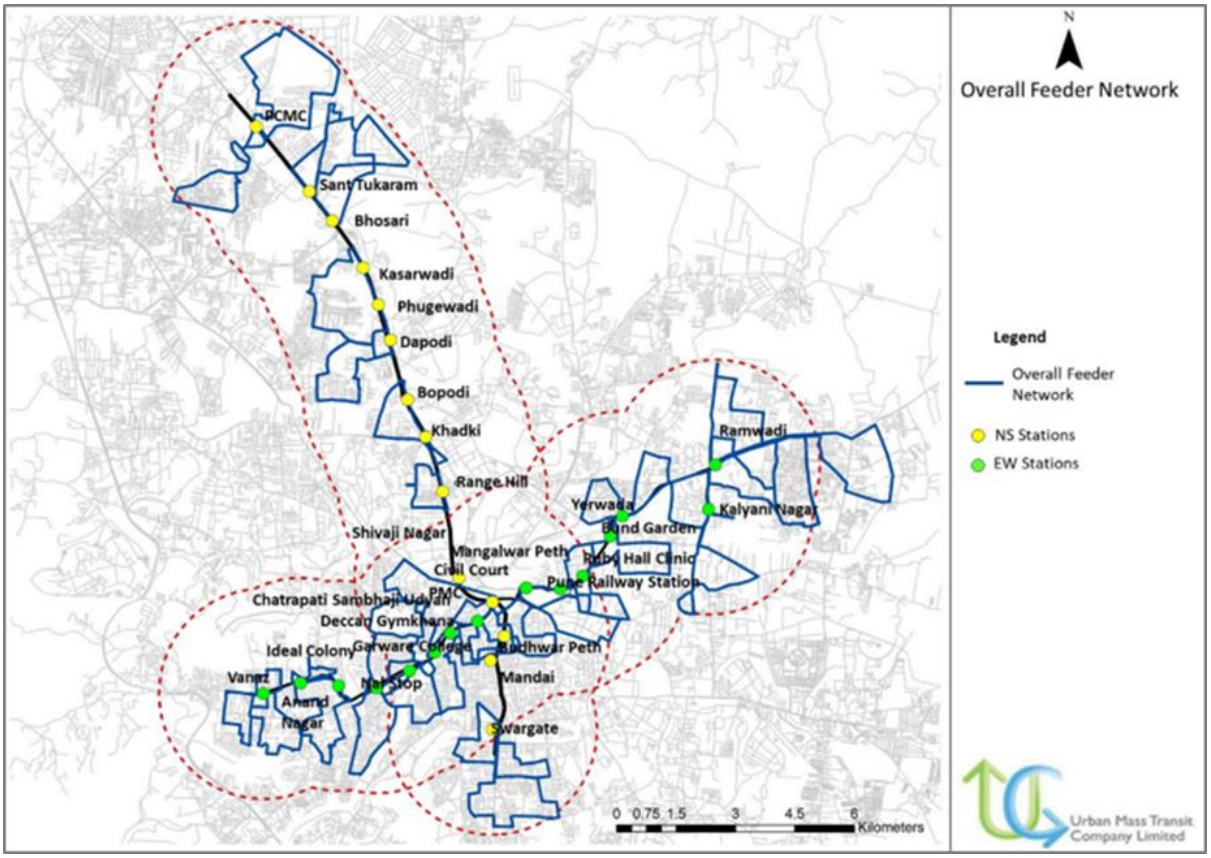


FIGURE 2-16: PROPOSED FEEDER NETWORK – DPR FOR METRO FEEDER CONNECTIVITY

The details of the proposed feeder vehicles and fleet size are given in Table 2-18.

TABLE 2-18: CATEGORY OF VEHICLES AND FLEET SIZES – DPR FOR METRO FEEDER CONNECTIVITY

Category of Buses	Capacity	Feeder Services 2018	Feeder Services 2021	Feeder Services 2031
E-Rickshaw/Mini Van	4 or 7 seater	43	165	196
Mini Bus	12 seater	37	56	62
Total		**80**	**221**	**258**

Module 2 – DPR for NMT and PBS Scheme

The DPR for the Non-Motorized Transport Plan was prepared in 2019. It deals with the provision of NMT facilities for a catchment area of 1.0 km radius around the metro stations. Pune, once known as 'Bicycle City', now has very high vehicular ownership. The city has gaps in its NMT infrastructure, compelling people to walk on the carriageway, hence safety is at risk.

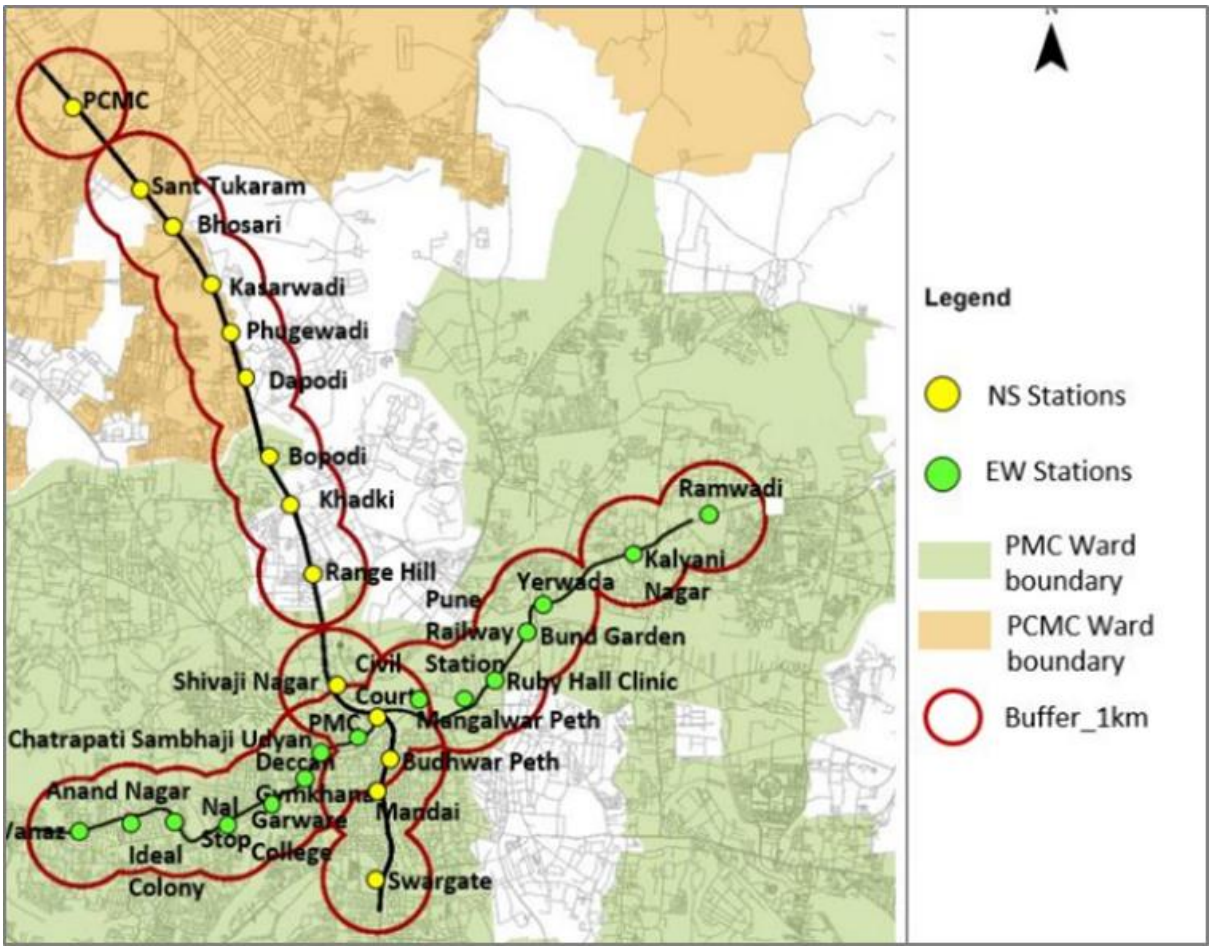


FIGURE 2-17: STUDY AREA FOR NMT MASTER PLAN – DPR FOR NMT PLAN AND PBS SCHEME

The aim of this study was to analyse and identify the potential NMT networks and infrastructure to enhance transit service. Figure 2-17 shows the study area considered for the NMT Master Plan.

Various primary surveys like the origin-destination survey, willingness to pay/shift survey, classified turning movement and pedestrian count survey were conducted as part of the study to understand the existing travel pattern of NMT users and their opinion on the current system. Major observations from the primary survey analysis are:

- The study area lacks adequate width of footpath making them unfit for use. Broken or discontinuous footpaths and encroachment in the form of hawking and parking were other issues observed within the existing infrastructure.
- The lack of proper pedestrian and cyclist crossing facilities at various junctions lead to delay in crossing and increase in travel time for NMT users.
- Only 33.7% of the existing pedestrians and 32.1% of cyclists are satisfied by the existing NMT facilities.
- About 75% of the people are willing to walk and cycle to and from metro stations if proper facilities are provided. Thus, proper NMT network and PBS schemes need to be developed within the study area to encourage users and enhance ridership.

Based on the inferences drawn from the data analysis and surveys, a pedestrian and cyclist infrastructure improvement plan has been proposed for a total of 160.3 km. Figure 2-18 shows the proposed NMT network as part of the study.

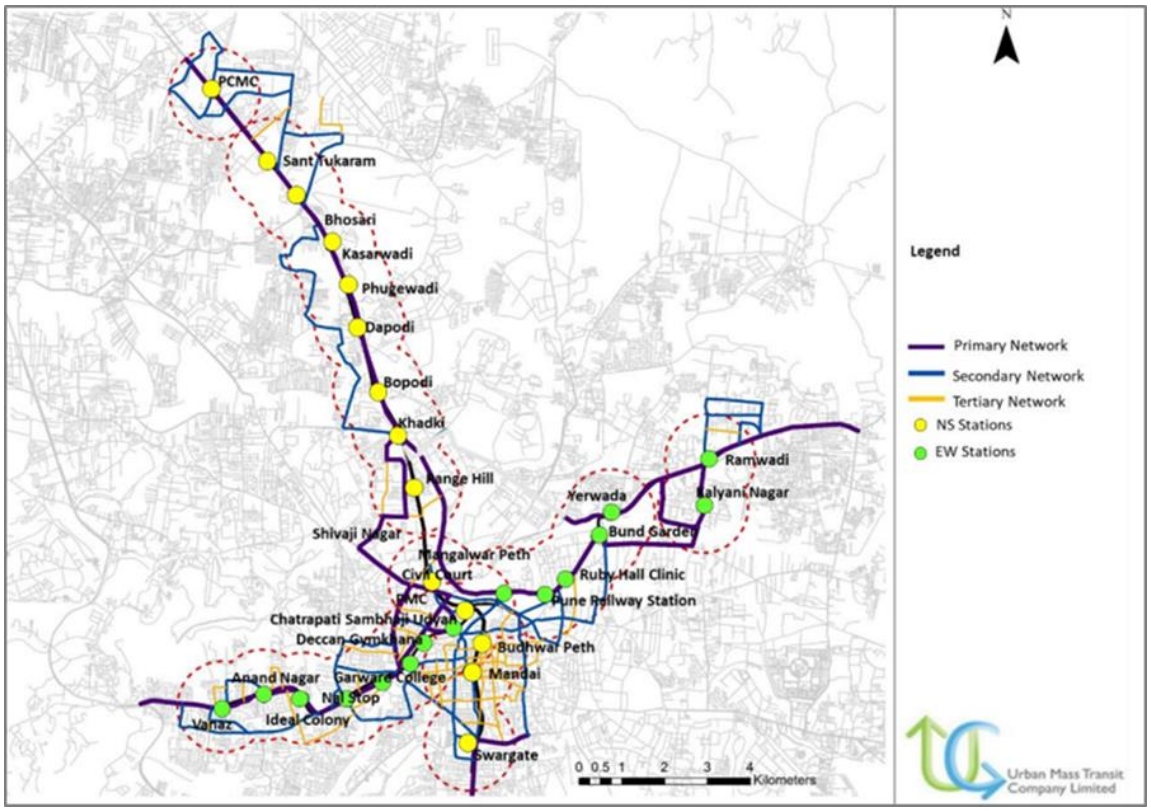


FIGURE 2-18: PROPOSED NMT NETWORK – DPR FOR NMT PLAN AND PBS SCHEME

Similarly, in response to promoting walking and cycling, Details of the proposed PBS docking locations are given in Table 2-19. PBS docking locations have been proposed, as shown in Figure 2-19.

TABLE 2-19: NUMBER OF PBS DOCKING LOCATIONS – DPR FOR NMT PLAN AND PBS SCHEME

Corridor	Cycle Parking Requirements	Number of PBS Docks per Station in 1 km Radius
North-South Corridor	506	384
East-West Corridor	445	468
Total	**951**	**852**

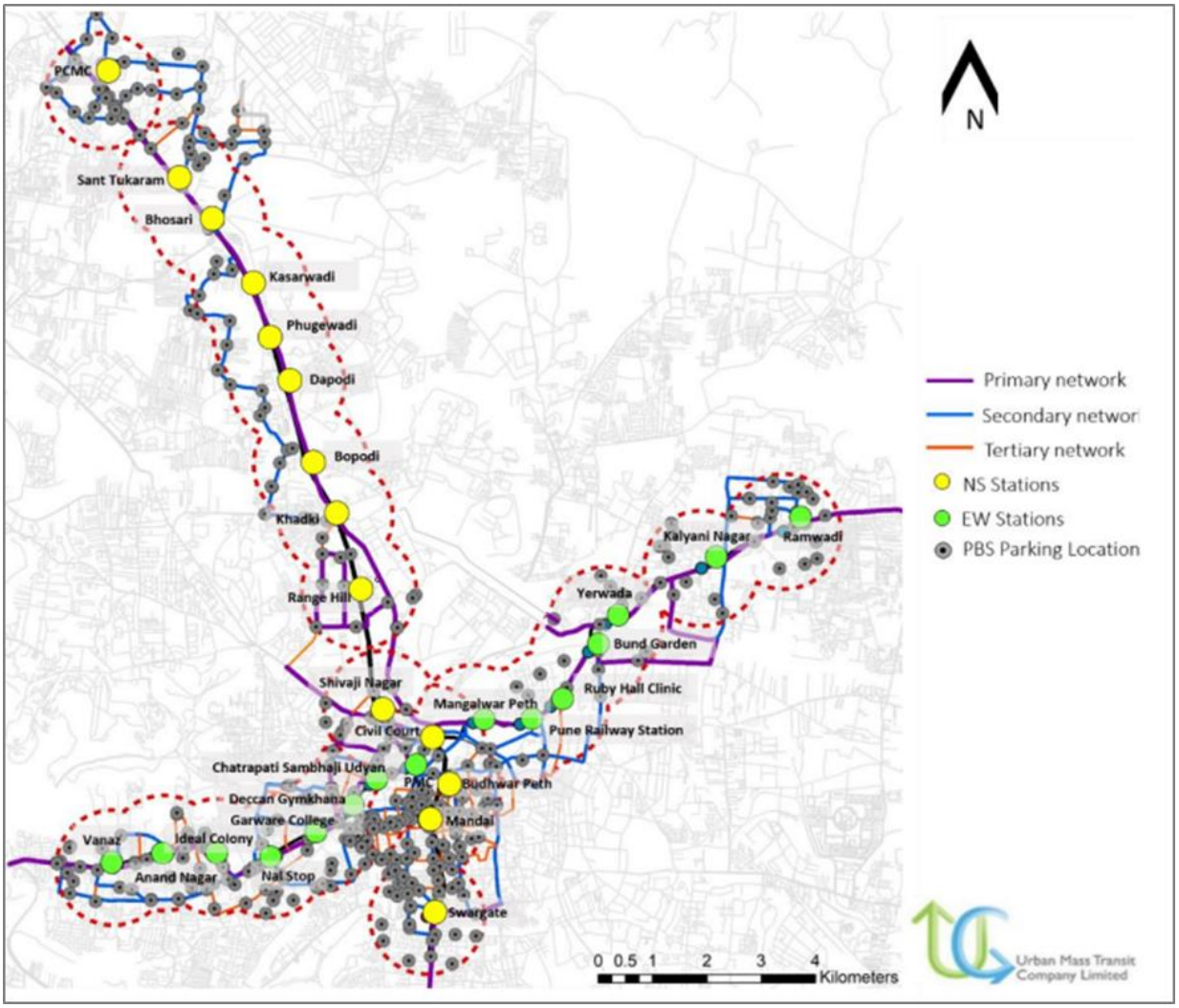


FIGURE 2-19: PROPOSED PBS DOCKING LOCATIONS – DPR FOR NMT PLAN AND PBS SCHEME

The total project cost is estimated to be Rs 474.18 crores and the project has been planned to be funded in three (03) phases. As per the study, Phase-1 needed to be completed by 2021.

2.11.5. FEASIBILITY STUDY FOR ELEVATED/AT-GRADE HCMTR – 2019

The Pune Municipal Corporation (PMC) has prepared a detailed study of the transportation requirements of the Pune Metropolitan Area in 1978-1982. Based on this study, a High Capacity Mass Transit Route Corridor (HCMTR) – a radial route connecting the major road network within the city of Pune has been identified. This HCMTR shall pass through Bopodi, Aundh, Shivajinagar, Erandwane, Kothrud, Karve Nagar, Dattawadi, Parvati, Bibvewadi, Wanawadi, Salisbury Park, Hadapsar, Mundhwa, Kalyani Nagar, Yerawada and Kalas areas.

The HCMTR corridor will help decongest roads in the city as heavy vehicles can travel via the ring road to bypass Pune instead of entering the city. The proposed High HCMTR in Pune City is proposed to ensure enhanced safety and level of service for road users, enhanced operational efficiency of the project highway, and minimal adverse impact on the local population and road users due to road construction.

The proposed six-lane HCMTR corridor with two (02) middle exclusive lanes for BRTS and four (04) lanes each on either end, integrating with other proposed MRT facilities such as BRT and metro rail corridors, as in the CMP, would serve the future travel demand in Pune City in the next two decades. The BRT corridor network shall also be completed as per the CMP to further increase the share of public transit and ensure seamless journeys. The proposed HCMTR with high capacity and high mobility corridor would act as a ring road/bypass to the core area, also meeting the travel/transport needs of the city in the intermediate zone.

In view of the above, a feasibility study for HCMTR alignment has been undertaken to justify the need for the route and the system for Pune city. Based on the trend analysis, travel demand and trip distribution, the ridership demand is estimated for the horizon years, as shown in Table 2-20.

TABLE 2-20: PT RIDERSHIP DEMAND ON THE HCMTR CORRIDOR[23]

Description	2021	2031	2041
Peak Hour Ridership (Passengers)	12534	29605	56683
Maximum Sectional Loading (PPHPD)	2625	6537	12711
Daily Ridership (Passengers)	125343	296045	566829

PMC and PCMC intend to complete the HCMTR Ring Road by connecting the start and end points at Bopodi and Vishrantwadi and also by integrating with the Pimpri Chinchwad HCMTR alignment. However, the balance alignment of HCMTR has to pass through Cantonment lands on either side for its completion. In this regard, a few options of link alignment with PCMC HCMTR have been identified to complete the Pune HCMTR Ring

23 Source: Feasibility Study for Elevated/At Grade Corridor for High Capacity Mass Transit Route (HCMTR) Alignment in Pune City - 2019

Road. But the balance ring portion of HCMTR and PCMC - HCMTR alignments are yet to be finalized and this might be taken up for detailing in the next phases along with integration with the metro alignment from Shivaji Nagar to PCMC.

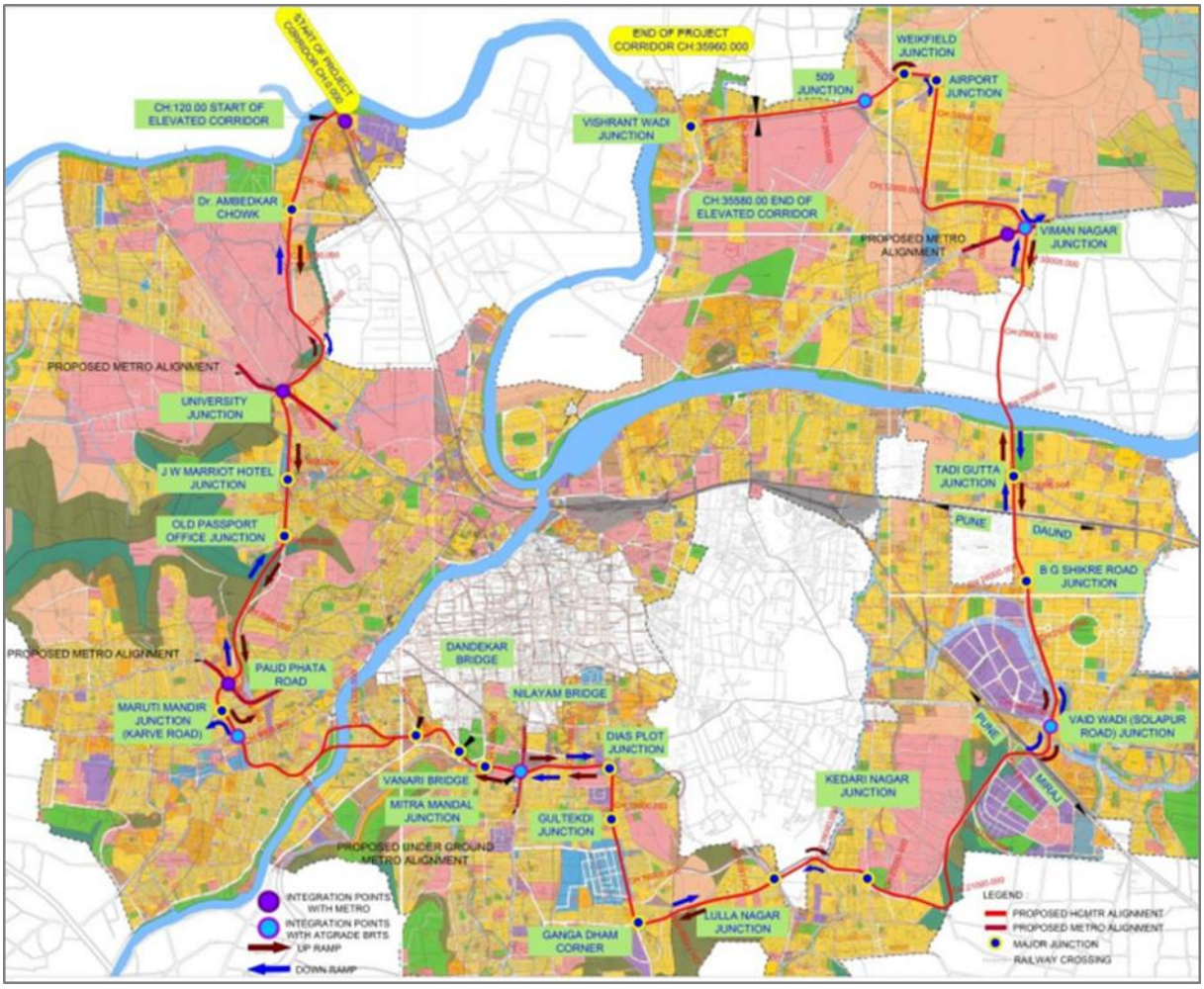


FIGURE 2-20: KEY PLAN SHOWING HCMTR CORRIDOR – FEASIBILITY STUDY FOR HCMTR ALIGNMENT

Some of the salient features of the HCMTR Corridor are:

- Proposed Corridor Length – 35.96 km – with Split carriageway of 11 m in each direction for a length of 1.2 km
- Proposed RoW – 24 m (Min.), 27 m at BRTS Station Location, 31 m at layby, 42 m at Ramp Location and 62 m at ramps with service road location
- Lane Configuration – Total 6 lanes with 2 dedicated BRTS lanes and the remaining 4 for private vehicles.
- Structure Type – Elevated with 33 nos. up and down ramps provided at major radial roads.
- No. of BRTS Stations – 26

- Access to BRTS – Elevated BRTS stations can be accessed by staircases and elevator/escalators provided at the at-grade median/footpath locations and from the concourse to station on top of elevated corridors.
- Design speed of main corridor of HCMTR and ramps – 50 kmph and 25 kmph.
- No. of Laybys – Two on both sides.

Figure 2-21 represents the integration of the proposed BRTS corridors, metro rail corridors, etc. with HCMTR.

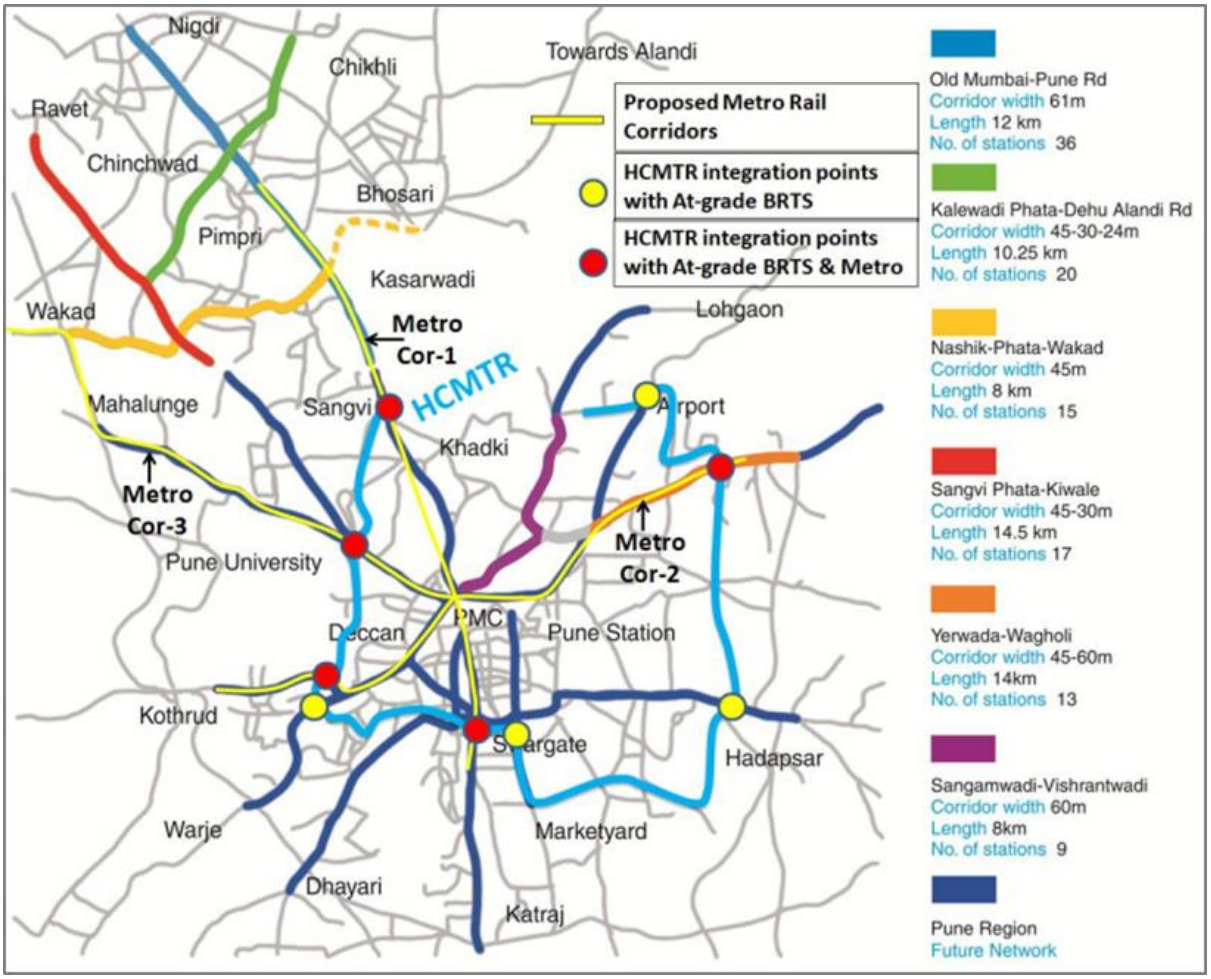


FIGURE 2-21: INTEGRATION OF HCMTR WITH OTHER INFRASTRUCTURE PROJECTS – FEASIBILITY STUDY FOR HCMTR ALIGNMENT

2.11.6. DETAILED PROJECT REPORT (DPR) – SWARGATE TO KATRAJ – 2019

With a view of developing an effective and efficient mass transit system an improving the share of public transport trips, the Government of Maharashtra conceived and implemented the Metro Rail System, covering 33.5 km in Phase-1. Corridor 1 (PCMC to Swargate) of it covers 17.8 km, which is now planned to be extended further in the north and south. The identified corridors are:

1. PCMC to Nigdi (4.413 km)
2. Swargate to Katraj (5.464 km)
3. Nashik Phata to Chakan (23.18 km)

The current section describes Swargate to Katraj corridor as a southward extension of Line 1 of Phase-1 and the details of the corridor are mentioned in Table 2-21 & Table 2-22.

TABLE 2-21: DETAILS OF THE METRO CORRIDOR – DPR 2019

S.N.	Corridor Name	Length	No. of Stations
1	Swargate to Katraj	5.464 km	03 (Underground)

TABLE 2-22: TRAVEL DEMAND FORECAST FOR PUNE METRO PHASE 1 EXTENSIONS (NO. OF PASSENGERS)

Corridor Name		2027	2037	2047	2057
Nigdi to Katraj	Peak Hour	64,100	85,200	98,700	1,02,900
	Daily	668,000	888,000	1,028,000	1,072,000
	PHPDT	18,070	22,980	27,020	28,170
Nigdi to Swargate	Peak Hour	55,000	70,100	80,700	84,000
	Daily	573,000	730,000	841,000	875,000
	PHPDT	16,610	21,300	24,830	25,840
Incremental	Peak Hour	9,100	15,100	18,000	18,900
	Daily	95,000	158,000	187,000	197,000
	PHPDT	1,460	1,680	2,190	2,330

2.11.7. DETAILED PROJECT REPORT (DPR) – PCMC TO NIGDI – 2019

This section describes PCMC to Nigdi corridor as a northward extension of Line 1 of Phase-1 and details of the corridor are mentioned in Table 2-23.

TABLE 2-23: DETAILS OF THE METRO CORRIDOR

S.N.	Corridor Name	Length	No. of Stations
1	PCMC to Nigdi	4.413 km	03 (Elevated)

TABLE 2-24: TRAVEL DEMAND FORECAST FOR PUNE METRO PHASE 1 EXTENSIONS

Corridor Name		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

Considering it is an extension and continuation of the existing Corridor 1 of Phase-1 (PCMC to Swargate), and also the PHPDT for the design year, it is recommended to adopt a Medium Capacity Metro Rail System that 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 trains run through the Swargate – PCMC – Nigdi Corridor.

2.11.8. DETAILED PROJECT REPORT - HCMTR (PCMC) - 2020

To meet the increasing travel demand of the city, the State Government has decided to introduce an efficient, safe, and high-capacity mass transit system in Pimpri Chinchwad. The Government of Maharashtra, through the Maharashtra Metro Rail Corporation Limited (Maha-Metro), has planned a ring radial High Capacity Mass Rapid Transit (HCMTR) corridor of 30.85 km around Pimpri Chinchwad.

The current section describes HCMTR in Pimpri Chinchwad & the details of the corridor are mentioned in Table 2-25.

TABLE 2-25: DETAILS OF THE METRO CORRIDOR

S.N.	Corridor Name	Length	No. of Stations
1	Kokane Chowk to Kokane Chowk Via Bhakti Shakti & Nashik Phata	Total - 30.85 km At Grade - 1.01 km Elevated - 29.84 km	Total - 23 At Grade - 1 Elevated 22

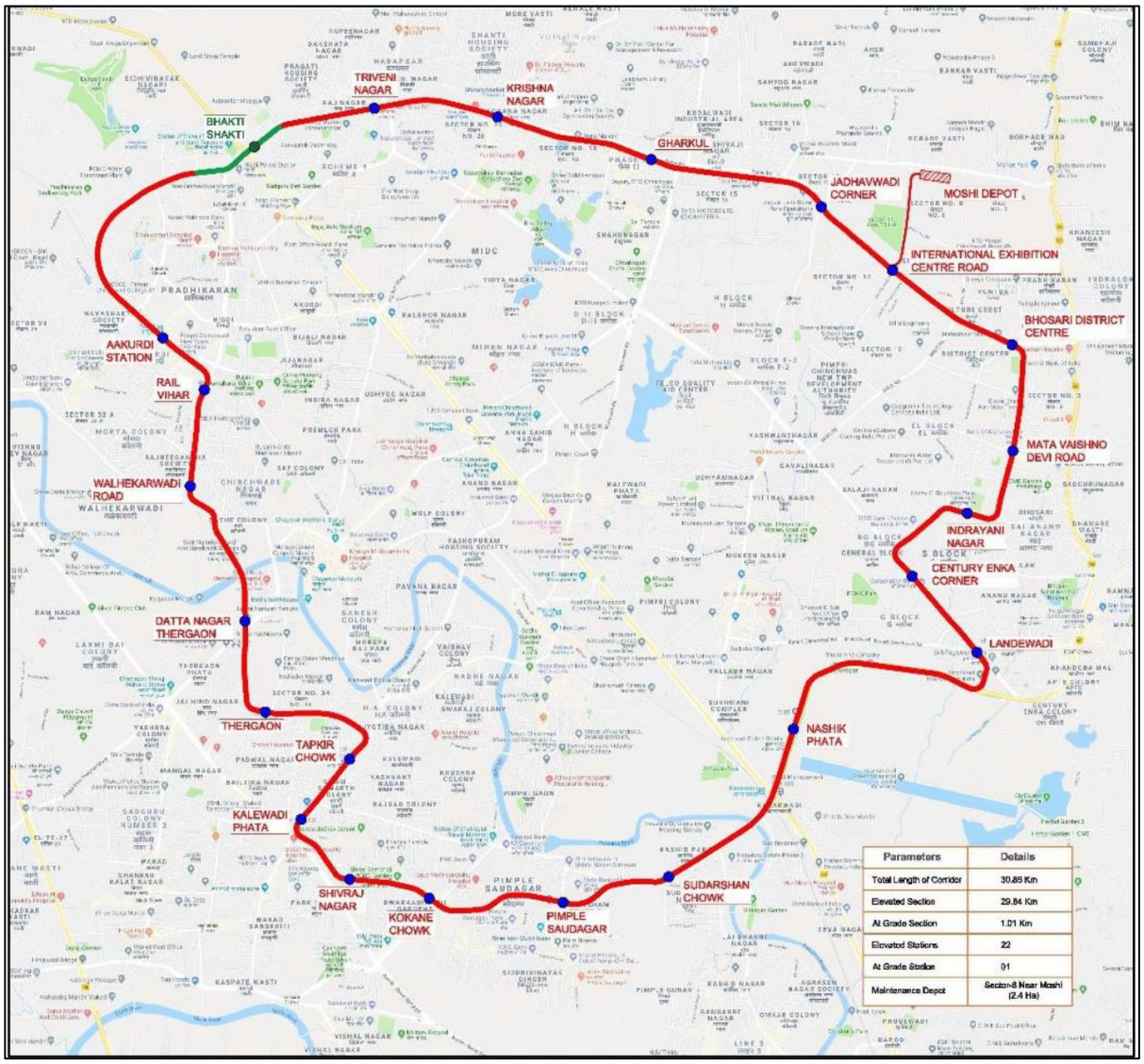


FIGURE 2-22: ALIGNMENT OF PROPOSED METRO NEO CORRIDOR IN PCMC[24]

As represented in Figure 2-22, the alignment of the proposed corridor passes through the congested and built-up areas of the city. The traffic demand for these areas has been estimated. The projected maximum PHPDT of the potential public transport corridor is indicated in the table below.

TABLE 2-26: DETAILS OF THE METRO CORRIDOR

Year	2024	2034	2044	2050
Max. PHPDT	3300	4300	5700	7200
Daily Ridership (in lakhs)	1.12	1.46	1.90	2.23

Considering the maximum PHPDT and other parameters, Pimpri Chinchwad has planned to have a Metro Neo system with bi-articulated electric bus coaches (24 m x 2.55 m) and

24Detailed Project Report (DPR) – Swargate to Katraj - 2019

overhead traction. The system will run on elevated and at-grade corridors. These bus coaches will also be capable runoff running on the proposed feeder routes using inbuilt batteries, allowing them to run without overhead traction up to a distance of about 20 km. The batteries will be charged while operating with overhead traction (In motion charging), thus eliminating the need for separate charging points/stations.

2.12. INTERCONNECTION WITH DEVELOPMENT/MASTER PLANS

Past studies have analysed the existing conditions in detail and have come up with possible improvement proposals for the Pune Metropolitan Region. The city requires a mass transport system that would cater to the increased demand, provide safe and convenient travel and alleviate the existing traffic woes. Various non-motorized transport facilities and road improvements have also been part of the proposals from these past studies.

2.13. ISSUES AND PROSPECTS

The identified issues and prospects are:

- Pune is the second-largest city in the State of Maharashtra, after Mumbai. The city has witnessed tremendous growth over the past decade, exerting pressure on the city's physical infrastructure, especially on the transport infrastructure.
- Globally, Pune is considered as a thriving, vibrant metropolis, a centre for academia and business. It is the ninth-most populous city in India and one of the fastest- growing cities in the Asia-Pacific region.
- Pune is motivated by its need to drive economic growth, increasing investments and adding jobs, allowing for better standards of living and the financial capability to manage the city infrastructure that serves the wider urban environment.
- The city is an important regional transportation hub. It is connected to Mumbai through the Mumbai-Pune Express Highway. NH-50 connects Pune to Nashik, NH-9 connects to Solapur, and NH-4 to Kolhapur.
- The growth of Pune in recent years has resulted in rapidly increasing commuting demands and dramatically rising private vehicles (the average CAGR of vehicle growth observed is 9.16% in Pune city). Since the existing public transport systems are unable to cater to the increase in travel needs, private vehicles are increasing rapidly.
- The total area under transport in Pune is 7%, against the desired 15%, as per URDPFI guidelines.

Pedestrian Facilities:

- The share of walk trips is about 25%, with an average trip length of 0.9 km.
- Some common issues pertaining to pedestrian facilities are:
    - Absence of footpaths and encroachments on the existing footpaths
    - Poor design of footpaths

- Poor upkeep and presence of utilities on the footpaths

Non-Motorised Vehicle (NMV) Facilities:

- The average trip length of the bicycle trips is 2.43 km.
- The average vehicle ownership per household in the study area is 1.55 vehicles including cycles
- The share of cycle trips is about 2.43% of the total trips in the study area.
- Total length of cycle tracks in the city is ~64 km
- Some common issues pertaining to NMV facilities are:
    - Absence of continuous obstruction-free cycle tracks and encroachments on the existing cycle tracks

Public Transportation:

- The current share of public transport (bus and rail) is 17% (in motorized trips), which is very low. 83% households own at least one 2-wheeler or car or both.
- Some common issues pertaining to public transportation are:
    - Public transport trips are declining over the years and users have moved towards private vehicles
    - Deterioration in the quality of the public transport service
    - Inadequate and aged fleet and frequent breakdowns of buses. The average age of PMPML bus is about 8 years.
    - Lack of comfort and safety
    - The coverage of the PMPML network is good but the frequency of service needs improvement
    - The route length of the PMPML service is quite long. As a result, PMPML is unable to maintain the time schedule. 58% of the PMPML bus routes have a route length of more than 15 km and 40% of the routes have a trip length of more than 20 km.
    - Poor maintenance of buses and inadequate terminal facilities and depots
    - High operating costs resulting in financial losses
    - Lack of financial resources to augment the system
    - Unavailability of real-time information system for the management of unexpected events, delays and service disruptions. However, in 2017, PMPML introduced a Command and Control Centre (as an IT initiative) that centrally monitors the daily operation of buses, tickets issuance schedule adherence, etc. Also, the centre is equipped with facilities that facilitate breakdown services, incident management and emergency helpline.
    - Route rationalization is essential to optimize operations.
    - BRT buses run in mixed traffic on several sections and some of the BRTS routes are overlapping with city bus routes. Partial implementation of BRTS, disjointed network, poor quality of buses, lack of good frequency of services, non-uniform standards, lack of network integration and intermodal facilities are major issues with the BRTS. Due to these, the BRTS has not been able to attract good ridership

- Suburban rail has limited scheduled services as it shares tracks with long-distance trains. The frequency of suburban rail cannot be increased unless additional tracks are laid.
- Lack of multi-modal integration
- Lack of proper dissemination of information on bus routes and schedules
- Lack of high-quality public transport options for high- and middle-income groups whose value of time is high
- Lack of mini-buses as feeder services as well as regular service in core areas where the streets are narrow

Land Use and Transport Network:

- Though radial roads are well-developed, ring roads are yet to be developed since a large share of land is under defence (cantonment areas), some fall under environmentally sensitive areas (hills), and others have land acquisition issues (built-up areas).
- Land use transport integration is encouraged by permitting the higher FSI along the mass transit corridors.

Road Infrastructure:

- PMC has several topographical constraints to the development of ring roads due to dense developments, defence land, etc.
- PCMC has a well-developed hierarchical road network, except the older areas.
- While a ring and radial pattern is followed in PMC, a grid road network pattern exists in PCMC.
- Narrow road sections – About 22% of the road network in the study area has single-lane carriageway.
- Intersections are unsafe for pedestrians and cyclists, and there is a lot of scope for junction improvement.
- On-street parking of vehicles obstructs traffic movement.
- Encroachment of carriageway/footpaths by hawkers reduce effective carriageway width.
- The study area presently lacks bypass roads and ring roads.

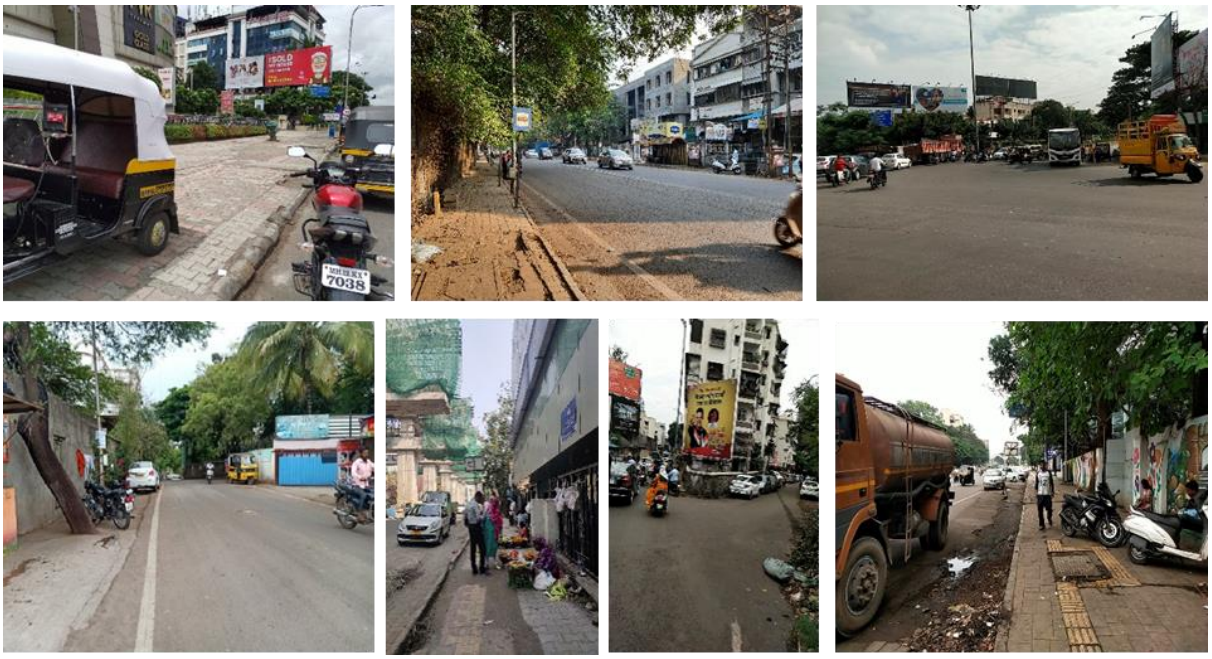


FIGURE 2-23: ISSUES & CHALLENGES W.R.T TRANSPORTATION IN PUNE CITY

Parking:

- No penalty for unauthorized on-street parking
- Inadequate off-street parking facilities
- Widespread on-street parking, which is free except on MG road and in the Cantonment area.
- Unauthorized on-street parking at several locations (about 28% of roads) especially in central business district and market areas.

Traffic Management Measures:

- Most signals are observed to be not functional.
- Absence of traffic personnel at intersections
- Traffic is being managed manually at some intersections by the traffic police
- Lack of one-way traffic schemes and pedestrianization in CBD area

FIGURE 2-24: ON-STREET PARKING NEAR KOTHRUD BUS DEPOT (TOWARDS CHANDANI CHOWK)

Prospects:

- As mentioned in the previous sections, Pune, like any other metropolitan city in India, is witnessing a sharp increase in the total growth of private vehicles. Past reports and studies reveal that the existing transport infrastructure is inadequate to serve the future demand. In addition, the analysis of the mode-wise growth of registered vehicles shows that personalized modes of transport, i.e., 2-wheelers and cars, have been growing tremendously, with an annual increase of 9.19% and 11.59%, respectively. This condition has created massive traffic management issues and increased pollution in most parts of the city.
- The Comprehensive Mobility Plan for PMC & PCMC for PMR – 2018, Metro DPRs of Line 1 and Line 2 of Phase-1, Line 3, Corridor 1A and Corridor 2A reveal that the existing transport infrastructure is inadequate to serve the future demand and recommends the introduction of Medium Capacity Metro systems for the major mobility corridors.
- To address the increased travel demand of the city and provide a high capacity public transport system to the citizens, the State Government of Maharashtra (GoM) through Maha-Metro Pune identified two lines of 16.59 km and 14.67 km, respectively. These lines, along with Corridor 1A and Corridor 2A, have been recommended for Medium Metro, and Line 3 has been recommended for Light Metro, which would address the existing and future needs of the city.
- In order to develop a comprehensive vision for mass transit systems for PMR, PMRDA also undertook a study on the “Comprehensive Mobility Plan for PMC and PCMC in PMR” in 2018. This study identified a total mass transit network of 10 corridors covering a route length of 195.76 km (Detailed description of the study has been represented in Section 2.11.3 of this report).
- Based on the corridors identified in the CMP for PMC and PCMC in PMR in 2018 and further deliberation in the PUMTA meeting held on 19th December 2020 and also in various meetings chaired by the then Deputy CM, Government of Maharashtra, it has been decided to undertake preparation of AAR and DPR for seven (07) corridors with a route length of ~82.5 km.
- A summary of the corridor stretches is indicated below:
    - Line 2A: Vanaz to Chandani Chowk (01.12 km)
    - Line 2B: Ramwadi to Wagholi (11.63 km)
    - Kharadi-Hadapsar-Swargate-Khadakwasla, consisting of 3 sections;
        - Kharadi to Hadapsar (07.35 km),
        - Hadapsar to Swargate (07.07 km), and
        - Swargate to Khadakwasla (11.22 km)
    - SNDT-Warje-Manik Baug Via Baji Pasalkar Rao Bridge (06.03 km)
    - PMC-High Capacity Mass Transit Route (HCMTR) (43.84 km).

CHAPTER 3. TRAVEL CHARACTERISTICS & DEMAND ESTIMATES

3.1 INTRODUCTION

A detailed study of the traffic and travel characteristics of the study area is required for planning Mass Rapid Transit Systems (MRTS). This is to be done through a detailed analysis of the available city characteristics, like road infrastructure, public transport, parking, vehicular and pedestrian movement, etc. For this purpose, secondary data from various published sources has been collected and analysed, which is duly complemented by a series of primary traffic and travel surveys conducted within the study area. This chapter summarizes the traffic and travel characteristics of the study area along with the ridership assessment for Line 2A and Line 2B of Pune MRTS Phase-2

3.2 METHODOLOGY

The objective of this study is to provide a realistic estimation of the Metro Rail Ridership for the proposed metro corridors in the present year as well as for the horizon years. The scope/methodology of the work is represented in Figure 3-1.

The assessment of traffic and travel characteristics have been undertaken in six (06) stages, which are as follows:

1. Delineation of the Study Area (Refer to Section 1.2.2 and Figure 1-3 in Chapter 1)
2. Data Collection – Secondary and Primary Data
3. Data Analysis/Data Assessment
4. Base Year Travel Demand Model
5. Horizon Years Travel Demand Model
6. Ridership Assessment

The same are discussed in detail in the following sections.

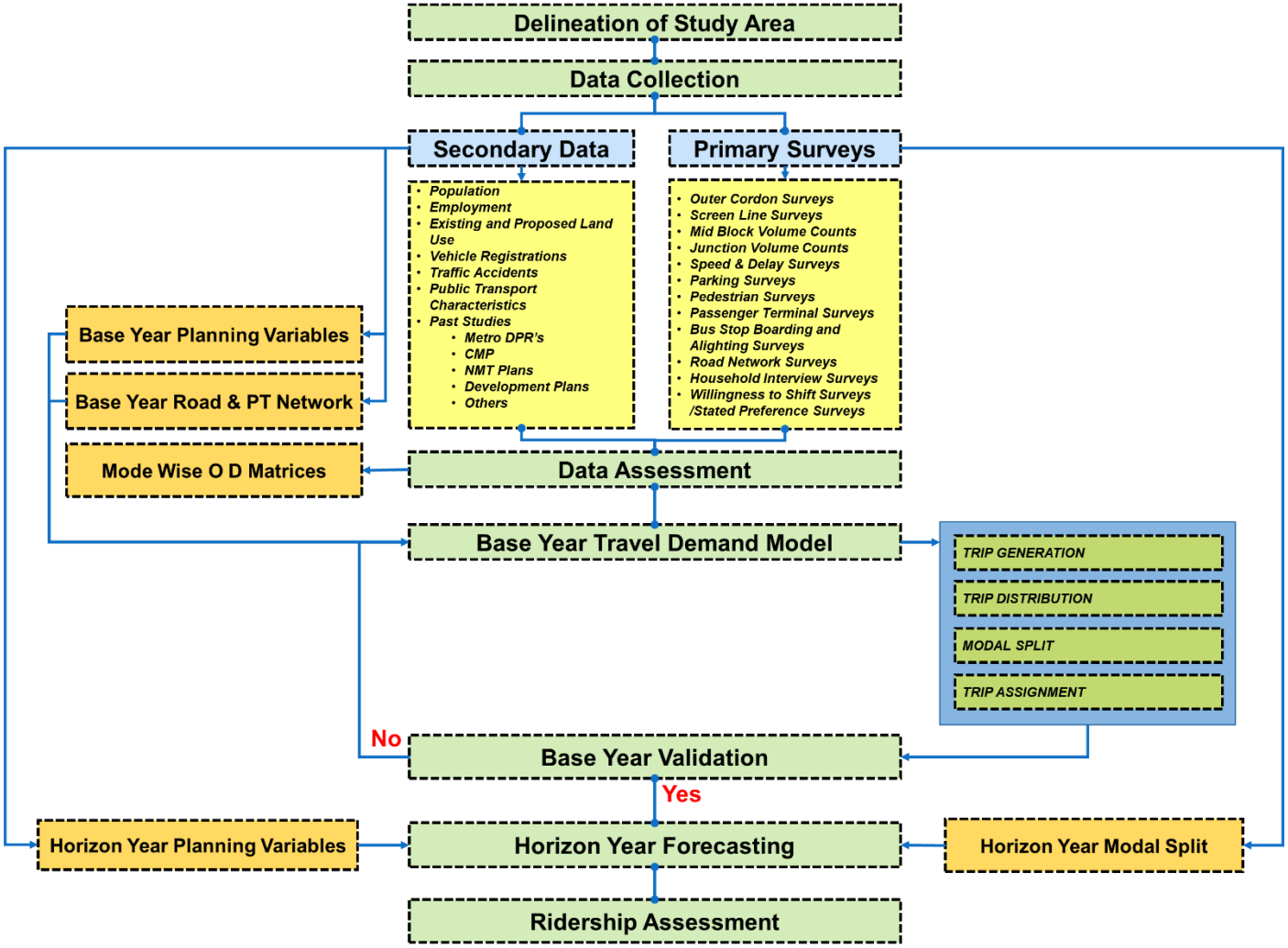


FIGURE 3-1: STUDY METHODOLOGY

3.3 STUDY AREA AND ZONING

As mentioned in Section 1.2.2 of Chapter 1, a study area of about 2,172 sq. km has been delineated (refer to Figure 1-3). This delineated study area includes the following:

- Pune Municipal Corporation (PMC)
- Pimpri Chinchwad Municipal Corporation (PCMC)
- Cantonment Boards – Pune, Khadki/Kirkee, Dehu
- Surrounding Municipal Councils
- MIDC areas
- Adjacent villages

The delineated study area has been segregated into smaller zones known as Traffic Analysis Zones (TAZs) to study the trip interactions amongst various zones. The total number of zones adopted for the study are 299, out of which 289 are internal zones and 10 zones are external. The zone map is presented in Figure 3-2.

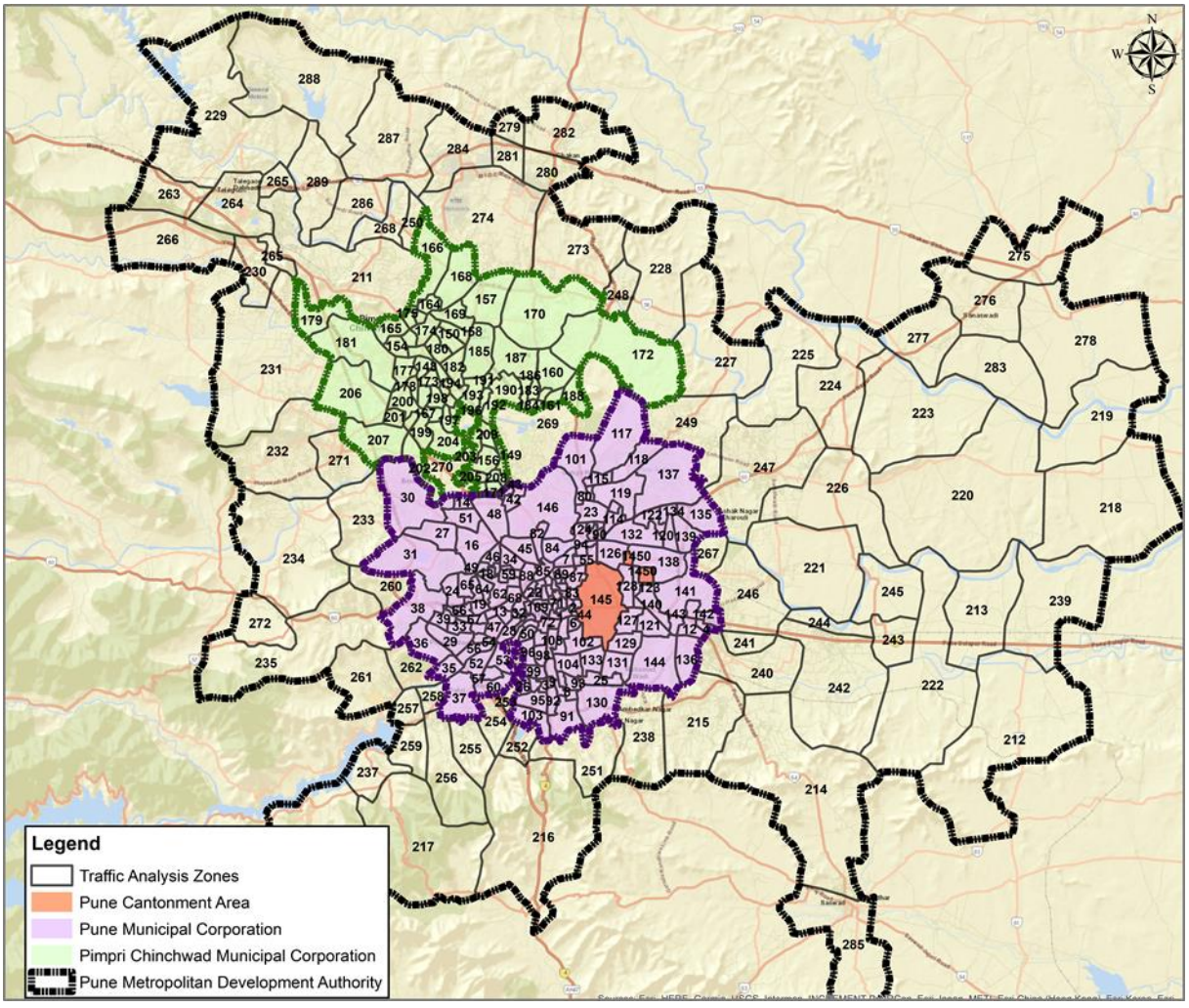


FIGURE 3-2: TRAFFIC ANALYSIS ZONE MAP

3.4 TRAFFIC STUDIES

Traffic and transportation characteristics help in appreciating the spatial and temporal characteristics of travel within the study area. This is critical while planning a mass transit system. Typically, to understand the traffic and transportation characteristics of a study area, two (02) types of data are collected:

1. **Secondary Data/Literature Study** – This refers to gathering information that is already available/published, such as census data, vehicle registration, public transport routes, etc. The assessment of this data is represented in Chapter 2 of this Report.
2. **Primary Data** – This refers to the gathering of information through surveys, interviews or experiments. Data, such as traffic volume, OD information, etc., is collected through surveys and interviews. The assessment of this data is represented in this chapter.

The exercise of primary data collection is a major component of the current study. The coverage details of various traffic and travel surveys carried out for this study are listed in Table 3-1.

The survey locations have been selected in a manner that would cover the traffic pattern of the entire study area and its interaction with adjacent urban settlements. The analysed survey data has been presented in subsequent sections.

TABLE 3-1: LIST OF PRIMARY TRAFFIC SURVEYS

S. N.	Type of Survey	Purpose of Survey	Locations /Details	Duration of Survey	Methodology of Survey	Outcomes
1	Classified Traffic Volume Counts at OC Locations	To capture the number of people moving in and out of the study area on a typical non-event working day	19	24 hours	Videographic Survey	• Peak hour traffic • Traffic composition • Mode-wise hourly variation of flow – during peak and off-peak
2	Classified Traffic Volume Counts at Screen Lines	Screen lines are natural/man-made barriers such as a river/canal, railway line, etc. which divides the study area into two distinctive parts. The two parts of a screen line are considered to capture the crossing of vehicles and people from one part of the city to another part on a typical non-event working day	30	16 hours	Videographic Survey	• Peak hour traffic • Traffic composition • Mode-wise hourly variation of flow – during peak and off-peak
3	Classified Traffic Volume Counts at MB	To capture the number of people moving in and out of the study area on a typical non-event working day	13	16 hours	Videographic Survey	• Peak hour traffic • Traffic composition • Mode-wise hourly variation of flow – during peak and off-peak
4	Origin and Destination Survey at OC	To record the origin and destination of trips made by various modes on a sample basis	7	24 hours	Interview Surveys	• Traffic movement patterns of Inter City and through traffic • Trip Purpose

S. N.	Type of Survey	Purpose of Survey	Locations /Details	Duration of Survey	Methodology of Survey	Outcomes
						• Mode • Frequency • Occupancy
5	Turning Volume Counts at Intersections	To capture the number of people moving around in the study area on a typical non-event working day	27	16 hours	Videographic Survey covering all the arms of and movements at the junctions	• Peak hour traffic • Traffic composition • Mode-wise hourly variation of flow – during peak and off-peak
6	Passenger Terminal Counts (Rail and Bus)	To assess the magnitude of the movement of passengers in/out of the terminal	13	16 hours	Videographic Survey at all the entry and exit points of the terminals	• Peak hour passenger movement • Hourly variation of passenger flow – during peak and off-peak
7	Passenger Terminal OD Surveys (Rail and Bus)	To assess the travel characteristics of the passengers (such as origin and destination, purpose, frequency, trip characteristics such as travel distance, trip cost, trip time, etc.)	3500 samples	16 hours	Interview Surveys using a pre-designed questionnaire	• Socio-economic Characteristics • Trip characteristics
8	Bus Stop Boarding and Alighting Surveys	To assess the magnitude of the movement of passengers boarding and alighting at the bus stops	30	16 hours	Videographic Survey at the bus stops on both sides of the road	• Peak hour passenger movement • Hourly variation of passenger flow – during peak and off-peak.

S. N.	Type of Survey	Purpose of Survey	Locations /Details	Duration of Survey	Methodology of Survey	Outcomes
						• Occupancy of the bus
9	Bus Stop OD Surveys	To assess the travel characteristics of the passengers (such as origin and destination, purpose, frequency, trip characteristics such as travel distance, trip cost, trip time, etc.)	5000 samples	16 Hours	Interview Surveys using a pre-designed questionnaire	• Socio-economic characteristics • Trip characteristics
10	Household (HH) Interview Surveys (0.5% of the households in the study area)	To understand and assess the socio-economic and travel characteristics of the residents in the project catchment area	9693 samples	----	Interview Surveys using a pre-designed questionnaire	• Socio-economic characteristics • Trip characteristics • Revealed and stated preference characteristics
11	Road Network Inventory Surveys	Aimed at identifying and updating the network configurations in the study area	610.26 km	----	Detailed Manual Documentation of Surface Network Inventory between the property lines in major corridors	• Width of the road in terms of RoW, carriageway, footpath, median, encroachments, lighting, traffic control measures, public facilities, etc. • Capacity of the road links
12	Speed and Delay Surveys (Private	To assess the corridor travel times, journey and running speeds and time along with the bottlenecks	350 km	----	Moving Car Method	• Journey speeds • Running speeds

S. N.	Type of Survey	Purpose of Survey	Locations /Details	Duration of Survey	Methodology of Survey	Outcomes
	and Public Transport)					• Delay and its causes
13	Pedestrian Surveys	To assess the intensity of pedestrian movement at high pedestrian locations	21	16 hours	Videographic Surveys	• Pedestrian movement demand
14	On-Street and Off-Street Parking Surveys	To assess the parking demand and provide adequate on-road and off-road parking facilities	24	16 hours	Videographic Surveys	• Section-wise parking demand • Hourly variation of parking demand • Peak turnover rates • Demand and supply gap

As mentioned above in the table, all the surveys were undertaken on a non-event working day through videographic and interview surveys. The following section presents the existing traffic and travel characteristics of the study area based on the comprehensive primary surveys.

3.4.1 TRAFFIC SURVEY DATA ASSESSMENT

3.4.1.1. ANALYSIS OF ROAD NETWORK INVENTORY

The road network inventory aims at updating the network database with the existing features of roadway sections covering all arterial, sub-arterial and other important local/connecting links in the study area. The survey validates the existing road network data available for the region and collects the road network details for the roadway sections. Figure 3-3 represents the survey network identified for the road network inventory.

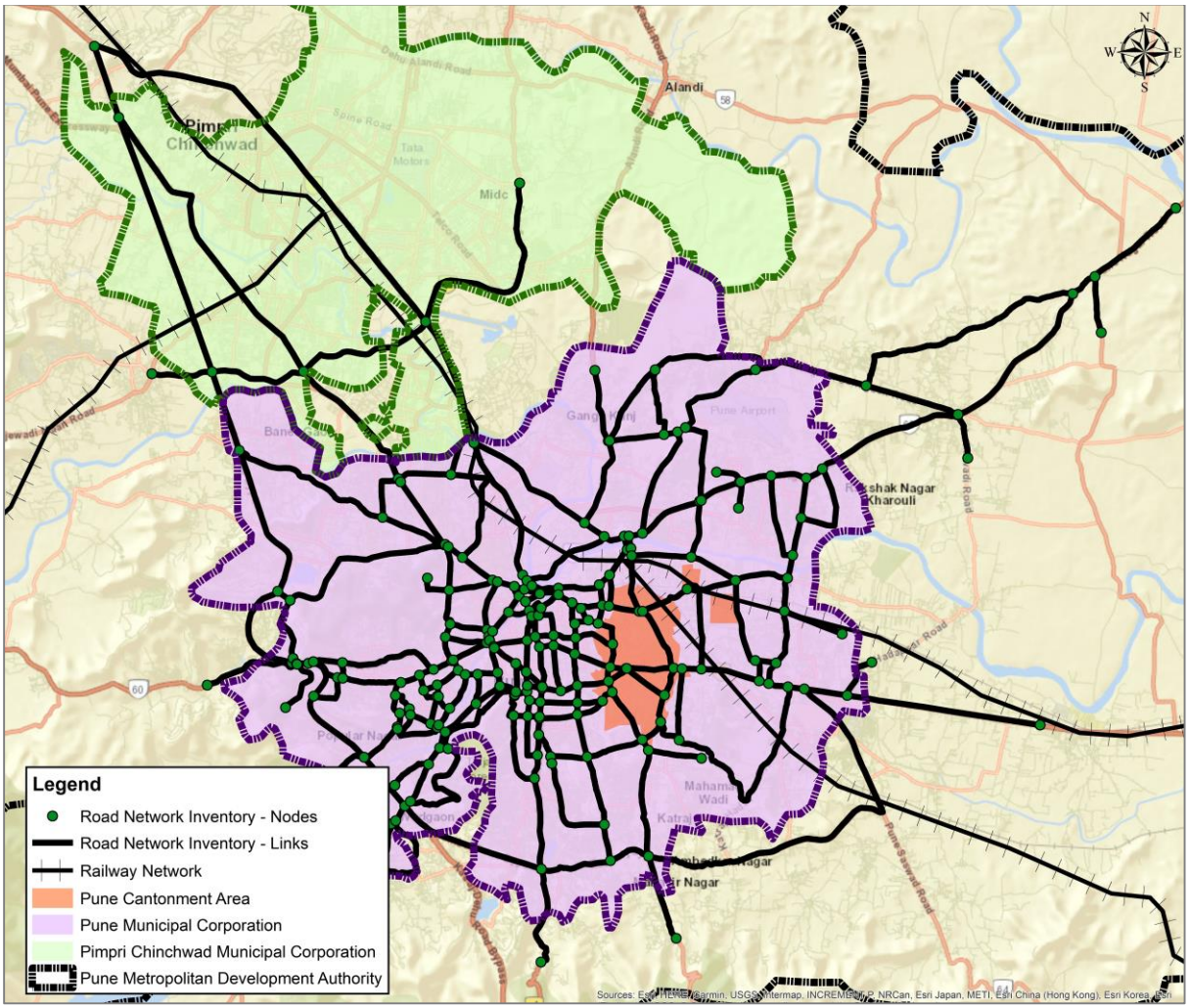


FIGURE 3-3: ROAD NETWORK IDENTIFIED FOR THE ROAD NETWORK INVENTORY

The existing road condition can be identified by evaluating road network characteristics through identifying parameters like lane configuration, road capacity, parking character, encroachment, etc.

It also helps in identifying constraints that would affect the progress of the project. The study area for the road inventory analysis consists of PMC, PCMC, Hinjewadi and

Cantonment Areas. About 610 km of the road network is covered as part of the road network inventory survey.

Right of Way (RoW)

Right of way is the land reserved for road formation, including utilities. For the inventory survey, the spacing between building lines is considered as RoW. Figure 3-4 represents the RoW of the surveyed network in the study area.

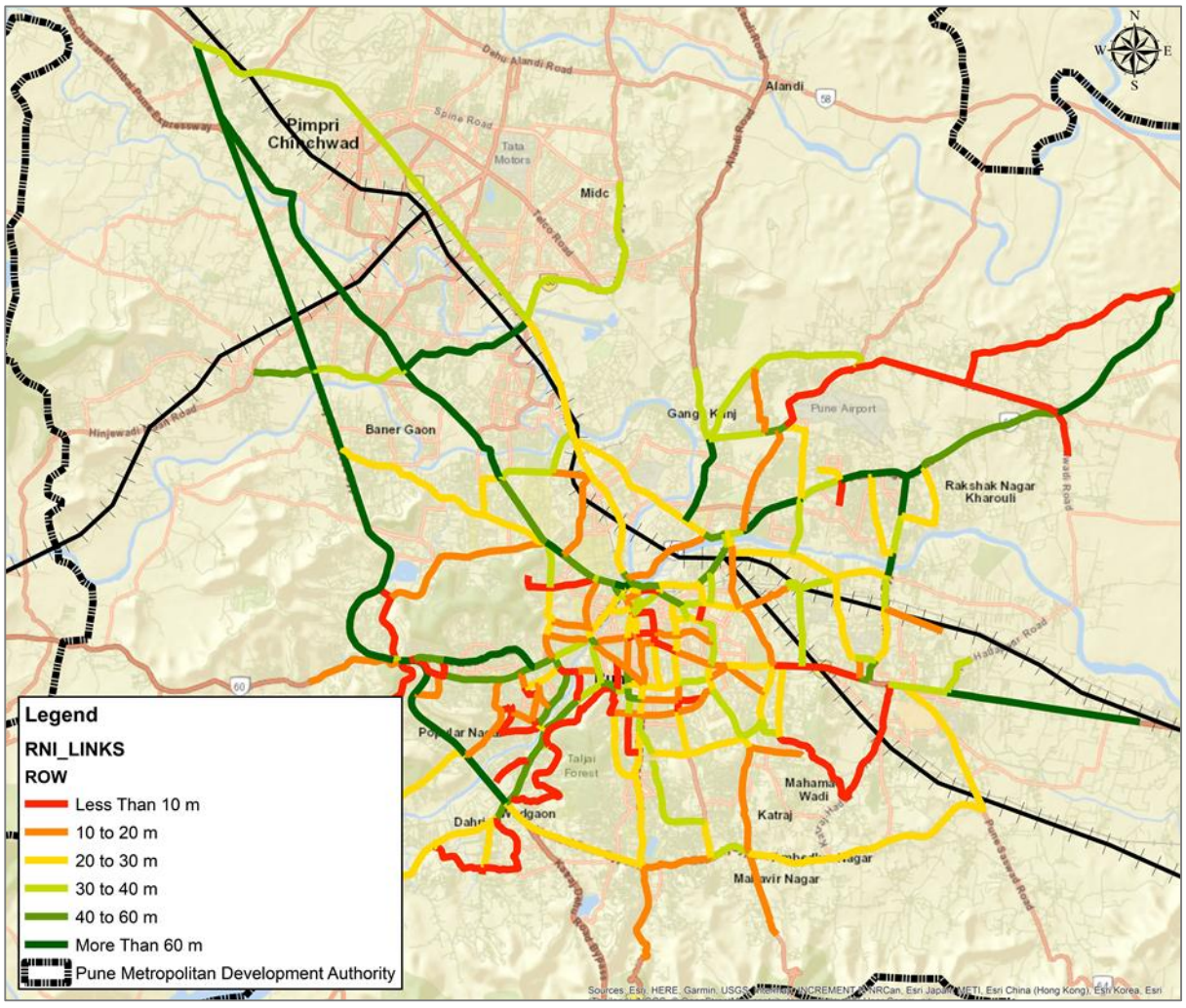


FIGURE 3-4: DISTRIBUTION OF THE SURVEYED NETWORK BY RIGHT OF WAY

The distribution of road length with respect to RoW based on the road network inventory survey is presented in Table 3-2.

TABLE 3-2: DISTRIBUTION OF ROAD LENGTH BY RIGHT OF WAY[1]

S.N..	RoW (m)	Study Area	
		Length in km	Length in %
1	<10	299.64	49.1%
2	10 to 20	217.25	35.6%
3	20 to 30	65.91	10.8%
4	30 to 40	17.70	2.9%
5	40 to 60	9.15	1.5%
6	>60	0.61	0.1%
	Total	**610.26**	**100%**

It is observed that about 84.7% of the total surveyed roads have a RoW of less than 20 meters, followed by 10.8% of the roads with RoW between 20 to 30 meters.

Lane Configuration of Carriageway

Figure 3-5 represents the lane configuration of the surveyed network in the study area and the distribution of road length by lane configuration of the carriageway is presented in Table 3-3.

TABLE 3-3: DISTRIBUTION OF ROAD LENGTH BY CARRIAGEWAY[2]

No.	Lane Configuration	Road Length (Kms)	% of Road Length
1	Single Lane	134.25	22%
2	Intermediate Lane	183.07	30%
3	Two Lane	152.56	25%
4	Three Lane	24.41	4%
5	Four Lane	85.43	14%
6	Six Lane and Above	30.54	5%
Total Road Length (Kms)		**610.26**	**100%**

It could be observed from the table above that Intermediate lane constitutes to around 30% of the total roads in the study area followed by two lane road which is about 25%.

TABLE 3-4: DISTRIBUTION OF ROAD LENGTH BY TYPE OF CARRIAGEWAY [3]

No.	Lane Configuration	Length in Kms	% of Road Length
1	Un-Divided	109.84	18%
2	Divided	500.42	82%
Total Road Length (Kms)		**610.26**	**100%**

From the table above, it could be observed that ~ 82% of the surveyed roads in the study area have divided carriageway

1 UMTC Primary Surveys 2021
2 UMTC Primary Surveys 2021
3 UMTC Primary Surveys 2021

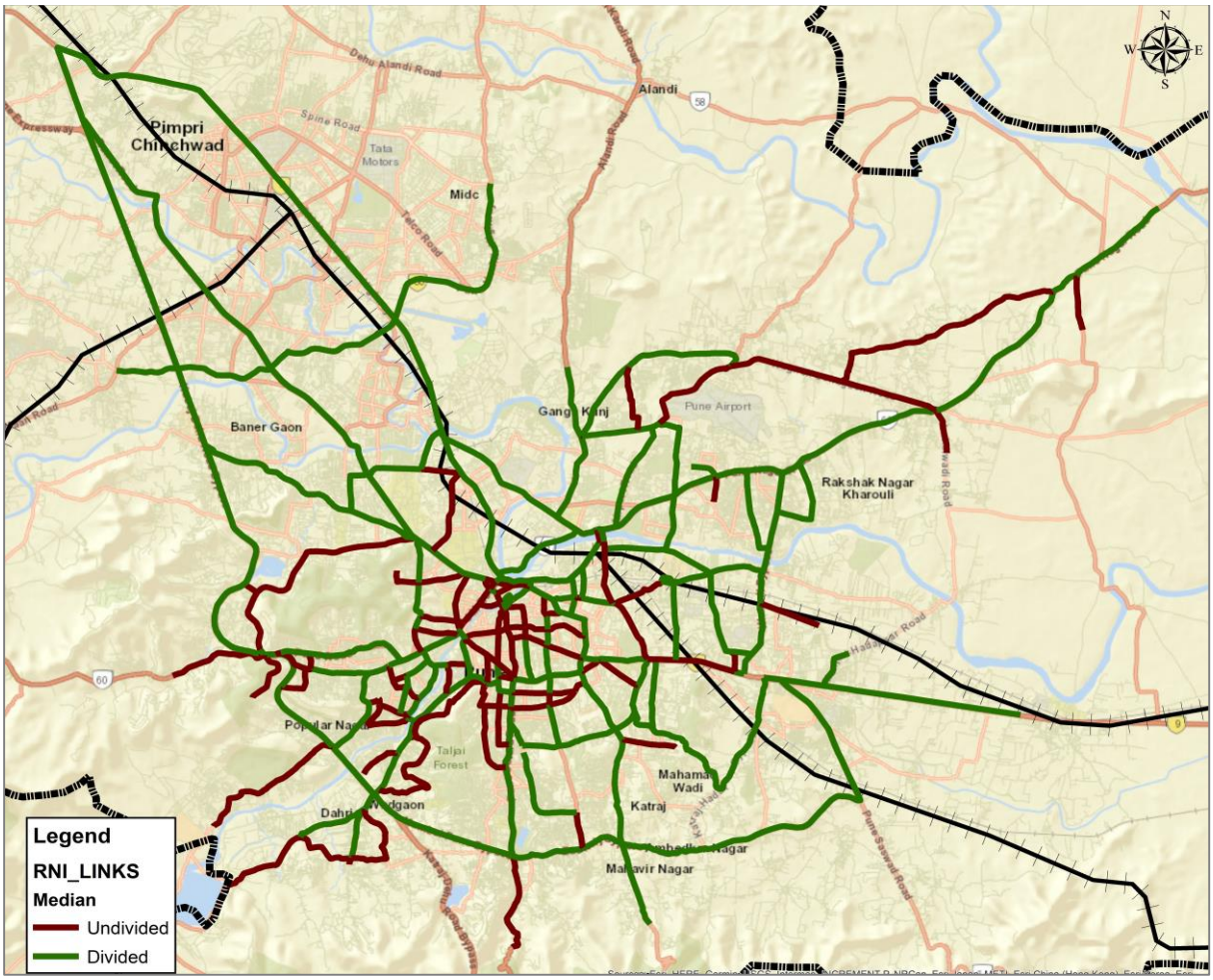


FIGURE 3-5: DISTRIBUTION OF SURVEYED NETWORK BY LANE CONFIGURATION

One-Way Traffic Movement

It can be observed that, of the total road surveyed, about 11.25% of the roads have one-way movement (represented in Figure 3-6 in red), while about 88.75% of the roads have two-way traffic movement (represented in Figure 3-6 in green).

Availability of Service Lane

The availability of service lanes is represented in Table 3-5. Of the total 610.26 km, only 11% (~67.13 km) of the total surveyed roads have a service lane.

TABLE 3-5: DISTRIBUTION OF AVAILABILITY OF SERVICE LANE[4]

S.N.	Availability of Service Lane	Study Area	
		Length in km	Length in %
1	Present	67.12	11%
2	Absent	543.14	89%
		610.26	**100%**

4 UMTC Primary Surveys 2021

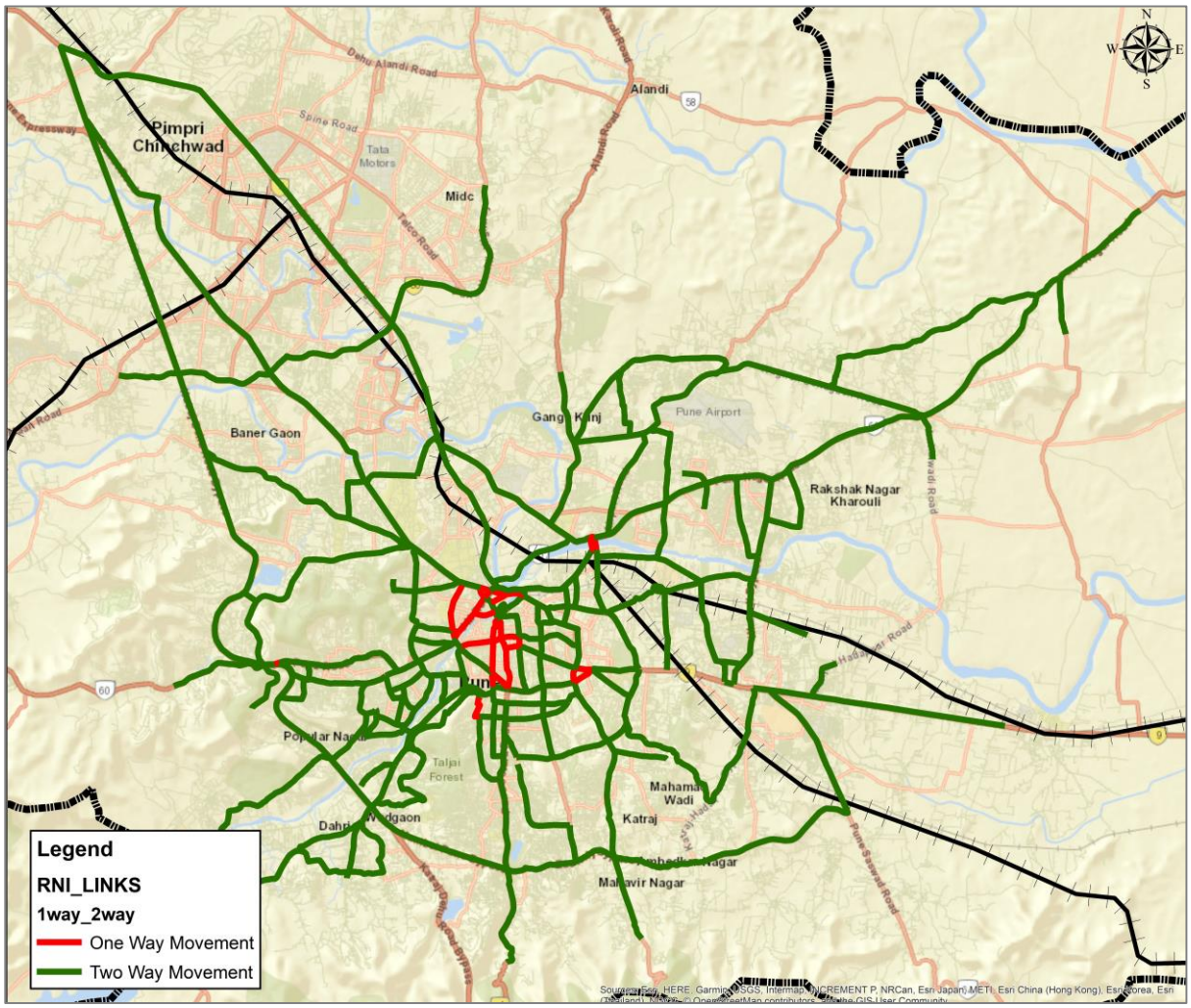


FIGURE 3-6: DISTRIBUTION OF SURVEYED ROAD NETWORK BY ONE-WAY MOVEMENTS

Abutting Land Use

The distribution of the surveyed road network with respect to the abutting land use is represented in Table 3-6. It is seen that the majority of the roads are abutted by residential land use (i.e. 58.30%), followed by commercial at 18.76%, remaining 22.95% roads have mixed use, institutional, wastelands and other purposes alongside the surveyed road network.

TABLE 3-6: DISTRIBUTION OF ROADS BY ABUTTING LAND USE[5]

Land Use	LHS		RHS	
	Road Length (km)	%	Road Length (km)	%
Residential	362.61	59.42%	348.90	57.17%
Commercial	103.42	16.95%	125.50	20.57%
Mixed Use	43.60	7.14%	43.57	7.14%

5 UMTC Primary Surveys 2021

Land Use	LHS		RHS	
	Road Length (km)	%	Road Length (km)	%
Institutional	7.13	1.17%	8.47	1.39%
Waste Land	8.47	1.39%	4.95	0.81%
Others	85.03	13.93%	78.87	12.92%
	610.26	**100.00%**	**610.26**	**100.00%**

Footpath Availability

Details of the availability of footpaths are presented in Table 3-7.

TABLE 3-7: DISTRIBUTION OF ROADS BY AVAILABILITY OF FOOTPATH WIDTH[6]

S.N.	Footpath Width (in meters)	Study Area	
		Length in km	Length in %
1	< 1	194.62	31.90%
2	1 to 2	215.36	35.29%
3	2 to 5	196.56	32.21%
4	More than 5	3.71	0.61%
	Total	**610.26**	**100%**

It is observed that about 35.29% of the total roads surveyed have footpaths with a width of 1 to 2 meters and 32.21% of the total roads surveyed have footpaths with a width of 2 to 5 meters.

The availability of footpaths is represented in Table 3-8. Of the total 610.26 km, 39.8% of the total surveyed roads have a footpath on only one side of the road, 28.3% have a footpath on both sides of the surveyed roads, whereas the remaining 31.9% do not have footpaths on either side of the surveyed roads.

TABLE 3-8: DISTRIBUTION OF ROADS BY AVAILABILITY OF FOOTPATH[7]

S.N.	Availability of Footpath	Study Area	
		Length in km	Length in %
1	Present	415.58	68.10%
	One Way	*242.88*	*39.80%*
	Two Way	*172.70*	*28.30%*
2	Absent	194.68	31.90%
		610.26	**100%**

3.4.1.2. ANALYSIS OF SPEED AND DELAY SURVEY

Journey speed is an important parameter to measure traffic flow and the level of service of traffic. Measurement of speed is essentially required to evaluate the road network

6 UMTC Primary Surveys 2021
7 UMTC Primary Surveys 2021

system and provide vital inputs for the transport demand modelling process and assist in the economic analysis for network improvement plans.

The speed and delay survey is carried out in peak hours on all major roads in the study area, covering all road configurations. Figure 3-7 represents the road network for the speed and delay survey.

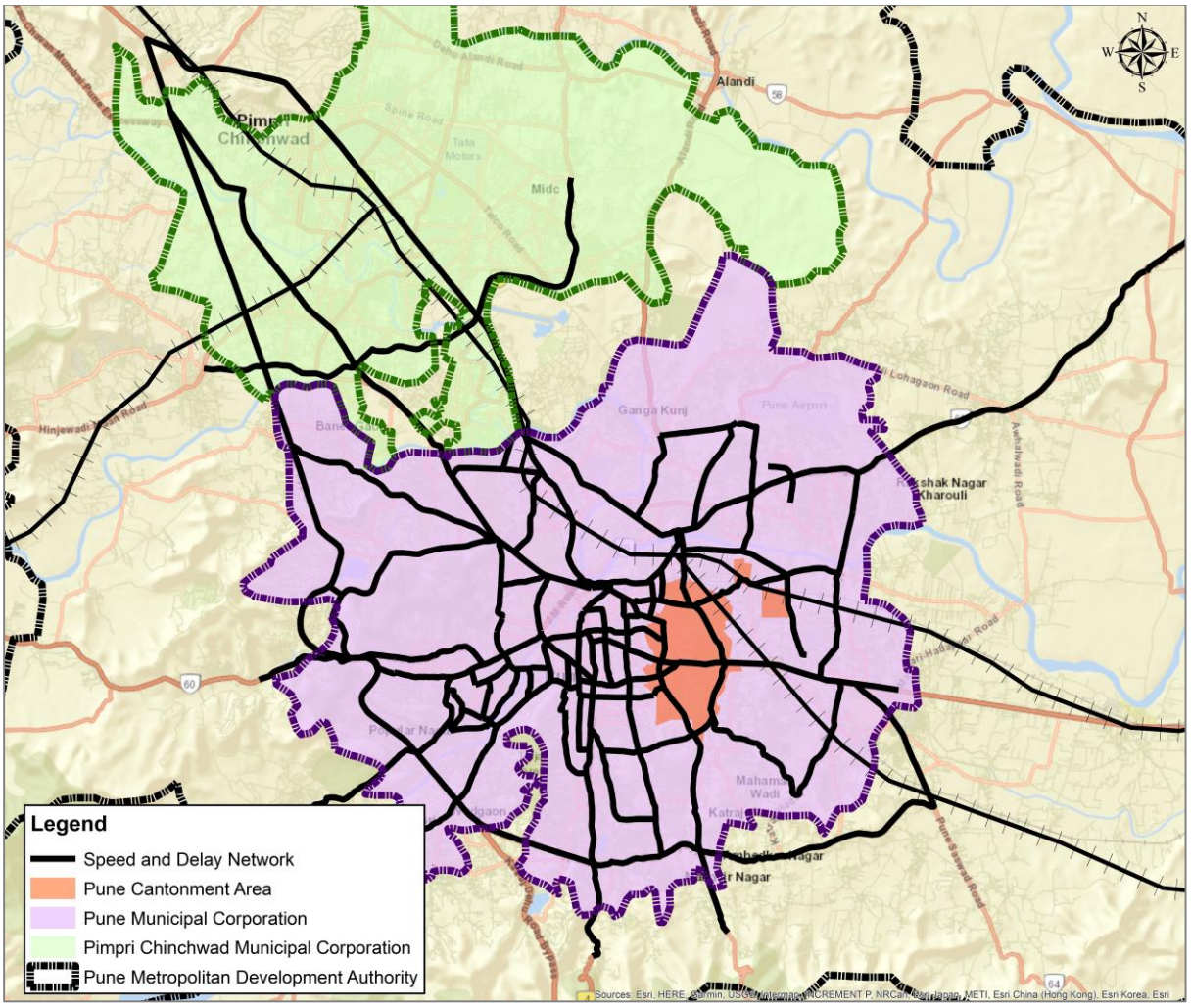


FIGURE 3-7: ROAD NETWORK IDENTIFIED FOR SPEED AND DELAY SURVEY

Speed and delay analysis is presented in Table 3-9.

TABLE 3-9: AVERAGE JOURNEY AND RUNNING SPEED ON MAJOR ROAD NETWORKS[8]

S.N.	Road Name	Journey Speed (kmph)	Running Speed (kmph)	Reasons for Delay
1	Aundh - Ravet BRTS Road	25.7	28.5	Signalized/Non-Signalized Intersection, Congestion

8 UMTC Primary Surveys 2021

S.N.	Road Name	Journey Speed (kmph)	Running Speed (kmph)	Reasons for Delay
2	Aundh Road, Range Hill Road	27	30.4	Signalized/Non-Signalized Intersection, Congestion
3	Baner Road	23.5	28.1	Signalized/Non-Signalized Intersection, Congestion
4	Canal Road	15.8	18	Signalized/Non-Signalized Intersection, Congestion
5	DP Road	13.1	17.7	Signalized/Non-Signalized Intersection, Congestion
6	Ghorpadi Road	25.5	29.1	Congestion
7	Dr Baba Saheb Ambedkar Road	7.5	22.5	Signalized/Non-Signalized Intersection
8	Ganeshkhind Road	13.5	13.5	Signalized/Non-Signalized Intersection
9	Ghorpadi Road, Vibgyor School Road	28.7	36	Signalized/Non-Signalized Intersection, Congestion
10	Jawaharlal Nehru Road	21	22	Signalized/Non-Signalized Intersection
11	Hinjawadi - Wakad Road, Aundh - Ravet BRTS Road	32.7	34.5	Signalized/Non-Signalized Intersection
12	Gulawani Maharaj Road, Late GA Kulkarni Path	20.3	27	Signalized/Non-Signalized Intersection
13	Katraj - Kondhwa Road	12.5	21.5	Signalized/Non-Signalized Intersection
14	Koregaon Park Road	20.7	27.8	Signalized/Non-Signalized Intersection
15	Karve Road	11	12.5	Signalized/Non-Signalized Intersection
16	Khilare Patil Road, Lions Club Path	11.3	27	Signalized/Non-Signalized Intersection, Congestion
17	Mumbai Pune Bypass Road	45.9	48	Signalized/Non-Signalized Intersection, Congestion
18	Moshi, Wakad Road	26.9	35.2	Congestion
19	Old Mumbai Road	37	40	Signalized/Non-Signalized Intersection, Congestion
20	Mumbai - Pune Hwy	15	27	Signalized/Non-Signalized Intersection, Congestion
21	NDA Pashan Road	28.8	32.8	Congestion
22	Lions Club Path, Lal Bahadur Shastri Road	15	28	Signalized/Non-Signalized Intersection
23	Shiv Darshan Road	24.3	24.3	No Delay
24	Sir Maneckji Mehta Road, Bund Garden Road, Sadhu Vaswani Rd	17.8	19.4	Signalized/Non-Signalized Intersection

S.N.	Road Name	Journey Speed (kmph)	Running Speed (kmph)	Reasons for Delay
25	Shivaji Nagar Wakdewadi Road	17.3	23	Congestion
26	Sinhagad Road, Lal Bahadur Shastri Road	17.3	22.5	Signalized/Non-Signalized Intersection
27	Paud Road	18.5	19.8	Signalized/Non-Signalized Intersection
28	Senapati Bapat Road, Nargis Dutt Road	16.5	27	Signalized/Non-Signalized Intersection
29	Swami Vivekanand Road	19	22	Signalized/Non-Signalized Intersection
30	VR Shinde Road, Bibwewadi Kondhwa Road	26	33	Signalized/Non-Signalized Intersection
31	Vidyapeeth Road, Aundh - Ravet BRTS Road	26.6	27.1	Signalized/Non-Signalized Intersection
32	Veer Santaji Ghorpade Road	19.7	21.5	Signalized/Non-Signalized Intersection

The average journey speed varies from 7.5 kmph to 46 kmph. A maximum journey speed of about 50 kmph is observed on the Mumbai Pune Bypass Road. Speeds are very low on roads like Lakdi Bridge, Karve Road, DP Road, and Canal Road as these roads are in the CBD area with many intersections which causing vehicular built-up and vehicular-pedestrian conflicts and other reasons include narrow roads, heavy vehicular flow, on-street parking, encroachments, etc.

The distribution of road length as per running speed and journey speed is presented in Table 3-10.

TABLE 3-10: DISTRIBUTION OF ROAD LENGTH AS PER RUNNING AND JOURNEY SPEED [9]

Speeds (kmph)	Running Speed (% share of Roads)		Journey Speed (% share of Roads)	
	Peak Hour	Off Peak Hour	Peak Hour	Off Peak Hour
<15	23%	18%	33%	26%
15 to 20	8%	14%	14%	24%
20 to 25	16%	15%	16%	15%
25 to 30	20%	19%	16%	15%
> 30	34%	33%	20%	19%

9 UMTC Primary Surveys 2021

Figure 3-8 and Figure 3-9 represent the journey and running speeds of the surveyed network in the study area.

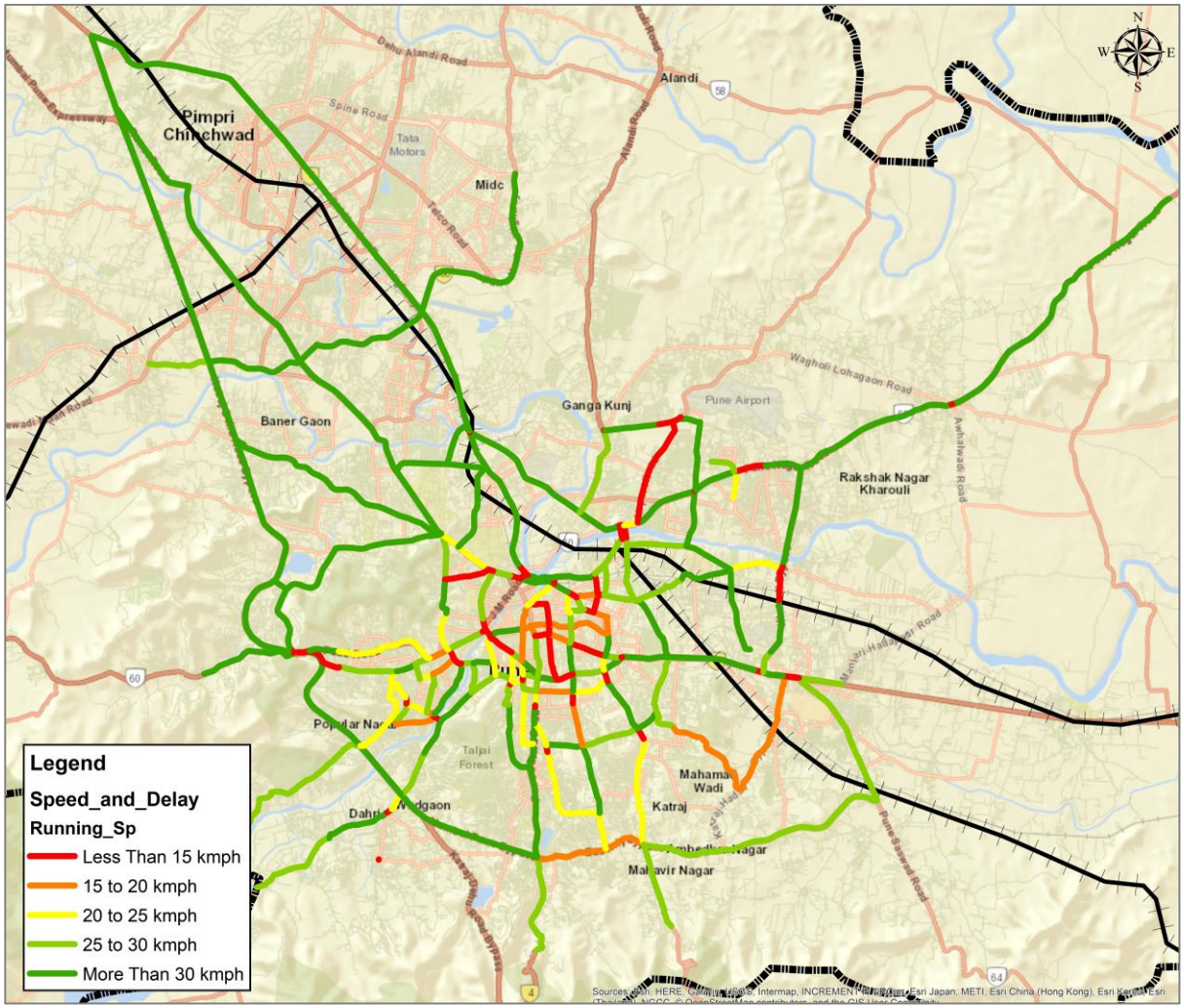


FIGURE 3-8: DISTRIBUTION OF SURVEYED ROADS BY RUNNING SPEED [10]

The average running speeds indicate that about 23% of the surveyed roads have average speeds below 15 kmph and 34% of the surveyed roads have average speeds above 30 kmph.

The average journey speeds indicate that about 33% of the surveyed roads have average speeds below 15 kmph and 20% of the surveyed roads have average speeds above 30 kmph. It is noticed that even in the off peak period about 50% of road network has an average journey speed less than 20 kmph.

About 70% of the delays along the surveyed roads were caused due to congestion at the signalized/non-signalized intersections, whereas the remaining 30% is due to congestion along the roads caused by on-street and off-street parking, loading and unloading of

10 UMTC Primary Surveys 2021

vehicles on the main roads, encroachment of the road space by hawkers and ad-hoc pedestrian movements.

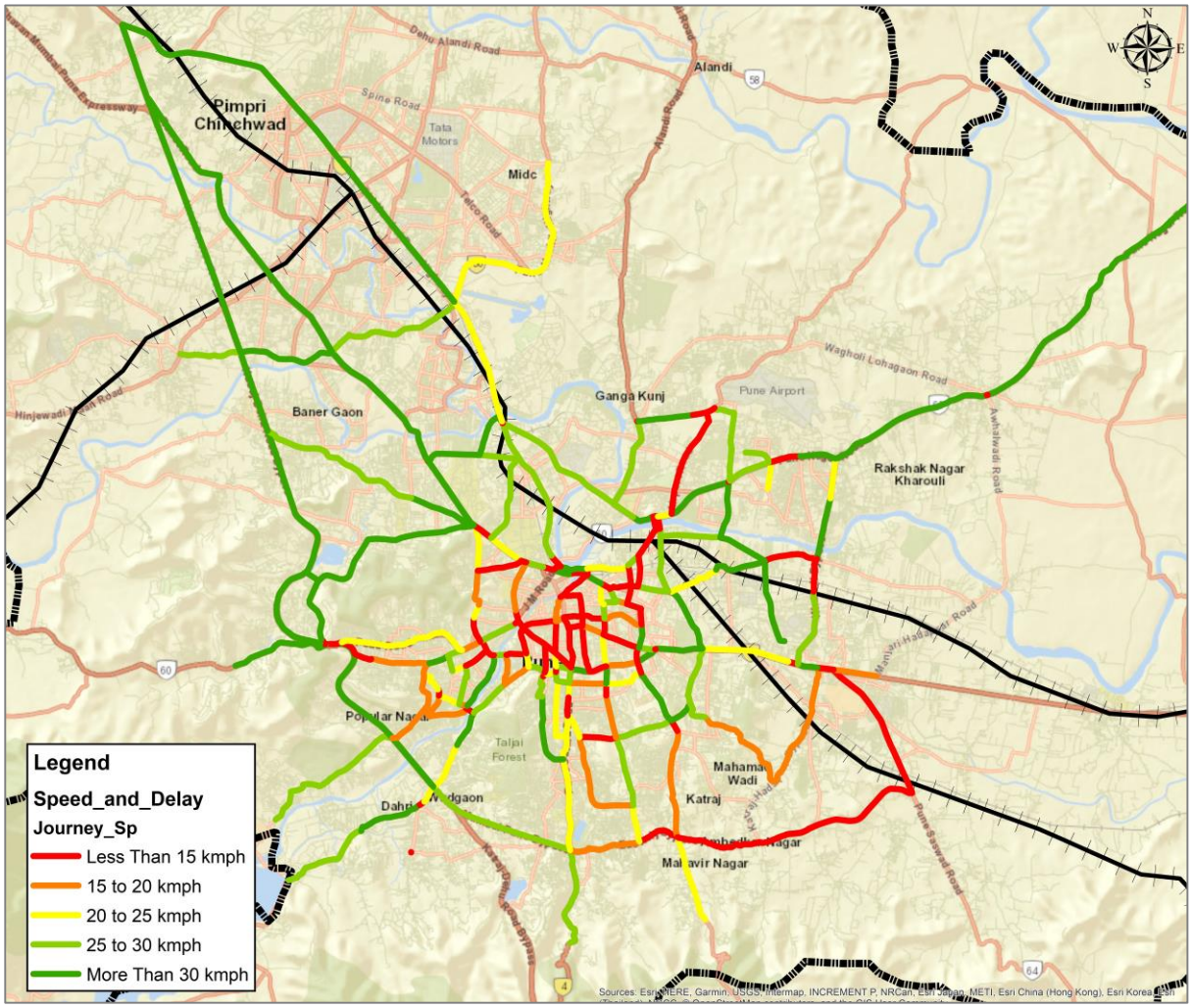


FIGURE 3-9: DISTRIBUTION OF SURVEYED ROADS BY JOURNEY SPEED [11]

3.4.1.3. ANALYSIS OF VOLUME COUNTS AT OUTER CORDON LOCATIONS

Figure 3-10 represents the outer cordon volume count survey locations. The survey was carried out at nineteen (19) locations for 24 hours on a typical non-event working day through videographic surveys in November and December 2021. The assessment of the volume counts at the cordon locations is discussed in the following section.

11 UMTC Primary Surveys 2021

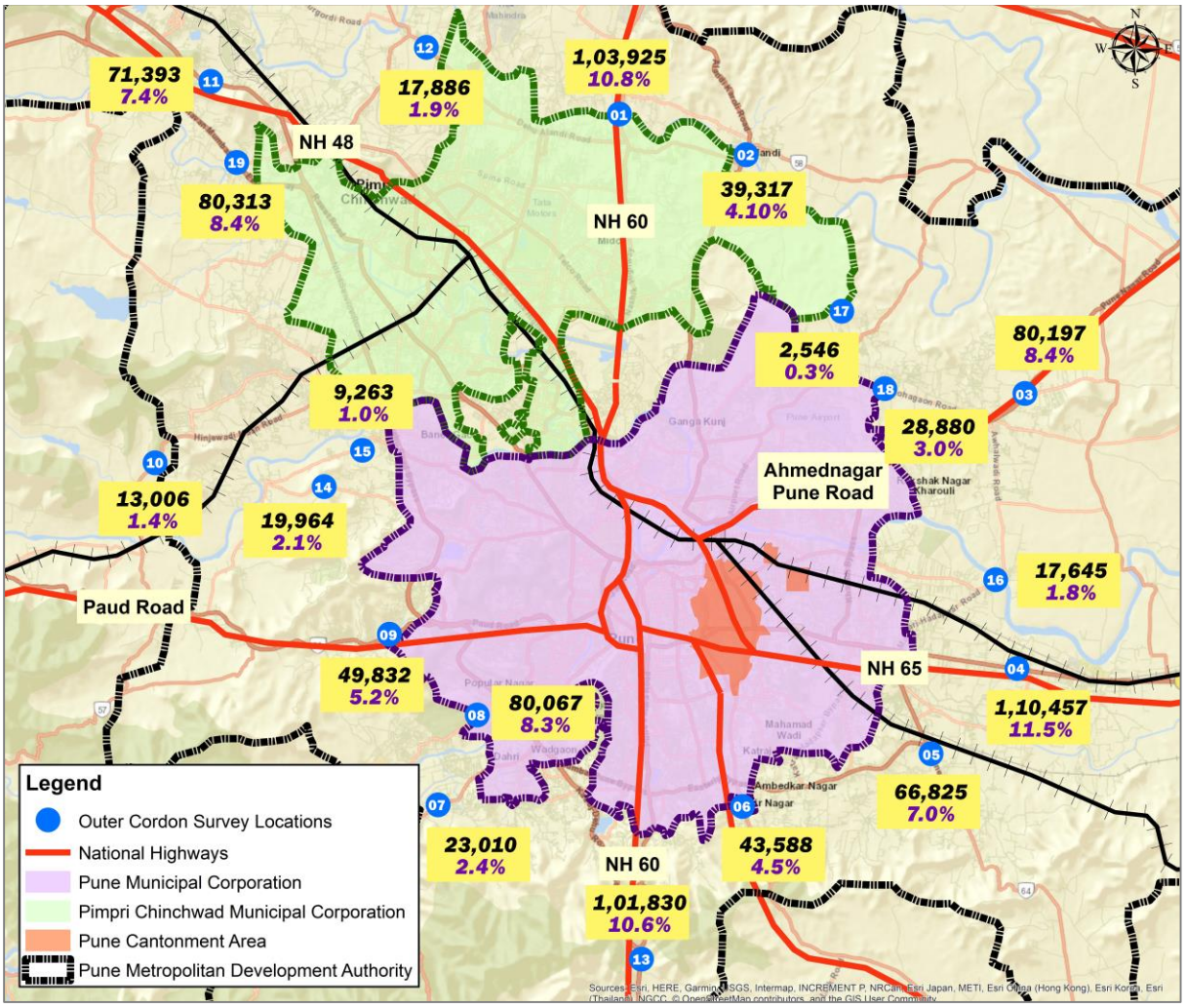


FIGURE 3-10: LOCATION-WISE INTENSITY (PCU) AND SHARE ON OUTER CORDON LOCATIONS[12]

Traffic Intensity

Classified traffic volume counts were conducted at the nineteen (19) cordon locations. Based on the survey results, it is observed that about 8.6 lakh vehicles (9.5 lakh PCUs) enter and leave the study area every day. The daily traffic at the cordon locations is presented in Table 3-11.

TABLE 3-11: DAILY TRAFFIC AT OUTER CORDON LOCATIONS[13]

S. N.	Location ID	Location Name	Total Vehicles		Total PCUs	
			Count	% Share	Count	% Share
1	OC_01	Moshi Toll Plaza	85307	9.8%	103925	10.8%
2	OC_02	Sambhaji Chowk Alandi Road	38500	4.4%	39317	4.1%

12 UMTC Primary Surveys 2021. Map Values are in PCU's and %age share w.r.t the Total PCU's observed at all Outer Cordon Locations.
13 UMTC Primary Surveys 2021

S. N.	Location ID	Location Name	Total Vehicles		Total PCUs	
			Count	% Share	Count	% Share
3	OC_03	Nagar Road Bakori Phata_Wagholi	72659	8.4%	80197	8.4%
4	OC_04	Kawadipeth Toll Plaza Solapur Road	92779	10.7%	110457	11.5%
5	OC_05	Saswad Road	59440	6.9%	66825	7.0%
6	OC_06	Saswad - Bopdev Road	43685	5.0%	43588	4.5%
7	OC_07	Kiratwadi	24384	2.8%	23010	2.4%
8	OC_08	NDA Academy Road	86988	10.0%	80067	8.3%
9	OC_09	Near Bhugaon Mulshi Road	55176	6.4%	49832	5.2%
10	OC_10	Hinjawadi Phase II	12348	1.4%	13006	1.4%
11	OC_11	Dehu Road Toll Plaza Mumbai-Pune	65353	7.5%	71393	7.4%
12	OC_12	Talwade Dehu Alandi Road	16529	1.9%	17886	1.9%
13	OC_13	Katraj - Satara Road	84398	9.7%	101830	10.6%
14	OC_14	Sus Road	20533	2.4%	19964	2.1%
15	OC_15	Nande-Balewadi Road (Mahalunge)	9680	1.1%	9263	1.0%
16	OC_16	Manjari Village, Manjari Road	19634	2.3%	17645	1.8%
17	OC_17	Lohagaon- Nirgudi Road	2738	0.3%	2546	0.3%
18	OC_18	Lohagaon- Wagholi Road	29016	3.3%	28880	3.0%
19	OC_19	Maharashtra Cricket Association	48135	5.6%	80313	8.4%
Total			**867282**	**100%**	**959945**	**100%**

Among all the cordon locations, the highest traffic volume of about 92,779 vehicles, is observed on the Kawadipeth Toll Plaza Pune-Solapur Road, followed by the NDA Academy Road. The least traffic is observed on the Lohagaon-Nirgudi Road as it does not connect to any major settlements and carries only local traffic.

Traffic Volume

It is observed that the traffic at different locations varies from 1,10,457 PCUs (92,779 vehicles) on the Kawadipeth Toll Plaza (Pune-Solapur Road) to 2,546 PCUs (2738 vehicles) on the Lohagaon-Nirgudi Road.

Around 9.59 lakh PCUs in both directions were observed at the cordon locations. Mode-wise vehicles observed at the cordon locations are presented in Table 3-12.

TABLE 3-12: MODE-WISE TRAFFIC VOLUME AT OUTER CORDON LOCATIONS[14]

Location ID	Total		Mode-Wise Vehicles						
	Vehicles	PCUs	2W	4W	3W	Bus	Goods	NMT	Others*
OC_01	85307	103924	36288	23970	6874	2957	15078	133	7
OC_02	38500	39316	22761	9524	1937	513	3563	189	13
OC_03	72659	80197	30574	25461	3551	3151	9754	141	27
OC_04	92779	110457	42804	26887	6722	1791	14175	381	19
OC_05	59440	66824	30862	14357	4155	732	9146	167	21
OC_06	43685	43588	29254	7306	3219	310	3405	185	6
OC_07	24384	23010	17540	2973	2272	216	1087	286	10
OC_08	86988	80067	65023	9593	6996	1327	3486	546	17
OC_09	55176	49831	33774	14842	2721	651	3082	93	13
OC_10	12348	13006	6711	3347	319	140	1803	25	3
OC_11	65353	71392	27493	24931	2977	1758	7992	196	6
OC_12	16529	17886	8192	4735	2233	302	926	140	1
OC_13	84398	101830	27323	37084	2491	2469	14978	30	23
OC_14	20533	19964	11612	6075	1079	358	1340	56	13
OC_15	9680	9262	6363	1586	453	11	1116	139	12
OC_16	19634	17644	14771	2371	1097	97	1028	259	11
OC_17	2738	2546	2156	137	52	0	324	65	4
OC_18	29016	28880	18940	5357	1757	197	2593	169	3
OC_19	48135	80313	224	32440	4	1717	13750	0	0
Others – Ambulance, Road Roller, etc.									

The maximum share of private traffic (i.e., 2-wheelers and 4-wheelers) is observed on the NDA Academy Road (OC_08), with 74,616 private vehicles (65,023 of 2-wheelers and 9,593 4-wheelers). The maximum 2-wheeler traffic is observed on the NDA Academy Road (OC_08), with 65,023 vehicles, and the maximum 4-wheeler traffic is observed on the Katraj-Satara Road (OC_13), with 37,084 vehicles.

The maximum bus traffic is observed at Nagar Road Bakori Phata, with 3,151 buses, and the maximum goods traffic is observed at the Moshi Toll Plaza, i.e., along Nashik Road, with 15,078 goods vehicles.

Traffic Composition

Traffic composition varies considerably, depending on the location and connectivity of the roads. The road-wise traffic composition at the cordon locations is presented in Table 3-13.

14 UMTC Primary Surveys 2021

TABLE 3-13: COMPOSITION OF VEHICLES (IN %AGE) AT OUTER CORDON LOCATIONS[15]

S. N.	Location ID	In %age						
		2W	4W	3W	Bus	Goods	NMT	Others
1	OC_01	42.54%	28.10%	8.06%	3.47%	17.67%	0.16%	0.01%
2	OC_02	59.12%	24.74%	5.03%	1.33%	9.25%	0.49%	0.03%
3	OC_03	42.08%	35.04%	4.89%	4.34%	13.42%	0.19%	0.04%
4	OC_04	46.14%	28.98%	7.25%	1.93%	15.28%	0.41%	0.02%
5	OC_05	51.92%	24.15%	6.99%	1.23%	15.39%	0.28%	0.04%
6	OC_06	66.97%	16.72%	7.37%	0.71%	7.79%	0.42%	0.01%
7	OC_07	71.93%	12.19%	9.32%	0.89%	4.46%	1.17%	0.04%
8	OC_08	74.75%	11.03%	8.04%	1.53%	4.01%	0.63%	0.02%
9	OC_09	61.21%	26.90%	4.93%	1.18%	5.59%	0.17%	0.02%
10	OC_10	54.35%	27.11%	2.58%	1.13%	14.60%	0.20%	0.02%
11	OC_11	42.07%	38.15%	4.56%	2.69%	12.23%	0.30%	0.01%
12	OC_12	49.56%	28.65%	13.51%	1.83%	5.60%	0.85%	0.01%
13	OC_13	32.37%	43.94%	2.95%	2.93%	17.75%	0.04%	0.03%
14	OC_14	56.55%	29.59%	5.25%	1.74%	6.53%	0.27%	0.06%
15	OC_15	65.73%	16.38%	4.68%	0.11%	11.53%	1.44%	0.12%
16	OC_16	75.23%	12.08%	5.59%	0.49%	5.24%	1.32%	0.06%
17	OC_17	78.74%	5.00%	1.90%	0.00%	11.83%	2.37%	0.15%
18	OC_18	65.27%	18.46%	6.06%	0.68%	8.94%	0.58%	0.01%
19	OC_19	0.47%	67.39%	0.01%	3.57%	28.57%	0.00%	0.00%

It is observed that 2-wheeler traffic is significantly high on all the roads as these locations are on the periphery of the urban area, which basically carry more local trips. The share of goods vehicles is considerably high on Saswad Road, Solapur Road, Nashik Road and Mumbai Highway Road, as compared to other roads.

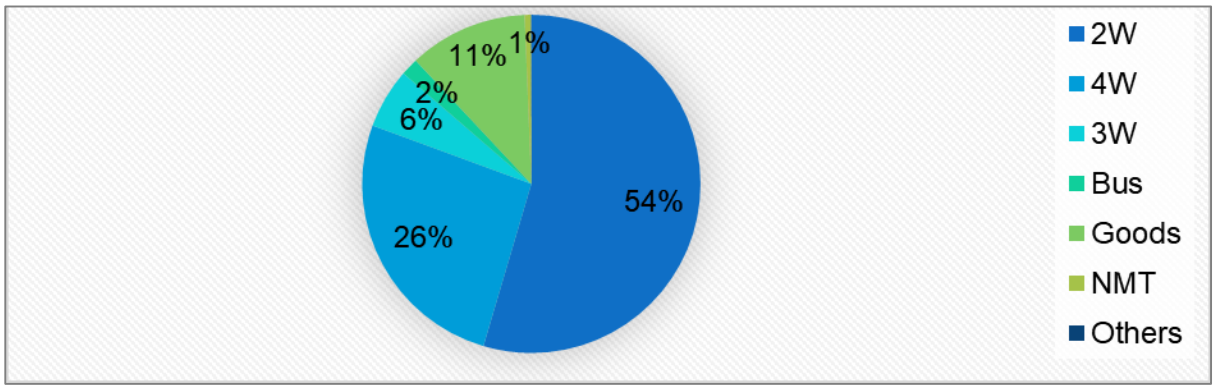


FIGURE 3-11: AVERAGE TRAFFIC COMPOSITION AT OUTER CORDON LOCATIONS[16]

15 UMTC Primary Surveys 2021
16 UMTC Primary Surveys 2021

Temporal Variation of Traffic

The temporal variation of traffic implies an hourly variation of traffic over the entire survey period. This variation is important for transport system operation planning. Table 3-14 represents peak hour traffic and its share in the daily traffic at the cordon locations.

TABLE 3-14: HOURLY VARIATION OF TRAFFIC AT OUTER CORDON LOCATIONS[17]

S. N.	Location Name	Peak Hour			
		Time	Vehicles	PCUs	%age
1	Moshi Toll Plaza	0845-0945	6754	7309	7.92%
2	Sambhaji Chowk Alandi Road	1800-1900	2942	2884	7.64%
3	Nagar Road Bakori Phata_Wagholi	1745-1845	5118	5237	7.0%
4	Kawadipeth Toll Plaza Solapur Road	1815-1915	6255	6813	6.7%
5	Saswad Road	0915-1015	4526	4633	7.6%
6	Saswad - Bopdev Road	0900-1000	3550	3384	8.1%
7	Kiratwadi	0830-0930	2100	1893	8.61%
8	NDA Academy Road	0900-1000	7787	6837	8.95%
9	Near Bhugaon Mulshi Road	0900-1000	4527	3906	8.20%
10	Hinjawadi Phase II	1715-1815	998	996	8.08%
11	Dehu Road Toll Plaza Mumbai-Pun	1745-1845	5053	5141	7.7%
12	Talwade Dehu Alandi Road	0815-0915	1286	1267	7.78%
13	Katraj - Satara Road	1730-1830	6223	6704	7.37%
14	Sus road	0830-0930	2097	1930	10.21%
15	Nande-Balewadi Road (Mahalunge)	0900-1000	938	896	9.69%
16	Manjari Village, Manjari Road	0900-1000	1735	1525	8.84%
17	Lohagaon- Nirgudi Road	0845-0945	284	258	10.37%
18	Lohagaon- Wagholi Road	1800-1900	2417	2307	8.33%
19	Maharashtra Cricket Association	1000-1100	2661	4395	5.53%

It is observed that the percentage of traffic during the peak hour ranges between 5.53% and 10.37% with an average of 8.15%.

3.4.1.4. ANALYSIS OF O-D SURVEY AT CORDON LOCATIONS

To understand the travel pattern of the study area, O-D surveys were carried out at seven (07) cordon locations for 24 hours. The study area is divided into 299 Traffic Analysis Zones (TAZ's), of which 289 are internal TAZ's and 10 are external TAZ's. These external TAZ's have been divided based on the cordon roads entering/leaving the study area. The assessment of the same is discussed in the following section.

17 UMTC Primary Surveys 2021

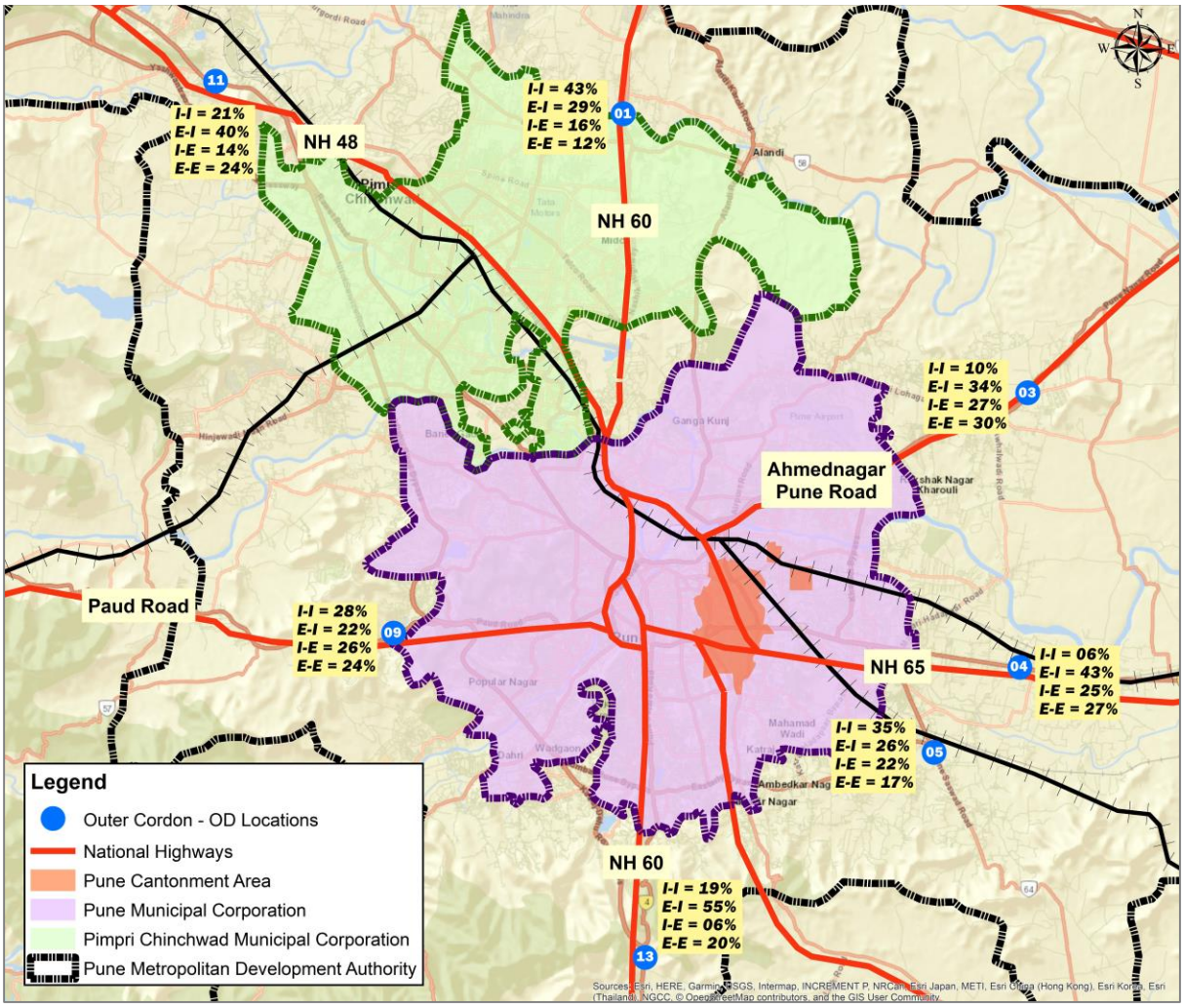


FIGURE 3-12: OUTER CORDON SURVEY LOCATIONS FOR ORIGIN AND DESTINATION SURVEYS[18]

Sample Size

The O-D sample size collected at the seven (07) cordon locations of the nineteen (19) cordon locations selected for the classified traffic volume counts has been discussed below.

The total samples account for ~4% of the total private passenger vehicles recorded at the selected cordon locations. Of the total collected samples, 2-wheelers constitute around 26%, 4-wheelers, including the White Plate and Yellow Plate types, account for 72% of the samples, whereas auto-rickshaws (3-seater and 7-seater) account for 1.66%.

18 UMTC Primary Surveys 2021

Travel Pattern of Passenger Vehicles

The location-wise travel pattern of passenger vehicles at the cordon locations is summarized and presented in Table 3-15.

TABLE 3-15: TRAVEL PATTERN OF PASSENGER VEHICLE AT OUTER CORDON LOCATIONS[19]

Location ID	Road Name	I - I	I - E	E - I	E - E
OC_01	Moshi Toll Plaza	43%	16%	29%	12%
OC_03	Nagar Road Bakori Phata_Wagholi	10%	27%	34%	30%
OC_04	Kawadipeth Toll Plaza Solapur Road	6%	25%	43%	27%
OC_05	Saswad Road	35%	22%	26%	17%
OC_09	Near Bhugaon Paud Road	28%	26%	22%	24%
OC_11	Dehu Road Toll Plaza Mumbai-Pune	21%	14%	40%	24%
OC_13	Katraj - Satara Road	19%	6%	55%	20%
Internal to Internal (I-I); Internal to External (I-E); External to Internal (E-I); External to External (E-E)					

Internal to External trips account for an average of about 19%, External to Internal trips account for an average of about 36%, whereas External to External trips account for an average of about 22%. External to External trips are quite high (i.e. 30%) on the Nagar Road (OC_03), suggesting that a lot of traffic continues on this road.

Trip Purpose

The mode-wise distribution of trip purpose at the cordons is presented in Table 3-16.

TABLE 3-16: TRIP PURPOSE BY MODE AT OUTER CORDON LOCATIONS[20]

Trip Purpose	2-Wheeler	Car/Jeep/ Van (White Board)	Car / Jeep / Van (Yellow Board)	Auto-Rickshaw-3 Seater	Auto-Rickshaw-7 Seater
Return Home	8%	8%	8%	6%	0%
Work	15%	17%	19%	32%	16%
Business	12%	14%	13%	18%	8%
Education	9%	8%	5%	14%	0%
Shopping	7%	9%	16%	7%	0%
Health	6%	4%	4%	4%	0%
Entertainment/ Recreation	20%	17%	14%	5%	44%
Social	8%	11%	11%	10%	8%

19 UMTC Primary Surveys 2021
20 UMTC Primary Surveys 2021

Trip Purpose	2-Wheeler	Car/Jeep/ Van (White Board)	Car / Jeep / Van (Yellow Board)	Auto-Rickshaw-3 Seater	Auto-Rickshaw-7 Seater
Others	15%	13%	11%	4%	24%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

It is observed that trips are made predominantly for work and business, followed by trips made for entertainment/recreational purposes.

Trip Frequency by Passenger Vehicles

The mode-wise trip frequency distribution at the cordon locations and the results obtained are presented in Table 3-17.

TABLE 3-17: MODE-WISE DISTRIBUTION OF TRIP FREQUENCY FOR PASSENGER VEHICLES AT CORDON LOCATIONS[21]

Trip Frequency	2-Wheeler	Car/Jeep/ Van (White Board)	Car / Jeep / Van (Yellow Board)	Auto-Rickshaw - 3-Seater	Auto-Rickshaw - 7-Seater
Daily twice (up & down)	14%	10%	7%	14%	0%
Daily thrice or more	15%	14%	14%	26%	0%
Weekly once	24%	24%	25%	12%	40%
Several days of the week	20%	19%	21%	28%	40%
Occasionally	27%	33%	33%	21%	20%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Passenger Flows at Cordon Locations

The passenger vehicle occupancy survey was carried out at the identified cordon locations to estimate the average occupancy of passenger vehicles. The average occupancy factor for various passenger vehicles at the identified cordon locations are presented in Table 3-18.

TABLE 3-18: OCCUPANCY FACTOR OBTAINED AT EACH CORDON LOCATION[22]

S. N.	Vehicle Type	Occupancy Factor
1	2-Wheeler	1.87
2	Car/ Jeep/ Van (White Plate- Private Vehicles)	3.16
3	Car/Jeep/Van (Yellow Plate - Taxis)	3.12
4	Auto-rickshaw – 3-Seater (3w)	2.07
5	Auto-rickshaw – 7-Seater (3w)	2.32

21 UMTC Primary Surveys 2021
22 UMTC Primary Surveys 2021

S. N.	Vehicle Type	Occupancy Factor
6	Bus - City Bus (Govt.)	26.79
7	Bus – Inter-City Bus/Inter-State (Govt.)	24.41
8	Bus - Chartered Bus	21.47
9	Bus - Mini/Midi Bus	17.99

TABLE 3-19: VEHICULAR AND PASSENGER FLOW AT OUTER CORDON LOCATIONS[23]

S. N.	Location Name	Total Vehicular Flow		Total Passenger Flow	
		Towards Cordon	Away From Cordon	Towards Cordon	Away From Cordon
1	Moshi Toll Plaza	42,112	43,195	1,13,181	1,12,052
2	Sambhaji Chowk Alandi Road	20,730	17,770	46,205	42,143
3	Nagar Road Bakori Phata_Wagholi	36,828	35,831	1,09,664	1,06,669
4	Kawadipeth Toll Plaza Solapur Road	46,763	46,016	1,10,804	1,09,013
5	Saswad Road	28,953	30,487	62,261	66,243
6	Saswad-Bopdev Road	21,756	21,929	45,637	46,100
7	Kiratwadi	12,174	12,210	26,197	25,820
8	NDA Academy Road	42,819	44,169	97,642	99,506
9	Near Bhugaon Mulshi Road	27,088	28,088	63,934	66,555
10	Hinjawadi Phase II	6,093	6,255	13,335	13,597
11	Dehu Road Toll Plaza Mumbai-Pune	32,098	33,255	87,246	88,829
12	Talwade Dehu Alandi Road	7,223	9,306	18,443	23,490
13	Katraj - Satara Road	41,574	42,824	1,13,180	1,15,785
14	Sus Road	10,238	10,295	25,589	25,683
15	Nande-Balewadi Road (Mahalunge)	4,834	4,846	9,033	9,090
16	Manjari Village, Manjari Road	9,875	9,759	19,907	19,766
17	Lohagaon-Nirgudi Road	1,365	1,373	2,301	2,275
18	Lohagaon-Wagholi Road	14,460	14,556	30,165	30,396
19	Maharashtra Cricket Association	25,198	22,937	73,797	67,408

Overall, it can be seen that about 20 lakh person trips are crossing the outer cordon locations on an average on a daily basis.

23 UMTC Primary Surveys 2021

3.4.1.5. ANALYSIS OF VOLUME COUNTS AT SCREEN LINE LOCATIONS

The two (02) screen lines considered to capture the crossing of vehicles and people from one part of the study area to another part are:

1. Railway Line and Mutha River together are considered as the North-South Screen Line
2. Mula and Mutha Rivers are considered as the East-West Screen Line

The survey locations along the two (02) screen lines are represented in Figure 3-13. The survey was carried out for sixteen (16) hours on a typical non-event working day at 30 locations through videographic surveys between November and December 2021. The traffic volume counts conducted at the screen line locations are described in the following section.

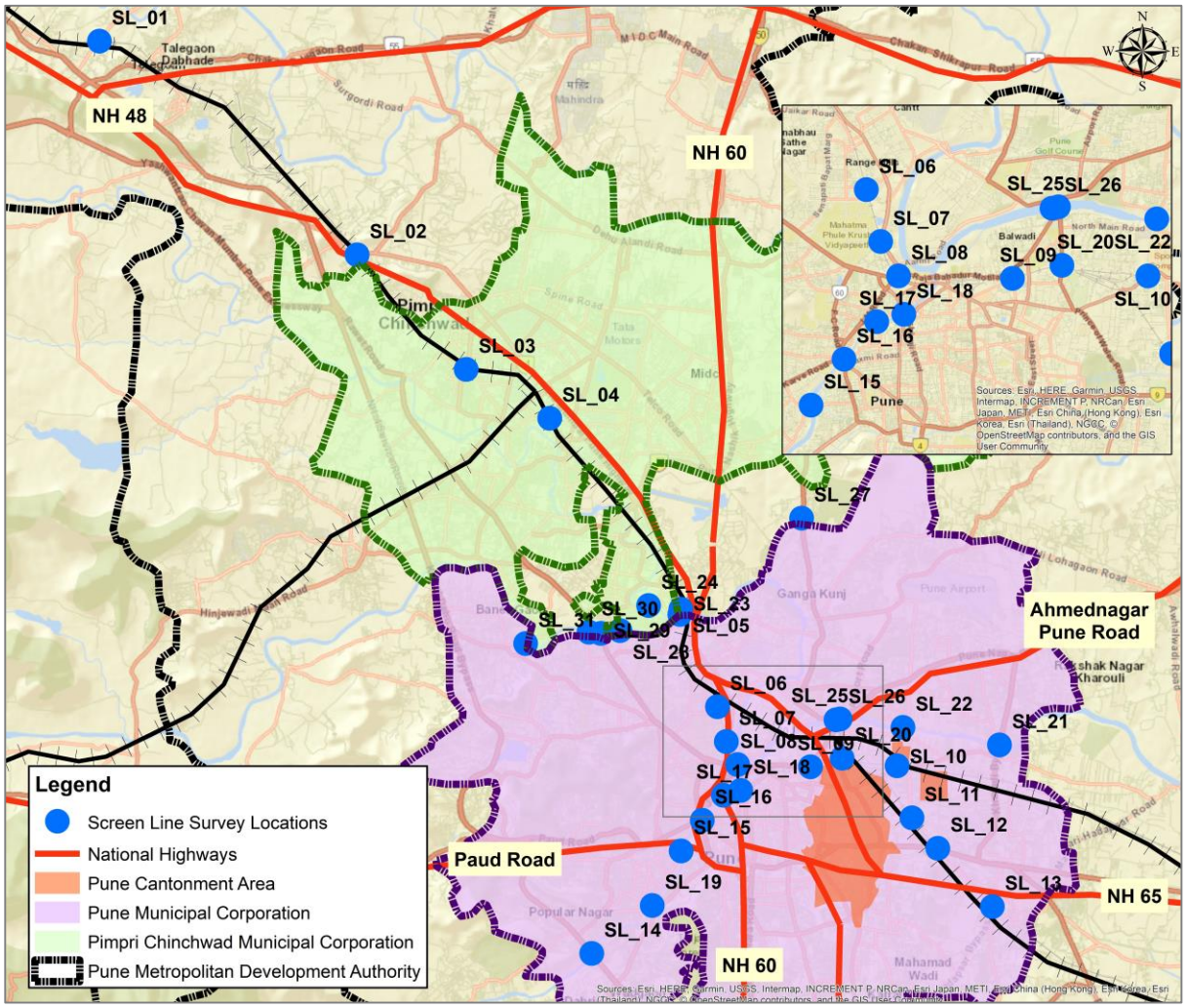


FIGURE 3-13: SCREEN LINE SURVEY LOCATIONS[24]

24 UMTC Primary Surveys 2021

Traffic Intensity

Table 3-20 represents the 16 hours' traffic (06:00 am to 10:00 pm) observed at the identified screen line locations.

TABLE 3-20: LOCATION-WISE TRAFFIC AT SCREEN LINE LOCATIONS[25]

S. N.	Location ID	Location Name	Total Vehicles		Total PCUs	
			Count	% Share	Count	% Share
North-South Screen Line						
1	SL_01	Talegaon MIDC	18129	0.78%	26510	1.14%
2	SL_02	Dehu Road	65971	2.84%	66254	2.85%
3	SL_03	Akurdi Chikhali Road	56043	2.41%	51243	2.20%
4	SL_04	Kalewadi road ROB	63568	2.74%	60647	2.61%
5	SL_05	Bhau Patil Road	74531	3.21%	74418	3.20%
6	SL_06	Dhanori Alandi Road	19252	0.83%	18665	0.80%
7	SL_07	KB Joshi Path	51449	2.22%	49462	2.13%
8	SL_08	HK Firodia Bridge	151631	6.53%	157082	6.76%
9	SL_09	Connaught Road	55726	2.40%	63463	2.73%
10	SL_10	Ghorpadi Road	29936	1.29%	28109	1.21%
11	SL_11	BT Kawade Road	38652	1.66%	35670	1.53%
12	SL_12	Solapur Road Kirloskar	154230	6.64%	155614	6.69%
13	SL_13	Hadapsar Road	34307	1.48%	34268	1.47%
14	SL_14	Westernly Bypass	161615	6.96%	166781	7.17%
15	SL_15	Mhatre Bridge	92281	3.97%	86109	3.70%
16	SL_16	Lakdi Bridge	68907	2.97%	78856	3.39%
17	SL_17	Maha Rishi Shinde Bridge	57093	2.46%	53029	2.28%
18	SL_18	Shivaji Bridge_Nava Pul	75001	3.23%	75716	3.26%
19	SL_19	Rajaram Bridge	94825	4.08%	94448	4.06%
20	SL_20	Koregaon Park Road	99095	4.27%	94132	4.05%
East-West Screen Line						
21	SL_21	Magarpatta River Bridge	102430	4.41%	106573	4.58%
22	SL_22	HH Aga Khan Bridge	72816	3.14%	71481	3.07%
23	SL_23	Harris Bridge	139761	6.02%	140199	6.03%
24	SL_24	Sangam Cross Road	25465	1.10%	24095	1.04%
25	SL_25	Yerwada Bridge 1	107556	4.63%	109619	4.71%
26	SL_26	Yerwada bridge 2	109393	4.71%	111858	4.81%
27	SL_27	Alandi Road	76577	3.30%	77156	3.32%

25 UMTC Primary Surveys 2021

S. N.	Location ID	Location Name	Total Vehicles		Total PCUs	
			Count	% Share	Count	% Share
28	SL_28	Jai Ganesh Chowk_Spicer road	60004	2.58%	54024	2.32%
29	SL_29	Aundh Ravet BRTS Road	116013	5.00%	113976	4.90%
30	SL_31	Mahatma Jyotiba Phule Bridge	50076	2.16%	45891	1.97%
Total (Including North-South and East-West Screen Line)			**2322333**	**100%**	**2325348**	**100%**

Among all the screen line locations, highest traffic volume of about 1,61,615 vehicles are observed on Westerly Bypass followed by Solapur Road. The least traffic is observed at Talegaon MIDC.

Based on the analysis, total of about 14,62,242 vehicles (14,70,475 PCUs) cross the North-South Screen Line and about 8,60,091 vehicles (8,54,873 PCUs) cross the East-West Screen Line every day.

Mode-Wise Traffic Volume

The mode-wise traffic volume at all screen line locations is presented in Table 3-21.

TABLE 3-21: MODE-WISE TRAFFIC VOLUME AT SCREEN LINE LOCATIONS[26]

S. N.	Location ID	2W	4W	3W	Bus	Goods	NMT	Others
North-South Screen Line								
1	SL_01	7896	4447	282	627	4828	35	14
2	SL_02	36347	19719	3703	1380	4542	264	16
3	SL_03	39439	7875	3284	1279	2628	1533	5
4	SL_04	41635	12999	3627	681	3561	1040	25
5	SL_05	47136	12587	10425	945	2033	1392	13
6	SL_06	10074	6828	1646	42	476	183	3
7	SL_07	37007	6104	7494	0	270	572	2
8	SL_08	78012	45185	17980	3295	6735	409	15
9	SL_09	30157	8288	13144	1650	1600	886	1
10	SL_10	21618	2910	3498	155	810	940	5
11	SL_11	28721	4361	3736	157	1105	565	7
12	SL_12	92996	32681	16636	2807	8668	433	9
13	SL_13	23398	2956	5380	181	1415	973	4
14	SL_14	86237	46348	8552	2452	17646	353	27

26 UMTC Primary Surveys 2021

S. N.	Location ID	2W	4W	3W	Bus	Goods	NMT	Others
15	SL_15	65933	12156	9747	412	2437	1592	4
16	SL_16	30090	18246	14695	2190	2269	1406	11
17	SL_17	43131	5159	6886	30	897	989	1
18	SL_18	49525	9981	10544	1498	2802	650	1
19	SL_19	54749	23886	12360	251	2739	835	5
20	SL_20	62323	24512	10485	40	1141	594	0
East-West Screen Line								
21	SL_21	61256	21026	10091	1258	7570	1198	31
22	SL_22	42578	17072	7863	225	3709	1363	6
23	SL_23	76904	40440	13267	3109	5515	511	15
24	SL_24	18428	2330	3281	105	581	734	6
25	SL_25	63232	23075	14206	2210	3688	1138	7
26	SL_26	64258	23612	14627	2254	3788	846	8
27	SL_27	47467	16591	5080	1988	4993	455	3
28	SL_28	45751	6007	5733	161	974	1378	0
29	SL_29	64535	34424	9494	2553	4281	720	6
30	SL_31	31735	12837	3432	91	1229	745	7

The maximum private traffic (i.e., 2-wheelers and 4-wheelers) is observed on the Westerly Bypass Road (SL_14), with 1,32,585 vehicles (86,237 2-wheelers and 46,348 4-wheelers).

The maximum 2-wheeler traffic is observed on Solapur Road (SL_12), with 92,996 vehicles, and the maximum 4-wheeler traffic is observed on Westerly Bypass Road (SL_14), with 46,348 vehicles.

The maximum bus traffic is observed on HK Firodia Bridge, with 3,295 buses, and the maximum goods traffic is observed at Westerly Bypass Road, with 17,646 goods vehicles.

Traffic Composition

The composition of traffic observed along the screen lines is presented in Table 3-22.

TABLE 3-22: MODE-WISE COMPOSITION OF TRAFFIC AT SCREEN LINE LOCATIONS[27]

S. N.	Location ID	In %age (rounded off)						
		2W	4W	3W	Bus	Goods	NMT	Others
North-South Screen Line								
1	SL_01	44%	25%	2%	3%	27%	0%	0%
2	SL_02	55%	30%	6%	2%	7%	0%	0%
3	SL_03	70%	14%	6%	2%	5%	3%	0%
4	SL_04	65%	20%	6%	1%	6%	2%	0%

27 UMTC Primary Surveys 2021

S. N.	Location ID	In %age (rounded off)						
		2W	4W	3W	Bus	Goods	NMT	Others
5	SL_05	63%	17%	14%	1%	3%	2%	0%
6	SL_06	52%	35%	9%	0%	2%	1%	0%
7	SL_07	72%	12%	15%	0%	1%	1%	0%
8	SL_08	51%	30%	12%	2%	4%	0%	0%
9	SL_09	54%	15%	24%	3%	3%	2%	0%
10	SL_10	72%	10%	12%	1%	3%	3%	0%
11	SL_11	74%	11%	10%	0%	3%	1%	0%
12	SL_12	60%	21%	11%	2%	6%	0%	0%
13	SL_13	68%	9%	16%	1%	4%	3%	0%
14	SL_14	53%	29%	5%	2%	11%	0%	0%
15	SL_15	71%	13%	11%	0%	3%	2%	0%
16	SL_16	44%	26%	21%	3%	3%	2%	0%
17	SL_17	76%	9%	12%	0%	2%	2%	0%
18	SL_18	66%	13%	14%	2%	4%	1%	0%
19	SL_19	58%	25%	13%	0%	3%	1%	0%
20	SL_20	63%	25%	11%	0%	1%	1%	0%
East-West Screen Line								
21	SL_21	60%	21%	10%	1%	7%	1%	0%
22	SL_22	58%	23%	11%	0%	5%	2%	0%
23	SL_23	11%	6%	2%	0%	1%	0%	0%
24	SL_24	72%	9%	13%	0%	2%	3%	0%
25	SL_25	59%	21%	13%	2%	3%	1%	0%
26	SL_26	59%	22%	13%	2%	3%	1%	0%
27	SL_27	62%	22%	7%	3%	7%	1%	0%
28	SL_28	76%	10%	10%	0%	2%	2%	0%
29	SL_29	56%	30%	8%	2%	4%	1%	0%
30	SL_31	63%	26%	7%	0%	2%	1%	0%

On an average, the share of 2-wheelers is observed to be predominant (62%), followed by cars (20%), among private motorized vehicles.

Passenger vehicles contribute to around 94% of the total traffic crossing the screen –lines, while goods vehicles constitute only around 5% of the total traffic. The average vehicle composition along the screen lines is presented in Figure 3-14.

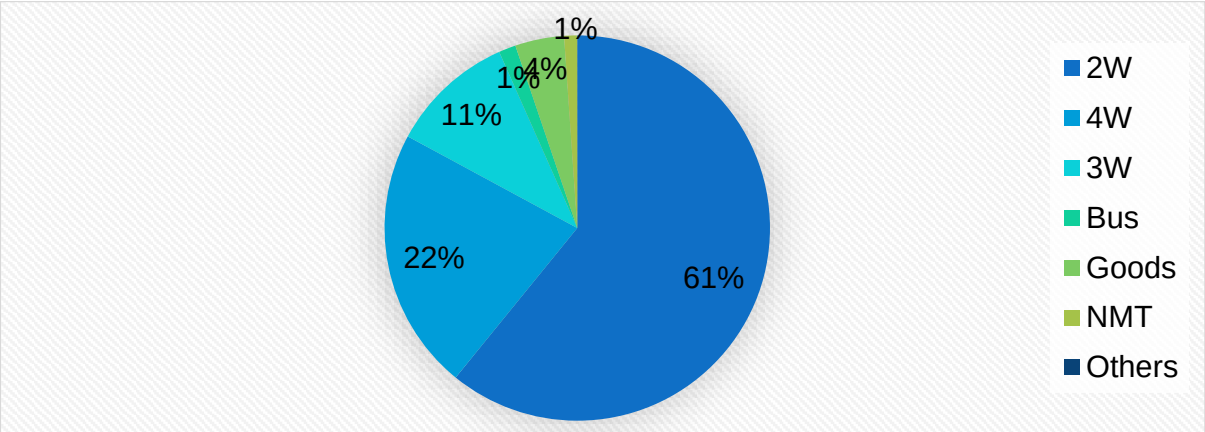


FIGURE 3-14: AVERAGE COMPOSITION OF VEHICLES AT SCREEN LINE LOCATIONS[28]

It is observed that the share of public transport is around 1% of the total traffic, whereas the share of Intermediate Public Transport (i.e., 3-wheelers/auto-rickshaws) constitutes around 11%.

Peak Hour Characteristics

Location-wise peak hour traffic along the screen lines is presented in Table 3-23

TABLE 3-23: PEAK HOUR TRAFFIC AT SCREEN LINE LOCATIONS[29]

S. N.	Location ID	Vehicles	PCUs	Peak Hour			
				Time	Vehicles	PCUs	%age
1	SL_01	18129	26510	1730-1830	1765	2268	10%
2	SL_02	65971	66254	1800-1900	5729	5567	9%
3	SL_03	56043	51243	1800-1900	5010	4510	9%
4	SL_04	63568	60647	1815-1915	6103	5707	10%
5	SL_05	74531	74418	1815-1915	4289	4214	9%
6	SL_06	19252	18665	0915-1015	1935	1836	10%
7	SL_07	51449	49462	0930-1030	4572	4368	9%
8	SL_08	151631	157082	1100-1200	12445	12805	8%
9	SL_09	55726	63463	1445-1545	4389	4996	8%
10	SL_10	29936	28109	1800-1900	2541	2336	8%
11	SL_11	38652	35670	1730-1830	3277	2997	8%
12	SL_12	154230	155614	0915-1015	12979	12429	8%
13	SL_13	34307	34268	1815-1915	2886	2764	8%
14	SL_14	161615	166781	0900-1000	15707	14620	10%
15	SL_15	92281	86109	1815-1915	9703	8501	11%
16	SL_16	68907	78856	0945-1045	5656	6357	8%
17	SL_17	57093	53029	1100-1200	5180	4905	9%
18	SL_18	75001	75716	1800-1900	5895	5917	8%
19	SL_19	94825	94448	0930-1030	10029	9194	11%
20	SL_20	99095	94132	0930-1030	8731	7931	9%
21	SL_21	102430	106573	0845-0945	8901	8620	9%

28 UMTC Primary Surveys 2021
29 UMTC Primary Surveys 2021

S. N.	Location ID	Vehicles	PCUs	Peak Hour			
				Time	Vehicles	PCUs	%age
22	SL_22	72816	71481	0915-1015	6315	6026	9%
23	SL_23	139761	140199	1830-1930	12039	11602	9%
24	SL_24	25465	24095	1830-1930	2415	2221	9%
25	SL_25	107556	109619	0930-1030	10575	10217	10%
26	SL_26	109393	111858	1800-1900	10289	9944	9%
27	SL_27	76577	77156	1830-1930	6878	6625	9%
28	SL_28	60004	54024	0915-1015	5303	4699	9%
29	SL_29	116013	113976	0900-1000	10877	10162	9%
30	SL_31	50076	45891	1830-1930	4960	4491	10%

It is observed that the percentage of traffic during the peak hour ranges between 7.9% and 10.6% with an average of 9.1%.

Passenger Flows Across Screen Lines

Occupancy surveys were carried out at thirty (30) screen line locations and thirteen (13) mid-block locations to estimate the average occupancy of passenger vehicles. The occupancy factors are used to convert vehicular flows into passenger flows. The average occupancy factors for various vehicles across the screen lines are presented in Table 3-24.

TABLE 3-24: OCCUPANCY FACTORS AT SCREEN LINES IN PEAK PERIOD[30]

S. N.	Vehicle Type	Occupancy Factor
1	2-Wheeler	1.51
2	Car/ Jeep/ Van (White Board- Private Vehicles)	2.47
3	Car/Jeep/Van (Yellow Board - Taxis)	2.77
4	Auto-Rickshaw – 3-seater (3w)	2.97
5	Auto-Rickshaw – 7-seater (3w)	3.44
6	Bus - City Bus (Govt.)	25.99
7	Bus – Inter-City Bus/Inter-State (Govt.)	23.68
8	Bus - Chartered Bus	20.83
9	Bus - Mini/Midi Bus	17.45
10	Cycle Rickshaw	1.92

It has been observed that for all modes of transport, the occupancy during the peak hour is more than that in the off-peak period. Also, the occupancy of smaller modes at the screen line locations is less than that observed for similar modes at the outer cordon locations.

30 UMTC Primary Surveys 2021

Based on Table 3-24, the total passenger vehicles and corresponding passenger flow across the screen lines is presented in Table 3-25

TABLE 3-25: TOTAL PASSENGER VEHICLES AND PASSENGERS AT SCREEN LINES[31]

S. N.	Location ID	Vehicles						Passengers					
		2W	4W	3W	Bus	NMT	Total	2W	4W	3W	Bus	NMT	Total
North-South Screen Line													
1	SL_01	7,896	4,447	282	627	49	13,301	11,955	11,657	904	13,785	67	38,368
2	SL_02	36,347	19,719	3,703	1,380	280	61,429	55,033	51,690	11,871	30,339	507	1,49,441
3	SL_03	39,439	7,875	3,284	1,279	1,538	53,415	59,715	20,643	10,528	28,119	2,944	1,21,949
4	SL_04	41,635	12,999	3,627	681	1,065	60,007	63,040	34,075	11,628	14,972	1,997	1,25,711
5	SL_05	47,136	12,587	10,425	945	1,405	72,498	71,369	32,995	33,421	20,776	2,673	1,61,234
6	SL_06	10,074	6,828	1,646	42	186	18,776	15,253	17,899	5,277	923	351	39,703
7	SL_07	37,007	6,104	7,494	-	574	51,179	56,032	16,001	24,025	-	1,099	97,156
8	SL_08	78,012	45,185	17,980	3,295	424	1,44,896	1,18,118	1,18,446	57,641	72,441	786	3,67,431
9	SL_09	30,157	8,288	13,144	1,650	887	54,126	45,661	21,726	42,138	36,275	1,702	1,47,501
10	SL_10	21,618	2,910	3,498	155	945	29,126	32,732	7,628	11,214	3,408	1,805	56,787
11	SL_11	28,721	4,361	3,736	157	572	37,547	43,486	11,432	11,977	3,452	1,085	71,432
12	SL_12	92,996	32,681	16,636	2,807	442	1,45,562	1,40,805	85,668	53,333	61,712	832	3,42,350
13	SL_13	23,398	2,956	5,380	181	977	32,892	35,427	7,749	17,247	3,979	1,869	66,271
14	SL_14	86,237	46,348	8,552	2,452	380	1,43,969	1,30,571	1,21,494	27,416	53,907	678	3,34,068
15	SL_15	65,933	12,156	9,747	412	1,596	89,844	99,829	31,865	31,247	9,058	3,058	1,75,057
16	SL_16	30,090	18,246	14,695	2,190	1,417	66,638	45,559	47,829	47,110	48,147	2,700	1,91,346
17	SL_17	43,131	5,159	6,886	30	990	56,196	65,305	13,524	22,075	660	1,899	1,03,463
18	SL_18	49,525	9,981	10,544	1,498	651	72,199	74,986	26,164	33,802	32,934	1,248	1,69,134

31 UMTC Primary Surveys 2021

S. N.	Location ID	Vehicles						Passengers					
		2W	4W	3W	Bus	NMT	Total	2W	4W	3W	Bus	NMT	Total
19	SL_19	54,749	23,886	12,360	251	840	92,086	82,895	62,614	39,624	5,518	1,604	1,92,255
20	SL_20	62,323	24,512	10,485	40	594	97,954	94,363	64,255	33,613	879	1,141	1,94,251
Total		**8,86,424**	**3,07,228**	**1,64,104**	**20,072**	**15,812**	**13,93,640**	**13,42,135**	**8,05,352**	**5,26,093**	**4,41,284**	**30,046**	**31,44,909**
East-West Screen Line													
21	SL_21	61,256	21,026	10,091	1,258	1,229	94,860	92,748	55,117	32,350	27,657	2,301	2,10,173
22	SL_22	42,578	17,072	7,863	225	1,369	69,107	64,467	44,752	25,208	4,947	2,618	1,41,991
23	SL_23	76,904	40,440	13,267	3,109	526	1,34,246	1,16,440	1,06,007	42,532	68,352	981	3,34,313
24	SL_24	18,428	2,330	3,281	105	740	24,884	27,902	6,108	10,518	2,308	1,410	48,246
25	SL_25	63,232	23,075	14,206	2,210	1,145	1,03,868	95,740	60,488	45,542	48,587	2,186	2,52,542
26	SL_26	64,258	23,612	14,627	2,254	854	1,05,605	97,293	61,895	46,892	49,554	1,625	2,57,259
27	SL_27	47,467	16,591	5,080	1,988	458	71,584	71,870	43,491	16,286	43,706	874	1,76,226
28	SL_28	45,751	6,007	5,733	161	1,378	59,030	69,272	15,746	18,379	3,540	2,647	1,09,583
29	SL_29	64,535	34,424	9,494	2,553	726	1,11,732	97,712	90,237	30,436	56,128	1,383	2,75,897
30	SL_31	31,735	12,837	3,432	91	752	48,847	48,050	33,650	11,002	2,001	1,431	96,134
Total		**5,16,144**	**1,97,414**	**87,074**	**13,954**	**9,177**	**8,23,763**	**7,81,494**	**5,17,491**	**2,79,146**	**3,06,779**	**17,454**	**19,02,365**

It can be observed that 31.44 lakh passengers are crossing the North-South Screen Line and 19.02 lakh passengers are crossing the East-West Screen Line. The highest passenger flow is observed at HK Firodia Bridge, followed by Solapur Road, and the lowest passenger flow is observed at Talegaon MIDC.

3.4.1.6. ANALYSIS OF VOLUME COUNTS AT MID-BLOCK LOCATIONS

Figure 3-15 represents the mid-block survey locations. The survey was carried out at thirteen (13)[32] locations for sixteen (16 hours) on a typical non-event working day through videographic surveys during November and December 2021. The assessment of the volume counts at the mid-block locations is discussed in the following section.

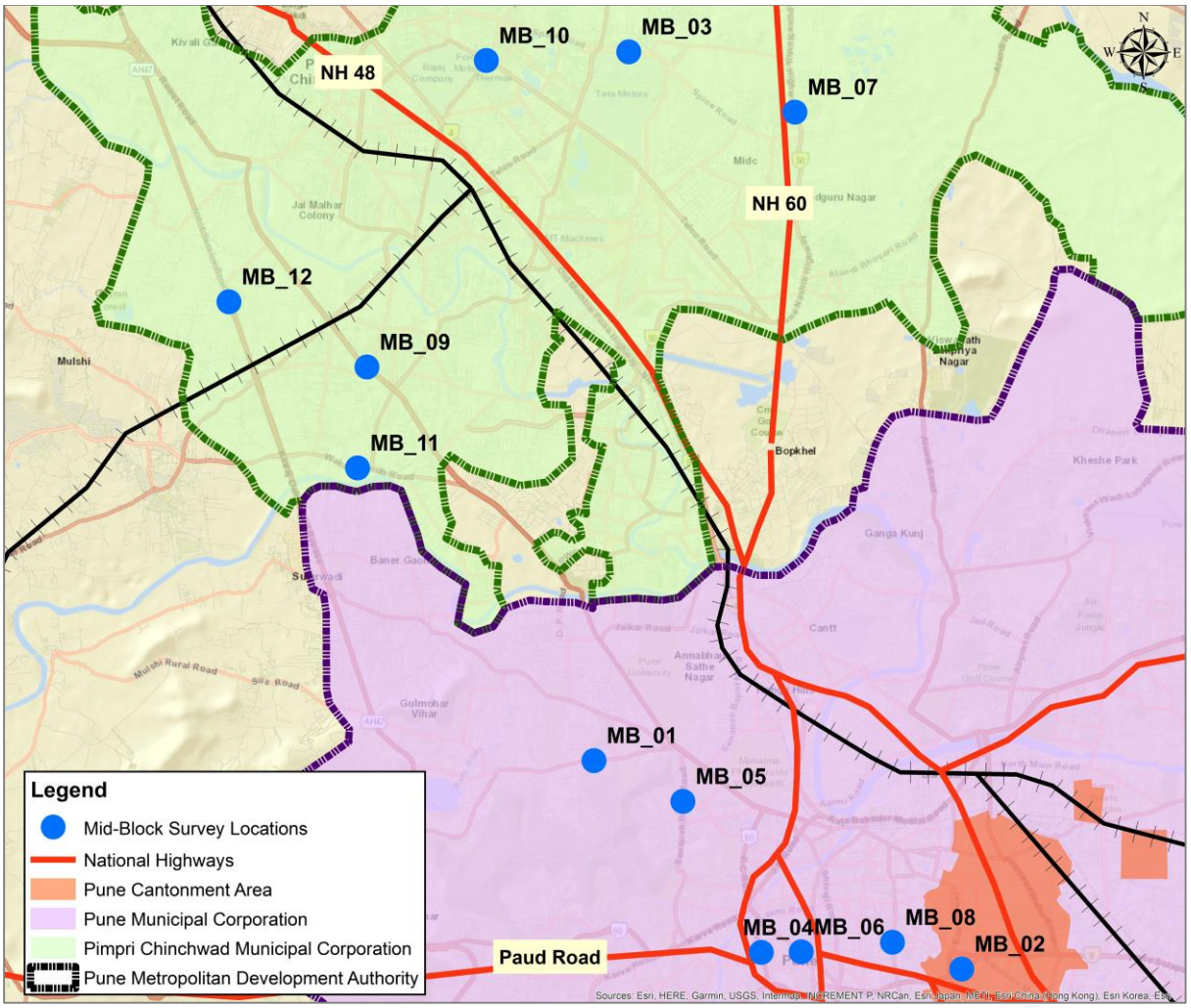


FIGURE 3-15: MID-BLOCK SURVEY LOCATIONS[33]

Traffic Intensity

The location-wise traffic details are presented in Table 3-26.

32 At MB-03_Spine Road, the Traffic Volume Counts have been conducted separately on the main carriageway and the service lane. Hence, this location has been considered separately for the Main Carriageway, which is MB-03 and Service Lanes, which is MB-03A.
33 UMTC Primary Surveys 2021

TABLE 3-26: LOCATION-WISE TRAFFIC AT MID-BLOCK LOCATIONS[34]

S.N.	Location ID	Location Name	Vehicles	PCUs
1	MB_01	Pashan Road	57553	55772
2	MB_02	Jagannath Shankarseth Road	50792	51461
3	MB_03	Spine Road	70374	71837
4	MB_03A	Spine Road Service Road	35135	35205
5	MB_04	LB Shastri Road	74531	74418
6	MB_05	Senapati Bapat Road	76857	72450
7	MB_06	Lokmanya Bal Gangadhar Tilak Road	62616	59847
8	MB_07	Nashik Road	68398	78416
9	MB_08	Timber Market Road	87967	98090
10	MB_09	Aundh Ravet BRTS Road	90042	86998
11	MB_10	Nigdi Bhosari Road	61019	64220
12	MB_11	Wakad Bhosari BRTS Road	95377	97452
13	MB_12	Mumbai Pune Bypass Road	108333	121621
		Total	**938994**	**967788**

Traffic on the Mumbai Pune Bypass Road, Wakad Bhosari BRTS Road, and Aundh Ravet BRTS Road is heavy as compared to the other locations.

Traffic Composition

The composition of traffic observed at the mid-block locations is presented in Table 3-27.

TABLE 3-27: MODE-WISE COMPOSITION OF TRAFFIC AT MID-BLOCK LOCATIONS[35]

S. N.	Location ID	In %age						
		2W	4W	3W	Bus	Goods	NMT	Others
1	MB_01	55.5%	30.2%	8.6%	0.9%	3.4%	1.3%	0.0%
2	MB_02	60.9%	20.2%	11.5%	2.9%	3.9%	0.5%	0.0%
3	MB_03	59.1%	24.1%	5.4%	1.4%	9.5%	0.5%	0.0%
4	MB_03A	60.1%	21.6%	5.7%	1.1%	8.9%	2.6%	0.0%
5	MB_04	63.2%	16.9%	14.0%	1.3%	2.7%	1.9%	0.0%
6	MB_05	63.1%	24.5%	9.3%	0.4%	1.9%	0.8%	0.0%
7	MB_06	70.4%	13.1%	11.7%	1.3%	2.0%	1.4%	0.0%
8	MB_07	48.5%	26.4%	11.9%	3.2%	9.9%	0.1%	0.0%
9	MB_08	62.3%	8.7%	18.1%	1.3%	8.3%	1.3%	0.0%
10	MB_09	62.6%	21.9%	8.0%	1.7%	5.1%	0.7%	0.0%
11	MB_10	59.1%	20.8%	8.4%	2.1%	8.5%	1.1%	0.1%
12	MB_11	50.9%	34.1%	6.3%	1.4%	6.8%	0.5%	0.0%
13	MB_12	36.0%	45.4%	3.3%	1.4%	13.5%	0.2%	0.0%

34 UMTC Primary Surveys 2021
35 UMTC Primary Surveys 2021

The traffic composition at the mid-block locations is presented in Figure 3-16.

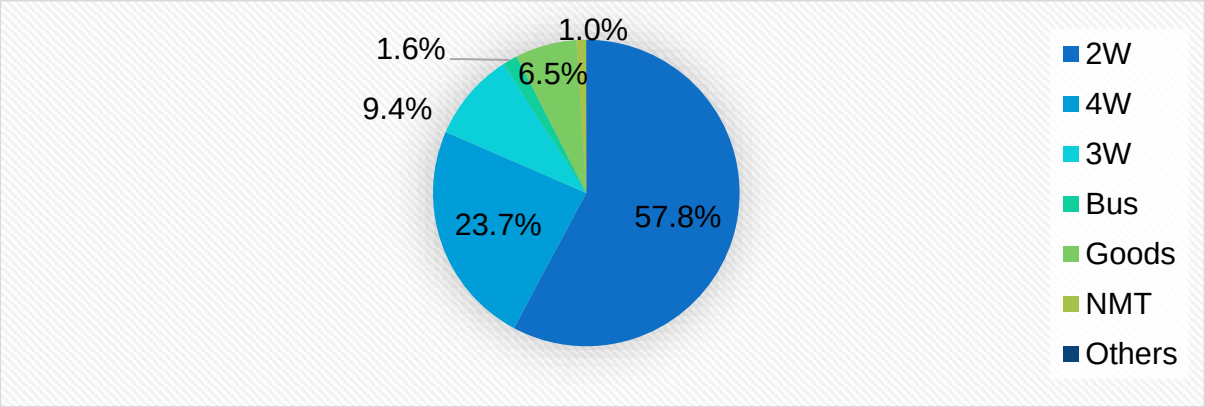


FIGURE 3-16: AVERAGE TRAFFIC COMPOSITION AT MID-BLOCK LOCATIONS[36]

The share of 2-wheelers is found to be very high on all the roads, followed by cars.

Peak Hour Characteristics

Table 3-28 represents the location-wise peak hour traffic at the mid-block locations.

TABLE 3-28: PEAK HOUR TRAFFIC AT MID-BLOCK LOCATIONS[37]

S. N.	Location ID	Peak Hour			
		Time	Vehicles	PCUs	%age
1	MB_01	0915-1015	5711	5336	10%
2	MB_02	0930-1030	4449	4307	9%
3	MB_03	1815-1915	6441	6312	9%
4	MB_03A	0815-0915	3370	3060	10%
5	MB_04	1815-1915	6489	6244	9%
6	MB_05	0930-1030	7061	6499	9%
7	MB_06	0945-1045	5419	5151	9%
8	MB_07	0900-1000	5773	6295	8%
9	MB_08	0945-1045	6834	7402	8%
10	MB_9	1815-1915	8148	7607	9%
11	MB_10	1815-1915	5229	5366	2%
12	MB_11	1815-1915	8330	8098	9%
13	MB_12	1800-1900	9137	9631	8%

The peak hour traffic share is observed to vary between 2% to 10% with an average of 8%. The peak hour share on Pashan Road is higher as it is an institutional area.

36 UMTC Primary Surveys 2021
37 UMTC Primary Surveys 2021

Passenger Flow at Mid-Block Locations

Total passenger vehicles and corresponding passenger flow across the mid-block locations are presented in Table 3-29.

TABLE 3-29: PASSENGER FLOW AT MID-BLOCK LOCATIONS[38]

S. N.	Location ID	Vehicles						Passengers					
		2W	4W	3W	Bus	NMT	Total	2W	4W	3W	Bus	NMT	Total
1	MB_01	31,960	17,380	4,975	495	789	55,599	48,391	45,559	15,949	10,883	1487	1,22,268
2	MB_02	30,931	10,265	5,820	1,492	280	48,788	46,833	26,908	18,658	32,802	526	1,25,727
3	MB_03	41,591	16,959	3,766	1,017	384	63,717	62,973	44,455	12,073	22,359	701	1,42,561
4	MB_03A	21,131	7,584	2,006	385	919	32,025	31,994	19,880	6,431	8,464	1744	68,514
5	MB_04	47,136	12,587	10,425	945	1405	72,498	71,369	32,995	33,421	20,776	2673	1,61,234
6	MB_05	48,459	18,861	7,125	342	643	75,430	73,372	49,441	22,842	7,519	1227	1,54,401
7	MB_06	44,076	8,200	7,325	838	909	61,348	66,735	21,495	23,483	18,423	1740	1,31,877
8	MB_07	33,162	18,032	8,147	2,203	107	61,651	50,211	47,268	26,118	48,433	173	1,72,203
9	MB_08	54,829	7,694	15,882	1,174	1123	80,702	83,017	20,169	50,915	25,810	2151	1,82,062
10	MB_09	56,388	19,704	7,160	1,530	648	85,430	85,377	51,651	22,954	33,637	1162	1,94,781
11	MB_10	36,051	12,694	5,113	1,268	698	55,824	54,585	33,275	16,392	27,877	1277	1,33,406
12	MB_11	48,575	32,545	5,987	1,328	462	88,897	73,547	85,312	19,193	29,196	847	2,08,096
13	MB_12	39,003	49,218	3,625	1,554	264	93,664	59,054	1,29,018	11,621	34,165	459	2,34,317
Total		**5,33,292**	**2,31,723**	**87,356**	**14,571**	**8,631**	**8,75,573**	**8,07,457**	**6,07,427**	**2,80,050**	**3,20,344**	**16,168**	**20,31,447**

38 UMTC Primary Surveys 2021

3.4.1.7. ANALYSIS OF TURNING MOVEMENT COUNTS AT INTERSECTIONS

Figure 3-17 represents the Turning Movement Count survey locations at the intersection. The survey was carried out at twenty-seven (27) locations for sixteen (16) hours on a typical non-event working day through videographic surveys during November and December 2021. The assessment of the volume counts at the intersection locations is discussed in the following section.

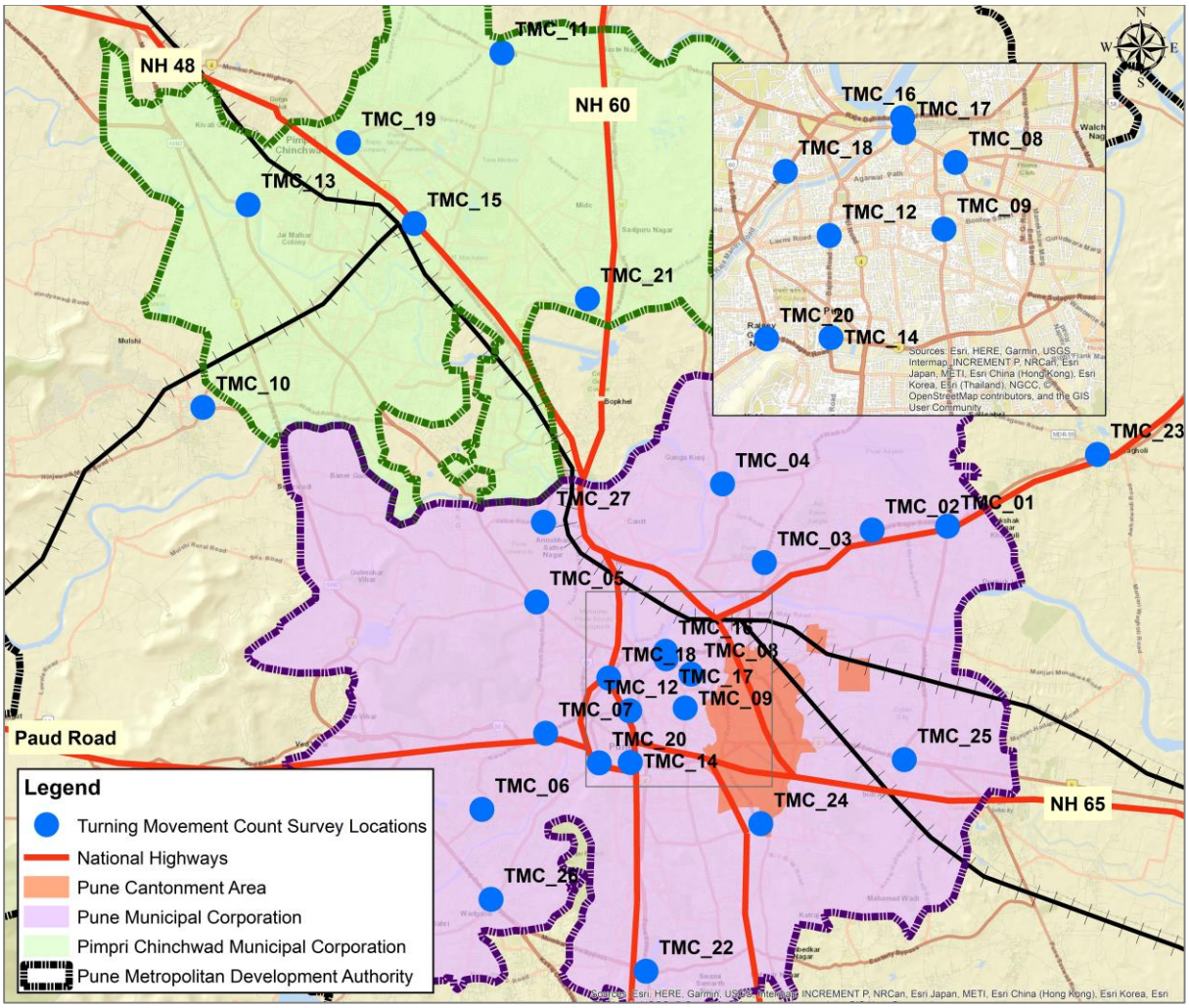


FIGURE 3-17: TURNING MOVEMENT COUNT LOCATIONS

Traffic Intensity

Total traffic observed at all the intersections is presented in Table 3-30.

TABLE 3-30: LOCATION-WISE TRAFFIC AT INTERSECTIONS[39]

S. N.	Location ID	Location Name	Type of Junction	Vehicles	PCUs
1	TMC_01	Kharadi Bypass Junction	3 Arm	153441	162864

39 UMTC Primary Surveys 2021

S. N.	Location ID	Location Name	Type of Junction	Vehicles	PCUs
2	TMC_02	Viman Nagar Corner Chowk	3 Arm	166820	165940
3	TMC_03	Netaji Chowk Junction	4 Arm	116781	119201
4	TMC_04	Vishrantwadi	4 Arm	133491	129181
5	TMC_05	Pune University	5 Arm	227273	222639
6	TMC_06	Karve Chowk	5 Arm	67353	64028
7	TMC_07	Nalstop Chowk	3 Arm	78513	82024
8	TMC_08	Collectorate Junction	4 Arm	124707	131079
9	TMC_09	Sant Kabir Chowk	4 Arm	122985	133270
10	TMC_10	Shivaji Chowk_Hinjewadi	4 Arm	69705	67436
11	TMC_11	Chikali	3 Arm	86298	92810
12	TMC_12	Nagarkar Tamil Chowk	4 Arm	81387	85190
13	TMC_13	Sant Tukaram Bridge	3 Arm	110316	102667
14	TMC_14	Saras Bagh Chowk	3 Arm	153771	151290
15	TMC_15	Chinchwad Station Chowk	4 Arm	131351	129967
16	TMC_16	RTO Junction	4 Arm	143012	147741
17	TMC_17	Juna Bazaar Chowk	4 Arm	151151	159403
18	TMC_18	Jhansi Lakshmibhai Chowk	4 Arm	138312	136490
19	TMC_19	Nigdi Flyover	4 Arm	94079	98291
20	TMC_20	Dhandekar Chowk	3 Arm	146511	150417
21	TMC_21	Nigdi Bhosari Road Junction	4 Arm	72824	72741
22	TMC_22	Katraj Chowk	4 Arm	167537	181216
23	TMC_23	Wagholi Circle	3 Arm	118984	127541
24	TMC_24	Lulla Nagar Chowk	4 Arm	84287	87004
25	TMC_25	Triangle Bridge	3 Arm	143909	153794
26	TMC_26	Baji Pasalkar Bridge	4 Arm	166863	160705
27	TMC_27	Ambedkar Chowk	3 Arm	90995	88712
		Total		**3342656**	**3403639**

Among all the intersections, the highest traffic volume, of about 2,27,273 vehicles, was observed at the Pune University intersection. The least traffic was observed at Karve Chowk.

Traffic Composition

The composition of traffic observed at the intersections is given in Table 3-31

TABLE 3-31: MODE-WISE COMPOSITION OF TRAFFIC AT INTERSECTIONS[40]

S. N.	Location ID	Total Vehicles					
		2W	4W	3W	Bus	Goods	NMT
1	TMC_01	79384	44837	13004	3453	12286	477

40 UMTC Primary Surveys 2021

S. N.	Location ID	Total Vehicles					
		2W	4W	3W	Bus	Goods	NMT
2	TMC_02	95395	43060	15393	3153	8801	1018
3	TMC_03	66962	27635	14305	1634	5380	865
4	TMC_04	85444	25860	11559	2237	7098	1293
5	TMC_05	129567	64747	20528	3235	8050	1146
6	TMC_06	49965	5689	7538	1155	2040	966
7	TMC_07	43926	17505	11359	2371	2263	1089
8	TMC_08	73086	24079	18277	3805	4593	867
9	TMC_09	80313	9625	23257	1245	6767	1778
10	TMC_10	41339	17966	4822	1520	3554	504
11	TMC_11	51747	15285	7418	955	10305	588
12	TMC_12	52313	8616	15709	1178	1997	1574
13	TMC_13	67365	30059	6150	730	5042	970
14	TMC_14	104132	21139	19679	2268	5008	1545
15	TMC_15	84244	24268	14212	2549	5167	911
16	TMC_16	79917	34685	21373	1122	5215	700
17	TMC_17	86034	31483	23961	2738	6040	895
18	TMC_18	89310	24996	17414	2356	2755	1481
19	TMC_19	56627	17218	12686	4255	2556	737
20	TMC_20	89567	24080	22629	1632	6582	2021
21	TMC_21	49603	8356	8771	2333	2874	887
22	TMC_22	100238	30435	17542	3961	15067	294
23	TMC_23	61814	33330	8071	3053	12510	206
24	TMC_24	51485	16699	9655	665	5203	580
25	TMC_25	87421	25187	18181	3135	9201	784
26	TMC_26	112333	28152	17071	1289	7360	658
27	TMC_27	53926	22411	10200	398	2721	1339

The maximum private traffic (i.e., 2-wheelers and 4-wheelers) is observed at the Pune University intersection (TMC_05), with 1,94,314 vehicles (1,29,567 2-wheelers and 64,747 4-wheelers).

The maximum bus traffic is observed at the Nigdi Flyover intersection, with 4,255 buses, and the maximum goods traffic is observed at the Katraj Chowk intersection, with 15,067 goods vehicles. The percentage of mode-wise composition of traffic observed at the intersections is given in Table 3-32.

TABLE 3-32: PERCENTAGE OF MODE-WISE COMPOSITION OF TRAFFIC AT INTERSECTIONS[41]

S. N.	Location ID	In %age Vehicles					
		2W	4W	3W	Bus	Goods	NMT
1	TMC_01	51.7%	29.2%	8.5%	2.3%	8.0%	0.3%
2	TMC_02	57.2%	25.8%	9.2%	1.9%	5.3%	0.6%
3	TMC_03	57.3%	23.7%	12.2%	1.4%	4.6%	0.7%
4	TMC_04	64.0%	19.4%	8.7%	1.7%	5.3%	1.0%
5	TMC_05	57.0%	28.5%	9.0%	1.4%	3.5%	0.5%
6	TMC_06	74.2%	8.4%	11.2%	1.7%	3.0%	1.4%
7	TMC_07	55.9%	22.3%	14.5%	3.0%	2.9%	1.4%
8	TMC_08	58.6%	19.3%	14.7%	3.1%	3.7%	0.7%
9	TMC_09	65.3%	7.8%	18.9%	1.0%	5.5%	1.4%
10	TMC_10	59.3%	25.8%	6.9%	2.2%	5.1%	0.7%
11	TMC_11	60.0%	17.7%	8.6%	1.1%	11.9%	0.7%
12	TMC_12	64.3%	10.6%	19.3%	1.4%	2.5%	1.9%
13	TMC_13	61.1%	27.2%	5.6%	0.7%	4.6%	0.9%
14	TMC_14	67.7%	13.7%	12.8%	1.5%	3.3%	1.0%
15	TMC_15	64.1%	18.5%	10.8%	1.9%	3.9%	0.7%
16	TMC_16	55.9%	24.3%	14.9%	0.8%	3.6%	0.5%
17	TMC_17	56.9%	20.8%	15.9%	1.8%	4.0%	0.6%
18	TMC_18	64.6%	18.1%	12.6%	1.7%	2.0%	1.1%
19	TMC_19	60.2%	18.3%	13.5%	4.5%	2.7%	0.8%
20	TMC_20	61.1%	16.4%	15.4%	1.1%	4.5%	1.4%
21	TMC_21	68.1%	11.5%	12.0%	3.2%	3.9%	1.2%
22	TMC_22	59.8%	18.2%	10.5%	2.4%	9.0%	0.2%
23	TMC_23	52.0%	28.0%	6.8%	2.6%	10.5%	0.2%
24	TMC_24	61.1%	19.8%	11.5%	0.8%	6.2%	0.7%
25	TMC_25	60.7%	17.5%	12.6%	2.2%	6.4%	0.5%
26	TMC_26	67.3%	16.9%	10.2%	0.8%	4.4%	0.4%
27	TMC_27	59.3%	24.6%	11.2%	0.4%	3.0%	1.5%

41 UMTC Primary Surveys 2021

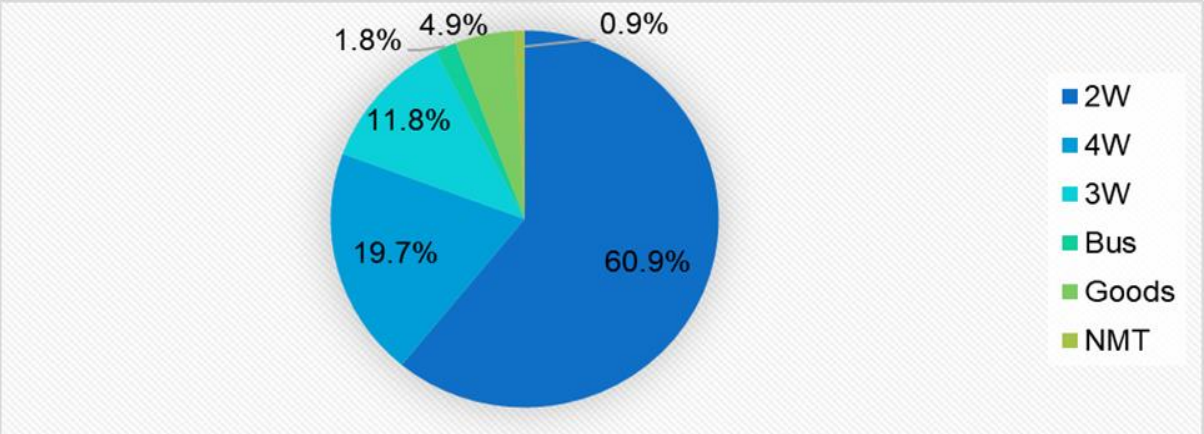


FIGURE 3-18: AVERAGE TRAFFIC COMPOSITION AT INTERSECTIONS[42]

On an average, 2-wheelers are observed to be predominant (60.9%), followed by cars (19.7%), among private motorized vehicles. Passenger vehicles contribute to around 94.2% of the total traffic crossing the intersections, whereas goods vehicles constitute only around 4.9% of the total traffic.

It is observed that the share of public transport is around 1.8% of the total traffic, whereas the share of Intermediate Public Transport (i.e., 3-wheelers/auto-rickshaws) constitutes around 11.8%.

Peak Hour Characteristics

The location-wise peak hour traffic at the intersections is presented in Table 3-33.

TABLE 3-33: PEAK HOUR TRAFFIC AT INTERSECTIONS[43]

S. N.	Location ID	Peak Hour			
		Time	Vehicles	PCUs	%age
1	TMC_01	9:00-10:00	13146	12999	8.6%
2	TMC_02	9:15-10:15	14687	14218	8.8%
3	TMC_03	9:30-10:30	9969	9785	8.5%
4	TMC_04	18:45-19:45	11049	10349	8.3%
5	TMC_05	9:30-10:30	20862	19662	9.2%
6	TMC_06	18:45-19:45	5860	5324	8.7%
7	TMC_07	10:30-11:30	5989	6394	7.6%
8	TMC_08	9:45-10:45	10551	10828	8.5%
9	TMC_09	12:00-13:00	9490	10492	7.7%
10	TMC_10	9:00-10:00	6053	5684	8.7%
11	TMC_11	18:00-19:00	7718	7793	8.9%
12	TMC_12	12:45-13:45	6456	6952	7.9%

42 UMTC Primary Surveys 2021
43 UMTC Primary Surveys 2021

S. N.	Location ID	Peak Hour			
		Time	Vehicles	PCUs	%age
13	TMC_13	18:15-19:15	9132	8408	8.3%
14	TMC_14	10:00-11:00	14692	13891	9.6%
15	TMC_15	17:45-18:45	10617	10250	8.1%
16	TMC_16	10:00-11:00	11856	12026	8.3%
17	TMC_17	9:30-10:30	12971	13058	8.6%
18	TMC_18	18:00-19:00	11972	11400	8.7%
19	TMC_19	10:00-11:00	7229	7497	7.7%
20	TMC_20	18:00-19:00	12535	12581	8.6%
21	TMC_21	11:30-12:30	5821	5668	8.0%
22	TMC_22	18:15-19:15	13288	13699	7.9%
23	TMC_23	10:00-11:00	9772	10342	8.2%
24	TMC_24	18:45-19:45	7140	6953	8.5%
25	TMC_25	19:00-20:00	12929	12759	9.0%
26	TMC_26	9:15-10:15	15098	13958	9.0%
27	TMC_27	9:15-10:15	7831	7505	8.6%

It is observed that the percentage of traffic during the peak hour ranges between 7.7% and 9.6% with an average of 8.5%.

3.4.1.8. ANALYSIS OF PEDESTRIAN SURVEY

Pedestrian volume counts were carried out at twenty-one (21) major junctions of the twenty-seven (27) intersections identified for the TMC surveys. The survey was carried out continuously for a period for sixteen (16) hours.

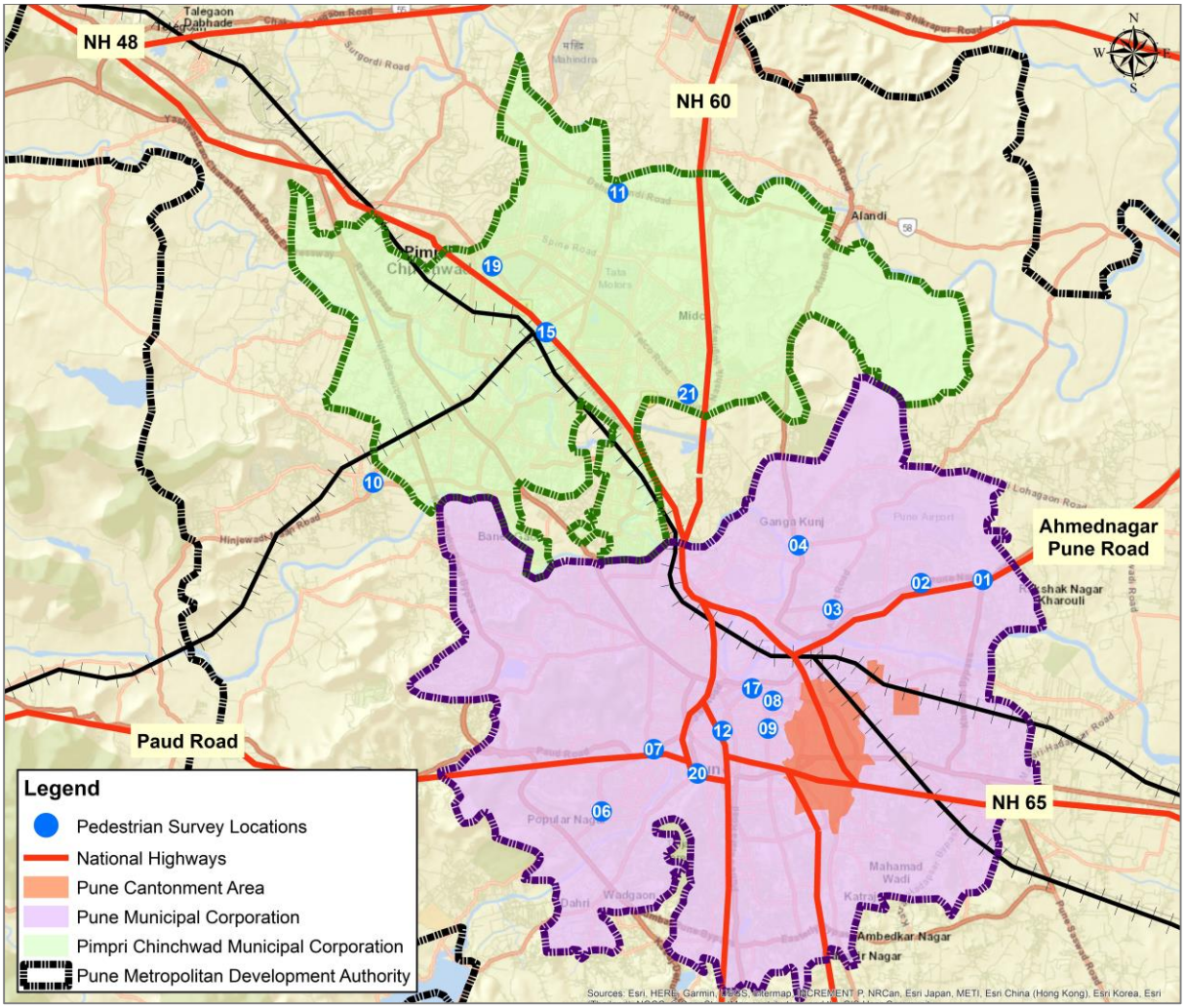


FIGURE 3-19: PEDESTRIAN SURVEY LOCATIONS[44]

The daily and peak hour pedestrian flows at various surveys locations are presented in the Table 3-34.

TABLE 3-34: DAILY AND PEAK HOUR PEDESTRIAN TRAFFIC AT SURVEY LOCATIONS

S. N.	Location ID	Location Name	Total Daily Pedestrian (16 Hours)	Peak Hour Pedestrian
1	TMC_01	Kharadi Bypass Junction	4659	399
2	TMC_02	Viman Nagar Corner Chowk	3541	312
3	TMC_03	Netaji Chowk Junction	2525	216
4	TMC_04	Vishrantwadi	7414	614
6	TMC_06	Karve Chowk	3499	304
7	TMC_07	Nalstop Chowk	4210	321

44 UMTC Primary Surveys 2021

S. N.	Location ID	Location Name	Total Daily Pedestrian (16 Hours)	Peak Hour Pedestrian
8	TMC_08	Collectorate Junction	10987	930
9	TMC_09	Sant Kabir Chowk	3386	261
10	TMC_10	Shivaji Chowk_Hinjewadi	8954	778
11	TMC_11	Chikali	7225	646
12	TMC_12	Nagarkar Tamil Chowk	9038	717
15	TMC_15	Chinchwad Station Chowk	8644	699
17	TMC_17	Juna Bazaar Chowk	5049	433
19	TMC_19	Nigdi Flyover	9994	768
20	TMC_20	Dhandekar Chowk	3991	341
21	TMC_21	Nigdi Bhosari Road Junction	3935	315

3.4.1.9. BUS PASSENGER BOARDING AND ALIGHTING SURVEY

The bus stop boarding and alighting count survey was conducted for sixteen (16) hours at bus stops, covering the morning and evening peak periods. Figure 3-20 represents the bus stop boarding and alighting survey locations.

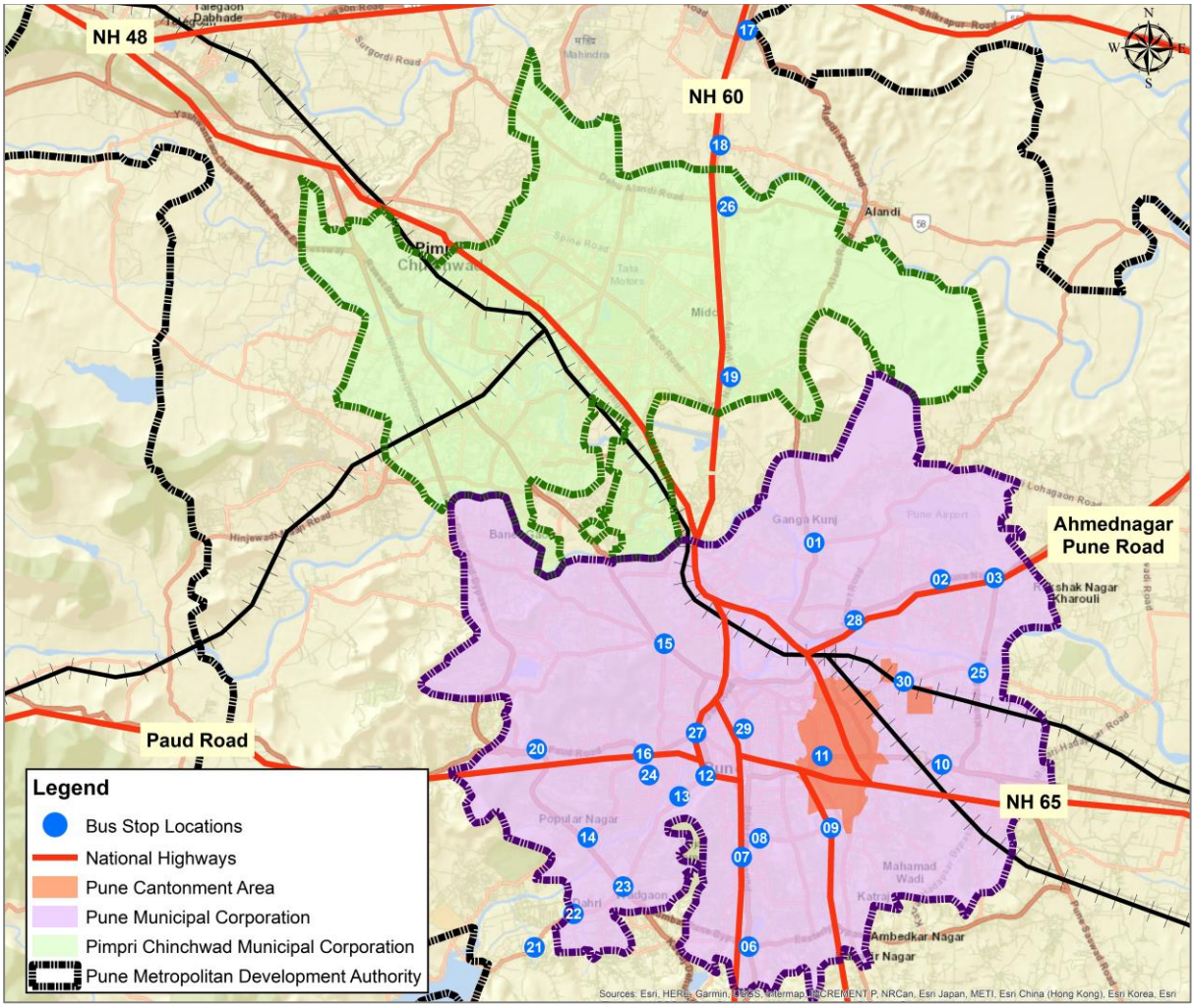


FIGURE 3-20: BUS STOP BOARDING AND ALIGHTING SURVEY LOCATIONS[45]

Table 3-35 below summarizes the daily total boarding and alighting counts observed at the bus stop locations.

TABLE 3-35: BUS STOP BOARDING AND ALIGHTING COUNTS

Code	Bus Stop Location Name	Boarding	Alighting	Total
BS_01	Kasturba Gandhi General Hospital	137	44	181
BS_02	Viman Nagar Corner	124	87	211
BS_03	Kharadi Bypass	941	480	1421
BS_04	Sri Satyam Society	663	586	1249
BS_05	Wagholi	33	19	52
BS_06	Katraj	2815	139	2954
BS_07	Padmavati Private Bus Stop	610	393	1003
BS_08	Vasantbaug Chowk	113	73	186
BS_09	Mount Caramel School	343	243	586
BS_10	Vaidwadi	263	271	534
BS_11	MG Road	121	138	259

45 UMTC Primary Surveys 2021

Code	Bus Stop Location Name	Boarding	Alighting	Total
BS_12	Ramakrishna Math	282	233	515
BS_13	PL Deshpande Udyan	41	12	53
BS_14	Warje	204	117	321
BS_15	Pune Vidyapeeth	51	49	100
BS_16	Paud Fata	18	9	27
BS_17	Alandi Phata	6	35	41
BS_18	Chimbali Phata	49	18	67
BS_19	Bhosari PMT Chowk	795	199	994
BS_20	Shinde Farm	1301	1120	2421
BS_21	Malwadi Kiratwadi	73	39	112
BS_22	Nanded City	245	76	321
BS_23	Vadgaon Phata	467	286	753
BS_24	Prasanna Bungalow	2	1	3
BS_25	Mundhwa Gaon	165	119	284
BS_26	Moshi Gaon	261	201	462
BS_27	Deccan Corner	580	177	757
BS_28	Wadia Bungalow	52	99	151
BS_29	Mandai Stand	239	120	359
BS_30	Army College	37	28	65
Grand Total		**11031**	**5411**	**16442**

The hourly variation of the bus passenger movement at the bus stops is presented in Figure 3-21 below. It can be observed that the maximum flow of bus passengers during the morning peak, which is during 11:15 to 12:15 is 11.8% and the evening peak, which is 16:00 to 17:00 is 18.5%. These are important inputs regarding suggestions for a feeder system to enhance last-mile connectivity for the Metro.

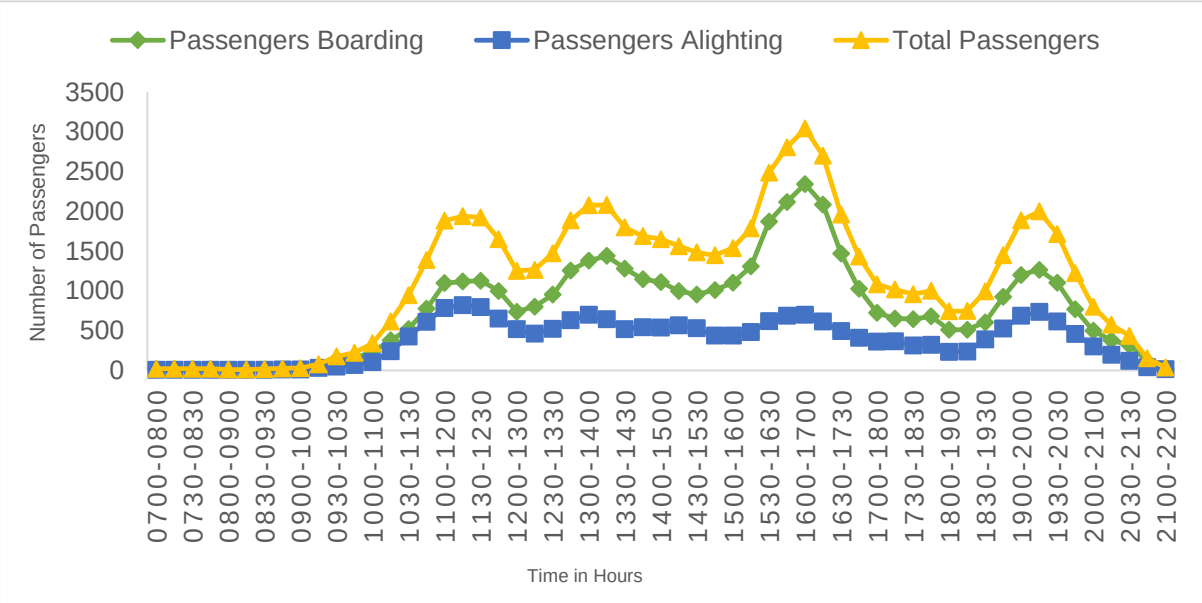


FIGURE 3-21: HOURLY VARIATION OF BUS STOP BOARDING AND ALIGHTING[46]

46 UMTC Primary Surveys 2021

Along with bus stop boarding and alighting, bus occupancy surveys were carried out. Figure 3-22 below represents the bus occupancy observed at the surveyed bus stops. The average bus occupancy (sitting + standing) observed at these locations is 31.21.

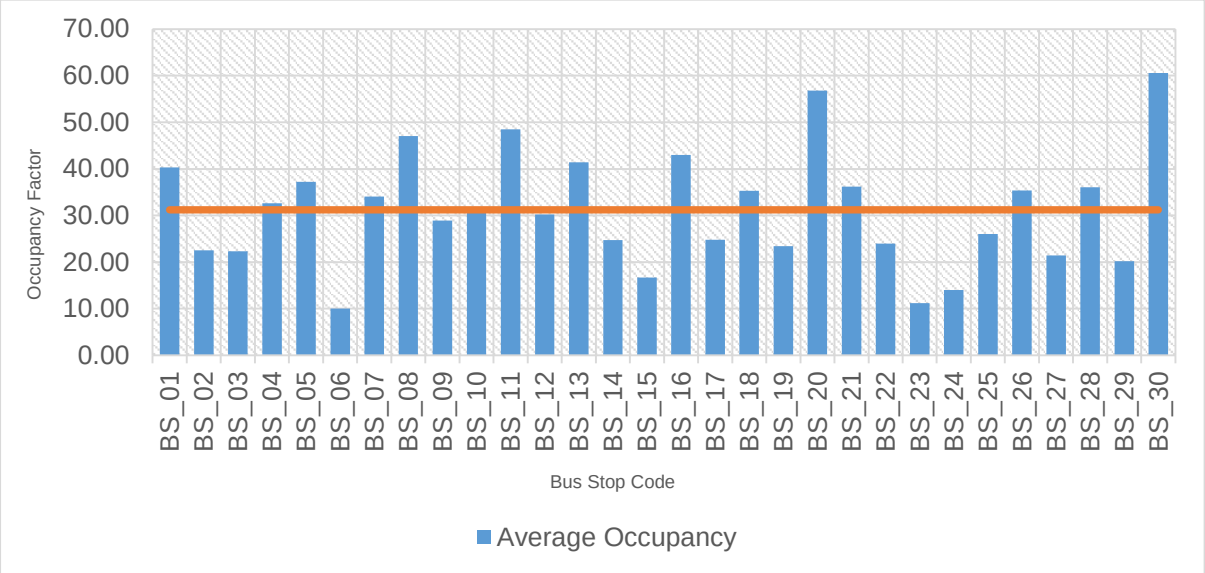


FIGURE 3-22: AVERAGE OCCUPANCY AT SURVEYED BUS STOP LOCATIONS[47]

From Figure 3-23, it can be observed that the maximum bus occupancy is during the morning period between 07:00 to 08:00 , wherein the occupancy observed at 50.0, which is higher than the observed average bus occupancy.

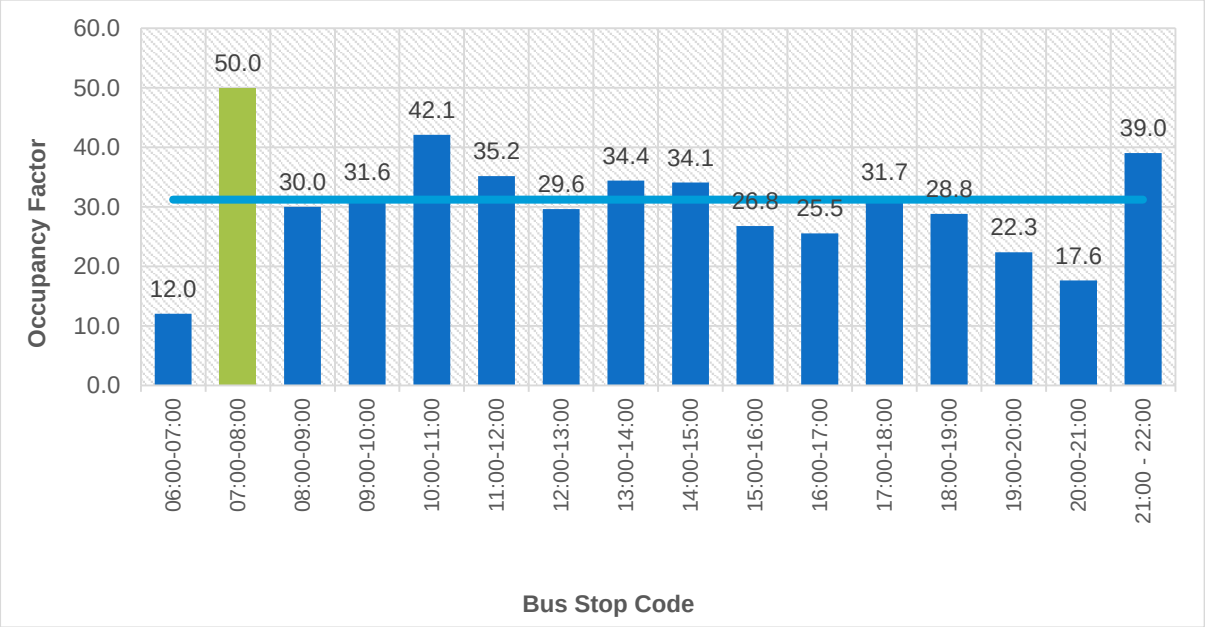


FIGURE 3-23: HOURLY VARIATION OF AVERAGE BUS OCCUPANCY AT BUS STOP LOCATIONS[48]

47 UMTC Primary Surveys 2021
48 UMTC Primary Surveys 2021

3.4.1.10. ANALYSIS OF BUS PASSENGER O-D SURVEY

Bus stop O-D surveys were undertaken at the same locations where the bus stop boarding and alighting surveys were undertaken (refer to Figure 3-20) for a period of sixteen (16) hours on a non-event working day.

Trip Purpose

Figure 3-24 represents the distribution of trips made by boarding passengers and alighting passengers by virtue of their purpose.

It can be observed from the figure below that 47.2% of the boarding bus passenger trips are work-related, followed by home-related return trips which account for 25.0%. Similarly, in the case of the alighting bus passenger trips, 42% of the trips are work-related, followed by home-related return trips which account 40.9%.

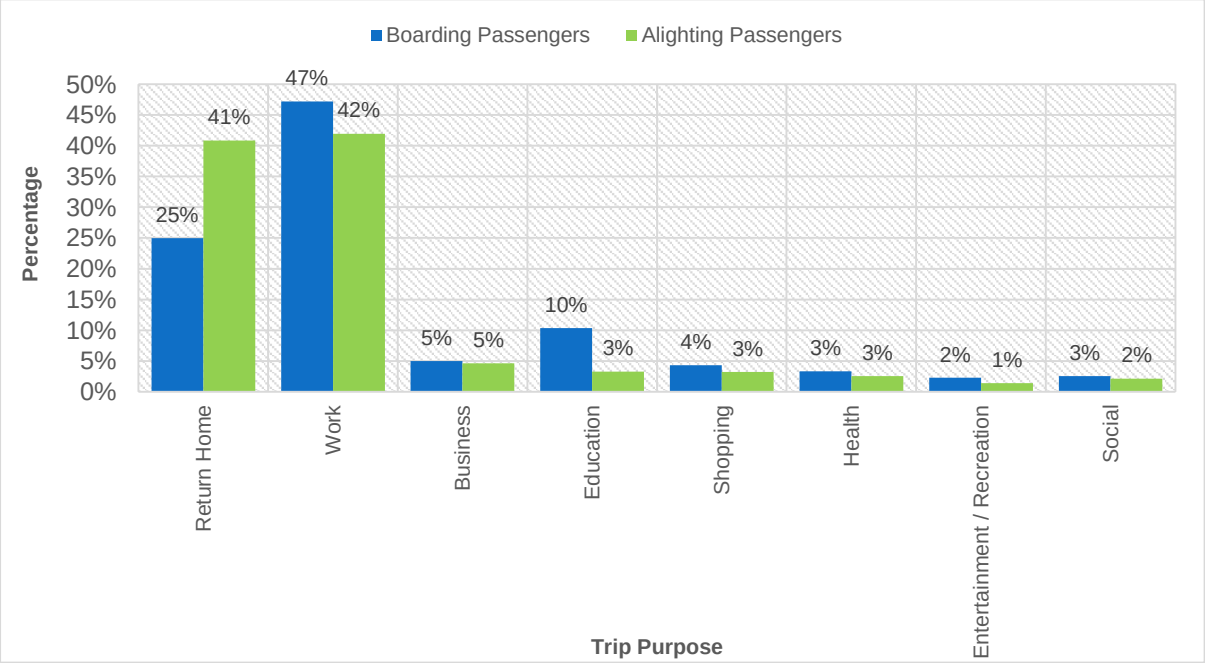


FIGURE 3-24: TRIP PURPOSE OF BOARDING AND ALIGHTING PASSENGERS[49]

Access and Egress Modes

The share of access mode from the origin to boarding point and dispersal mode from alighting point to the destination of the boarding bus passengers, as well as the alighting bus passengers are represented in Table 3-36.

It could be observed from the table that the majority of bus passengers walk from the origin point or to the destination point.

49 UMTC Primary Surveys 2021

TABLE 3-36: BUS PASSENGER ACCESS AND DISPERSAL MODES OF BOARDING AND ALIGHTING BUS PASSENGERS

Vehicle Type	Boarding Passengers		Alighting Passengers	
	Access Mode	Dispersal Mode	Access Mode	Dispersal Mode
2-Wheeler	4.2%	2.0%	5.5%	3.8%
4-Wheeler	0.5%	0.2%	0.7%	0.1%
3-Wheeler	11.5%	4.7%	12.7%	11.8%
Walk	74.2%	78.2%	64.0%	68.6%
Cycle	0.8%	0.8%	0.9%	0.4%
Bus	8.9%	13.9%	16.3%	15.2%
Others	0.0%	0.1%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%

Proximity to the Bus Stops

Proximity to the bus stops shows how close the stops are to either the origin or the destination. To analyse the proximity of bus stops, walking distance from the origin to the bus stop and from the bus stop to the destination has been considered. The access trip distance from the origin to the boarding point and egress trip distance from the alighting point to the destination point for the boarding passengers and alighting passengers are represented in Figure 3-25.

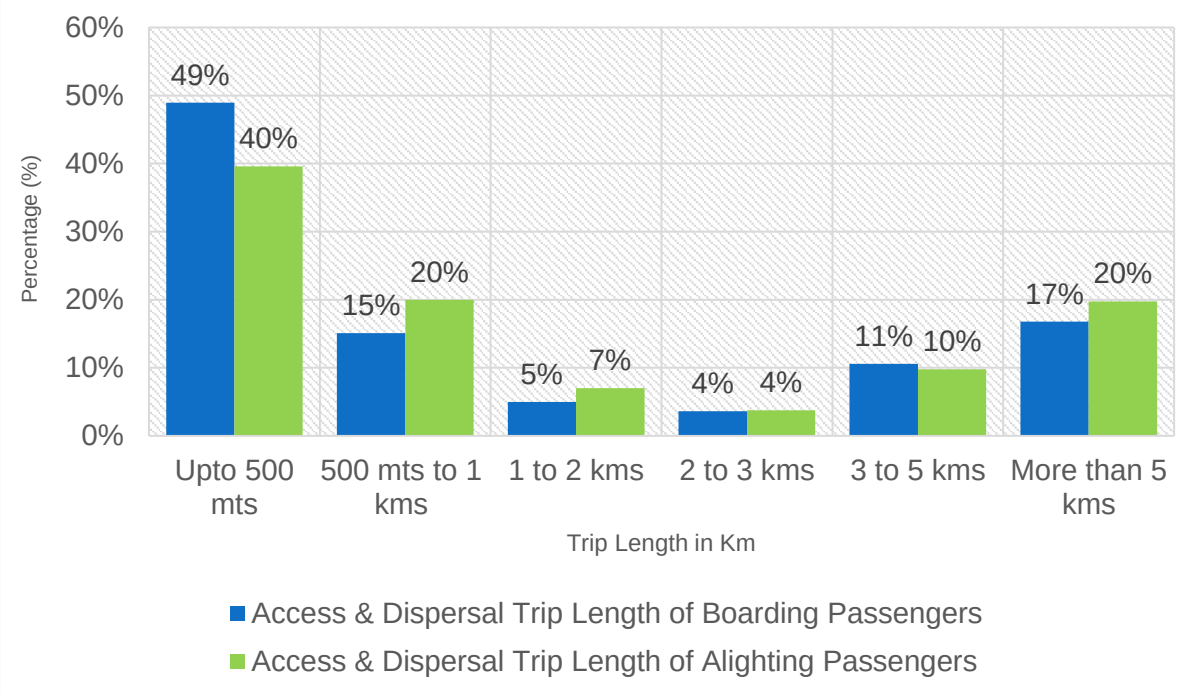


FIGURE 3-25: ACCESS AND DISPERSAL TRIP LENGTH OF THE BOARDING PASSENGERS AND ALIGHTING PASSENGERS[50]

50 UMTC Primary Surveys 2021

- It can be observed that 49% of the boarding passengers either access or disperse from the bus stops within 500 m, whereas 40% of the alighting passengers either access or disperse from the bus stops within 500 m.
- The average access or dispersal trip length of a boarding passenger is 3.22 km and that of an alighting passenger is 3.61 km, respectively.

Access and Egress Travel Time and Travel Cost

- **Access and Egress Travel Time:** 47% of the boarding passengers and 41% of the alighting passengers access bus stop from the origin point and disperse from the bus stop to the destination point in 7.5 minutes to 15 minutes. The average access and dispersal time to and from the bus station taken by the boarding passengers and alighting passengers is 13.29 minutes and 13.00 minutes, respectively.
- **Access and Egress Travel Cost:** 69% of the boarding passengers and 58% of the alighting passengers access or disperse from the bus stop for cost under Rs 5. The average cost incurred to access and disperse from the bus stop by the boarding and alighting passengers is Rs 5 and Rs 7, respectively.

Waiting Time at the Bus Stop

72% of the Boarding passengers and 69% of the alighting passengers wait at the bus stop for less than 5 minutes. The average waiting time of boarding and alighting passengers at the bus stops is 5.42 minutes and 5.73 minutes, respectively.

Main Haul Trip Length, Trip Time and Trip Fare

- **Trip Length:** 57% of the main trip length of the boarding passengers and 36% of the main trip length of the alighting passengers is within 5 km. The average main trip length of boarding passengers and alighting passengers is 6.58 km and 10.94 km, respectively.
- **Trip Time:** 40% of the main trip time of the boarding passengers and 38% of the main trip time of the alighting passengers is in the range of 20 to 40 minutes. The average main trip time of boarding and alighting passengers is 20 minutes and 25 minutes, respectively.
- **Trip Cost:** 53% of the main trip cost of the boarding passengers and 54% of the main trip cost of the alighting passengers is in the range of Rs 7 to Rs 15. The average main trip cost of the boarding passengers and the alighting passengers is Rs 16.35 and Rs 17.03, respectively. These inputs are useful for suggestions on the fare structure (base level and slabs) of the proposed MRTS.

Willingness to Use and Pay Analysis

Willingness to Use MRTS:

- **Yes:** 81% of the boarding passengers and 75% of the alighting passengers showed a willingness to use a Mass Rapid Transit System.

- **Maybe:** 4% of the boarding passengers and 3% of the alighting passengers mentioned that they might be willing to use the MRTS.
- **No:** 15% of the boarding passengers and 22% of the alighting passengers showed no willingness to use MRTS.

When the bus passengers were asked why they were not willing to use MRTS as their primary mode of transport, the majority of the boarding and alighting passengers indicated they thought the Metro is costly and preferred bus services over the Metro or any other mass transit system.

Willingness to Pay to Use MRTS: It can be observed from the Figure 3-26, that 23% of the boarding passengers and 28% of the alighting passengers intend to pay the same fare for MRTS that they are paying for the bus. It can also be observed that 53% of the boarding passengers and 45% of the alighting passengers are interested in paying between Rs 10 to Rs 40. The average fare that the boarding passengers intend to pay is Rs 20.89 for a trip length of 7 km and the average fare that the alighting passengers intend to pay is Rs 29.40 for a trip length of 11 km.

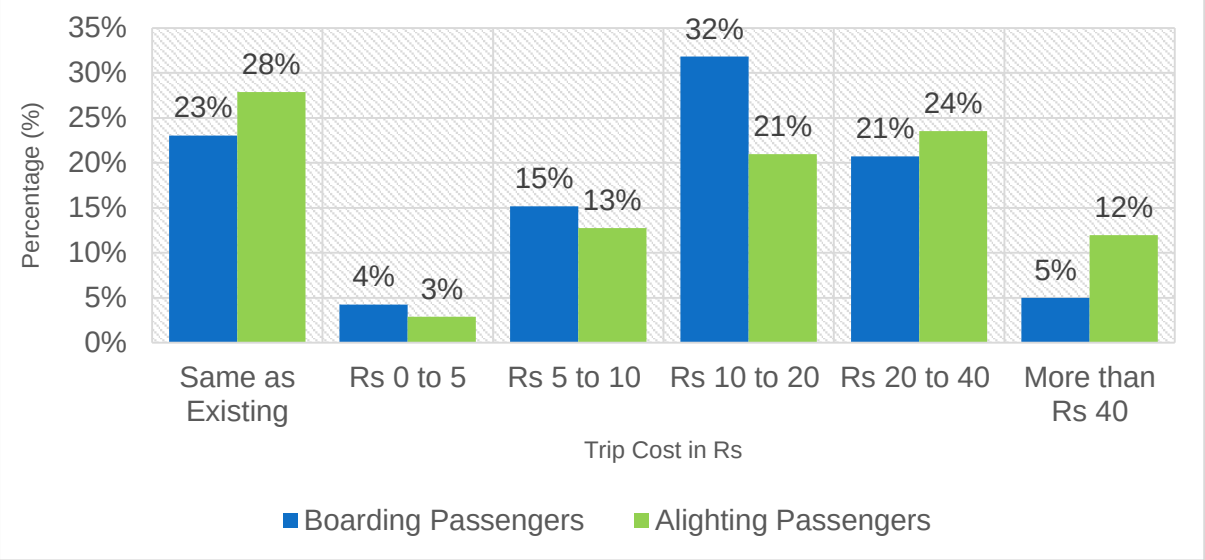


FIGURE 3-26: WILLINGNESS TO PAY FOR MRTS BY BOARDING AND ALIGHTING PASSENGERS[51]

3.4.1.11. ANALYSIS OF TERMINAL INTERVIEW SURVEY

Passenger surveys were carried out at thirteen (13) terminals in the study area (6 rail terminals, 5 inter-city bus and 2 intra-city bus terminals) to assess the trip characteristics of passengers. At the terminals, two (02) types of surveys were conducted, i.e., entry and exit counts and passenger OD/interview surveys. The surveys were undertaken for sixteen (16) hours on a non-event working day. The entry and exit counts were conducted through videographic surveys and passenger OD/interview surveys were conducted through interviews.

51 UMTC Primary Surveys 2021

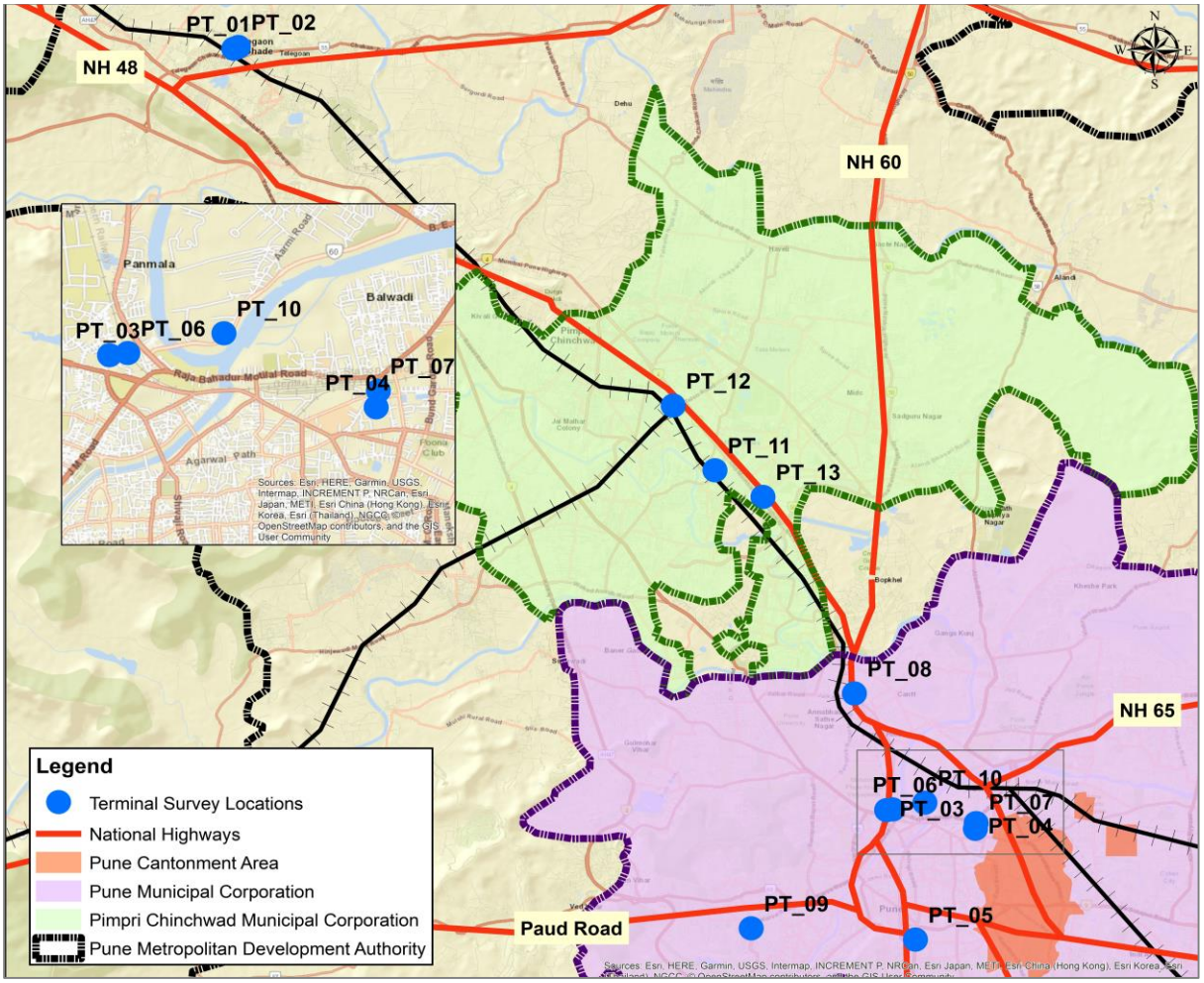


FIGURE 3-27: TERMINAL SURVEY LOCATIONS IN THE STUDY AREA[52]

Entry and Exit Counts at the Terminals

1. Railway Terminals

Table 3-37 represents the number of passengers entering and exiting the major rail terminals over a duration of sixteen (16) hours on a normal working day.

TABLE 3-37: RAILWAY TERMINAL ENTRY AND EXIT COUNTS[53]

Location ID	Location Name	Passengers		
		In	Out	Total
PT_02	Talegaon Railway Station	4,496	4,543	9,039
PT_06	Shivaji Nagar RS	4,824	5,872	10,696
PT_07	Pune RS	19,378	19,998	39,376
PT_08	Khadki RS	1,753	1,850	3,603
PT_11	Pimpri RS	3,232	3,361	6,593
PT_12	Chinchwad RS	6,380	6,605	12,985

52 UMTC Primary Surveys 2021
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It can be observed that the maximum passenger movement is observed at the Pune Railway Station, with 39,376 passengers.

2. Bus Terminals

Table 3-38 represents the number of passengers entering and exiting the inter-city bus terminals over a duration of sixteen (16) hours on a normal working day.

TABLE 3-38: INTER-CITY BUS TERMINAL ENTRY AND EXIT COUNTS[54]

Location ID	Location Name	Passengers		
		In	Out	Total
PT_01	Talegaon Bus Terminal	761	740	1,501
PT_03	Shivaji Nagar BS	3,443	3,462	6,905
PT_04	Pune	16,801	10,324	27,125
PT_05	Swargate	15,959	12,079	28,038
PT_09	Kothrud City Bus Stand	1,320	1,015	2,335
PT_10	Sangamwadi Private Bus Terminal	2,118	1,712	3,830
PT_13	Nigdi BS	3,629	2,885	6,514

It can be observed that the maximum passenger movement is observed at the Swargate Bus Terminal, with 28,038 passengers.

Variation of Passenger Flows at Rail and Bus Terminals

1. Rail Terminals

The following section details the passenger flow profile of the surveyed railway terminals for a period of 16 hours. Table 3-39 shows the 16-hour passenger flow profiles for each of the surveyed locations individually.

TABLE 3-39: HOURLY VARIATION OF PASSENGER FLOWS AT RAILWAY TERMINALS[55]

Time Interval	Rail Terminal					
	PT_02	PT_06	PT_07	PT_08	PT_11	PT_12
06:00 to 07:00	3%	2%	8%	5%	6%	4%
07:00 to 08:00	8%	5%	5%	6%	4%	5%
08:00 to 09:00	11%	6%	7%	5%	4%	6%
09:00 to 10:00	7%	13%	7%	7%	9%	7%
10:00 to 11:00	10%	8%	6%	8%	6%	5%
11:00 to 12:00	5%	6%	7%	7%	7%	6%
12:00 to 13:00	4%	5%	4%	7%	5%	9%
13:00 to 14:00	4%	4%	4%	4%	5%	6%
14:00 to 15:00	4%	6%	6%	9%	5%	5%
15:00 to 16:00	7%	6%	7%	11%	6%	7%
16:00 to 17:00	5%	7%	9%	9%	8%	7%

54 UMTC Primary Surveys 2021
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Time Interval	Rail Terminal					
	PT_02	PT_06	PT_07	PT_08	PT_11	PT_12
17:00 to 18:00	9%	7%	11%	6%	7%	8%
18:00 to 19:00	12%	8%	6%	6%	11%	10%
19:00 to 20:00	4%	7%	5%	5%	6%	6%
20:00 to 21:00	6%	6%	4%	3%	5%	4%
21:00 to 22:00	1%	4%	4%	4%	7%	4%
Total	100%	100%	100%	100%	100%	100%

It can be observed that the highest passenger flow at the railway station is observed during 1800 hrs to 1900 hrs at the surveyed railway terminals.

2. Bus Terminals

The following section details the passenger flow profile of the surveyed inter-city bus terminals for a period of 16 hours. Table 3-40 shows the 16-hour passenger flow profiles for each of the surveyed locations individually.

TABLE 3-40: HOURLY VARIATION OF PASSENGER FLOWS AT BUS TERMINALS[56]

Time Interval	Bus Terminal						
	PT_01	PT_03	PT_04	PT_05	PT_09	PT_10	PT_13
06:00 to 07:00	5%	2%	8%	4%	1%	2%	3%
07:00 to 08:00	5%	4%	5%	5%	3%	7%	4%
08:00 to 09:00	4%	6%	9%	6%	5%	3%	7%
09:00 to 10:00	6%	7%	8%	8%	8%	3%	7%
10:00 to 11:00	8%	7%	7%	7%	8%	4%	6%
11:00 to 12:00	7%	7%	8%	7%	10%	5%	7%
12:00 to 13:00	5%	8%	6%	8%	7%	5%	6%
13:00 to 14:00	6%	9%	6%	8%	5%	5%	6%
14:00 to 15:00	6%	8%	6%	8%	9%	5%	7%
15:00 to 16:00	10%	7%	6%	7%	10%	4%	7%
16:00 to 17:00	5%	6%	7%	7%	5%	6%	7%
17:00 to 18:00	8%	7%	6%	7%	8%	9%	8%
18:00 to 19:00	12%	8%	6%	6%	9%	11%	10%
19:00 to 20:00	6%	5%	4%	5%	6%	14%	7%
20:00 to 21:00	4%	4%	4%	4%	4%	12%	5%
21:00 to 22:00	3%	3%	3%	4%	2%	6%	3%
Total	100%	100%	100%	100%	100%	100%	100%

It can be observed that the highest passenger flow at the bus terminals is observed during 1800 hrs to 1900 hrs at the surveyed bus terminals.

56 UMTC Primary Surveys 2021

Origin-Destination Surveys Counts at the Terminals

1. *Access and Egress Mode of Rail Passengers*

The access and egress mode choice of the rail passengers is represented in the Figure 3-28.

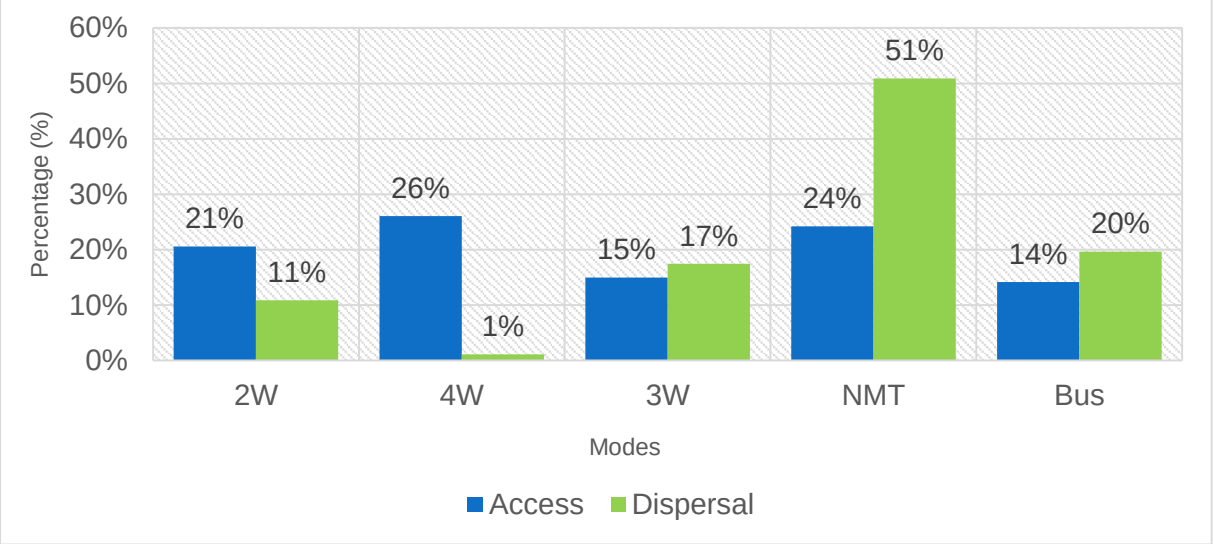


FIGURE 3-28: ACCESS AND EGRESS MODES OF RAIL PASSENGERS[57]

2. *Access and Egress Mode of Bus Passengers*

The access and egress mode choice of the bus passengers is represented in the Figure 3-29.

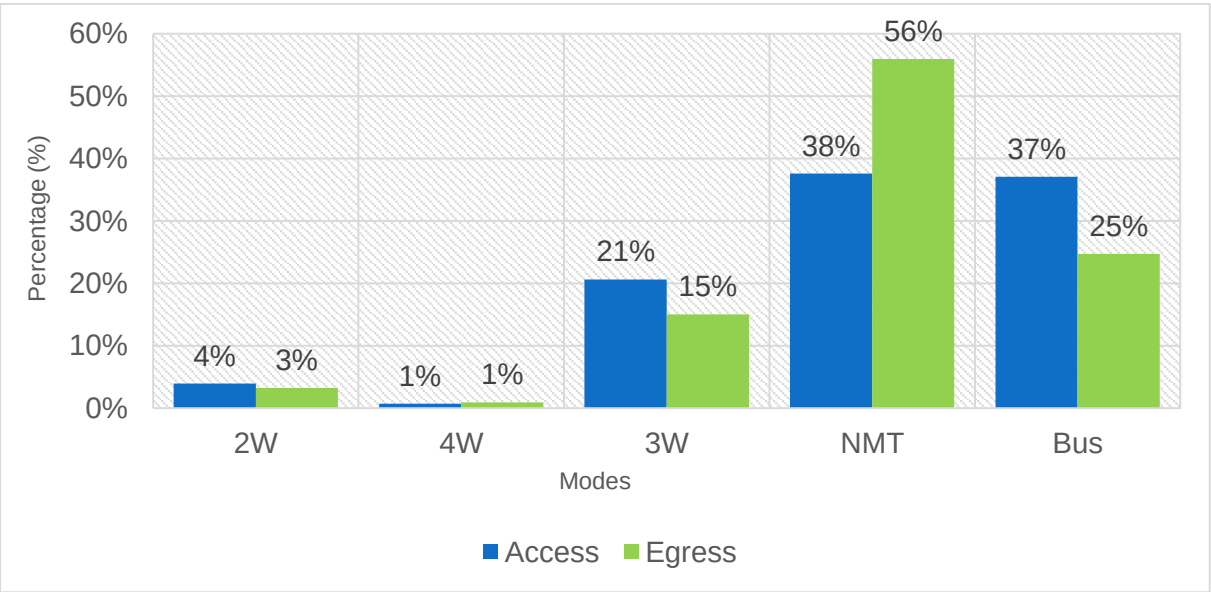


FIGURE 3-29: ACCESS AND EGRESS MODES OF BUS PASSENGERS[58]

57 UMTC Primary Surveys 2021
58 UMTC Primary Surveys 2021

Trip Purpose

The distribution of trips taken by rail and bus passengers by their purpose is represented in Table 3-41. It is observed that work and business trips contribute to about 66.5% of the total trips, while social trips contribute about 14.8%.

TABLE 3-41: DISTRIBUTION OF RAIL AND BUS PASSENGERS BY TRIP PURPOSE [59]

Trip Purpose	Work	Business	Education	Social	Health	Total
Passenger Share (%)	49.0%	17.5%	11.3%	14.8%	7.5%	100.0%

Access and Egress Trip Length and Trip Cost

The average trip length for a bus passenger accessing a bus terminal is 4.06 km, whereas the average trip length for a rail passenger accessing a rail terminal is 6.22 km. It is observed that most of the trips are under 3 km. The average trip time for a bus passenger accessing a bus terminal is 18.49 minutes, whereas the average trip time for rail passengers accessing the rail terminal is 25.77 minutes.

Willingness to Use and Pay for MRTS

1. Rail Terminal Passengers

Willingness to Use MRTS – 78% of the passengers captured at the railway stations showed a willingness to use a Mass Rapid Transit System. 5% of the passengers mentioned that they may be willing to use the MRTS, whereas 17% of the passengers showed no willingness to use MRTS.

When the passengers were questioned why they were not willing to use MRTS as their primary mode of transport, the majority of the passengers indicated they thought that the Metro is costly and the travel time to access and egress the rail/metro terminals shall be more in comparison to the current mode.

Willingness to Pay to Use MRTS – It can be observed from the Figure 3-30, that 32% of the passengers intend to pay the same fare for MRTS that they are paying for their current mode. It can also be observed from the Figure 3-30 that 54% of the passengers are interested in paying more than Rs 20. The average fare passengers intend to pay is Rs 29.34 for a trip length of 6.5 km to use MRTS to access and egress from rail terminals.

59 UMTC Primary Surveys 2021

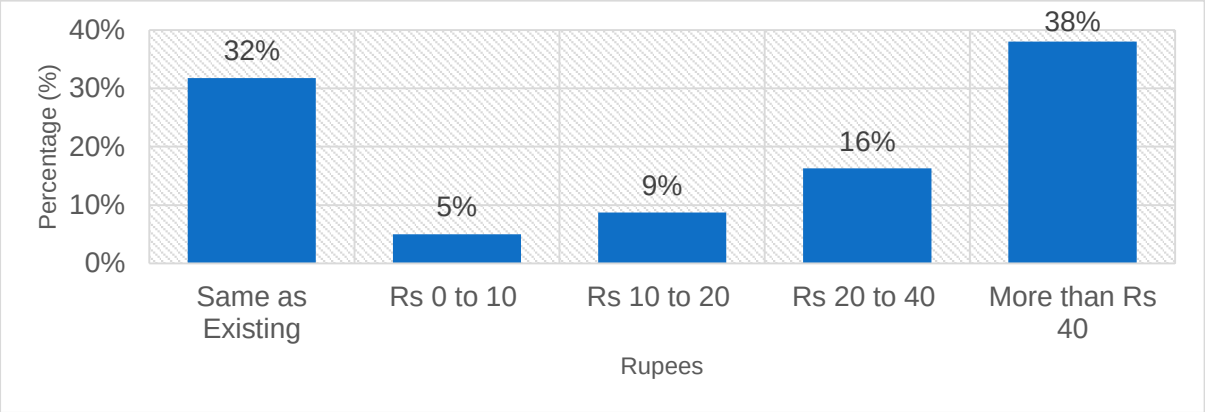


FIGURE 3-30: WILLINGNESS TO PAY FOR MRTS BY RAIL PASSENGERS[60]

2. Bus Terminal Passengers

Willingness to Use MRTS – 68% of the passengers captured at the bus terminals showed a willingness to use a Mass Rapid Transit System. 11% of the passengers mentioned that they may be willing to use MRTS, whereas 22% of the passengers showed no willingness to use MRTS.

When the bus passengers were questioned why they were not willing to use MRTS as their primary mode of transport, the majority of them indicated they thought that the Metro is costly and the travel time to access and egress the bus terminals shall be more in comparison to their current mode.

Willingness to Pay to Use MRTS – It can be observed from the Figure 3-31, that 59% of the passengers intend to pay the same fare for MRTS that they are paying for their current mode. It can also be observed from the Figure 3-31, that 27% of the passengers are interested in paying a maximum of Rs 20. The average fare passengers intend to pay is Rs 15.34 for a trip length of 5 km to use MRTS to access and egress from bus terminals.

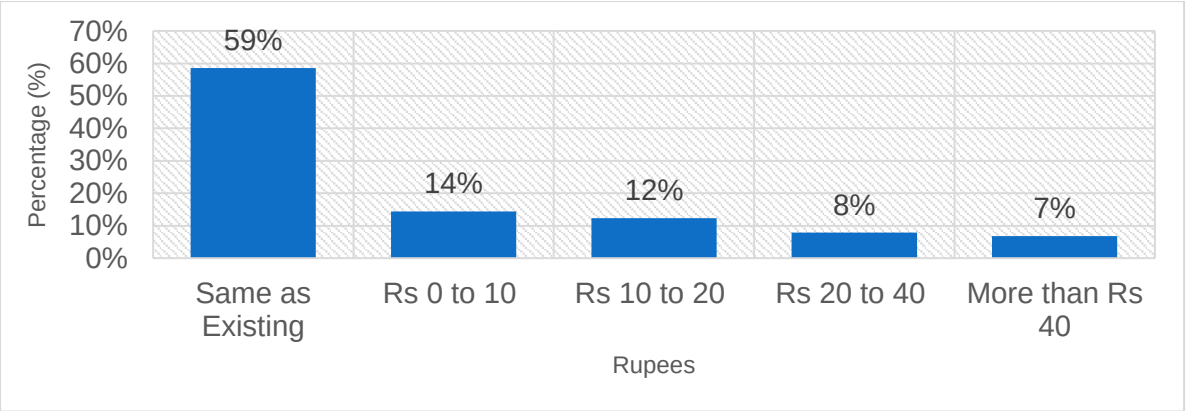


FIGURE 3-31: WILLINGNESS TO PAY FOR MRTS BY BUS TERMINAL PASSENGERS[61]

60 UMTC Primary Surveys 2021
61 UMTC Primary Surveys 2021

3.4.1.12. ANALYSIS OF PARKING

On-street/Off-street parking surveys were carried out at several locations within PMC as part of “Impact Assessment Study for Transit Oriented Development Zones in Pune City”. The parking surveys (on-street and off-street) were undertaken in 2021. Some critical roads from the same were extracted for the current study and have been discussed in the following section.

The equivalent car space (ECS) units used for converting all categories into a single unit for various modes are presented in Table 3-42.

TABLE 3-42: EQUIVALENT CAR SPACE (ECS) UNITS FOR VARIOUS MODES OF VEHICLES

S.N.	Vehicle Type	ECS
1	2-Wheeler	0.20
2	Auto-Rickshaw/Share Auto	0.50
3	Car	1.00
4	Van/Maxi Cab/Big Car	1.50
5	LCV/Tata Magic	1.75
6	Multi-Axle Vehicles	3.0
7	Trucks	2.5
8	Cycles	0.20
9	Cycle Rickshaw	0.80

TABLE 3-43: PARKING ACCUMULATION AT VARIOUS ON-STREET PARKING LOCATIONS[62]

S. N.	Location	Parking Demand		Total Parking Accumulation (ECS)
		LHS	RHS	
1	Wagholi Parner Pune Highway	762	867	1,629
2	Solapur Highway Loni Kalbhor (A) (Main Road)	152	102	254
3	Solapur Highway Loni Kalbhor (B) (Service Road)	253	104	357
4	Alandi Road (Dehu Phata to Sambhaji Chowk)	665	667	1,333
5	Along Dange Chowk Road from Shivaji Chowk Hinjewadi	797	909	1,705
6	Westernly Bypass from Katraj Chowk to Wondercity Bus Stop	1,345	999	2,343
7	Kondhwa	1,909	1,035	2,944
8	MG Road	1,836	2,690	4,526
9	Bajirao Road	1,397	1,749	3,146
10	Shivaji Road	3,850	3,348	7,198
11	Laxmi Road	6,474	3,329	9,802
12	Station Road	879	851	1,731
13	Pimpri Chinchwad Link Road, Near Chinchwad Bus Stand	922	-	922
14	Near PCMC Office	730	621	1,351

62 UMTC Primary Surveys 2021

Table 3-43 represents the parking accumulation at various on-street parking locations. It can be observed that parking accumulation at MG Road, Shivaji Road, Bajirao Road, and Laxmi Road is high due to the commercial activities on these roads.

Table 3-44 represents the parking duration at various locations. It was observed that vehicles were parked mostly for a short while, i.e., between 30 minutes and 1 hour.

TABLE 3-44: PARKING DURATION AT VARIOUS ON-STREET PARKING LOCATIONS [63]

S. N.	Location	Quick (Up to 30 mins)		Short Stay (0.5 hr to 1 hr)		Short Stay (1 hr to 2 hr)		Long Stay (2 hr to 3 hr)		Very Long Stay (>3 Hr)	
		LHS	RHS	LHS	RHS	LHS	RHS	LHS	RHS	LHS	RHS
1	Wagholi Parner Pune Highway	2%	2%	73%	71%	17%	19%	6%	7%	2%	2%
2	Solapur Highway Loni Kalbhor (A) (Main Road)	1%	0%	87%	90%	9%	9%	4%	1%	0%	1%
3	Solapur Highway Loni Kalbhor (B) (Service Road)	2%	5%	71%	76%	18%	7%	7%	9%	2%	3%
4	Alandi Road (Dehu Phata to Sambhaji Chowk)	1%	1%	74%	78%	15%	13%	8%	7%	3%	2%
5	Along Dange Chowk Road from Shivaji Chowk Hinjewadi	6%	6%	63%	61%	16%	17%	11%	11%	4%	5%
6	Westernly Bypass from Katraj Chowk to Wondercity Bus Stop	3%	4%	67%	53%	16%	23%	11%	16%	3%	4%
7	Kondhwa	3%	5%	66%	65%	16%	17%	11%	10%	3%	4%
8	MG Road	13%	8%	53%	48%	16%	22%	12%	16%	6%	6%
9	Bajirao Road	10%	13%	58%	50%	16%	16%	10%	13%	6%	8%
10	Shivaji Road	9%	11%	60%	56%	16%	16%	10%	11%	5%	6%
11	Laxmi Road	14%	10%	48%	41%	17%	27%	14%	17%	7%	5%
12	Station Road	9%	14%	63%	57%	16%	16%	9%	10%	3%	3%
13	Pimpri Chinchwad Link Road, Near Chinchwad Bus Stand	4%	-	63%	-	19%	-	10%	-	4%	-
14	Near PCMC Office	5%	2%	54%	56%	19%	18%	16%	20%	6%	4%

63 UMTC Primary Surveys 2021

3.4.1.13. ANALYSIS OF HOUSEHOLD (HH) SURVEY

General

The objective of carrying out household surveys is to obtain household and travel characteristics for a typical working day. Household surveys help in understanding the travel characteristics of residents, which later help in the identification of transportation improvement proposals and policy formulation.

The household survey was carried out using a random sample technique comprising of 9693 households (accounting for ~0.5% of the total number of households in the study area) spread over 289 internal traffic analysis zones to find out the socio-economic and travel characteristics.

As mentioned in Section 3.1, the study area is divided into Traffic Analysis Zones (TAZs) in order to have a spatially disaggregated idea of origin and destination trips. A Comprehensive Zoning System was adopted to reveal not only the travel patterns within the study area but also the pattern of interaction with areas outside the study area.

The household survey data is analysed and presented under the following heads:

1. Socio-economic Characteristics
2. Personal Characteristics
3. Travel Characteristics

Socio-Economic Characteristics

1. Household Size

The average household size in PMR is 3.41. The distribution of the households in terms of size in the PMR area is represented in Figure 3-32.

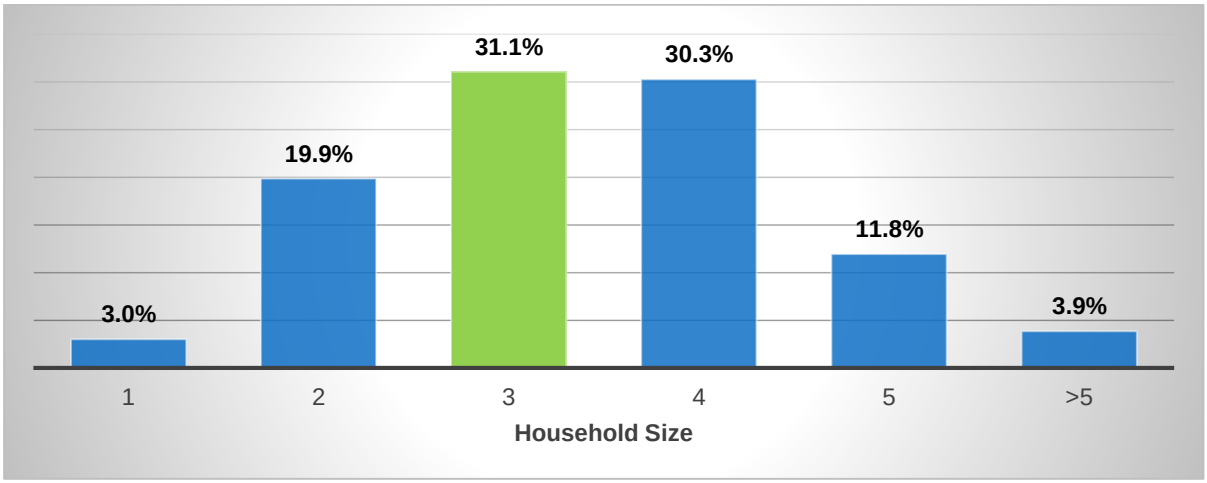


FIGURE 3-32: DISTRIBUTION OF HOUSEHOLDS BY HOUSEHOLD SIZE [64]

64 UMTC Primary Surveys 2021

TABLE 3-45: HH DETAILS

S No	HH Size	No. of Households	% of HHs
1	1	291	3.0%
2	2	1929	19.9%
3	3	3015	31.1%
4	4	2937	30.3%
5	5	1144	11.8%
6	6	378	3.9%
Total		**9693**	**100.0%**

2. Age-Wise Distribution

Figure 3-33 represents the distribution of residents by age group and gender. It can be noticed that the majority of the residents of Pune and Pimpri Chinchwad are young and in the age group of 25 to 29 years. It is also observed that ~77% of the residents of the Pune and Pimpri Chinchwad are less than 40 years old.

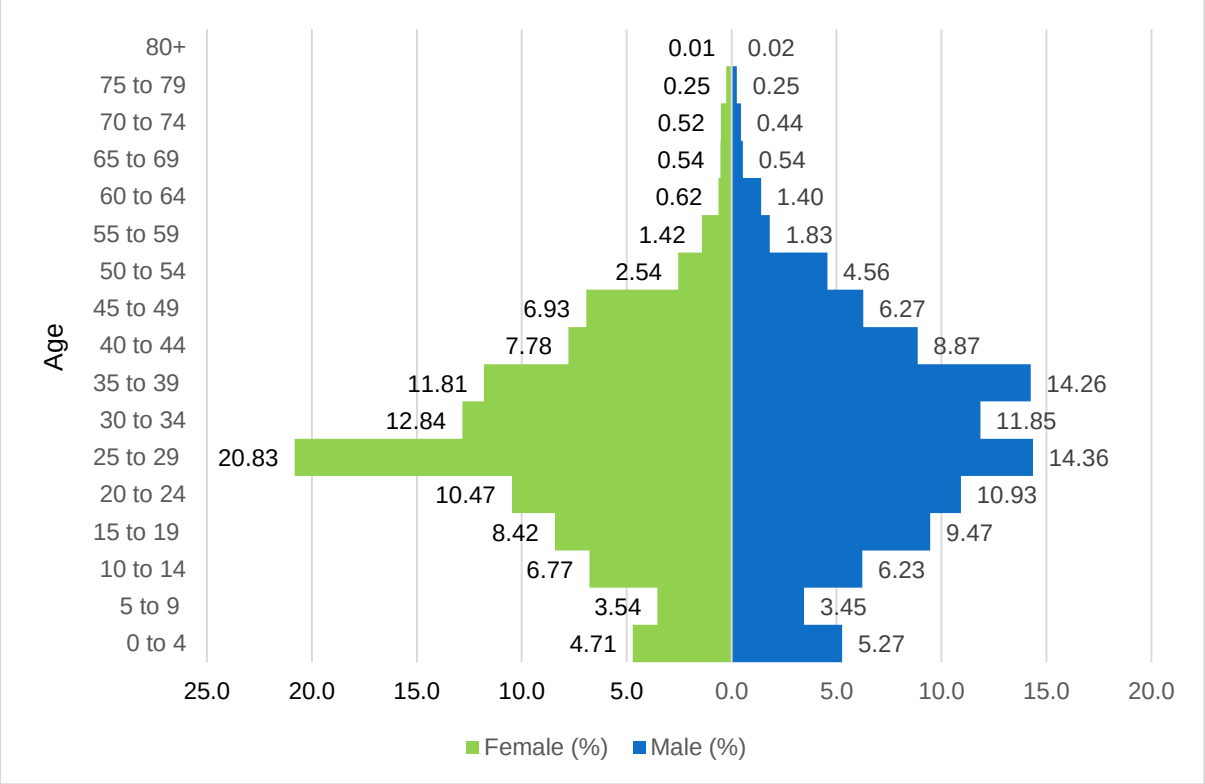


FIGURE 3-33: DISTRIBUTION OF RESIDENTS BY GENDER AND AGE GROUP[65]

3. Household Income

The average monthly HH income in the PMR area is observed to be Rs 27,098/-. The distribution of household income in the PMR area is presented in Table 3-46.

65 UMTC Primary Surveys 2021

TABLE 3-46: DISTRIBUTION OF HOUSEHOLDS BY MONTHLY HOUSEHOLD INCOME[66]

S. N.	Monthly HH Income	No. of HH's	%age
1	Upto Rs 5000	291	3%
2	Rs 5001 - Rs 10,000	775	8%
3	Rs 10001 - Rs 15000	1260	13%
4	Rs 15001 - Rs 20000	2229	23%
5	Rs 20001 - Rs 40000	3392	35%
6	Rs 40001 - Rs 60000	1066	11%
7	Above Rs 60000	485	5%
8	No Response	195	2%
Total		9693	100%

The distribution of households under the various income groups shows that around 35% of the households fall in the income range of Rs 20,001 to Rs 40,000, around 23% are in the range of Rs 15001 to Rs 20000, while the share of households with an income more than Rs 60,000 account for only 5%.

4. Household Expenditure Pattern

The average monthly household expenditure on travel is around Rs 1,614 in PMR. The average travel expenditure is about 5.65% of the total monthly household income.

TABLE 3-47: DISTRIBUTION OF HOUSEHOLDS BY MONTHLY EXPENDITURE ON TRANSPORT[67]

S. N.	Monthly Household Income	Median HH Income	%age share of the HH Income spent on transport
1	Upto Rs 5000	2500	18.27%
2	Rs 5001 - Rs 10,000	7501	18.36%
3	Rs 10001 - Rs 15000	12501	13.28%
4	Rs 15001 - Rs 20000	17501	8.78%
5	Rs 20001 - Rs 40000	30001	5.21%
6	Rs 40001 - Rs 60000	50001	4.27%
7	Above Rs 60000	80001	3.21%
Average % Expenditure		**28572**	**5.65%**

5. Vehicle Ownership

It is observed that about 85% of the households in PMR have one (01) vehicle, followed by 8% with two (02) vehicles. The distribution of vehicle ownership in PMR is represented in Table 3-48

TABLE 3-48: DISTRIBUTION OF HOUSEHOLDS BY VEHICLE OWNERSHIP[68]

S. N.	Type of Vehicles Owned	No. of HHS	%age
1	Cars/Vans/Taxi	698	7.2%
2	2-Wheelers	7415	76.5%

66 UMTC Primary Surveys 2021
67 UMTC Primary Surveys 2021
68 UMTC Primary Surveys 2021

S. N.	Type of Vehicles Owned	No. of HHS	%age
3	Bicycles	87	0.9%
4	Auto	78	0.8%
5	Others	19	0.2%
6	Car & 2W	698	7.2%
7	Car & Bicycle	19	0.2%
8	Car & Auto	0	0.0%
9	2W & Bicycle	97	1.0%
10	2W & Auto	10	0.1%
11	Car, 2W & Auto	10	0.1%
12	2W, Car & Bicycle	19	0.2%
13	2W, Bicycle & Auto	0	0.0%
14	No Vehicle	553	5.7%
	Total	**9693**	**100%**

It is observed that the share of 2-wheelers is high, at 76.5%, followed by cars/vans/taxi at 7.2%. Households that own both cars and 2-wheelers stand at 7.2% in PMR.

Personal Characteristics

1. Education Profile

95.7% of the total population in PMR area is literate. The distribution by the education level of the population in PMR is presented in Table 3-49

TABLE 3-49: DISTRIBUTION OF HOUSEHOLDS BY EDUCATION LEVEL[69]

S. N.	Education	No. of Persons	%age
1	Illiterate	1323	4.3%
2	Pre-Primary	1589	5.2%
3	Primary (5th Pass)	3613	11.8%
4	Secondary (10th Pass)	5279	17.2%
5	Higher Secondary (12th Pass)	9181	29.9%
6	Technical Diploma	2146	7.0%
7	Graduate	6265	20.4%
8	Postgraduate & above	916	3.0%
9	Others	368	1.2%
Total		**30680**	**100%**

About 20.4% of the population in PMR area are graduates.

2. Occupation Profile

The distribution of the population by occupation profile in PMR area is given in Table 3-50.

69 UMTC Primary Surveys 2021

TABLE 3-50: DISTRIBUTION OF HOUSEHOLDS BY OCCUPATION PROFILE [70]

S. N.	Occupation	No. of Persons	%age
1	Employed (Full-Time)	9493	30.9%
2	Employed (Part-Time)	1744	5.7%
3	Self-Employed	898	2.9%
4	Daily Wages	1528	5.0%
5	Student (all levels)	6706	21.9%
6	Seeking Employment	366	1.2%
7	Homemaker/Housewife	6499	21.2%
8	Retired	222	0.7%
9	Resident Maid/Driver/Caretaker	139	0.5%
10	Others	3085	10.1%
Total		**30680**	**100%**

Trip Characteristics

1. Per Capita Trip Rate (PCTR)

The overall Per Capita Trip Rate (PCTR) in PMR area is 1.13 (including walk and NMT), whereas the motorized PCTR (i.e., excluding walk and NMT) is 0.85.

2. Mode of Travel

The distribution of trips by various modes shows that the share of 2-wheeler trips is 43.74% in the PMR area. The mode-wise distribution of trips for PMR is shown in Table 3-51.

TABLE 3-51: MODE-WISE DISTRIBUTION OF TRIPS[71]

Mode of Travel	No. of Trips	Total Trips	Motorized Trips
Walk	9873	19.73%	
NMT[72]	1358	2.71%	
2W	21884	43.74%	56.40%
3W	9206	18.40%	23.73%
4W	2773	5.54%	7.15%
Taxi/Cab	820	1.64%	2.11%
Bus	4007	8.01%	10.33%
Train	108	0.22%	0.28%
Total	**50029**	**100.0%**	**100.0%**

The share of non-motorized trips (walk and cycle) accounts for 22.45% in the PMR area. The motorized trips of cars and 3-wheelers account for 7.15% and 23.73%, respectively.

70 UMTC Primary Surveys 2021
71 UMTC Primary Surveys 2021
72 NMT – Non Motorized Modes typically includes Cycle and Cycle Rickshaws. As in case of Pune, it is Cycles as Cycle Rickshaws are not operational.

3. Purpose of Travel

The trip distribution in terms of the purpose of travel reveals that work/business trips account for 56.22% of the trips in the PMR area. Educational trips are around 17%. The details of the purpose-wise distribution of trips in the PMR area are given in Table 3-52.

TABLE 3-52: DISTRIBUTION OF TRIPS BY PURPOSE[73]

S. N.	Trip Purpose	No. of Trips	%age
1	Work/ Business/Work- Related	14175	56.22%
2	Education	4287	17.00%
3	Shopping	5574	22.11%
4	Health	517	2.05%
5	Eating	71	0.28%
6	Social	219	0.87%
7	Entertainment/Recreation	242	1.96%
8	Others	129	0.51%
Total		**25214**	**100.00%**

4. Trip Length

The weighted average trip length of the motorized trips is observed to be 7.40 km. Figure 3-34 represents the mode-wise trip length for the PMR area. Table 3-53 represents the trip length frequency distribution (TLFD) observed from the HH survey.

It has been observed that the average trip length within the study area is 7.40 Kms, the average trip time is 21.54 mins and the average trip cost is Rs 37.56.

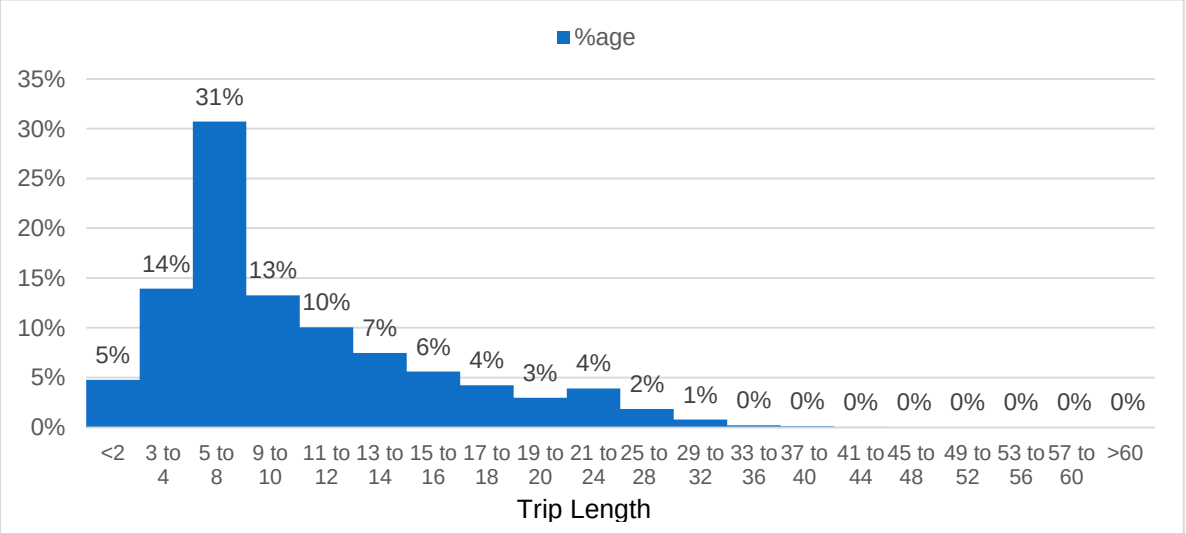


FIGURE 3-34: TRIP LENGTH FREQUENCY DISTRIBUTION (TLFD) [74]

73 UMTC Primary Surveys 2021
74 UMTC Primary Surveys 2021

TABLE 3-53 MODE-WISE TRIP LENGTH (KM) DETAILS[75]

Mode	Average Trip Length (km)
Walk	0.72
NMT[76]	4.04
2W	8.61
3W	6.74
4W	15.04
Taxi/Cab	8.85
Bus	9.75
Train	40.75
Weighted Average Trip Length	7.40

5. Other Trip Characteristics

- **Access Mode and Dispersal Mode:** ~50% of the access and dispersal trips are undertaken by walks, followed by 17% of 3-wheeler (autos and shared autos) trips.
- **Access and Dispersal Trip Length:** The average access and dispersal trip lengths are 3.94 km and 2.46 km, respectively.
- **Waiting Time:** The average waiting time at the bus stops is 5 minutes.
- **Transfer Time:** The average transfer time at the bus stops is 15 minutes.
- **Frequency of Travel by PT:** 48% of the residents use the bus as their primary mode of travel on a daily basis.

3.4.1.14. IMPACT OF COVID ON TRAFFIC IN PMR

The COVID-19 pandemic has changed the lifestyle of millions of people across the globe. With lockdowns and travel restrictions over two years, the travel demand in Pune has suffered considerably. As part of the present study, the impact of the pandemic on travel behaviour has been studied. The comparison between the pre- and post-COVID scenarios are presented below.

As mentioned in the current chapter, the traffic survey locations (outer cordons, screen line locations, mid-block locations, turning movement counts) were finalized duly considering the traffic survey locations from the Comprehensive Mobility Plan (2018) for Pune Metropolitan Region (PMR).

The same principle was adopted for the entry and exit surveys conducted at rail and bus terminals. This was considered to establish the variation in traffic due to the COVID-19 pandemic.

To establish the variation in traffic due to COVID-19, the traffic survey locations that are in common with the CMP have been extrapolated to arrive at 2021 values and duly compared with the 2021 traffic surveys undertaken as part of the current study.

75 UMTC Primary Surveys 2021
76 NMT – Non Motorized Modes typically includes Cycle and Cycle Rickshaws. As in case of Pune, it is Cycles as Cycle Rickshaws are not operational.

Methodology

1. Identify traffic survey locations common with the CMP study[77]
2. Apply growth rates to the identified CMP survey locations to arrive at 2021 values.
   a. Growth Rate – 3% for Outer Cordons & 5% for Inner Cordons[78]
3. Compare CMP projected 2021 with the primary traffic survey results of 2021.

The traffic variation observed are represented in the following tables.

TABLE 3-54: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT OUTER CORDON LOCATIONS

S. N.	Location ID	2021_DPR Phase 2 Surveys	CMP 2018	CMP 2021*	Variation in Traffic in %age
		Vehicles	Vehicles	Vehicles	
1	OC_01	85307	85455	93379	↓ -9.46%
2	OC_02	38500	63846	69766	↓ -81.21%
3	OC_03	72659	138570	151419	↓ -108.40%
4	OC_04	92779	75077	82039	↑ 11.58%
5	OC_05	59440	38514	42085	↑ 29.20%
6	OC_06	43685	38981	42596	↑ 2.49%
7	OC_07	24384	68432	74777	↓ -206.67%
8	OC_08	86988	84107	91906	↓ -5.65%
9	OC_09	55176	47080	51446	↑ 6.76%
10	OC_11	65353	61535	67241	↓ -2.89%
11	OC_12	16529	92980	101602	↓ -514.69%
12	OC_13	84398	51933	56749	↑ 32.76%
13	OC_14	20533	33449	36551	↓ -78.01%
14	OC_15	9680	19425	21226	↓ -119.28%
15	OC_16	19634	21115	23073	↓ -17.52%
16	OC_17	2738	1751	1913	↑ 30.12%
17	OC_18	29016	18217	19906	↑ 31.40%

Note:
* CMP 2018 observed traffic extrapolated to 2021

Table 3-54 represents the variation in traffic at various outer cordon points. It is to be noted that OC_01, OC_02, OC_03, OC_07, OC_08, OC_11, OC_12, OC_14, OC_15 and OC-16 have shown reduced traffic. OC_12 and OC_07, i.e., Talwade Dehu Alandi Road and Kiratwadi have shown a drastic reduction in traffic, by five times and two times, respectively, as against the extrapolated CMP traffic.

77 OC-19, MB-11, MB-12 and MB-13 are the locations which are not common to the CMP and the present study. Hence, not represented in the Impact of COVID on traffic in PMR.

78 The Growth Rates have been arrived based on the following;

- Past Studies undertaken for Pune and Pimpri Chinchwad
- Vehicle Registration Growth Rate – is 8.05% per annum.
- Population Projections of the Pune Metropolitan Region from various studies – i.e. avg. of 2.68% per annum
- Increase in Passenger Trips from the CMP Study – i.e. Avg of 3.46%.

It is also to be noted from the table above that OC_04, OC_05, OC_06, OC_09, OC_13, OC_17 and OC_18 have shown an increase in traffic.

The average variation of traffic at all the outer cordon locations between the CMP extrapolated 2021 traffic and the traffic surveys conducted as part of DPR Phase 2 has shown a reduction by 58.8%.

TABLE 3-55: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT SCREEN LINE LOCATIONS

S. N.	Location ID	2021_DPR Phase 2 Surveys	CMP 2018	CMP 2021*	Variation in Traffic in %age
		Vehicles	Vehicles	Vehicles	
1	SL_01	18129	16177	18684	↓ -3%
2	SL_02	65971	50694	58551	↑ 11%
3	SL_03	56043	63430	73260	↓ -31%
4	SL_04	63568	89995	103943	↓ -64%
5	SL_05	74531	28126	32485	↑ 56%
6	SL_06	19252	28680	33125	↓ -72%
7	SL_07	51449	76304	88130	↓ -71%
8	SL_08	151631	184933	213594	↓ -41%
9	SL_09	55726	42958	49616	↑ 11%
10	SL_10	29936	48023	55466	↓ -85%
11	SL_11	38652	45658	52734	↓ -36%
12	SL_12	154230	196812	227314	↓ -47%
13	SL_13	34307	76793	88694	↓ -159%
14	SL_14	161615	159621	184359	↓ -14%
15	SL_15	92281	108941	125825	↓ -36%
16	SL_16	68907	44615	51529	↑ 25%
17	SL_17	57093	71123	82146	↓ -44%
18	SL_18	75001	83941	96950	↓ -29%
19	SL_19	94825	134044	154818	↓ -63%
20	SL_20	99095	113462	131046	↓ -32%
21	SL_21	102430	100833	116460	↓ -14%
22	SL_22	72816	106985	123566	↓ -70%
23	SL_23	139761	169809	196126	↓ -40%
24	SL_24	25465	7861	9079	↑ 64%
25	SL_25	107556	133603	154309	↓ -43%
26	SL_26	109393	137401	158696	↓ -45%
27	SL_27	76577	80863	93395	↓ -22%
28	SL_28	60004	71265	82310	↓ -37%
29	SL_29	116013	113662	131277	↓ -13%
30	SL_31	50076	16177	18684	↑ 63%

Note:
* CMP 2018 observed traffic extrapolated to 2021

Table 3-55 represents the variation in traffic at various screen line locations. All the survey locations overlap with the CMP survey locations. It can be noted that except for SL_02,

SL_05, SL_09, SC_16, SL_24 and SL_31, all the locations have shown a reduction in traffic. The average reduction in traffic at all the screen line locations is 32%.

TABLE 3-56: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT MID-BLOCK LOCATIONS

S. N.	Location ID	2021_DPR Phase 2 Surveys	CMP 2018	CMP 2021*	Variation in Traffic in %age
		Vehicles	Vehicles	Vehicles	
1	MB_01	57553	71083	82100	↓ -43%
2	MB_02	50792	135707	156739	↓ -209%
3	MB_03	70374	56182	64889	↑ 8%
4	MB_05	76857	86623	100048	↓ -34%
5	MB_06	62616	90081	104042	↓ -35%
6	MB_07	68398	74449	85987	↓ -37%
7	MB_08	87967	86048	99384	↓ -45%
8	MB_09	90042	106169	122623	↓ -39%
Note: * CMP 2018 observed traffic extrapolated to 2021					

Table 3-56 represents the variation in traffic at various mid-block locations. It can be observed that, except for MB_03 at Spine Road, all the locations show reduced traffic.

The average reduction in traffic at all the screen line locations is 54%.

TABLE 3-57: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT INTERSECTIONS

S. N.	Location ID	2021_DPR Phase 2 Surveys	CMP 2018	CMP 2021*	Variation in Traffic in %age
		Vehicles	Vehicles	Vehicles	
1	TMC_01	13,146	13,065	15,090	↓ -15%
2	TMC_02	14,687	15,096	17,436	↓ -19%
3	TMC_03	9,969	12,711	14,681	↓ -47%
4	TMC_04	11,049	11,697	13,510	↓ -22%
5	TMC_05	20,862	22,655	26,166	↓ -25%
6	TMC_06	5,860	10,974	12,675	↓ -116%
7	TMC_07	5,989	12,390	14,310	↓ -139%
8	TMC_08	10,551	12,274	14,176	↓ -34%
9	TMC_09	9,490	12,926	14,929	↓ -57%
10	TMC_10	6,053	10,701	12,359	↓ -104%
11	TMC_11	7,718	6,539	7,552	↑ 2%
12	TMC_12	6,456	8,337	9,629	↓ -49%
13	TMC_13	9,132	7,748	8,949	↑ 2%
14	TMC_14	14,692	13,646	15,761	↓ -7%

S. N.	Location ID	2021_DPR Phase 2 Surveys	CMP 2018	CMP 2021*	Variation in Traffic in %age
		Vehicles	Vehicles	Vehicles	
15	TMC_15	10,617	10,750	12,416	↓ -17%
16	TMC_16	11,856	13,267	15,323	↓ -29%
17	TMC_17	12,971	15,385	17,769	↓ -37%
18	TMC_18	11,972	15,385	17,769	↓ -48%
19	TMC_19	7,229	11,090	12,809	↓ -77%
20	TMC_20	12,535	13,189	15,233	↓ -22%
21	TMC_21	5,821	6,060	6,999	↓ -20%
Note: * CMP 2018 observed traffic extrapolated to 2021					

Table 3-57 represents the variation in traffic at various intersections. The traffic flow during the peak hour is considered to establish the variation in traffic. It could also be noted that except for TMC_11 and TMC_13 all the intersections have shown a reduction in traffic.

The average variation of traffic at all the intersection locations is 42%, i.e., the city roads had 42% less traffic in 2021 when compared to the potential traffic in 2021 in a Business-As-Usual case, i.e., without the influence of the COVID-19 pandemic.

TABLE 3-58: VARIATION B/W CMP SURVEYS AND DPR PHASE 2 SURVEYS AT TERMINALS

Location ID	Location Name	2021 DPR Phase 2 Surveys	CMP 2018		CMP 2021*	Variation in Passenger Flow in %age
PT_01	Talegaon Bus Terminal	1,501	1,200		1386	↑ 8%
PT_02	Talegaon Railway Station	9,039	21,992		25400	↓ -181%
PT_03	Shivaji Nagar BS	6,905	47,925		55352	↓ -702%
PT_04	Pune BS	27,125	13,200		15246	↑ 44%
PT_05	Swargate BS	28,038	56,250		64968	↓ -132%
PT_06	Shivaji Nagar RS	10,696	17,381		20075	↓ -88%
PT_07	Pune RS	39,376	2,01,389		232600	↓ -491%
PT_08	Khadki RS	3,603	6,586		7607	↓ -111%
PT_10	Sangamwadi Private Bus Terminal	3,830	4,850		5602	↓ -46%
PT_11	Pimpri RS	6,593	18,124		20933	↓ -218%
PT_12	Chinchwad RS	12,985	20,256		23395	↓ -80%
Note: * CMP 2018 observed traffic extrapolated to 2021						

It can be observed from the Table 3-58 that public transport systems such as rail and bus services have been severely impacted by COVID-19. The highest variation is observed at the Pune and Shivaji Nagar Railway Stations. This is because the inter-city bus and rail services are yet to operate at full capacity.

Based on the above tables and descriptions, it can be noted that a significant variation in traffic is observed due to 'Work from Home' and rotational work in offices as well as online modes of education (in schools and colleges). Since 2020, due to the pandemic, there has been a decrease in work-related and education-related trips to the areas that are clustered with tertiary sector services such as IT & ITES, consultancies, etc. and educational institutes. Apart from this reduction, it is noted that residents of the Pune Metropolitan Region (PMR) have been generally avoiding unnecessary recreational, social and leisure trips. Hence, the areas where such activities were dominant have also witnessed a reduction in traffic.

Based on the various studies undertaken in the past two years and the assessment of the impact of COVID on travel behaviour, it is understood that the traffic pattern (both private and public transport) shall gradually reach the pre-COVID traffic flow levels over the next couple of years. It is anticipated that this reduced ridership and traffic flow of public transport is short-term in nature and would return to normalcy over the coming years. It is witnessed that people who used public transport still use it. However, they expect better service frequency and fares similar to those in the pre-COVID era.

The choice users of public transport are critical as they need to be accustomed to the public transport system. Choice users can be attracted by an increase in supply, regular disinfection, marketing and branding of public transport as a safe mode of transport in the city, and staggering of their work hours, while adhering to COVID-appropriate norms.

3.5 TRAVEL DEMAND MODELLING

Travel demand modelling is a process of simulating the "real world" transport system and forecasting the demand and the state of the system for the horizon years. Travel analysis through Urban Transport Planning (UTP) models are developed to assist in making informed transportation planning decisions. These models are often developed by using advanced state-of-the-art computer packages such as PTV VISUM, CUBE, EMME2, TRANSCAD, TRANSPLAN, etc., built explicitly for such purposes. In Pune, PTV VISUM 2022 (software) has been used.

The role of UTP models is to provide structured forecasts that can be interrogated to provide information on the implications of transport interventions. The model outputs are used both to:

- Establish a structured understanding of the performance of the transport systems today and forecasts of the future, and to identify the need to consider interventions, and

- Compare the performance of transport systems with and without interventions to understand their merits.

For the overall study area level analysis, and for modelling future impacts of the options to be tested, a transport demand model has been developed as part of the DPR. The model broadly consists of the following components:

- **Database:** A database populated by data from travel surveys across the region by various modes by time of day (peak hour), together with observed traffic volumes across the road network and passenger volumes on the public transport network, including current and projected land use data and demographics (population and employment).
- **Inputs:** The inputs for the modelling process, such as Traffic Analysis Zones, network (road and PT network), fares, travel costs, traffic management measures, access restrictions, road and public transport infrastructure, and public transport service provision.
- **Travel Demand Model:** The demand model to derive the quantum of travel demand across the region, which comprises trip generation, trip distribution, mode choice and traffic assignment modules, including travel purposes and the quantum of commercial vehicles.

3.5.1 TRANSPORTATION STUDY PROCESS

The Travel Demand Model has been developed for PMC, PCMC and the surrounding areas. The model follows the four-stage modelling process (refer to Figure 3-35),

- **Trip Generation:** This stage involves the usage of land use, population and economic forecasts to estimate the number of personal trips produced and attracted in each zone (Traffic Analysis Zones).
- **Trip Distribution:** At this stage, the number of trips between each origin zone and destination zone (O-D pair), based on the total trips produced from and attracted to a zone, where the input for this stage is from the trip generation stage.
- **Mode Choice:** This stage allocates the origin–destination trips derived from trip distribution to the available travel modes. The choice between travel modes will be estimated based on the characteristics of the trip maker (income, car ownership, age), the trip itself (trip purpose, the origin and destination) and the characteristics of the travel mode (fares, vehicle operating costs, travel time, parking availability and cost, reliability).
- **Trip Assignment:** This stage assigns the various mode-specific trip matrices to the alternative routes or paths across the transport network based on the least cost (travel distance, travel time). Public transport trips are assigned to the public transport network along fixed routes (where path choice includes all public transport modes) and vehicle trips (PCUs), and are assigned to the highway network.

Based on the above, it is understood that UTP is not just one model but a series of interlinked and interrelated models of varying levels of complexity, dealing with travel demand. Through these models, the transportation study process as a whole is validated and calibrated before it is used for future travel predictions, i.e. with reasonable confidence, which replicates the base year. The existing planning parameters of the study area are used for forecasting the future travel demand by projecting the planning parameters to the horizon years and given as inputs to the model to forecast the future travel demand. For Pune, this has been done by synthesizing the present-day movement patterns and adjusting the same until these represent the observed conditions. Only when the formulae have been adjusted or calibrated, so that they can adequately predict the present-day travel movement, these are used in true predictive mode to determine future conditions.

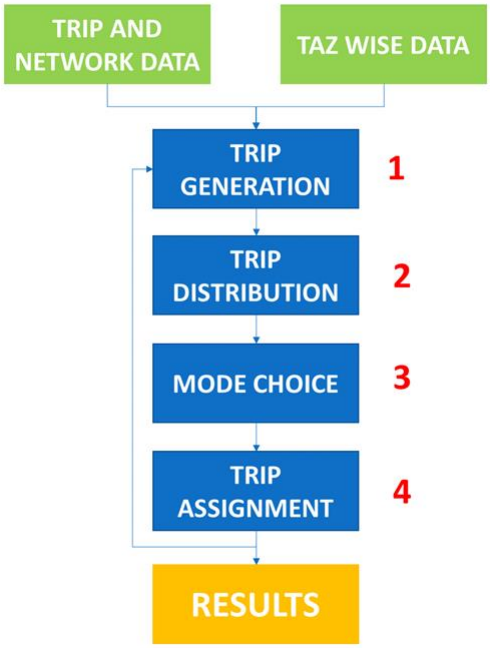


FIGURE 3-35: FOUR-STAGE TRAVEL DEMAND MODEL

By simulating roadway conditions and travel demand on those roadways, deficiencies in the system can be assessed. Potential future network improvements such as the introduction of MRTS/PT systems or land use modifications can be analysed by this tool and its efficacy can be established at the planning level. Thus, the UTP model allows to identify and build projects that will give the maximum utility for iterating and testing various scenarios. The identified projects are further prioritized to give the best value for public money for the implementation/governing agencies.

In the present study, an attempt has been made to develop operational models. The normal and easily available planning variables at the zonal levels such as population and employment have been used in this transport analysis.

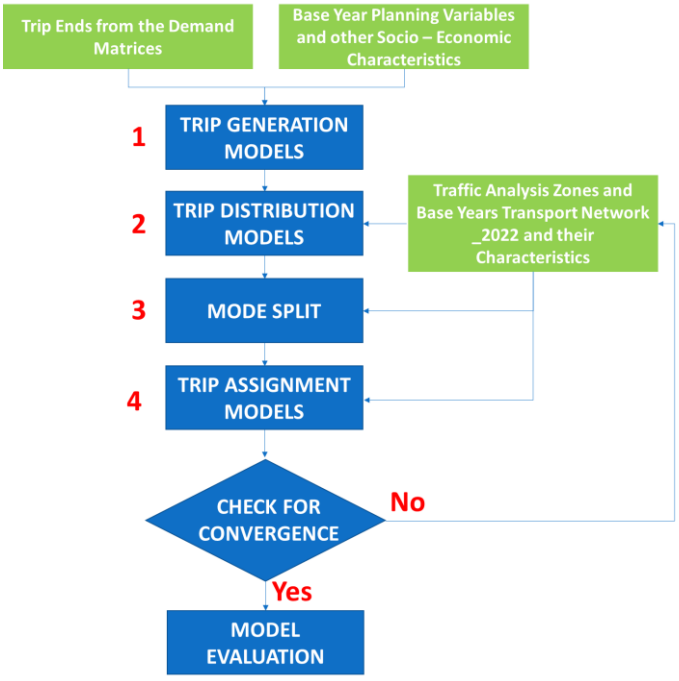
The “PTV VISUM 22” software developed by PTV Germany is used for the development of travel demand models. It is a user-friendly software for modelling a wide variety of planning policies and improvements at the urban, regional, and long-distance levels. This is very efficient software and used widely for building comprehensive network models and traffic assignment in large, complex urban networks. The model assigns the demand based on the assignment technique, which is a function of the travel impedance/generalized cost.

The modes that were modelled included 2-wheelers, 4-wheelers (cars and taxi cabs), 3-wheelers (auto-rickshaws and shared auto-rickshaws) and buses. The study area road network considered all the key arterials, sub-arterials and collectors. The transit system considered the existing public transport system in all its forms, i.e., city buses (total 385 routes). The parameters considered for the model are presented in Table 3-59**.**

TABLE 3-59: PARAMETERS CONSIDERED FOR TRAVEL DEMAND MODEL

S. N.	Parameters	Type/Value
1	Software	PTV VISUM 22
2	Network	18340 Links and 6287 Nodes
3	Zones	289 Internal Zones and 10 External Zones
4	Bus Routes	385 Intra-City and Inter-City Bus Routes
5	Modes	2W, 3W (Auto and Shared Auto), Car, Taxi & Cab and Bus
6	Population and Employment	From CMP 2018, Draft DP For PMR

Based on the above, a traditional four-stage modelling approach has been adopted for this study. The framework of the steps involved in this study for building a model is given below.



The framework for the four-stage model gets inputs from the demand matrices, planning variables such as population, employment, resident workers, students, etc., for building a mathematical equation for simulating the base year and future travel demand for the purpose of planning and policy making.

Each stage has its significance, as described in the section below. Each stage undergoes a series of iterations until the difference between the observed and modelled outputs converges to the desired level. Models developed for each stage have been described in forthcoming sections.

3.5.2 STUDY AREA ZONING

The zoning systems adopted need to be in coherence with those adopted by the local planning bodies and those by the past traffic studies conducted in the region. The zoning system for the study area comprises of 299 zones, of which 289 are Internal Zones and 10 are External Zones (refer to Figure 3-36).

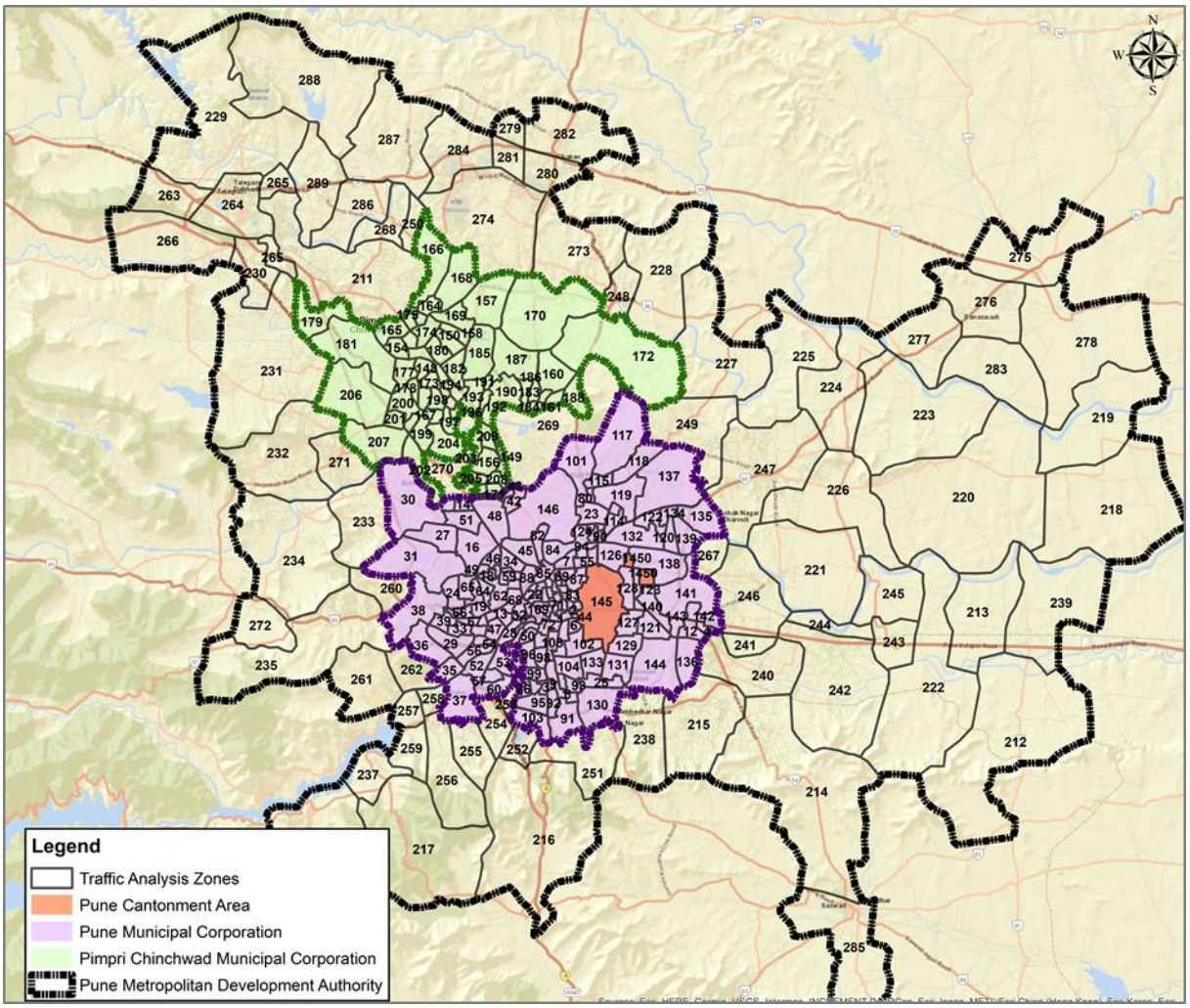


FIGURE 3-36: TRAFFIC ANALYSIS ZONE MAP

3.5.3 NETWORK DEVELOPMENT

The transport network development for the study area comprises two components:

- Highway Network (i.e., 2-Wheeler, Car, Taxi, Auto Rickshaw, and Institutional Bus)
- Transit Network (i.e., Bus and Shared Auto Rickshaw)

3.5.3.1. ROAD NETWORK

The arterials, sub-arterials and major collector roads have been considered for the development of the network. All links are coded as one-way links having A–node (after node) and B–node (before node) with their own characteristics.

The link attributes include road names, capacity, lane configuration, length, toll details (if any), volume count information at junctions, screen line and cordon locations, free flow speed, and bus preload. These link characteristics are compiled and categorized based on functional class for the basic network for study area. The salient features of the coded highway network are presented in Table 3-60.

The capacity of the links and PCU values are according to the IRC standards and Design Manual for Roads and Bridges (DMRB) standards

The form of the BPR function for speed flow is:

$$T_c = T_0 * (1+\alpha * (V/C)^{\beta})$$

Where,

- T_c = Congested Link Travel Time
- T_0 = Link Free Flow Time
- V = Link Volumes
- C = Link Capacity
- α and β – Calibrated Speed Flow Parameters

TABLE 3-60: SALIENT FEATURES OF CODED HIGHWAY NETWORK

S. N.	Lane Configuration	No. of Lanes	Divided/Undivided	Type of Flow	Capacity Per Direction (PCU/Hr)	Free Flow (KMPH)
1	1L-1W-UD	1 Lane	Undivided	One Way	1800	30
2	2L-1W-UD	2 Lane	Undivided	One Way	3600	40
3	3L-1W-UD	3 Lane	Undivided	One Way	5400	40
4	4L-1W-UD	4 Lane	Undivided	One Way	7200	50
5	4L-1W-D	4 Lane	Divided	One Way	7200	50
6	6L-2W-D	6 Lane	Divided	Two Way	7000	60
7	1L-2W-UD	1 Lane	Undivided	Two Way	1200	25
8	2L-2W-UD	2 Lane	Undivided	Two Way	2400	35
9	3L-2W-UD	3 Lane	Undivided	Two Way	3600	35
10	4L-2W-UD	4 Lane	Undivided	Two Way	2150	40

S. N.	Lane Configuration	No. of Lanes	Divided/Undivided	Type of Flow	Capacity Per Direction (PCU/Hr)	Free Flow (KMPH)
11	6L-2W-UD	6 Lane	Undivided	Two Way	3600	50
12	2L-2W-D	2 Lane	Divided	Two Way	1500	40
13	4L-2W-D	4 Lane	Divided	Two Way	4800	50
14	6L-2W-D	6 Lane	Divided	Two Way	7200	60
15	8L-2W-D	8 Lane	Divided	Two Way	4800	60
16	4L-2W-D-Express	4 Lane (Expressway)	Divided	Two Way	3000	80
17	2L-1W-UD-Express	2 Lane (Expressway)	Undivided	One Way	3840	50
18	4L-1W-UD-Flyover	4 Lane (Flyover)	Undivided	One Way	6360	60
19	2L-2W-UD-Flyover	2 lane (Flyover)	Undivided	Two Way	1320	45
20	6L-2W-UD-Flyover	6 Lane (Flyover)	Undivided	Two Way	4320	60
21	4L-2W-D-Flyover	4 Lane (Flyover)	Divided	Two Way	3120	60
22	6L-2W-D-Flyover	6 Lane (Flyover)	Divided	Two Way	4560	70
23	1.5L-2W-UD	Intermediate Lane	Undivided	Two Way	1800	35
24	1.5L-1W-UD	Intermediate Lane	Undivided	One Way	2700	30
25	3L-2W-D	3 Lane	Divided	Two Way	3600	50
L – Lane, 1W – One Way, 2W – Two Way, D – Divided and UD – Undivided						

The coded highway network is presented in Figure 3-37.

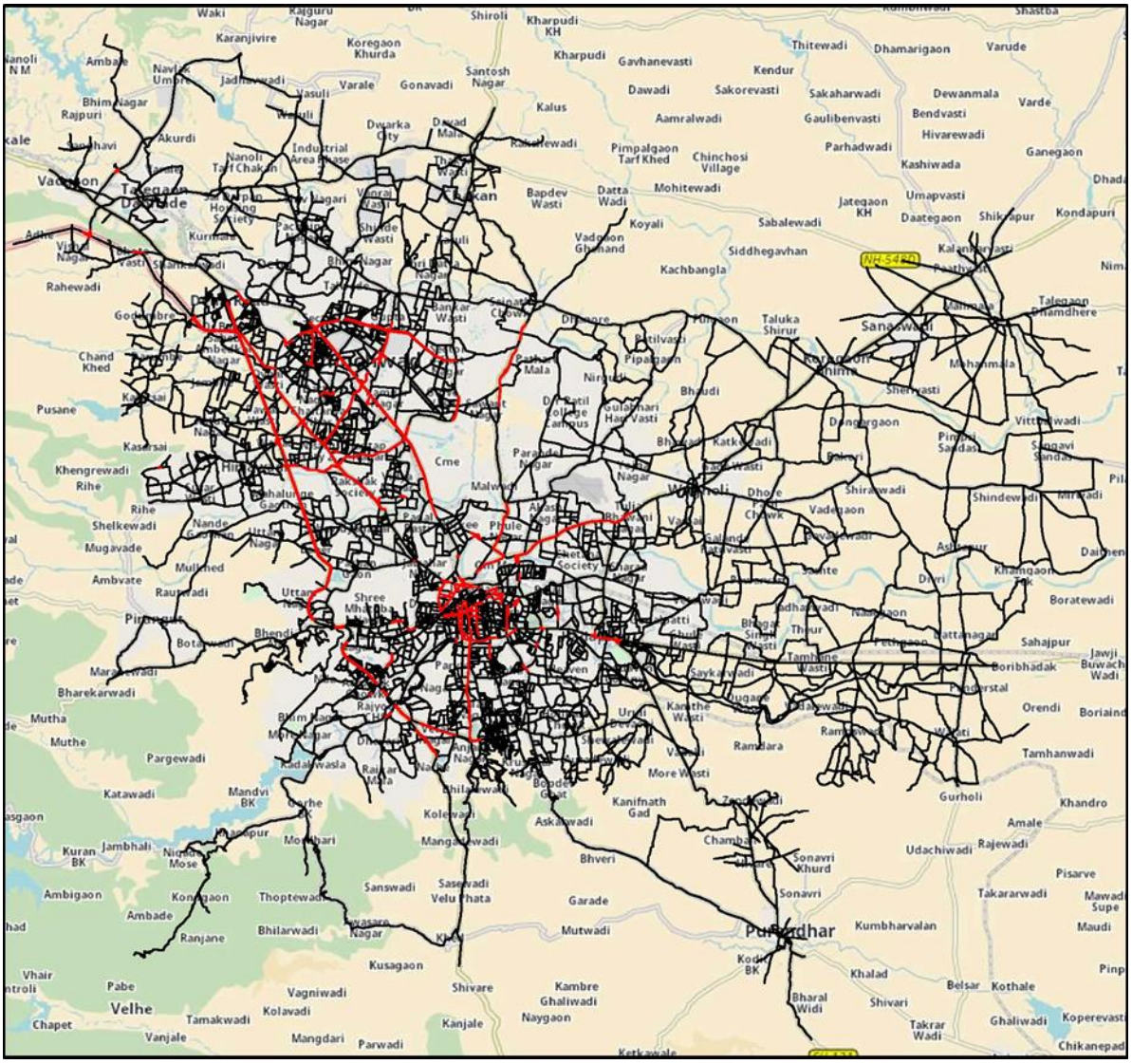


FIGURE 3-37: CODED HIGHWAY NETWORK

3.5.3.2. TRANSIT NETWORK

The transit network represents the connectivity, headways, speeds, and accessibility of the transit services. In PMR, the existing public transport services, i.e., bus, BRTS, and suburban rail, have been included in the model's transit network. The transit routes are specified as those using transport links and having stops/stop at determined locations. The access to the stops from the zone centroid and other nodes is provided either by existing highway links or by defining exclusive walk links. The transit network represents the access/egress connectivity, headways, speeds, and accessibility of transit services to support the estimation of travel times on individual links and passenger volumes on individual transit lines and links.

A total of 385 bus routes with 2594 stops along with public transport schedules and fare structure with reference to different services have been obtained from the respective organizations and are coded for the public transport assignment.

The coded existing public transport network is presented in Figure 3-38.

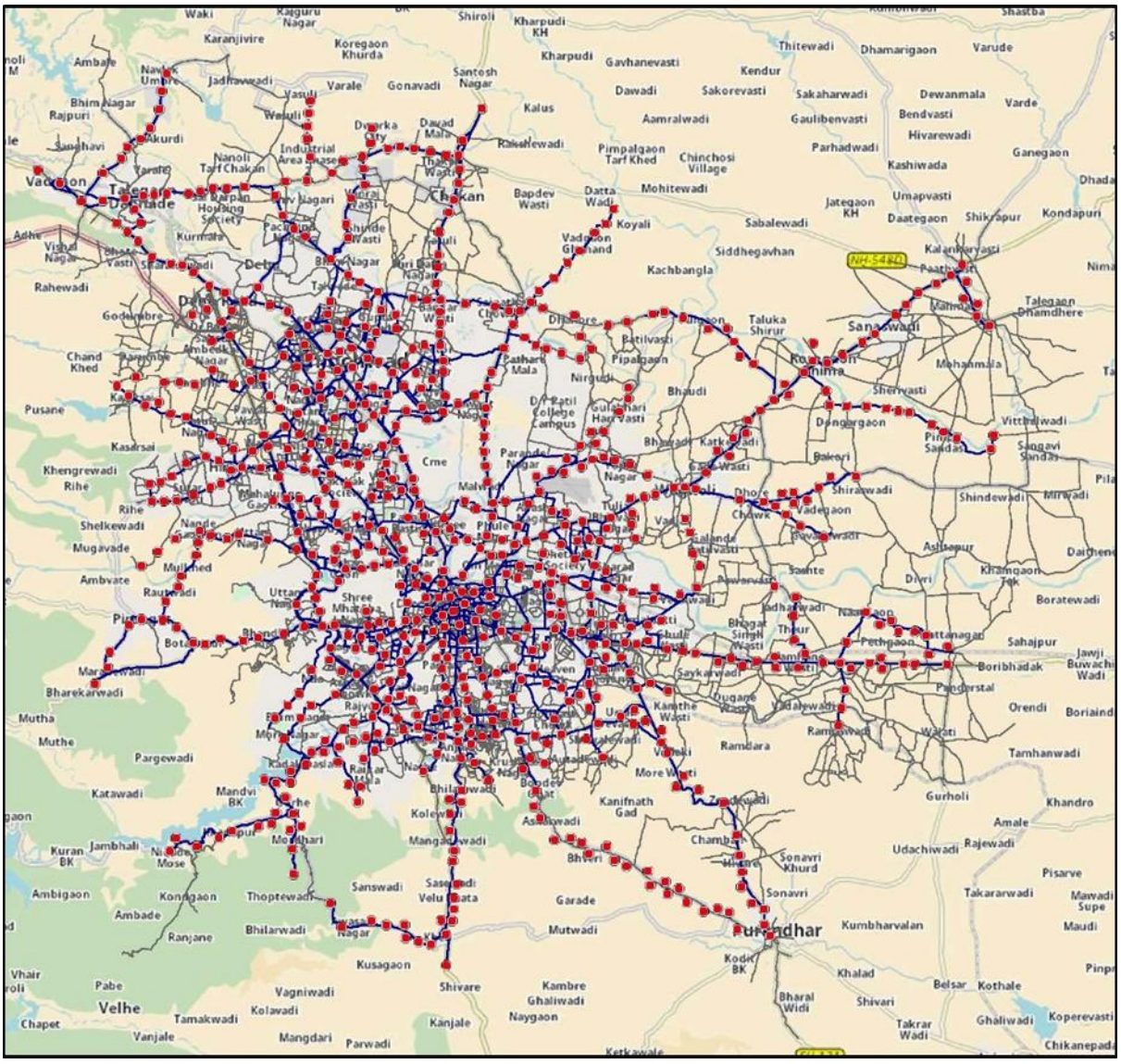


FIGURE 3-38: BASE YEAR PUBLIC TRANSPORT NETWORK

3.5.4 ESTIMATION OF BASE YEAR PLANNING PARAMETERS

For the purpose of the study, Census of India – 2011, DP Plan for PMC, DP Plan for PCMC, Draft DP Plan of PMR, the CMP of PMC and PCMC in PMR – 2018, and various other studies were considered, along with consultations with stakeholders to assess the existing development, the future development directions, and the required transport infrastructure.

Based on the CMP, the anticipated population and employment in the study area for 2022 has been estimated, considering the existing growth, as represented in the above-mentioned studies.

TABLE 3-61: STUDY AREA POPULATION AND EMPLOYMENT FOR THE BASE YEAR

Year	PMC	PCMC	PC	KC	DC	Rest of PMR	Total PMR
Population							
2011	31,24,458	17,27,692	71,781	78,684	48,961	9,39,494	59,91,070
2018	37,13,999	22,73,525	71,781	78,811	52,303	15,62,488	77,52,907
2022	40,41,214	24,70,038	78,831	82,224	56,987	17,08,282	84,37,576
Employment							
2011	11,98,602	5,96,184	27,743	33,674	18,912	5,73,181	24,48,296
2018	14,57,335	6,83,664	27,743	33,674	18,912	8,94,398	31,15,726
2022	15,50,328	7,66,983	27,901	32,639	18,761	10,62,805	34,59,417

3.5.4.1. BASE YEAR TRAVEL PATTERN

O-D matrices were extracted from various sources as mentioned below:

1. Mode-Wise Validated Peak Hour O-D Matrices of CMP – 2018: These matrices covered both inter-city and intra-city trips and were extrapolated to 2022 based on appropriate growth factors.
2. Mode-Wise Peak Hour O-D Matrices for the current study were extracted from the following:
    a. Household Survey
    b. Outer Cordon O-D Surveys
    c. Terminal O-D Surveys
    d. Bus Stop O-D Surveys

Based on the variation observed between the CMP-validated matrices, which were extrapolated to 2022, and the base year O-D matrices derived from the primary surveys, area-wise COVID-appropriate factors were applied to derive a combined matrix which represents the trip movement of the study area.

The mode-wise matrices have been developed for the morning peak hour. From the primary surveys, the morning peak is observed to be during 09:30 am to 10:30 am.

The base year daily travel demand for Pune is presented in Table 3-62.

TABLE 3-62: SUMMARY OF BASE YEAR DAILY TRAVEL DEMAND

Trip Component	TW	Car	Auto	Taxi	PT	Total
Peak Hour Passenger Trips						
I to I	37,04,658	9,31,699	5,70,080	1,15,241	12,78,257	65,99,934
I to E	94,917	99,062	2,852	4,648	58,519	2,59,998
E to I	60,952	86,705	3,220	7,283	51,876	2,10,036
E to E	27,139	32,693	822	1,548	12,234	74,435
Total	38,87,665	11,50,159	5,76,974	1,28,720	14,00,885	71,44,402

Trip Component	TW	Car	Auto	Taxi	PT	Total
%age of Peak Hour Passenger Trips by Travel Pattern						
I to I	95%	81%	99%	90%	91%	92%
I to E	2%	9%	0%	4%	4%	4%
E to I	2%	8%	1%	6%	4%	3%
E to E	1%	3%	0%	1%	1%	1%
Total	100%	100%	100%	100%	100%	100%
%age of Peak Hour Passenger Trips by Mode Share						
I to I	56%	14%	9%	2%	19%	100%
I to E	37%	38%	1%	2%	23%	100%
E to I	29%	41%	2%	3%	25%	100%
E to E	36%	44%	1%	2%	16%	100%
Total	54%	16%	8%	2%	20%	100%

The base year matrices were calibrated to the traffic volumes counts and bus boarding and alighting count collected as part of the study.

This is an iterative process carried out using the T Flow Fuzzy Model in VISUM, where the corrected matrices in the first iteration are assigned again after the relevant network corrections until a satisfactory error is achieved, i.e., calibrated and validated model. A very high level of network model accuracy is targeted to accurately represent the traffic and transportation conditions in the PMR. The validation process of the Base Year Passenger Matrices is represented in Figure 3-39.

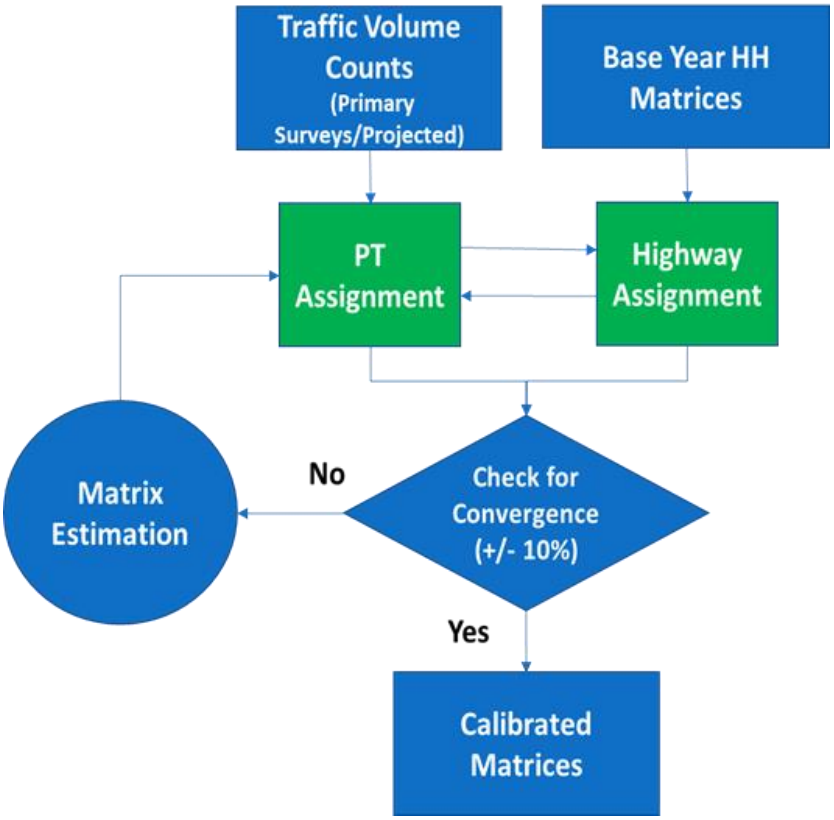


FIGURE 3-39: METHODOLOGY FOR THE CALIBRATION OF MATRICES

Trip Generation

Trip generation is the first stage of travel demand modelling which involves the process of estimating the total number of trips produces by (Oi) and attracted to (Dj) each zone of a study area. The trip generation model outputs the scalar data (column data).

TABLE 3-63: TRIP GENERATION MODELS

Equation	R^2	F Value	T-Stat	Trips (Observed)	Trips (Modelled)	%Error
Production = 0.0810 X Population +190.92	0.70	251.96	2.24	7,39,192	7,16,645	-3.1%
Attraction = 0.1342 X Employment +982.39	0.72	541.93	9.77	7,51,112	7,16,653	-4.6%

Trip productions are influenced by the population of a zone, while trip attractions are influenced by the employment in a zone.

Trip Distribution

Trip generation outputs are fed into the trip distribution model to generate the production-attraction matrix. Trip generation output is a scalar data (column data), which is converted to scalar data (matrix data), using the trip distribution model.

In this study, the doubly constrained gravity model of the following form has been calibrated to represent the base year travel pattern for the study area

$$Tij = Ai\ Oi\ Bj\ Dj\ Fij$$

Where,

- T= Number of inter-zonal trips
- O= Total generation trip ends by zone
- D= Total attraction trip ends by zone
- I= Generation Zone
- J= Attraction Zone
- A, B= Balancing factors (constants)
- Fij= Deterrence function = $C^{\alpha}ije^{-\beta Cij}$
  - Where C= Travel distance between zones
  - α= Calibration Constant – Power function
  - β= Calibration Constant – Exponential function

The gravity model was calibrated on the intra-region trips performed using the zone to zone shortest distance matrix generated. Friction factors were calibrated for obtaining observed and estimated trip lengths. Iterative procedure has been used to calibrate the friction factors. The calibrated deterrence function for trip distribution is presented in Table 3-64.

TABLE 3-64: CALIBRATED DETERRENCE FUNCTION

Mode	α	β	OBSERVED AVG.TL	MODELLED AVG. TL	COINCIDENCE RATIO
2W	0.079628	-0.1607	8.4	8.8	0.97632249
Car	0.151772	-0.07565	13.0	13.5	0.96950742
Auto	0.908104	-0.49565	4.6	5.2	0.9698304
PT	0.579329	-0.20158	9.4	9.7	0.96427288
Taxi	0.284627	-0.14477	10.4	10.7	0.95970463
All	-0.30385	-0.09489	9.0	9.4	0.94389765

The comparison of trip length frequency distribution between the observed and the modelled trips is represented in Figure 3-40.

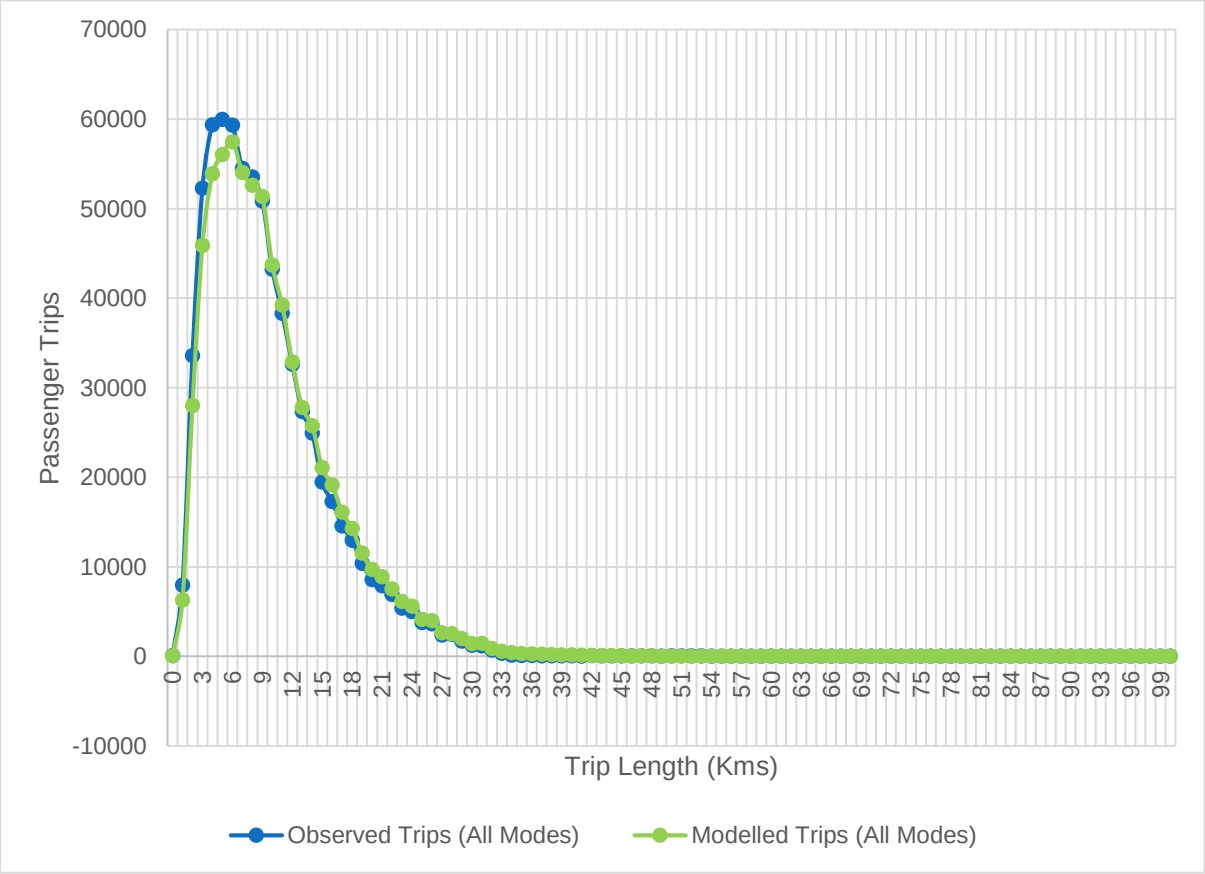


FIGURE 3-40: OBSERVED AND MODELLED TRIP LENGTH FREQUENCY DISTRIBUTION (ALL MODES)

Mode Split

For the assignment purposes, public and private modes were considered. As mentioned earlier, private transport comprises 2-wheelers, cars, autos and taxis, whereas public transport comprises of the bus. The mode-wise share of the public and private modes for the base year has been obtained from the primary surveys and compared with the modelled shares (refer to Table 3-65).

TABLE 3-65: BASE YEAR OBSERVED AND MODELLED MODE SHARES (MOTORIZED MODES)

Mode	Observed		Modelled		%age Error
	Trips	%age	Trips	%age	
2W	4,07,132	56.2%	4,07,131	56.8%	1.1%
Car	1,02,116	14.1%	1,02,112	14.2%	1.1%
Auto	62,964	8.7%	54,781	7.6%	-12.0%
PT	1,40,099	19.3%	1,40,097	19.5%	1.1%
Taxi	12,527	1.7%	12,527	1.7%	1.1%
All	7,24,839	100.0%	7,16,647	100.0%	-1.5%

Trip Assignment

Traffic assignment is the process allocating the estimated traffic volume on various links of the model to simulate present conditions.

The process requires as input a complete description of the existing transportation system, and a matrix of inter-zonal trip movements. The output of the process is an estimated trip on each link of the transportation system.

- **Assignment of the Private Trips**

  The calibrated O-D matrices generated from the various iterations were assigned to the supply road network. The daily matrices of the private modes, i.e., 2-wheeler, 3-wheeler and 4-wheeler person trips, are converted to peak hour O-D matrices in Passenger Car Units (PCUs) by applying peak hour percentage and passenger to PCU conversion factors. Then the matrices are assigned to the network for private trips assignment using Equilibrium Assignment in VISUM.

  Figure 3-41 represents the assignment of the private trips to the study area network. The V/C ratios more than 1.0 indicate that the operating conditions are beyond the road capacity, which is not desirable. V/C ratios between 0.70 and 1.0 indicate that there is less freedom to manoeuvre and high density of traffic volume.

- **Assignment of the Public Transport Trips**

  The public transport network consists of all the road links coded with appropriate characteristics like length, speed, etc. The bus routes are defined by specifying the links on which these routes traverse. Each route is characterised by its frequency, capacity, crush load, fares, etc. In addition, access and egress connectors for walk and transfers are built using a Public Transport Program. Public transport assignment is done based on a headway-based approach. The peak hour O-D matrix of public transport passenger trips is assigned to the preloaded highway network (refer to Figure 3-42).

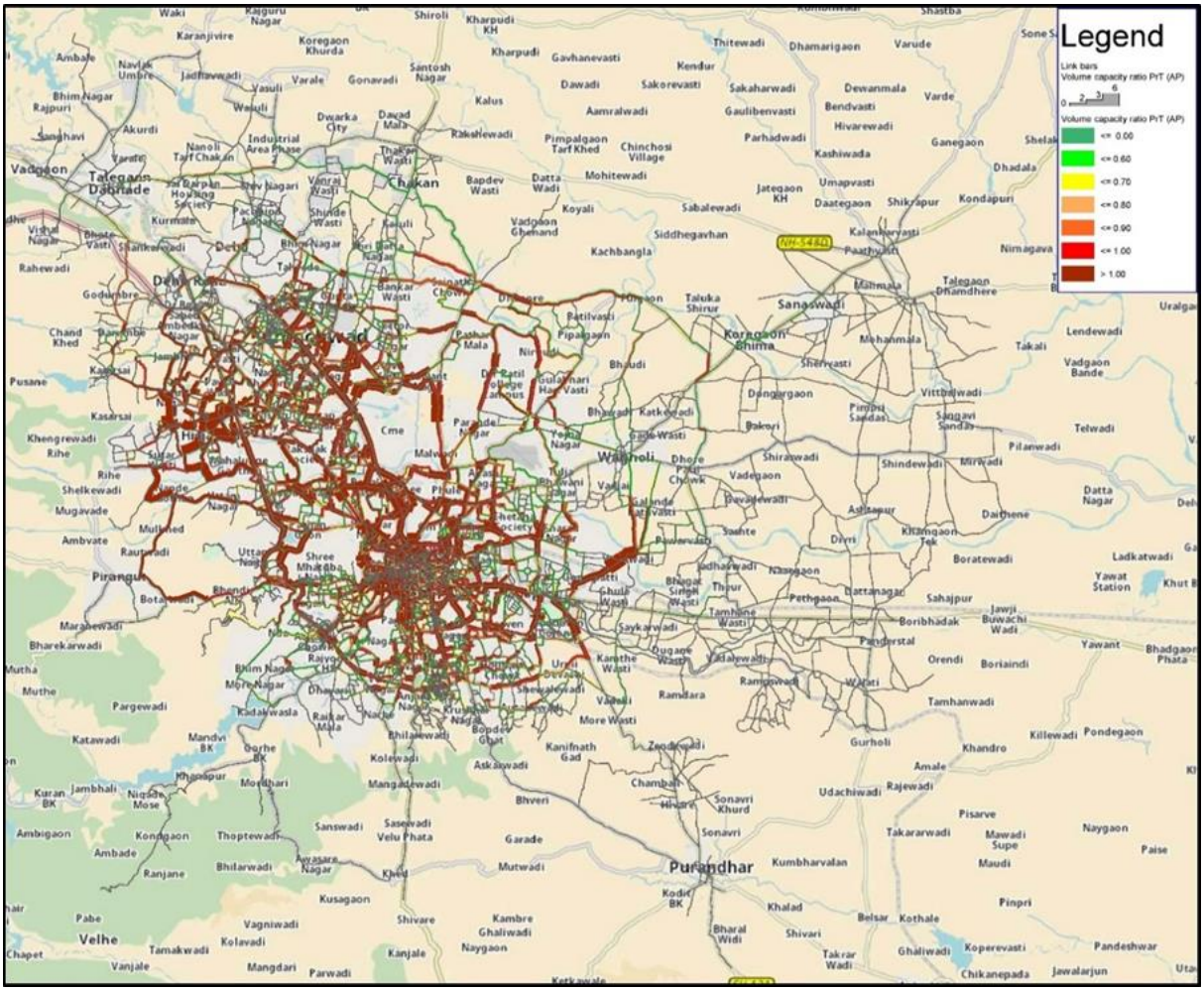


FIGURE 3-41: TRAFFIC FLOW MAP FOR PMR- 2022

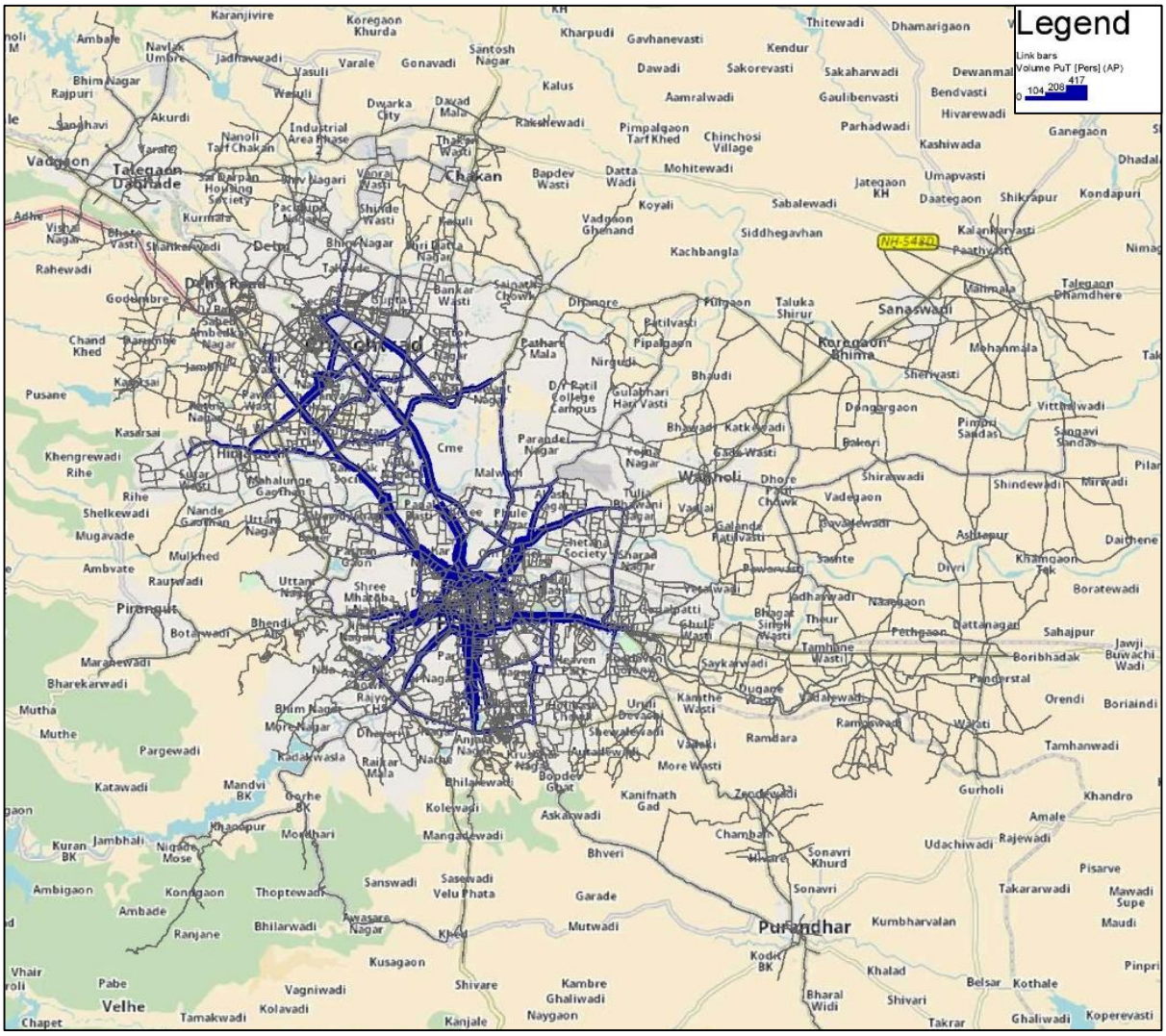

Legend
Link bars
Volume PuT [Pers] (AP)
0
104
208
417
Pune
Pimpri-Chinchwad
Hinjawadi
Wakad
Baner
Aundh
Kothrud
Karve Nagar
Warje
Dhankawadi
Katraj
Bibwewadi
Kondhwa
Hadapsar
Magarpatta
Wanowrie
Kharadi
Viman Nagar
Yerawada
Kalyani Nagar
Koregaon Park
Camp
Deccan Gymkhana
Shivajinagar
Model Colony
Erandwane
Bavdhan
Pashan
Sus
Mahalunge
Chakan
Talegaon Dabhade
Lonavala
Khadki
Dapodi
Bhosari
Alandi
Dehu
Sinhagad Road
Dhayari
Narhe
Ambegaon Budruk
Purandhar
Velhe
Haveli
Mulshi
Pirangut
Mundhwa
Wagholi
Lohegaon
Vishrantwadi
Dhanori
Kharadi
Chandan Nagar
Khadki
Shivajinagar
Deccan Gymkhana
Camp
Koregaon Park
Kalyani Nagar
Yerawada
Viman Nagar
Kharadi
Wanowrie
Magarpatta
Hadapsar
Kondhwa
Bibwewadi
Katraj
Dhankawadi
Warje
Karve Nagar
Kothrud
Erandwane
Model Colony

TABLE 3-66: COMPARISON OF OBSERVED AND MODELLED TRIPS

S. N.	Name of the Location	Private Vehicles (PCUs)			Public Transport		
		Observed	Modelled	% Error	Observed Passengers	Modelled Passengers	% Error
1	MB_01_Pashan Road	5231	5660	8%	1245	1341	8%
2	MB_02_Jagannath Shankarseth Road	5459	5984	10%	5045	5667	12%
3	MB_03_Spine Road	9042	9810	8%	317	327	3%
4	MB_03_Spine Road service road	3294	3436	4%	675	629	-7%
5	MB_03-Spine Road service road	1814	1946	7%	0	0	0%
6	MB_04_LB Shastri Road	5080	4430	-13%	3126	3017	-3%
7	MB_05_Senapathi Bapat Road	6931	6510	-6%	1902	1818	-4%
8	MB_06_Lokmanya Bal Gangadhar Tilak Road	5149	4728	-8%	5166	5120	-1%
9	MB_07_Nashik Road	4815	4465	-7%	1441	1511	5%
10	MB_08_Timber Market Road	7934	7829	-1%	4965	5097	3%
11	MB_09_Aundh Ravet BRTS Road	6707	7000	4%	1450	1400	-3%
12	MB_10_Nigdi Bhosari Road	2369	2307	-3%	2540	2760	9%
13	MB_11_Wakad Bhosari BRTS Rd	5502	5732	4%	3126	3390	8%
14	MB_12_Mumbai Pune Bypass Rd	5785	5896	2%	1406	1350	-4%
15	SL_01_Talegaon MIDC	331	341	3%	204	210	3%
16	SL_02_Dehu Road	4569	4405	-4%	666	672	1%
17	SL_03_Akurdi Chikhali Road	9075	8554	-6%	714	718	1%
18	SL_04_Kalewadi road ROB	12178	10981	-10%	272	252	-7%
19	SL_05_Bhau Patil Road	4931	5078	3%	2356	2088	-11%
20	SL_06_Dhanori Alandi Road	3686	4344	18%	68	55	-19%
21	SL_07_KB Joshi Path	6758	7130	6%	488	488	0%
22	SL_08_HK Firodia Bridge	11783	9815	-17%	3378	3940	17%

S. N.	Name of the Location	Private Vehicles (PCUs)			Public Transport		
		Observed	Modelled	% Error	Observed Passengers	Modelled Passengers	% Error
23	SL_09_Connought Road	10368	10723	3%	7752	8470	9%
24	SL_10_Ghorpadi Road	4406	4754	8%	952	899	-6%
25	SL_11_BT Kawade Road	2710	2865	6%	816	841	3%
26	SL_12_Solapur Road Kirloskar	12120	11767	-3%	4659	4934	6%
27	SL_13_Hadapsar Road	7284	7811	7%	1034	1076	4%
28	SL_14_Westernly Bypass	20555	21695	6%	2131	2052	-4%
29	SL_15_Mhatre Bridge	6701	7060	5%	425	461	8%
30	SL_16_Lakdi Bridge	6489	7292	12%	10248	10903	6%
31	SL_17_Maha Rishi Shinde Bridge	4329	4724	9%	23	20	-13%
32	SL_18_Shivaji Bridge_Nava Pul	10220	11230	10%	8884	9411	6%
33	SL_20_Koregaon Park Road	8612	7438	-14%	460	432	-6%
34	SL_21_Magarpatta River Bridge	18878	17566	-7%	1864	1752	-6%
35	SL_22_HH Aga Khan Bridge	8978	8824	-2%	204	192	-6%
36	SL_23_Harris Bridge	10866	11230	3%	1054	1024	-3%
37	SL_24_Sangam Cross Road	3566	3893	9%	405	352	-13%
38	SL_25_Yerwada Bridge 1	7049	7336	4%	5894	6047	3%
39	SL_26_Yrwada bridge 2	5391	4916	-9%	3590	3877	8%
40	SL_27_Alandi Road	7208	7274	1%	1959	1853	-5%
41	SL_28_Jai Ganesh Chowk_Spicer Road	5125	5949	16%	0	0	0%
42	SL_29_Aundh Ravet BRTS Road	10048	9415	-6%	8433	8498	1%
43	SL_31_Mahatma Jyotiba Phule Bridge	4129	3596	-13%	3	3	9%

The model is validated for the passengers boarding and alighting at major bus stops at the peak hour, which is represented in Table 3-67**.** The error between the observed and the modelled trips at the bus stop locations falls within +/-15%

TABLE 3-67: COMPARISON OF OBSERVED AND MODELLED PASSENGERS AT BUS STOPS

Code	Bus Stop Location Name	Observed	Modelled	% Error
BS_01	Kasturba Gandhi General Hospital	181	173	-4%
BS_02	Viman Nagar Corner	211	248	17%
BS_03	Kharadi Bypass	1421	1212	-15%
BS_04	Sri Satyam Society	1249	1264	1%
BS_05	Wagholi	52	57	9%
BS_06	Katraj	2954	2841	-4%
BS_07	Padmavati Private Bus Stop	1003	1178	17%
BS_08	Vasantbaug Chowk	186	211	14%
BS_09	Mount Caramel School	586	486	-17%
BS_10	Vaidwadi	534	543	2%
BS_11	MG Road	259	288	11%
BS_12	Ramakrishna Math	515	497	-3%
BS_13	PL Deshpande Udyan	53	44	-16%
BS_14	Warje	321	336	5%
BS_15	Pune Vidyapeeth	100	110	10%
BS_16	Paud Fata	27	29	7%
BS_17	Alandi Phata	41	41	1%
BS_18	Chimbali Phata	67	78	16%
BS_19	Bhosari PMT Chowk	994	829	-17%
BS_20	Shinde Farm	2421	1948	-20%
BS_21	Malwadi Kiratwadi	112	123	10%
BS_22	Nanded City	321	367	14%
BS_23	Vadgaon Phata	753	834	11%
BS_24	Prasanna Bungalow	3	4	40%
BS_25	Mundhwa Gaon	284	247	-13%
BS_26	Moshi Gaon	462	500	8%
BS_27	Deccan Corner	757	790	4%
BS_28	Wadia Bungalow	151	137	-9%
BS_29	Mandai Stand	359	318	-11%
BS_30	Army College	65	63	-3%

Since the difference between the observed and modelled flows at the screen lines and bus stop locations is within +/-20%, the base year network modelled is validated and is used for the transport demand forecasting.

3.6 TRAVEL DEMAND FORECASTING

The calibrated/validated travel demand model is used to forecast the horizon year demand forecast on all the proposed MRTS corridors for the horizon years under the planned growth scenarios. The model output has been used to assess the ridership of the Mass Transit Corridors identified as part of Phase-2 MRTS for Pune.

3.6.1 GROWTH DIRECTION

Spatial growth of the study area is guided by the development of transport corridors, industrial and commercial developments, as well as major projects such as Ring Road and New Airport. Some major transport infrastructure proposals that will have a significant influence on land use are:

- Metro corridors
- PMRDA Ring Road
- Bypass Rail Line
- Green Field Airport at Purandar
- Hyperloop connecting Mumbai with Pune

During the last decade, the population has expanded majorly towards the north, north-west and west. The recent and upcoming growth direction based on real estate activity is summarized in **Table** 3-68.

TABLE 3-68: GROWTH DIRECTION BASED ON REAL ESTATE ACTIVITY[79]

S.N.	Direction	Areas	Remarks
1	South-east	Saswad, Undri, Pisoli	Development of residential areas. Connectivity of Undri to Hadapsar, Magarpatta, Kharadi is the key advantage As Wanowrie, Kondhwa and NIBM Road areas are developed, the focus is shifted to Undri, Pisoli, etc., Once the Ring Road is built, this pocket will see major development.
2	North-west	Punawale/Ravet	It has good connectivity to Hinjewadi IT Park. It has good social infrastructure such as road connectivity, schools/colleges, etc. The first TP Scheme is proposed in Mann Mhalunge near Hinjewadi.
3	East	Kharadi, Wagholi	Kharadi is the IT hub which has developed. It has good accessibility to the airport, railway station, and areas like Kalyani Nagar, Hadapsar. Wagholi has tremendous potential as the Ring Road passes before Wagholi.
4	North-east	Alandi/Dighi/Charoli	Residential Growth

79 Source: CMP for PMC and PCMC in PMC – March 2019

- The current development is happening mainly towards Mumbai along NH-4, Hinjewadi, Mahalunge, Gahunje, Talegaon and Dehu.
- The second level of development is along the Pune-Nagar Road, towards Kharadi, Wagholi, Kesnand, Loni, Ranjangaon, Shikrapur, etc.
- The third level of developments are along the Pune-Nasik Road, towards Moshi, Chakan, but development here is stunted due to the withdrawal of the airport plan. But the proposed Pune-Nasik rail corridors and expansions in MIDC development may accelerate development in the future.
- Developments along the Pune-Solapur Road are happening at a slower pace due to water scarcity. However, development along the Solapur Road may pick up pace with the proposed greenfield airport in Purandar. Some developments are also happening along Pune-Satara Road, after the Ghats section, i.e., Nasrapur, etc.

The Ring Road is likely to attract developments in the south-eastern side in the future due to the proposed airport in Purandar. Over ten Town Planning Schemes (TPS) have been proposed between Satara Road and Solapur Road, where major development is envisaged at Urali, Wadaki, Fursungi, Hinjewadi, Holkarwadi, Nimbalkarwadi. Jambhulwadi, Ambegaon, etc. However, this belt is getting developed haphazardly. TPS may come up between the Solapur to Nasik Road with Nagar Road Wagholi as the center, where a mix of IT, industrial and residential development is proposed.

The proposed ring road will redefine the boundary of urban growth. As mentioned above, Pune region's future growth direction is mapped and the same is shown in Figure 3-43.

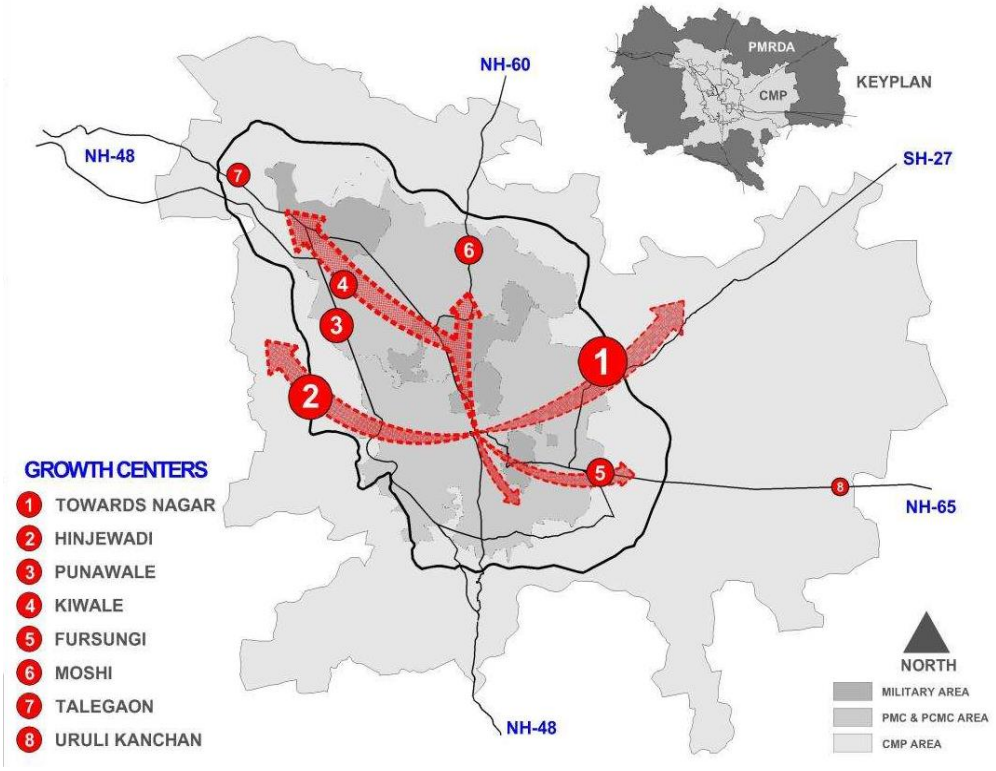


FIGURE 3-43: GROWTH DIRECTION OF PUNE

West, North-West and North: IT and Auto Hub

PCMC MIDC is fully developed but there is further scope for development in Talwade etc., Two phases of Hinjewadi are fully functional, whereas two further phases are in the development and land acquisition stage. The phase-wise stage of development as per MIDC is presented below.

- Phase-1: 96.42 acres (100% completed)
- Phase-2: 236.25 acres (100% completed)
- Phase-3: 351.17 acres (30% completed)
- Phase-4: 464.39 acres (planning stage)

The next stage of developments in Hinjewadi will depend largely upon the space for IT developments as well as land acquisition for the third and fourth phases, in which the cost of land acquisition will play a critical role. The high land cost may make the developments unviable. It is observed that large-scale residential development is coming up in and around Hinjewadi. The Mann Mahalunge Town planning scheme is the first TPS launched by PMRDA. Big townships like Blue Ridge, Xerbia, Megapolis, etc., are catering to the residential demand of employees in Hinjewadi.

Since the area was not planned for residential use and is now getting converted to a high-end residential area, there is a need for social and neighbourhood level planning in Hinjewadi. The existing employment is around 1.75 lakhs, which are direct employees as per Hinjewadi Industrial Association sources. Employment is likely to cross 5 lakhs in the next 5-10 years.

In the north-west, Punawale/Ravet is going to develop due to good connectivity and proximity to the Hinjewadi IT hub. The Chakan area has been developed as an auto component hub. Some of the SEZs proposed in this area could not take off. Shifting the airport from this area has also affected development activity, but it may pick up once there are more investments in the manufacturing sector in surrounding areas.

The proposed Pune-Nashik railway line will also trigger development.

Areas like Wakad, Baner, Balewadi, Sutarwadi, Pashan, and Aundh have developed over the last 5-10 years in the west, north-west, and north. However, there is still scope for development in these areas. The areas that are likely to be developed in the future are Mann, Mahalunge, Punavale, Kiwale, Ravet, etc.

North-East: IT, BPO and Manufacturing

The north-east has major potential for growth, especially the corridor along the Nagar Road which connects industrial areas like Shikrapur and Ranjangaon. IT and BPO companies have established offices in Wagholi, Kharadi, Kalyani Nagar, Yerwada, Bund Garden along Pune-Nagar Road and are developed. Residential development in Viman Nagar, Lohagaon, Dhanori, Kesnand, Kharadi, and Wagholi is happening rapidly.

PCMC has large developable lands along the north-east, i.e., Charoli, Moshi, Chimbali and Talwade. This area is zoned under 'residential' in the PCMC Master Plan. Internal road development in this area will trigger development; in fact, a road connecting Lohagaon to Charoli will be developed shortly as per PCMC.

The stay on development along stone quarries is being gradually lifted and development is also taking place at locations like Alandi, Wadmukhwadi, Chovisawadi, etc.

The land portion between Pune-Nagar Road and Pune-Solapur Road is mainly agricultural. Improved connectivity can trigger development in these areas.

South and South-East: Airport

IT-related developments have already taken place in the Hadapsar area. Magarpatta Cyber City and Amanora City have also developed. PMC's growth towards the extreme south and beyond its boundaries has limitations due to the presence of hills and forests. However, due to the development of the airport and TP schemes along the road, plain areas will get developed.

Access to these areas, especially to the airport, should be given high priority. Saswad Town will also receive a boost due to airport development.

South-Western Development Constraints

Expansion in the south and south-west areas has been triggered by the Mumbai-Pune expressway link. The areas of Kothrud, Warje, Karve Nagar, and Wadgaon have developed. Development is also happening in Pirangut, Bhugaon Bavdhan, etc., but since this area has the geographical constraints of the Western Ghats and dams, the development here will be restricted.

3.6.2 PLANNING VARIABLES PROJECTIONS

Review of Past Growth

As mentioned in Section 1.3 of Chapter 1, the population of the study area is 59.73 lakhs, as per the 2011 census, and the estimated current population (2022) is about 84.37 lakhs. Past trends of the population in the study area are presented in Table 1-1. It can be observed that, during the last decade, 5.76 lakhs and 7.22 lakh population were added to PMC and PCMC, respectively. The corresponding decadal growth of population is 23% and 72%, respectively. The overall population growth rate in the study area in the last decade is 42%.

Population Forecast

Population forecast is based on several considerations:

- Development plan, existing and proposed land use
- Past growth trends

- Major transport infrastructure projects such as Metro, BRTS, Ring Road and Airport, TP schemes, etc.
- Growth direction and transport infrastructure likely to be developed
- Density already achieved and scope for further densification ward-wise based on developed land

Based on the above considerations, a population forecast has been made for 30 years and presented in the table below.

TABLE 3-69: POPULATION FORECAST

Year	PMC[80]	PCMC	PC	KC	DC	Rest of PMR	Total PMR
Population							
2011	31,24,458	17,27,692	71,781	78,684	48,961	9,39,494	59,91,070
2018	37,13,999	22,73,525	71,781	78,811	52,303	15,62,488	77,52,907
2022	40,41,214	24,70,038	78,831	82,224	56,987	17,08,282	84,37,576
2027	45,93,097	27,86,902	90,201	94,083	65,366	19,38,022	95,67,671
2037	57,21,404	34,22,584	1,13,943	1,18,848	82,975	24,06,628	1,18,66,382
2047	66,17,232	39,05,200	1,33,430	1,39,500	97,858	27,76,768	1,36,69,988
2057	72,28,939	42,10,036	1,47,259	1,54,318	1,09,011	30,26,298	1,48,75,861

Employment Forecast

At present, the Work Force Participation Rate (WFPR) for PMC and PCMC is 39% and 38%, respectively. Current employment in the study area is 34.59 lakhs, which is expected to increase to 69.01 lakhs by 2057. The employment data is compiled based on the census, household survey and industrial employment data obtained from the Directorate of Industries, Pune. The forecast is based on the current and proposed land use, discussions with various agencies like MIDC and Hinjewadi Industrial Association, etc. The employment forecast thus obtained is presented in Table 3-70.

TABLE 3-70: EMPLOYMENT FORECAST

Year	PMC	PCMC	PC	KC	DC	Rest of PMR	Total PMR
Employment							
2011	11,98,602	5,96,184	27,743	33,674	18,912	5,73,181	24,48,296
2018	14,57,335	6,83,664	27,743	33,674	18,912	8,94,398	31,15,726
2022	15,50,328	7,66,983	27,901	32,639	18,761	10,62,805	34,59,417
2027	18,01,139	8,90,419	32,570	38,101	21,900	12,33,240	40,17,369
2037	23,16,120	11,43,344	42,283	49,463	28,432	15,81,982	51,61,624
2047	27,31,778	13,46,593	50,349	58,899	33,855	18,61,370	60,82,844
2057	31,02,013	15,26,887	57,720	67,521	38,812	21,08,513	69,01,466

80 Abbreviations represented in the Table 3-69 and Table 3-70
- PMC – Pune Municipal Corporation,
- PCMC – Pimpri Chinchwad Municipal Corporation,
- PC – Pune Cantonment,
- KC – Kirkee Cantonment,
- DC – Dehu Cantonment,
- PMR – Pune Metropolitan Region

3.6.3 MODE SHARE

The assessment of the modal share for the horizon years is undertaken based on the stated preference (SP) survey undertaken as part of the current study. The same is discussed in the section below.

Mode Share Projections – Stated Preference

The stated preference model is constructed using the stated preference data collected using the household survey. The survey records the preferences of people using a questionnaire which gives individuals an option to rate an alternative choice of improved public transport with respect to their existing mode of travel.

The stated preference model is a Multi Nomial Logit (MNL) model that works on the principle of utility maximization, which assumes that people choose a mode with the highest utility (least disutility).

The probability of an individual choosing the alternative 'j' (Pj) among 'i' modes using MNL model is given as,

$$Pj = \frac{e^{V_j}}{\sum_{all} e^{V_i}} \quad \text{.....Equation 2}$$

Where,

- V_j = aj+b1*X1+b2*X2+…….
- aj = Alternative specific constant for mode 'j'
- b1, b2 are calibrated beta coefficients for the explanatory variable X1, X2 for each of the alternative mode, and
- i, j are the indices for alternative modes in a choice set.

As in the current case, the stated preference model is developed considering the choice between the existing mode and an improved public transport mode. The data set where the respondents have mentioned that they 'may shift' and they 'will shift' have been considered for building the stated preference model.

Model Parameter Estimations

Based on the above, the Generalized Cost for each mode has been worked out using the following equation:

GC = VOT*TT+TC

Where,

- VOT = Value of Travel Time
- TT = Travel Time – which comprises of Wait Time +Access Time +In Vehicle Time + Egress Time of the respective modes

- TC = Travel Cost - which comprises of Access Egress Cost+Travel Cost+Parking Cost of respective modes.

The parameters of the Generalized Cost are given in the Table 3-71.

TABLE 3-71: GENERALIZED COST PARAMETERS

Mode	Generalized Cost (Rs/Min)
2W	**88.52**
4W	**125.00**
3W	**165.48**
Taxi	**145.00**
Improved PT[81]	**105.00**

Based on the above Generalized Cost, the utility equations for the alternative modes in a choice set are represented in the Table 3-72.

TABLE 3-72: UTILITY EQUATION FOR ALTERNATIVE MODES

2W	V1 = 0.257136*Log (GC of 2W)-0.974287	Equation 3
4W	V2 = 0.257136*Log (GC of Car)+0.37478	Equation 4
3W	V3 = 0.257136*Log (GC of 3W)+0.913077	Equation 5
Taxi	V4 = 0.257136*Log (GC of Taxi)+2.2975	Equation 6
Improved PT	V5 = 0.257136*Log (GC of Improved PT)	Equation 7

Model Interpretation

- Estimated parameters show that people are more sensitive to travel time than travel cost (travel time has higher disutility than travel cost)
- A higher proportion of private mode users are willing to shift to improved public transport than bus and auto-rickshaw users.

Model Assumptions

- Mass Transit Network – covering ~65 km of Phase 1 Metro, including the extensions of Line 1, i.e., PCMC to Nigdi and Swargate to Katraj, PMRDA Line 3 and its proposed extensions, all proposed corridors of Phase 2 of Pune MRTS i.e., Vanaz to Chandani Chowk, Ramwadi to Wagholi/Vitthalwadi, Kharadi to Khadakwasla with spur line of Paud Phata to Manik Baug and PMC HCMTR.

- Vehicle Operating Cost (VOC) for 2-wheelers will grow at -1% per annum and for cars will grow at -0.5% per annum considering that the efficiency of the engines will improve in the future due to improved vehicle technology, resulting in fuel efficiency and better road conditions. The maintenance cost shall also decrease due to the improved technology.

81 Improved PT includes Bus and Metro

- With the onset of electric vehicle technology in both private and public section vehicles, some impact on the VOC and VOT has been considered (i.e., 10% to 20% reduction in the unit travel cost).
- The travel cost of private vehicles is assumed to grow at 2% per annum in line with the per capita income growth in real terms (above inflation).
- The fare of Metro/Mass Transit is expected to increase at the rate of ½ time lower than the actual, whereas the fare of bus services and auto rickshaws will grow w.r.t inflation.

Model Outputs

The mode-wise projected travel demand for the horizon years of 2027 to 2057 is represented in Table 3-73**.**

TABLE 3-73: MODE-WISE PROJECTED TRAVEL DEMAND IN THE HORIZON YEARS (PEAK HOUR)

Mode	Peak Hour Passenger Trips				Mode Share (%)			
	2027	2037	2047	2057	2027	2037	2047	2057
2W	426,703	430,283	419,488	408,774	51.48%	42.80%	36.56%	32.71%
3W	75,558	55,125	50,753	49,546	9.12%	5.48%	4.42%	3.96%
4W	81,827	107,740	105,214	105,104	9.87%	10.72%	9.17%	8.41%
Taxi	16,703	15,913	13,318	12,740	2.02%	1.58%	1.16%	1.02%
Bus	162,618	194,904	272,957	327,282	19.62%	19.39%	23.79%	26.19%
Metro	65,408	201,401	285,763	346,153	7.89%	20.03%	24.90%	27.71%
Total	828,817	1,005,366	1,147,493	1,249,599	100.00%	100.00%	100.00%	100.00%

It can be observed from the Table 3-73, that the share of public transport, i.e., Bus + Phase 1 Metro + Phase 2 Mass Transit Corridors, is expected to increase from 27.51% in 2027 to 53.9% in 2057, whereas the share of private modes (i.e., 2W, 3W, car and taxi) is expected to decrease to 46.1% in 2061 from 72.5%.

TABLE 3-74: PASSENGERS SHIFTED TO MASS TRANSIT

Mode	Passenger Trips Shifted to MRT				Shift %			
	2027	2037	2047	2057	2027	2037	2047	2057
TW	15,698	52,364	80,014	100,384	24%	26%	28%	29%
Car	17,006	30,210	40,007	45,000	26%	15%	14%	13%
Auto	17,006	62,434	88,587	107,307	26%	31%	31%	31%
Bus	15,698	56,392	77,156	93,461	24%	28%	27%	27%
Total	65,408	201,401	285,763	346,153	100%	100%	100%	100%

3.7 FUTURE YEAR ASSIGNMENTS

The base year calibrated model has been applied for estimating the ridership on Line 2A and Line 2B. As mentioned in the previous sections, the base year of the project is assumed to be 2022, whereas the operational year of Line 2A and Line 2B for Pune is assumed to be 2027, with the horizon year till 2057.

The ridership forecast has been estimated for 2027, 2037, 2047 and 2057 in ten-year intervals. As mentioned in the previous section, the future population and employment growth trend and mode share projections were taken into consideration while estimating the ridership. These are explained in the following sections.

3.7.1 CORRIDOR ALIGNMENT AND STOPS

Line 2A and Line 2B, which are extensions to Line 2, i.e., Vanaz to Ramwadi of Phase-1, are coded in the travel demand model. The alignment, along with the location of stops, headways, and fare structure, were considered in estimating the ridership.

The details of Line 2A and Line 2B along with the list of stops are presented in the Table 3-75. The alignment and stop locations are represented in Figure 3-44.

TABLE 3-75: DETAILS OF LINE 2A AND LINE 2B

S. N.	Name of the Corridor	Length (km)	No. of Stations
1	Line 2A – Vanaz to Chandani Chowk – Western Extension	1.12	2
2	Line 2B – Ramwadi to Wagholi/Vitthalwadi – Eastern Extension	11.63	11
	Total Additional Length (km)	**12.75**	**13**

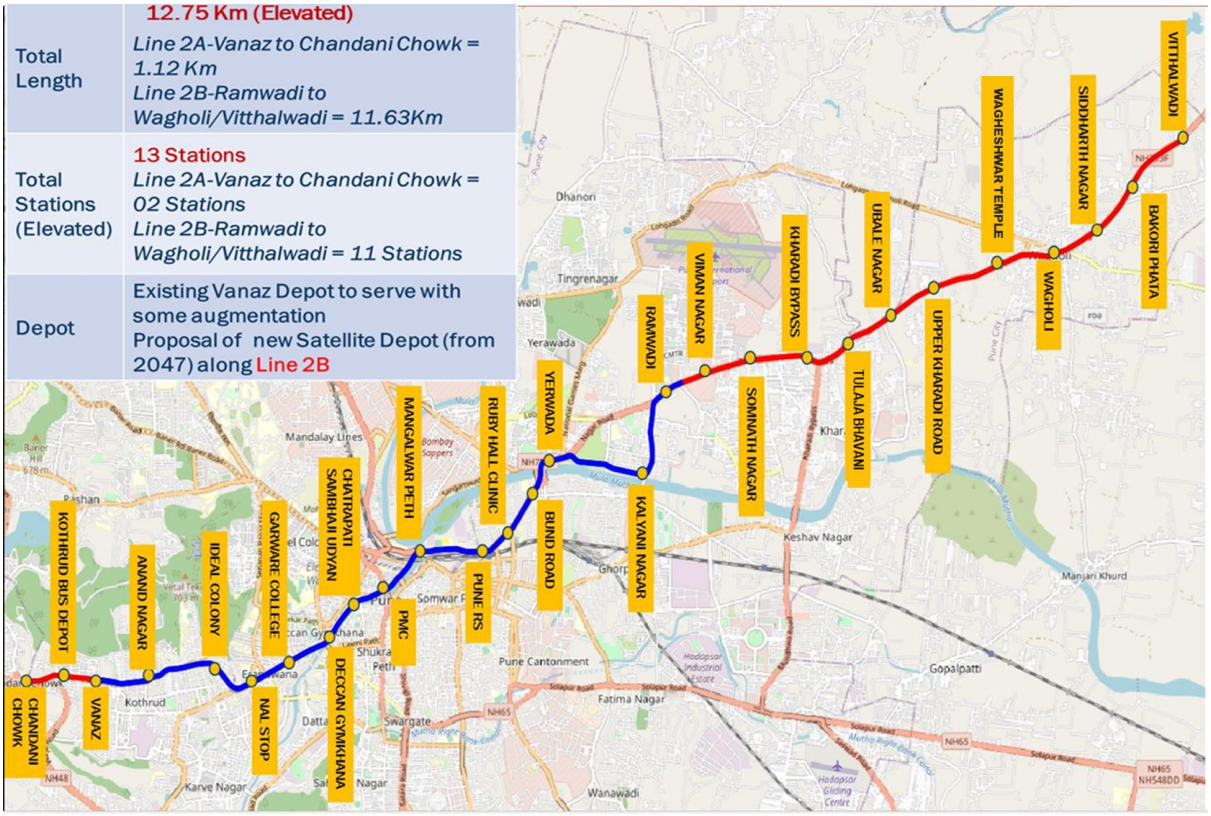


FIGURE 3-44: LINE 2A, LINE 2 & LINE 2B ALIGNMENT AND STOPS

For the ridership estimations for the extension corridors under the scenarios mentioned in previous sections, the TAZs which were within a 1.5-km radius of the Line 2 corridor were connected to the system directly. The rest were assumed to be accessing the system via some sort of mode interchange.

TABLE 3-76: LIST OF STATIONS OF THE PROPOSED CORRIDORS

S.N.	Station Name	Phase	Chainage from Phase-1 (m)	Inter-station Distance (m)
Line 2A Vanaz to Chandani Chowk Corridor – Western Extension				
	Vanaz Station of Phase 1	Phase 1	-22	
	Dead End of Phase 1	Phase 1	-757.929	
1	Kothrud Bus Depot	Phase 2	-964.048	942.048
2	Chandani Chowk	Phase 2	-1779.227	815.179
	Dead End	Phase 2	-1880	100.773
	Corridor Length		**1122.071**	
Line 2B Ramwadi to Wagholi/Vitthalwadi Corridor – Eastern Extension				
	Ramwadi Station of Phase 1	Phase 1	14484.469	
	Dead End of Phase 1	Phase 1	14991.719	
1	Viman Nagar	Phase 2	15464.618	980.149
2	Somnath Nagar	Phase 2	16700.889	1236.271
3	Kharadi Bypass	Phase 2	17601.929	901.04
4	Tulaja Bhavani	Phase 2	18843.676	1241.747
5	Ubale Nagar	Phase 2	19888.269	1044.593
6	Upper Kharadi Road	Phase 2	20930.634	1042.365

S.N.	Station Name	Phase	Chainage from Phase-1 (m)	Inter-station Distance (m)
7	Wagheshwar Temple	Phase 2	22312.06	1381.426
8	Wagholi	Phase 2	23269.317	957.257
9	Siddharth Nagar	Phase 2	24087.658	818.341
10	Bakori Phata	Phase 2	24948.286	860.628
11	Vitthalwadi	Phase 2	26232.966	1284.68
	Dead End	Phase 2	26625.00	392.034
	Corridor Length		**11633.281**	

3.7.1.1. RIDERSHIP ASSESSMENT FOR HORIZON YEARS

The ridership assessment of the corridor has been undertaken for two scenarios, i.e., With and Without Project for Metro Patronage Forecast. With Project Scenario includes the alignment from Chandani Chowk to Vanaz to Ramwadi to Vitthalwadi with 28 stations. The Without Project Scenario considers Vanaz to Ramwadi with 15 stations.

The proposed alignment of the corridor with all the stations are shown in Figure 3-44.

Maximum PHPDT

The trips between two adjacent stops on the proposed Line 2 with extensions have been worked out for the years 2027, 2037, 2047 and 2057 for the 'With Project' and 'Without Project' scenarios.

TABLE 3-77: MAX PHPDT ON LINE 2 IN HORIZON YEARS IN WITH AND WITHOUT PROJECT SCENARIOS

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Line 2 – With Project Scenario, i.e., Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	11,200	17,001	24,255	29,554
2	Line 2 – Without Project Scenario, i.e., Vanaz to Ramwadi	8,737	12,184	17,360	21,131

Daily Ridership

Daily ridership on Line 2 has been estimated for the horizon years 2027, 2037, 2047 and 2057 under the 'With Project' and 'Without Project' scenarios.

TABLE 3-78: DAILY RIDERSHIP ON LINE 2 IN HORIZON YEARS IN WITH AND WITHOUT PROJECT SCENARIOS

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Line 2 – With Project Scenario, i.e., Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	3,59,080	5,76,880	8,19,250	9,93,380
2	Line 2 – Without Project Scenario, i.e., Vanaz to Ramwadi	2,63,080	3,75,770	5,32,260	6,44,460

Peak Hour Sectional Loads and Station-Wise Boarding and Alighting on the Proposed Corridors

The section loads and direction-wise boarding/alighting in Scenario 1: Normal Growth Scenario as well as Scenario 2: Semi Rapid Growth Scenario for the horizon years 2027, 2037, 2047 and 2057 are presented in Table 3-79**.**

TABLE 3-79: PEAK HOUR SECTION LOADS ON THE PROPOSED CORRIDORS

S.N.	From Station Name	To Station Name	Max Sectional Loadings - Peak Hour Peak Direction Trips (PHPDT)							
			2027		2037		2047		2057	
			Forward[82]	Reverse[83]	Forward	Reverse	Forward	Reverse	Forward	Reverse
1	CHANDANI CHOWK	KOTHRUD BUS DEPOT	1402	1105	1960	1940	2782	2761	3374	3362
2	KOTHRUD BUS DEPOT	VANAZ	1913	1652	2865	2878	4074	4084	4947	4955
3	VANAZ	ANAND NAGAR	3029	2617	4810	4477	6835	6300	8291	7593
4	ANAND NAGAR	IDEAL COLONY	3707	3685	5881	6175	8350	8687	10130	10462
5	IDEAL COLONY	NAL STOP	4340	4203	6672	6813	9464	9590	11478	11548
6	NAL STOP	GARWARE COLLEGE	5450	5195	9467	9444	13429	13312	16279	16056
7	GARWARE COLLEGE	DECCAN GYMKHANA	5959	6123	9534	10077	13526	14218	16395	17164
8	DECCAN GYMKHANA	CHATRAPATI SAMBHAJI UDYAN	6315	6635	9885	10702	14022	15107	16992	18243
9	CHATRAPATI SAMBHAJI UDYAN	PMC	6524	6774	10178	10821	14428	15303	17477	18506
10	PMC	CIVIL COURT	7264	7996	10821	12880	15316	18294	18522	22206
11	CIVIL COURT	MANGALWAR PETH	8911	11200	12988	17001	18389	24255	22226	29554
12	MANGALWAR PETH	PUNE RS	9280	10866	13503	16397	19116	23405	23096	28533
13	PUNE RS	RUBY HALL CLINIC	9657	10728	13482	16132	19088	23044	23060	28112
14	RUBY HALL CLINIC	BUND GARDEN	9219	10623	12776	15919	18088	22743	21847	27747
15	BUND GARDEN	YERWADA	7439	10465	10604	15506	15037	22152	18174	27027

82 Forward Direction refers to the movement from Chandani Chowk to Vanaz to Ramwadi to Vitthalwadi
83 Reverse Direction refers to the movement from Vitthalwadi to Ramwadi to Vanaz to Chandani Chowk.

S.N.	From Station Name	To Station Name	Max Sectional Loadings - Peak Hour Peak Direction Trips (PHPDT)							
			2027		2037		2047		2057	
			Forward[82]	Reverse[83]	Forward	Reverse	Forward	Reverse	Forward	Reverse
16	YERWADA	KALYANI NAGAR	6470	8029	9600	12048	13672	17254	16566	21096
17	KALYANI NAGAR	RAMWADI	5669	7041	8491	10583	12088	15162	14644	18528
18	RAMWADI	VIMAN NAGAR	5475	6697	8254	10071	11766	14432	14264	17640
19	VIMAN NAGAR	SOMNTH NAGAR	4978	6012	8368	9647	11937	13832	14472	16914
20	SOMNATH NAGAR	KHARADI BYPASS	4581	5449	8004	9054	11422	12984	13851	15877
21	KHARADI BYPASS	TULAJA BHAVANI	3874	3888	7183	7340	10256	10530	12432	12886
22	TULAJA BHAVANI	UBALE NAGAR	3606	3589	6677	6798	9524	9754	11537	11938
23	UBALE NAGAR	UPPER KHARADI ROAD	3347	3441	6181	6345	8808	9105	10662	11146
24	UPPER KHARADI ROAD	WAGHESHWAR TEMPLE	3220	3392	5891	6210	8405	8909	10182	10904
25	WAGHESHWAR TEMPLE	WAGHOLI	1774	2179	3427	3908	4886	5576	5907	6789
26	WAGHOLI	SIDDHARTH NAGAR	387	1055	749	1905	1003	2683	1162	3241
27	SIDDHARTH NAGAR	BAKORI PHATA	338	662	661	1254	883	1763	1022	2128
28	BAKORI PHATA	VITTHALWADI	264	579	521	1095	698	1541	809	1862
Max Sectional Loading of Line 2 - Including the Extensions (Vanaz to Chandani Chowk and Ramwadi to Wagholi/Vitthalwadi)			**9657**	**11200**	**13503**	**17001**	**19116**	**24255**	**23096**	**29554**

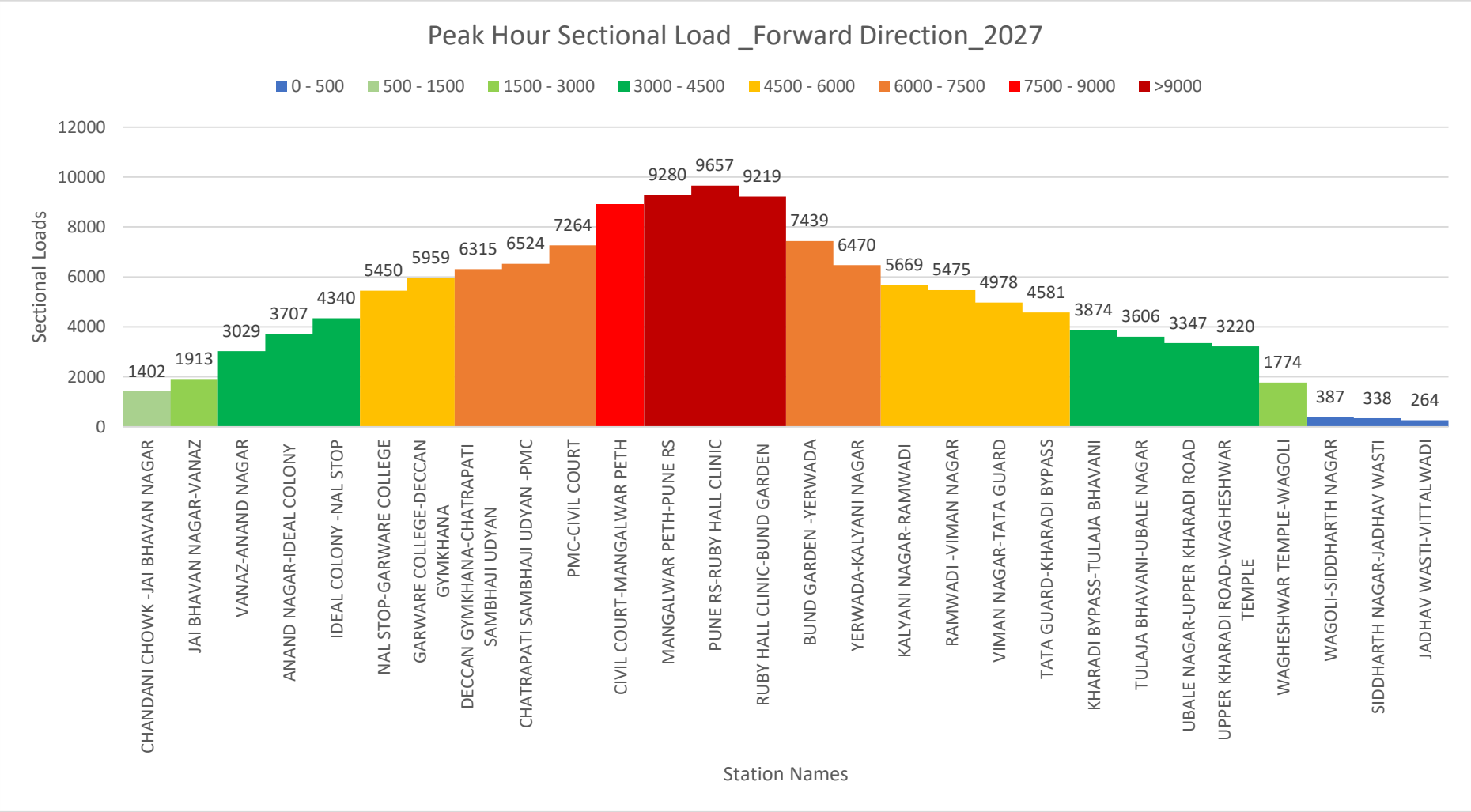


FIGURE 3-45: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2027

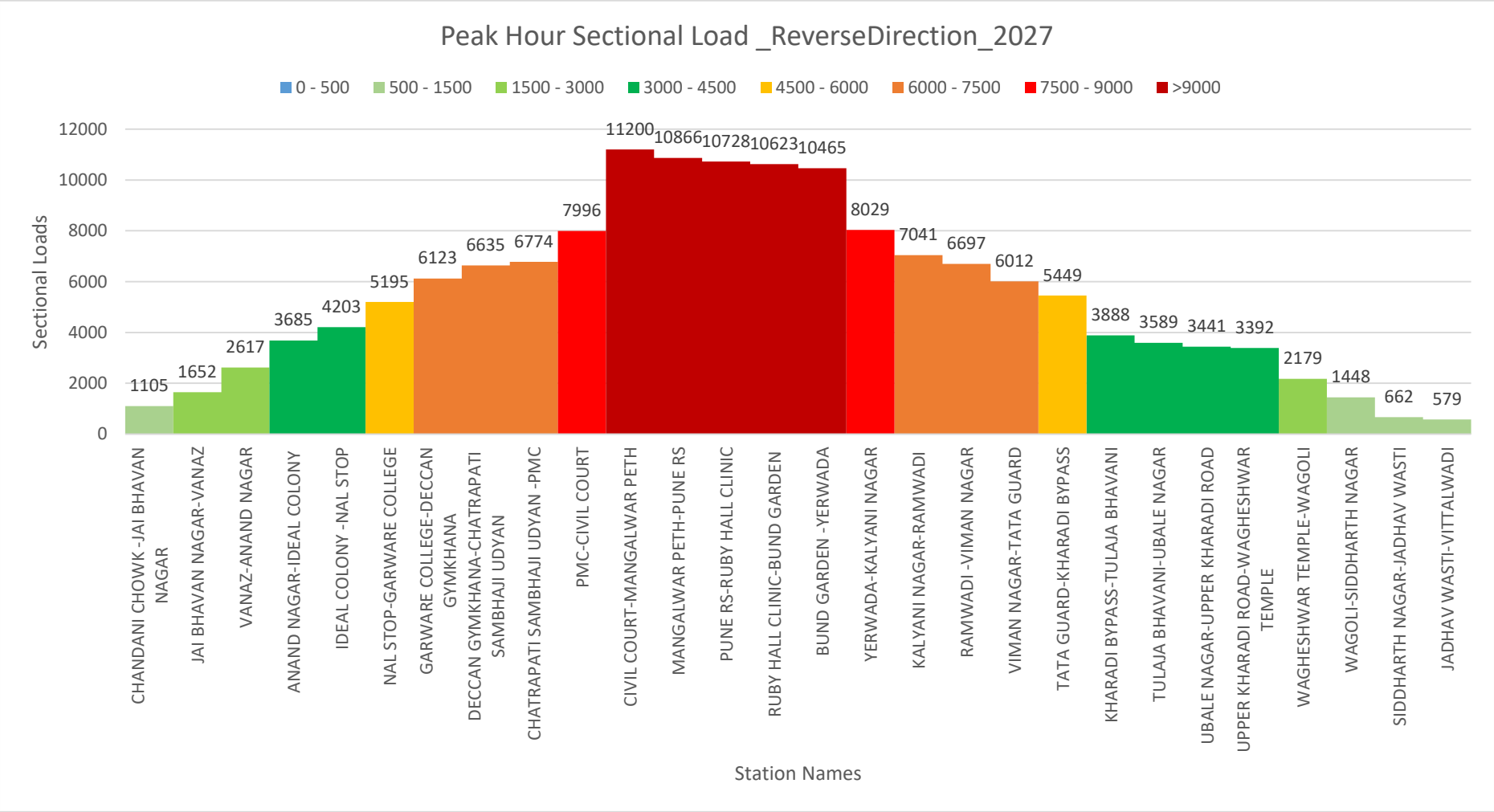


FIGURE 3-46: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2027

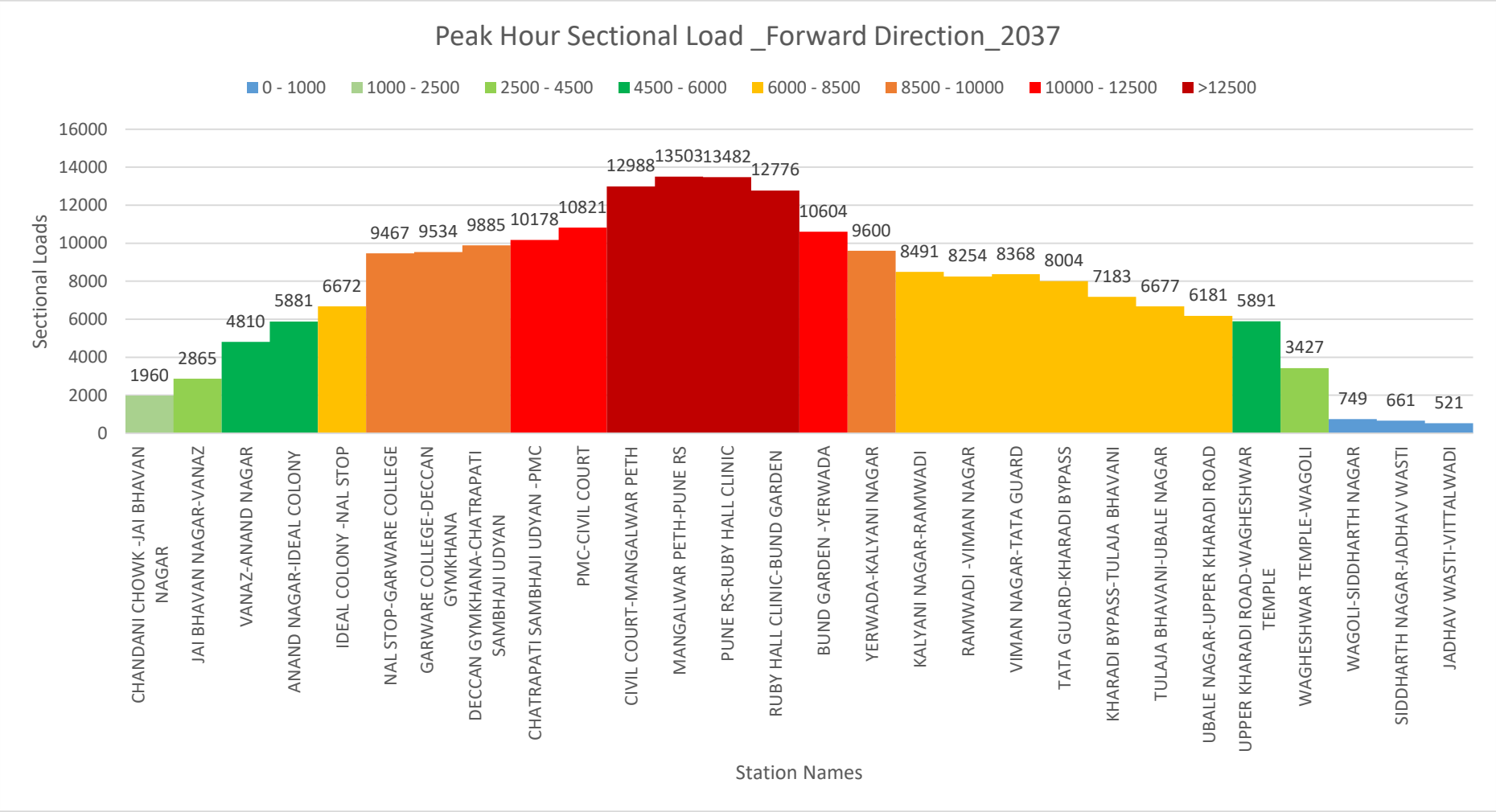


FIGURE 3-47: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2037

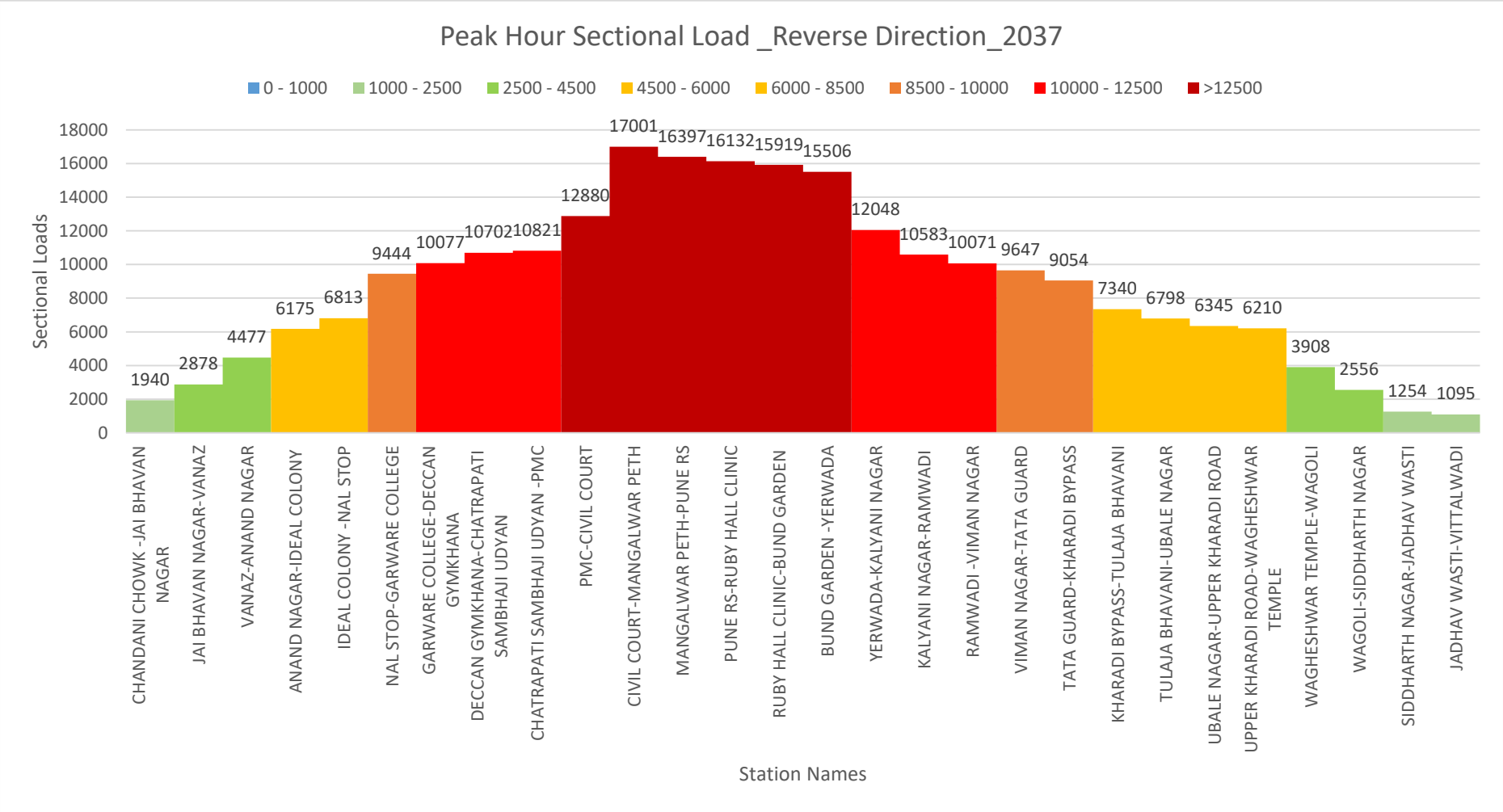


FIGURE 3-48: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2037

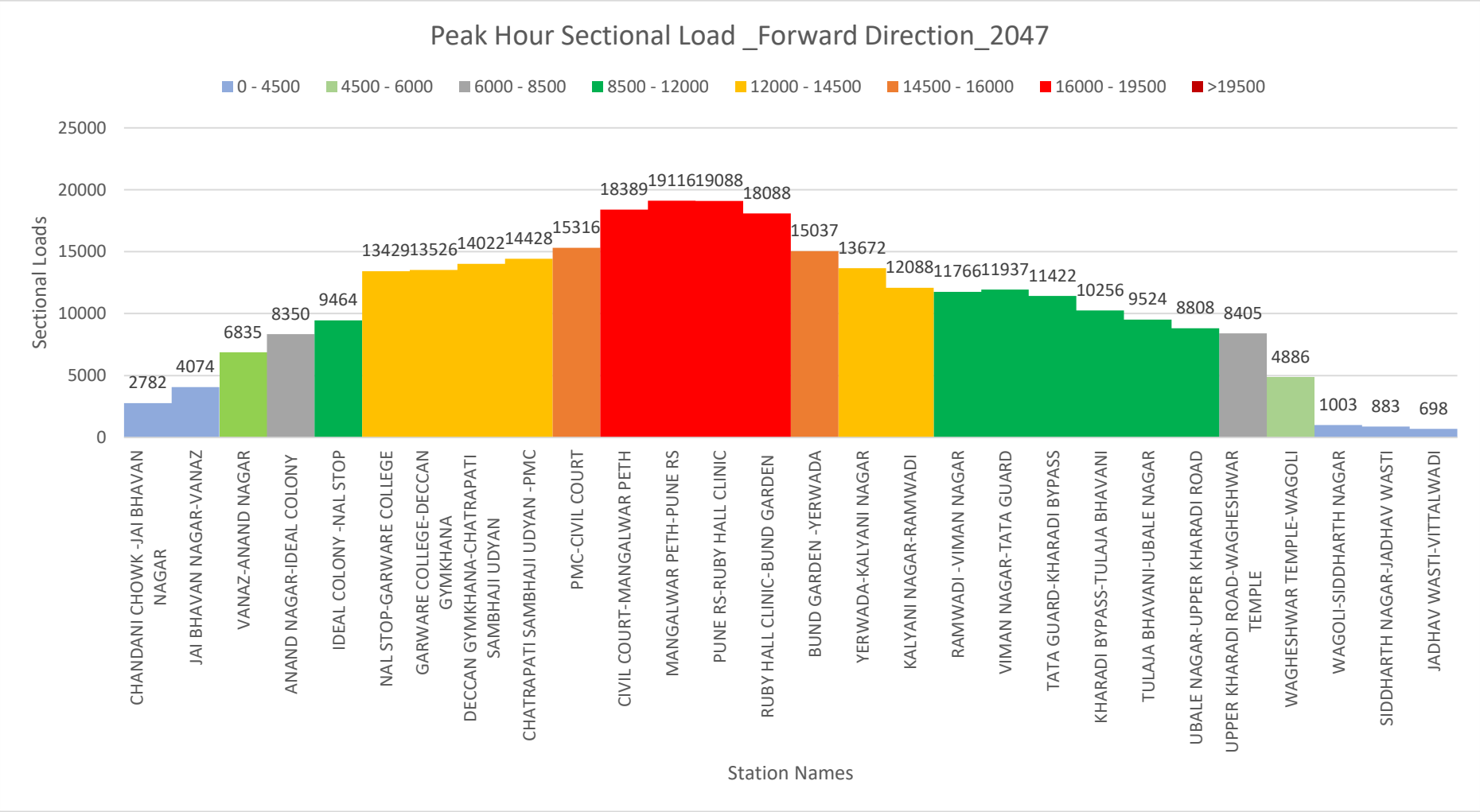


FIGURE 3-49: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2047

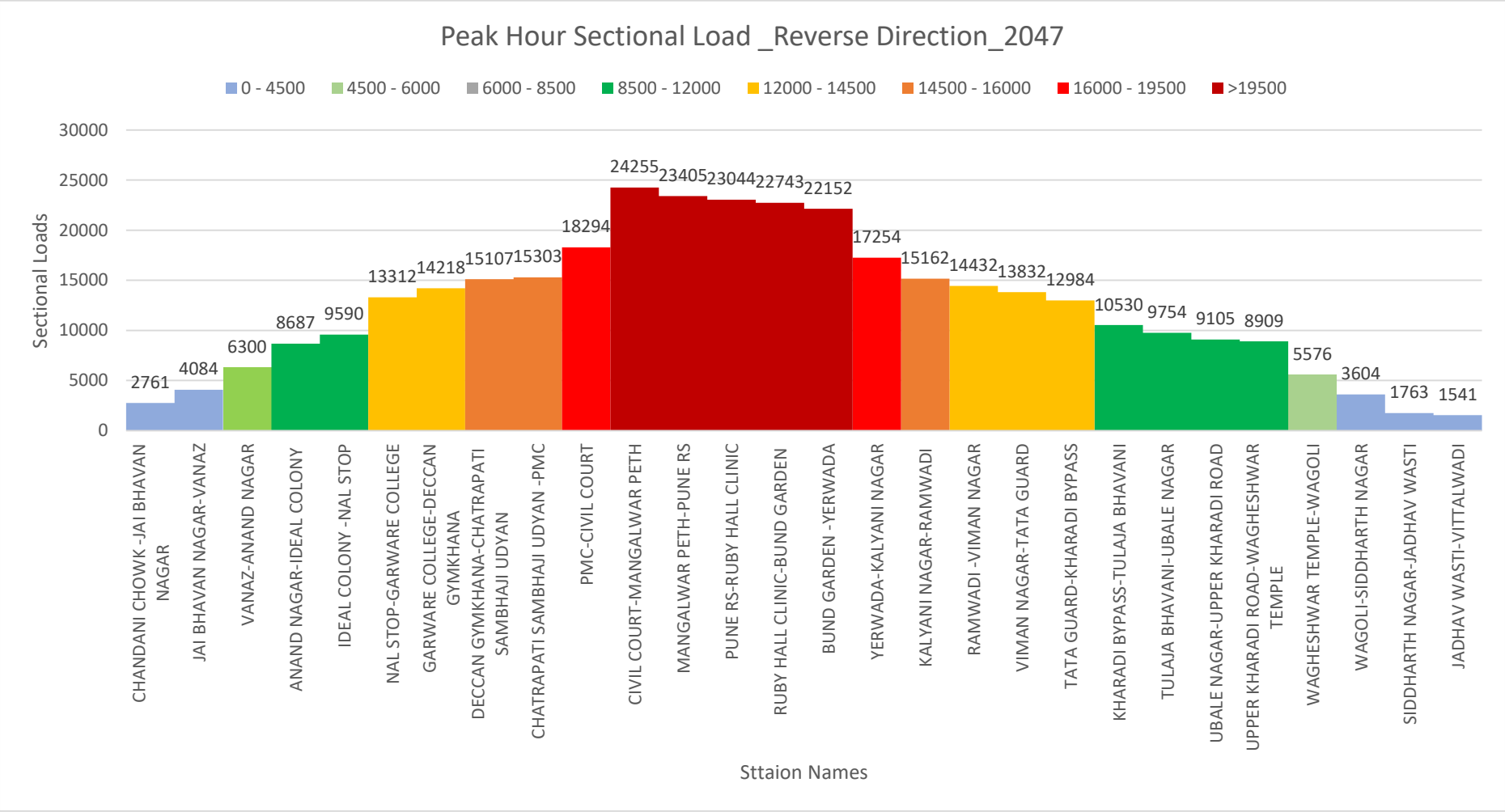


FIGURE 3-50: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2047

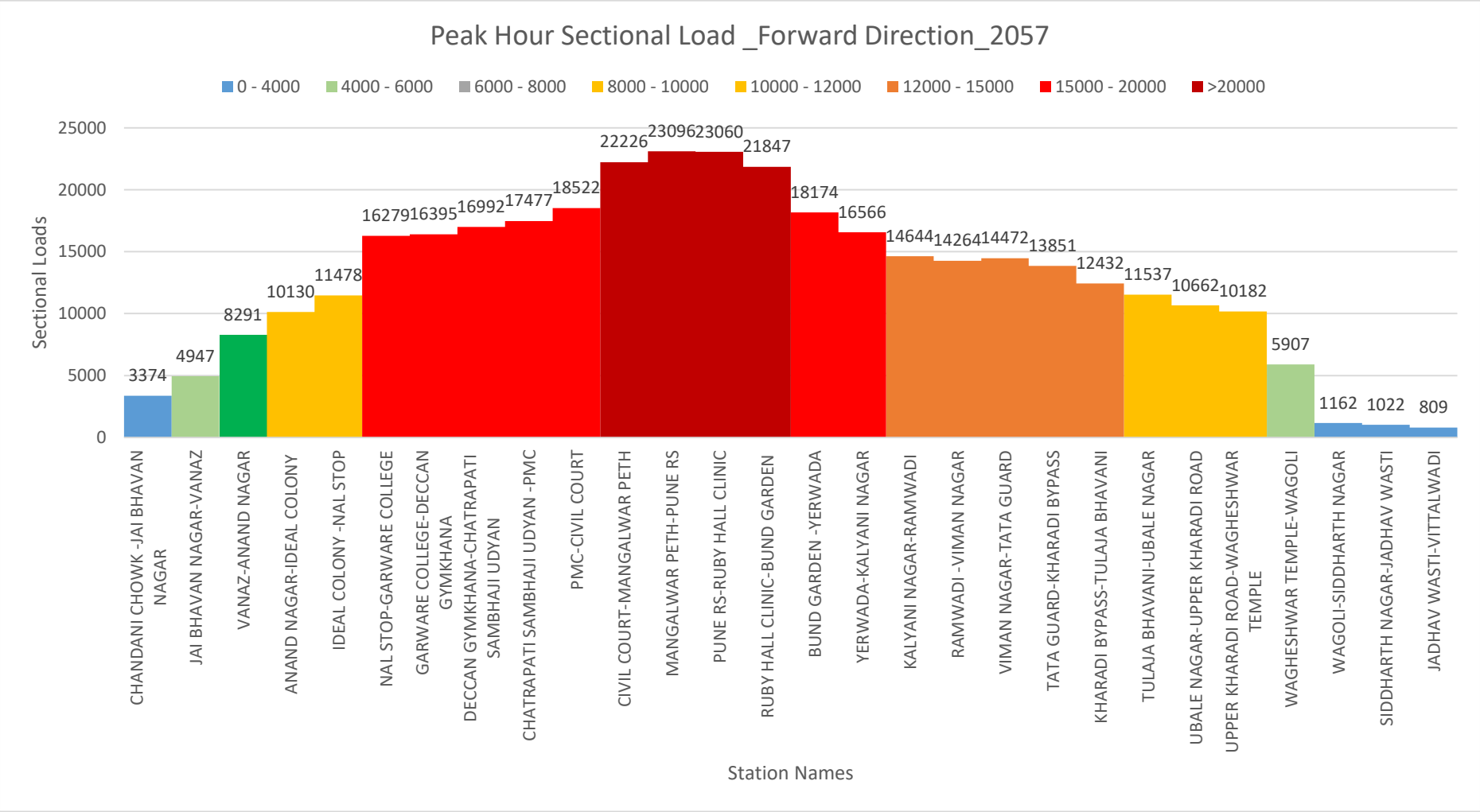


FIGURE 3-51: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR FORWARD DIRECTION_2057

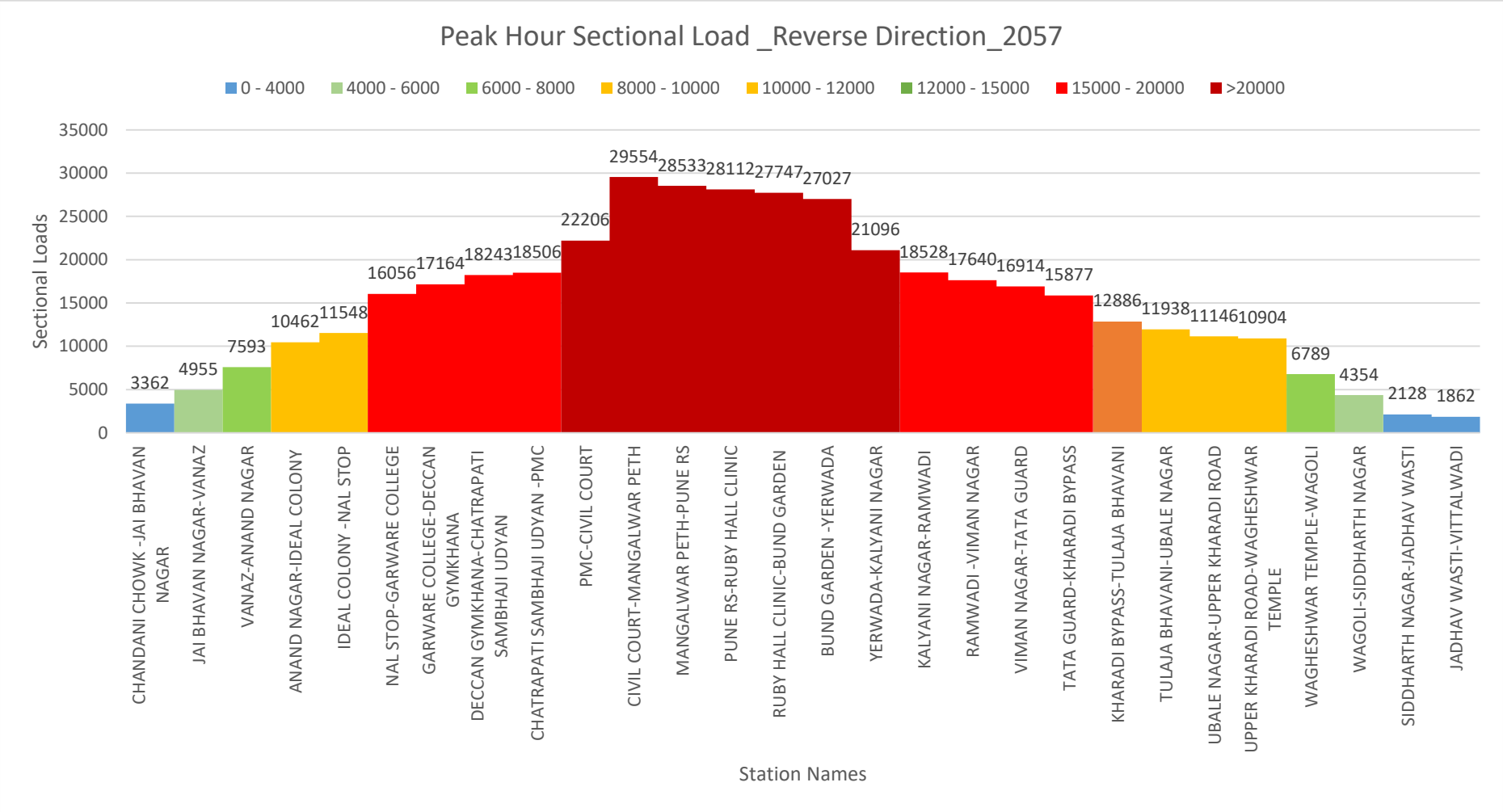


FIGURE 3-52: PEAK HOUR SECTION LOADING ON THE PROPOSED CORRIDORS FOR REVERSE DIRECTION_2057

TABLE 3-80: STATION-WISE DAILY BOARDINGS AND ALIGHTINGS ON THE PROPOSED CORRIDORS

S. N.	Station Name	Daily Boarding							
		2027		2037		2047		2057	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
1	CHANDANI CHOWK	14,020	11,050	19,600	19,400	27,820	27,610	33,740	33,620
2	KOTHRUD BUS DEPOT	5,640	6,000	9,870	10,200	14,100	14,410	17,170	17,370
3	VANAZ	12,180	10,670	20,950	17,490	29,730	24,280	36,010	28,950
4	ANAND NAGAR	7,610	11,510	11,930	18,200	16,880	25,600	20,490	30,790
5	IDEAL COLONY	7,420	6,270	11,930	10,400	16,820	14,710	20,340	17,720
6	NAL STOP	14,760	13,580	38,010	36,370	53,850	51,420	65,160	62,230
7	GARWARE COLLEGE	16,270	20,460	15,690	21,350	22,200	30,290	26,800	36,720
8	DECCAN GYMKHANA	5,110	6,670	6,000	8,740	8,470	12,400	10,230	15,050
9	CHATRAPATI SAMBHAJI UDYAN	7,360	6,660	12,780	11,040	17,900	15,800	21,480	19,260
10	PMC	32,910	37,730	44,230	58,390	62,370	83,400	75,120	1,01,670
11	CIVIL COURT	57,090	72,660	86,660	1,06,200	1,22,660	1,51,540	1,48,210	1,84,650
12	MANGALWAR PETH	11,490	4,460	18,640	7,450	26,210	10,440	31,470	12,560
13	PUNE RS	26,990	21,840	30,010	27,570	42,440	39,110	51,260	47,410
14	RUBY HALL CLINIC	2,700	6,030	4,130	9,060	5,860	12,850	7,120	15,600
15	BUND GARDEN	7,310	23,530	10,910	28,500	15,530	40,130	18,890	48,420
16	YERWADA	32,010	17,340	44,670	20,130	63,330	28,000	76,680	33,450
17	KALYANI NAGAR	13,090	11,220	23,750	20,190	33,940	28,860	41,570	35,110
18	RAMWADI	7,600	6,100	11,350	8,600	16,140	12,060	19,560	14,480
19	VIMAN NAGAR	10,170	8,290	30,380	25,000	43,430	35,720	52,810	43,470
20	SOMNATH NAGAR	6,480	4,820	8,160	5,870	11,650	8,320	14,210	10,050
21	KHARADI BYPASS	19,360	10,820	41,470	32,540	59,270	46,390	72,140	56,420

S. N.	Station Name	Daily Boarding							
		2027		2037		2047		2057	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
22	TULAJA BHAVANI	3,170	2,860	5,720	5,360	8,190	7,750	10,000	9,470
23	UBALE NAGAR	3,020	4,130	5,500	5,930	7,880	8,550	9,610	10,440
24	UPPER KHARADI ROAD	800	1,580	1,490	3,040	2,150	4,220	2,660	5,040
25	WAGHESHWAR TEMPLE	12,530	14,860	23,680	25,300	34,280	36,140	42,300	43,900
26	WAGHOLI	11,400	14,030	20,280	27,030	29,270	39,170	35,890	47,860
27	SIDDHARTH NAGAR	3,950	510	6,530	900	9,220	1,220	11,150	1,420
28	BAKORI PHATA	850	760	1,610	1,420	2,250	1,880	2,690	2,160
29	VITTHALWADI	5,790	2,640	10,950	5,210	15,410	6,980	18,620	8,090
Total of Line 2 - Including the Extensions (Vanaz to Chandani Chowk and Ramwadi to Wagholi/Vitthalwadi)		3,59,080	3,59,080	5,76,880	5,76,880	8,19,250	8,19,250	9,93,380	9,93,380

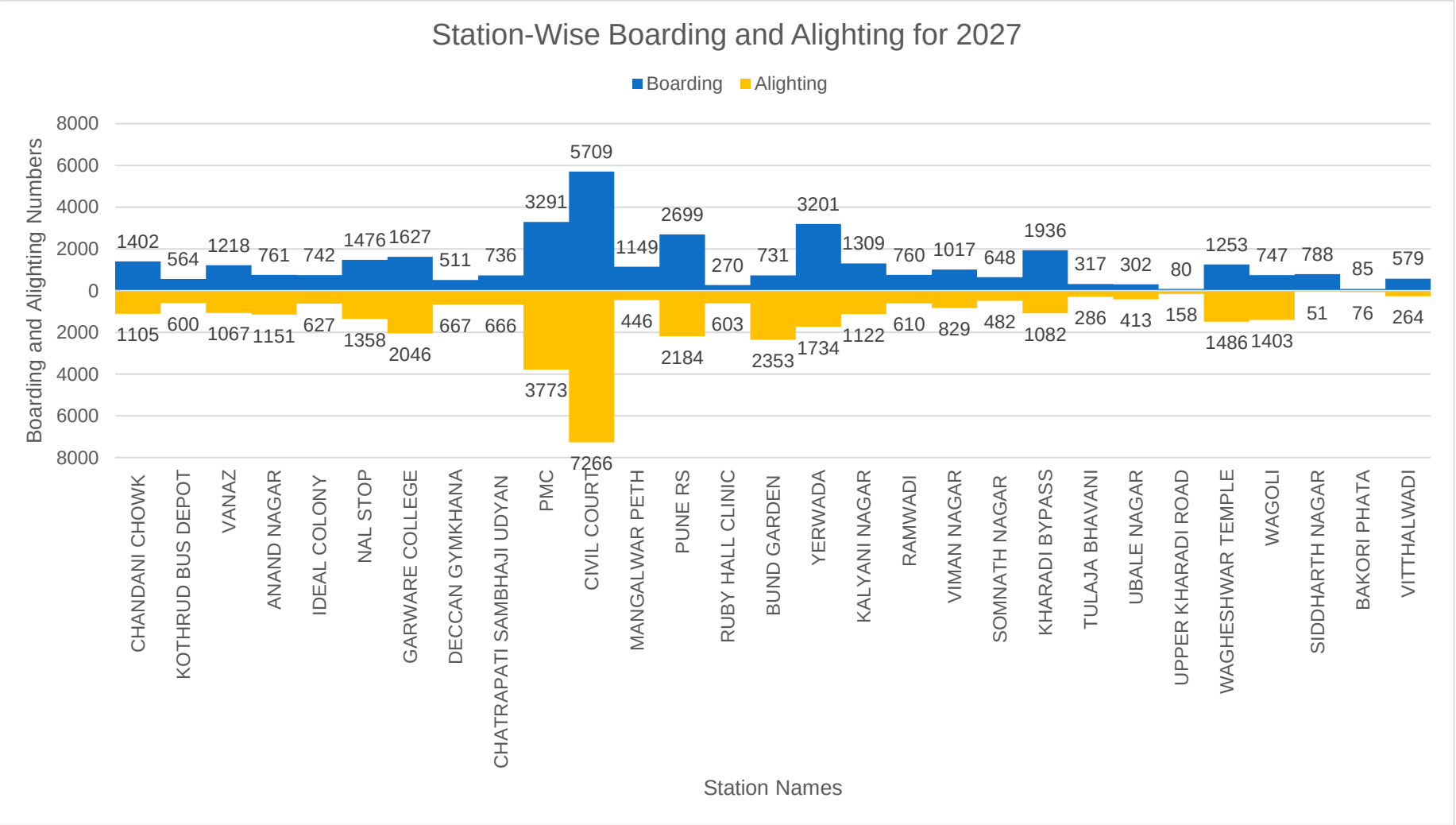


FIGURE 3-53: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2027

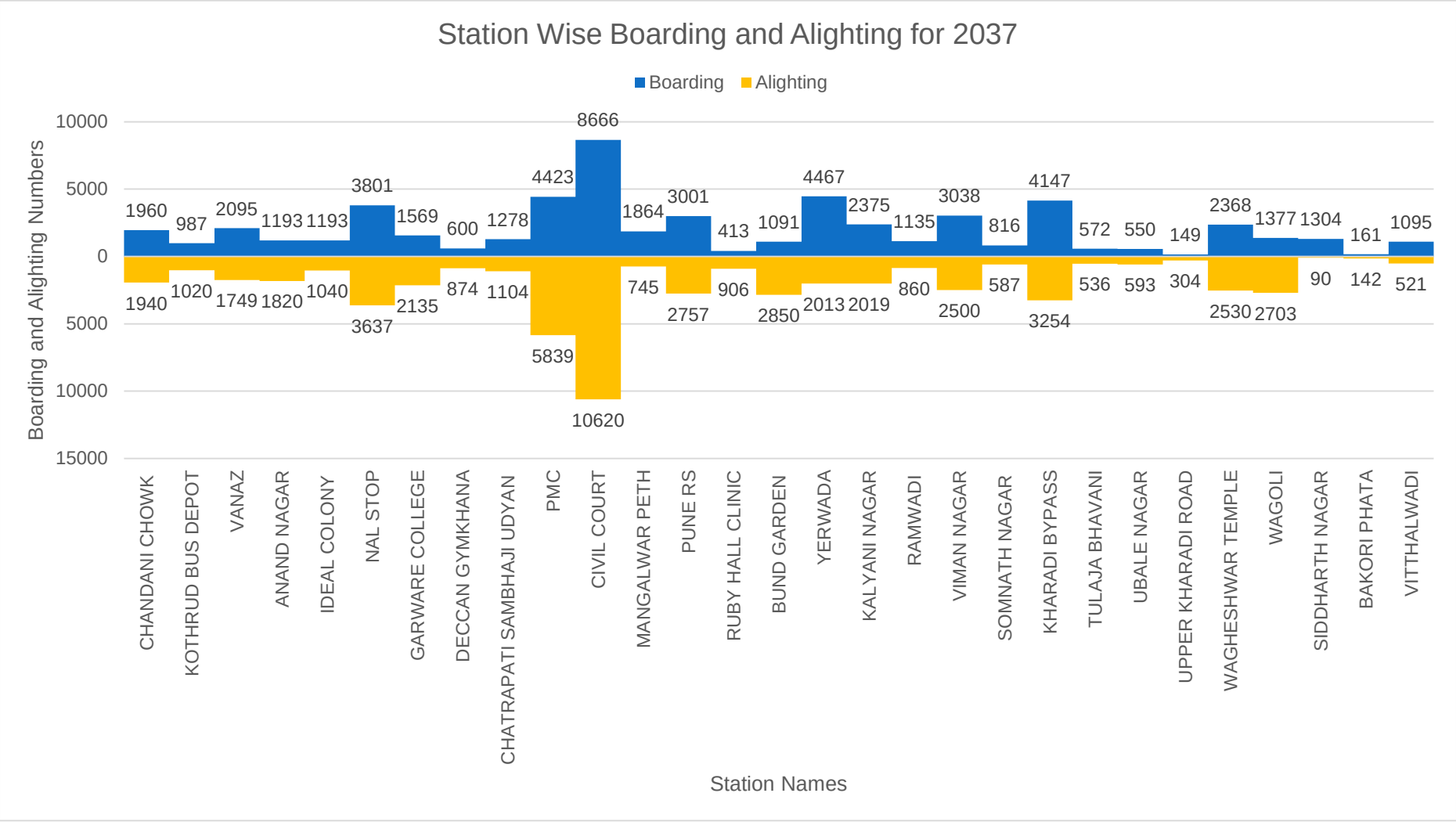


FIGURE 3-54: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2037

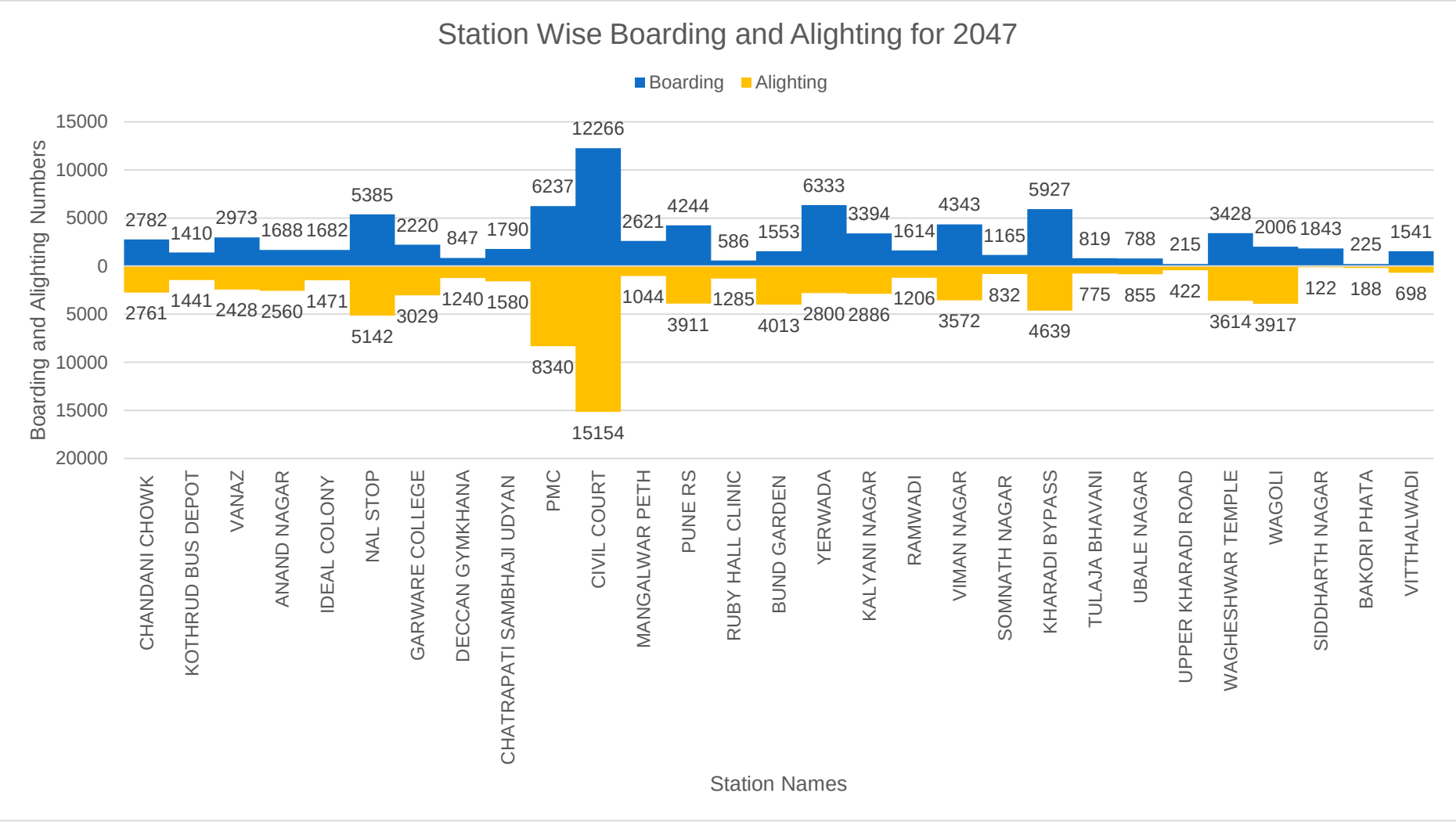


FIGURE 3-55: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2047

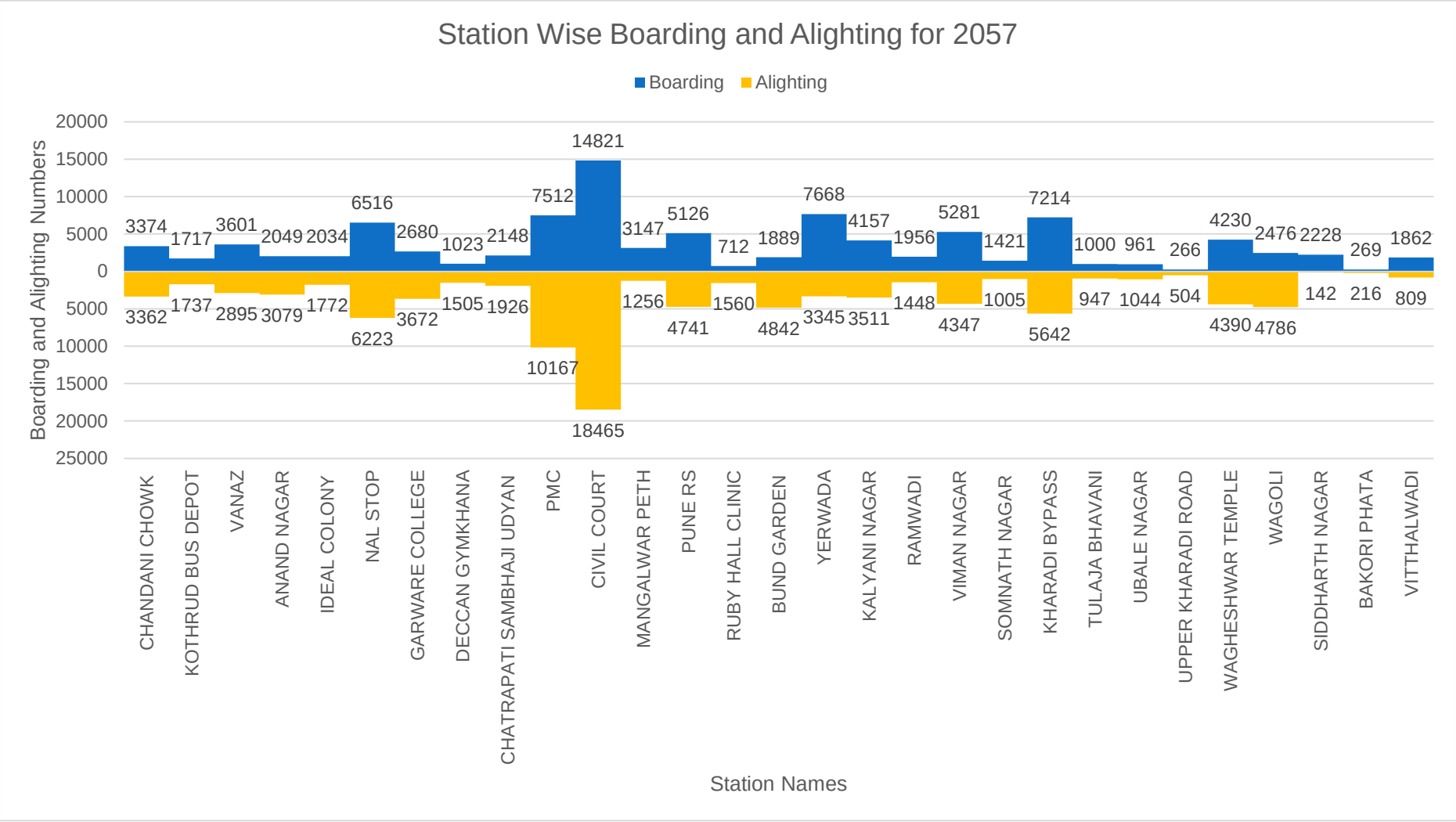


FIGURE 3-56: PEAK HOUR STATION BOARDING AND ALIGHTING ON THE PROPOSED CORRIDORS_2057

AVERAGE TRIP LENGTH (KM)

The estimated trip length of Line 2 with and without the extensions has been extracted from the model and is presented in the Table 3-81.

TABLE 3-81: AVERAGE TRIP LENGTH ON THE PROPOSED CORRIDORS

Scenario	Average Trip Length (km)			
	2027	2037	2047	2057
With Extensions	7.76	7.64	7.65	7.67
Without Extensions	5.08	5.11	5.12	5.12

The Average Trip Length (ATL) represented in the table above represents the ATL of Line 2 with and without extensions.

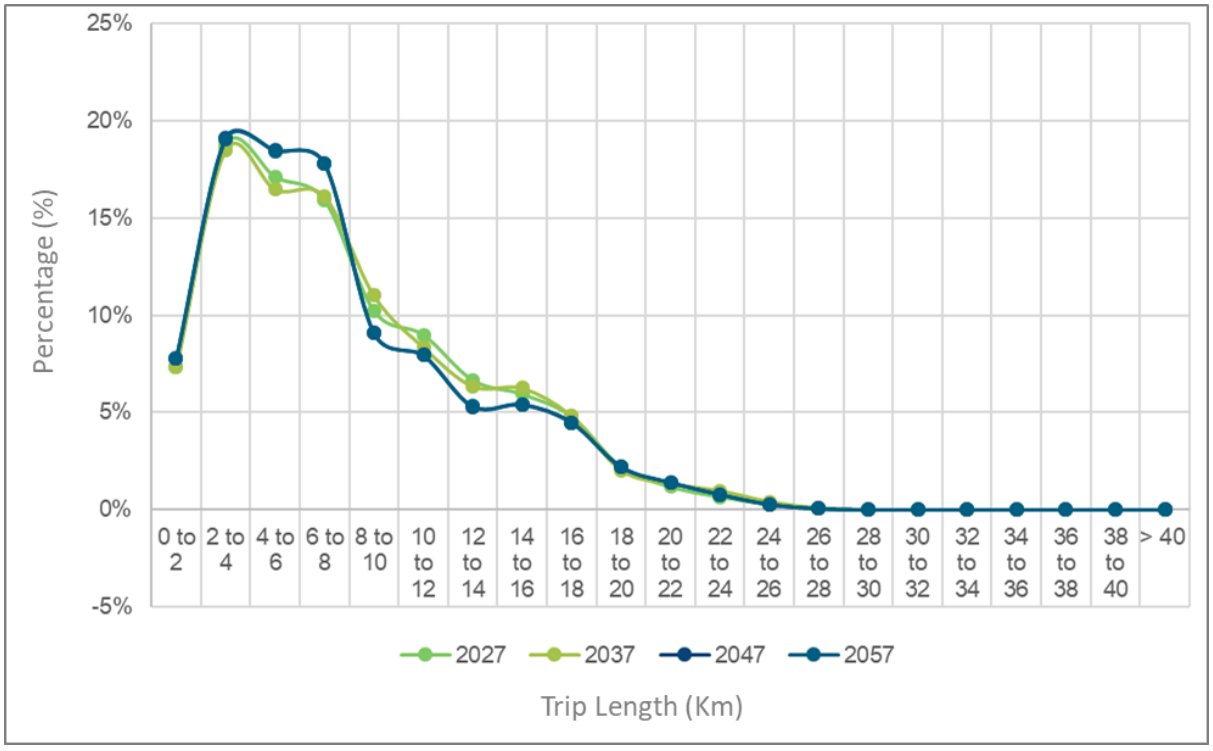


FIGURE 3-57: TRIP LENGTH FREQUENCY DISTRIBUTION WITH THE PROJECT FOR LINE 2

Based on the trip length distribution table extracted from the model, it has been observed, both with and without the extensions, that ~75% to 80% of the trips are performed under 8 km.

3.7.1.2. SUMMARY AND DESIGN RIDERSHIP

The study indicates that a major share in the city is of personalized motorized modes. The rate of growth in that share is much higher than in the provision of roads. This form of growth is not only unsustainable, but also undesirable for the growth and development of

Pune. Therefore, in this study, the proposed Line 2A and Line 2B have been tested using this travel demand model.

The assessment shows that MRTS has a significant impact in promoting the use of public transport. However, it has also been witnessed that the provision of MRTS on a couple of alignments alone would not result in adequate ridership for the system. Further transport or land use interventions are needed to increase the access of MRTS system to a wider catchment area. This could be in the form of an organized feeder service or transit-oriented development-based approach to land use planning. For the current study, Line 2: Ramwadi to Vanaz of Phase 1, with its proposed extensions of Line 2A – Vanaz to Chandani Chowk and Line 2B – Ramwadi to Wagholi/Vitthalwadi, has been studied as part of Phase 2 Pune MRTS.

As of March 2022, Line 2 is partially operational between Vanaz and Garware College, and with the extensions on the eastern end and the western end, Line 2 is expected to be operational by FY 2027-28. The ridership on Line 2 with extensions will be considered for designing the passenger facilities. Based on the comparison of all the above-mentioned scenarios and rational experiences from the various rail projects, it is observed that the 'With Extensions' scenario is the most realistically achievable in terms of daily ridership and section PHPDT in the operational year of 2027 and the horizon year of 2057.

TABLE 3-82: SUMMARY OF DAILY RIDERSHIP AND PHPDT ON LINE 2

		Daily Ridership (in Lakhs)				PHPDT			
S. N.	**Name of the Corridor**	**2027**	**2037**	**2047**	**2057**	**2027**	**2037**	**2047**	**2057**
1	Line 2 With Extensions	3.59	5.77	8.19	9.93	11,200	17,001	24,255	29,554
2	Line 2 Without Extensions	2.63	3.76	5.32	6.44	8,737	12,184	17,360	21,131
INCREAMENTAL DAILY RIDERSHIP		**0.96**	**2.01**	**2.87**	**3.49**				
INCREMENTAL PHPDT						**2,463**	**4,817**	**6,895**	**8,423**

The flows on Line 2 with extensions is presented in the figures below.

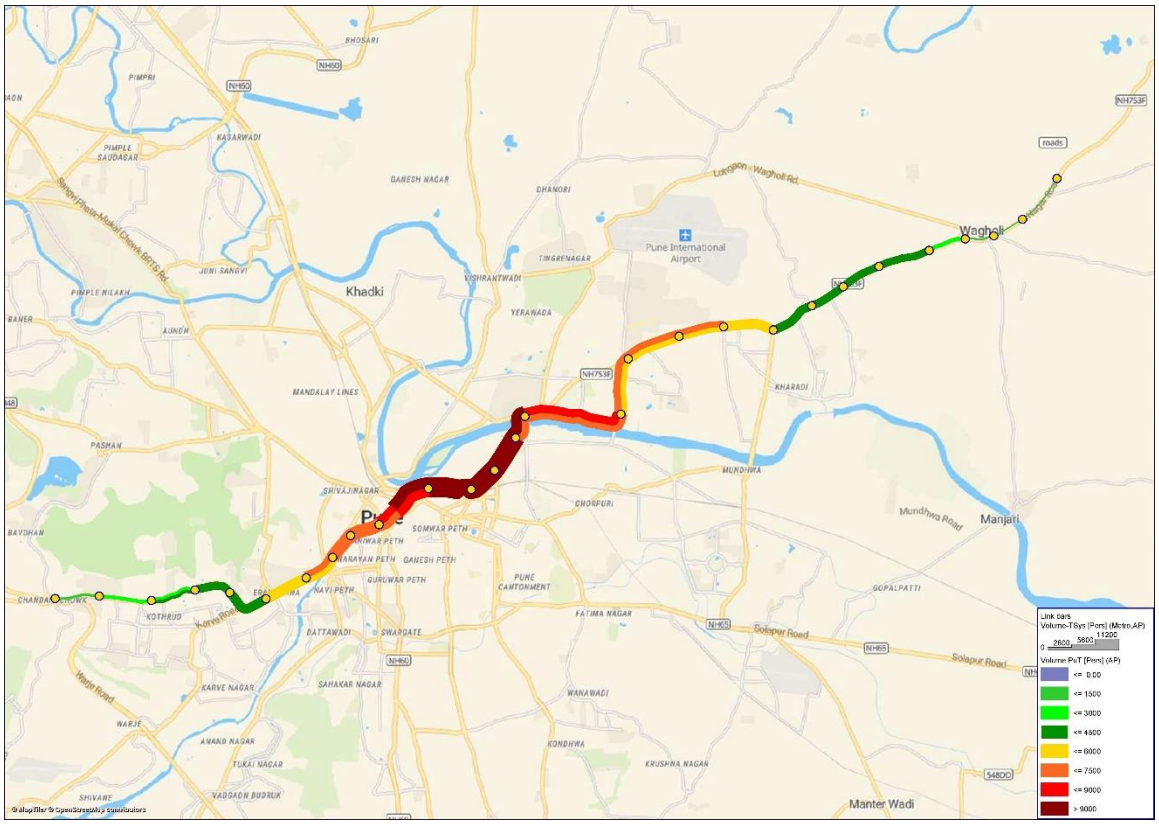


FIGURE 3-58: LINE 2 PHPDT FOR THE BASE YEAR 2027

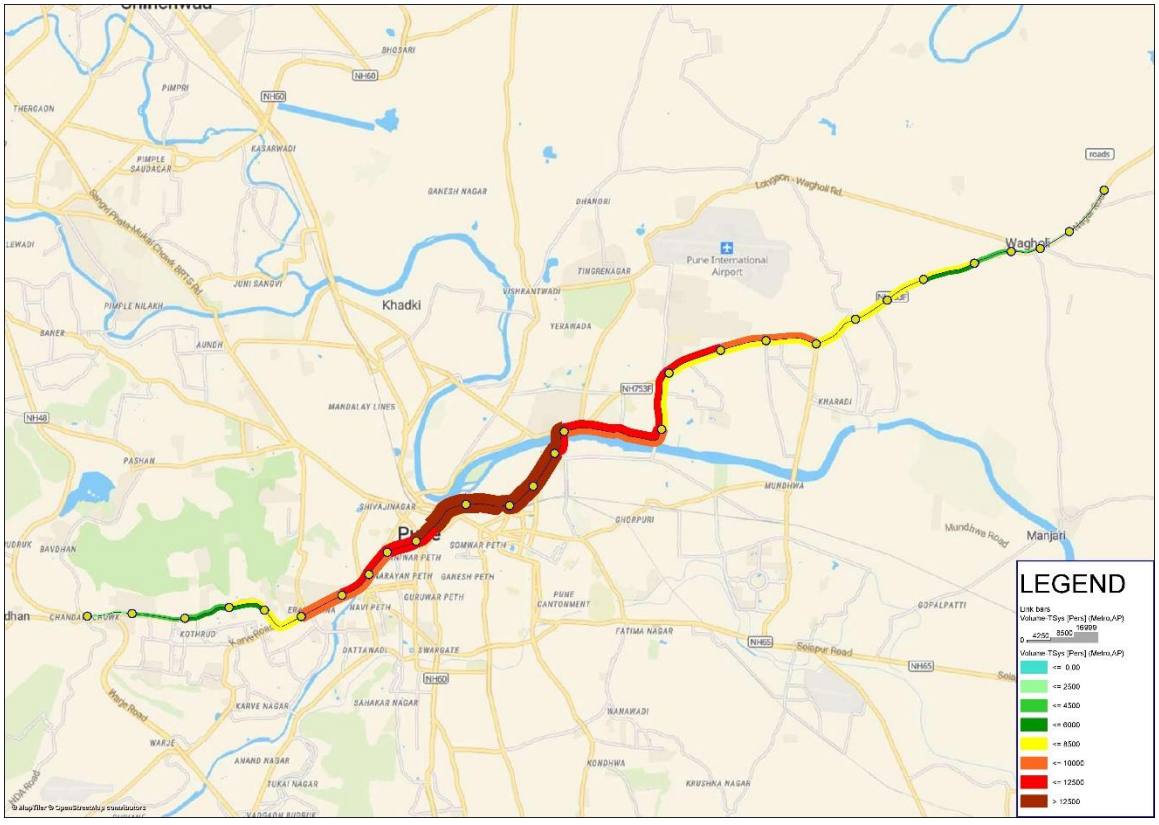


FIGURE 3-59: LINE 2 PHPDT FOR THE BASE YEAR 2037

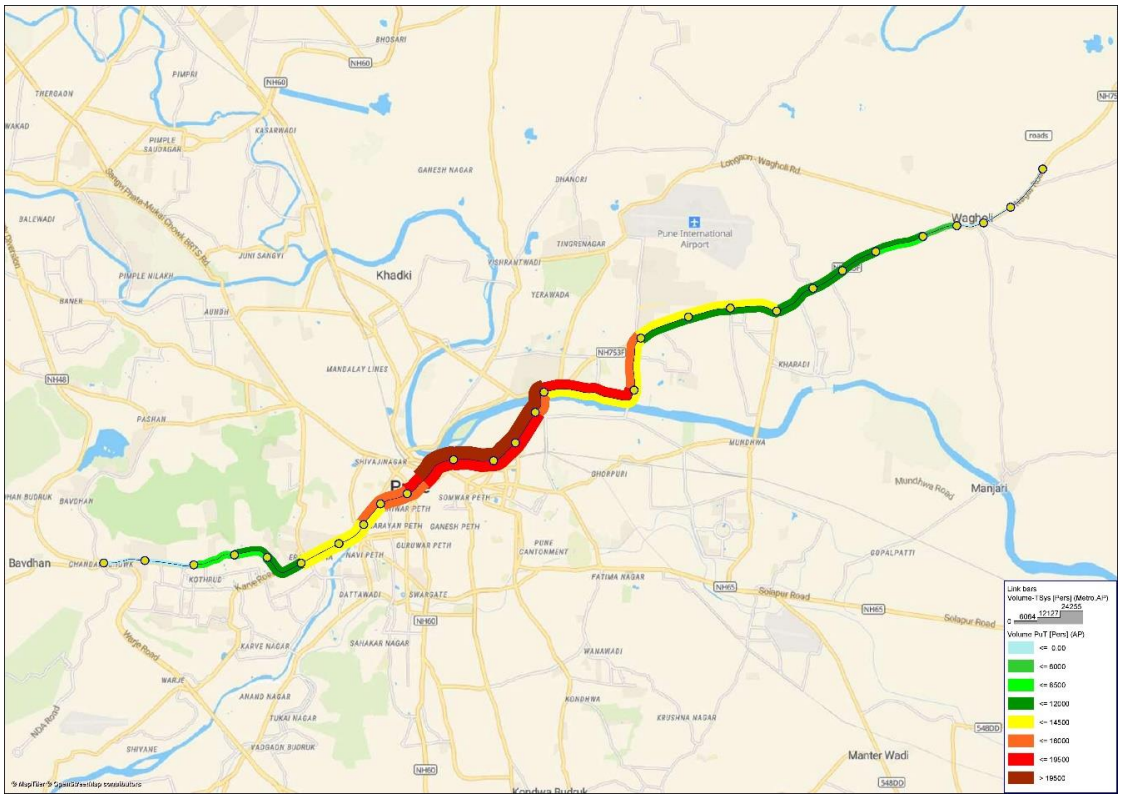


FIGURE 3-60: LINE 2 PHPDT FOR THE BASE YEAR 2047

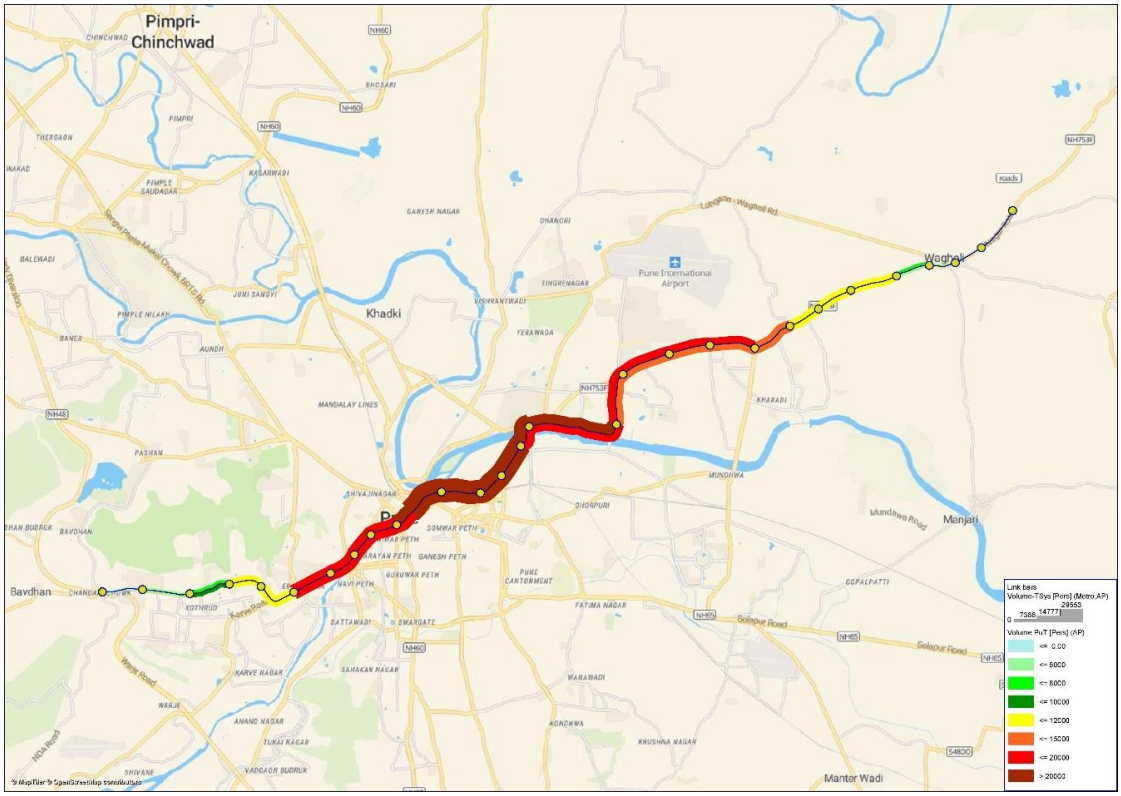


FIGURE 3-61: LINE 2 PHPDT FOR THE BASE YEAR 2057

CHAPTER 4: SYSTEM & TECHNOLOGY SELECTION

4.1. TECHNOLOGY

The selection of a particular mass transit system depends largely on the characteristics of the city and its metropolitan area, the projection of traffic demand for transit travel, and the availability of right of way (ROW). City-specific needs are the paramount considerations for the design of a transport system. If a new corridor is adjoining to an existing transport system, then it is generally prudent to adopt the same system as the one existing for the previously commissioned corridors.

System and technology selection is based on:

- Projected traffic (key consideration)
- Feasibility, least land requirements
- Sharp turns
- Technology in India, Indigenization, 'Make in India' and 'Atmanirbhar Bharat' policies
- Integration with the city and other modes
- Alignment design as per relevant standards, smooth ride, asset life cycle
- Exclusive or shared right of way
- Civil infrastructure design – geometric, survey/investigation, structure design as per codes, architectural designs to gel with city/area/localities, cultural ingredients
- Station design
- Guideway design
- System infrastructure design – balance between existing systems and multiple subsystems
- Relevant standards – Indian and international
- New technologies to reduce complexities, e.g., use of on-board battery/super-capacitor storage to avoid complicated and visually intrusive catenary wires at certain locations.
- Cost effectiveness and the economic benefits.

A mass transit system is selected and planned to provide comfortable, safe, reliable, and fast or high-frequency connectivity across the cityscape.

4.1.1 MOHUA GUIDELINES

The Ministry of Housing and Urban Affairs (MoHUA) of the Government of India (GoI) has laid down guidelines for appraisal and broad technical parameters for different modes.

- Metro Rail Policy (2017) and the Appraisal Guidelines for Metro Rail Project Proposals (September, 2017), which mandate the compulsory incorporation of an

Alternatives Analysis Report (AAR) in the Detailed Project Report while seeking Central assistance.

- Standard Specifications of Metro Neo (November 2020)
- Standard Specifications of Light Urban Rail Transit System "Metrolite" (July 2019)
- Report on Benchmarking for Cost Estimation of Metro Rail Project (February 2019)
- Standardization/Indigenization of Electrical & Electro-mechanical Metro Rail Components (August 2018)

4.1.2 COMPARISON OF PUBLIC TRANSPORT SYSTEMS

There are several mass transit systems and technological options available for public transport worldwide. The options available today are described in the following sections.

TABLE 4-1: SELECTION CRITERIA OF MASS RAPID TRANSIT MODES[1]

Parameter	Metro Rail	LRT (at-grade)	Monorail	BRTS	Organised City Bus Service
PHPDT in 2021	≥ 15000 for at least 5 km continuous length	≤ 10,000	≤ 10,000	≥ 4,000 and Upto 20,000	
Population as per 2011 census (Million)	≥ 2	> 1	> 2	> 1	> 1 lac Hilly towns (50,000)
Average Trip Length for Motorized Trips in km	> 7-8	> 7-8	About 5-6	> 5	> 2 to 3

Each type of mode is associated with a specific capacity range, expressed in Peak Hour Peak Direction Traffic (PHPDT).

4.1.2.1. NORMAL BUS SERVICES

Normal/ordinary bus system is the main transport system in many major Indian cities. They are usually characterized as sharing the common right of way with other modes of transport in the city. Ordinary buses often act as a feeder mode of transport for mass rapid transit systems such as Metro, LRT, Sub-Urban Rail Systems, etc.

1 Source: Recommendations of Working Group on Urban Transport for 12th Five Year Plan, 2012

4.1.2.2. BUS RAPID TRANSIT SYSTEM (BRTS)

Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capacities. It does this through the provision of dedicated lanes, with busways and iconic stations typically aligned to the centre of the road, off-board fare collection, and fast and frequent operations. The basic BRT system comprises a 2-lane at-grade operation that can cater to a PHPDT range of 3000 to 6000. A dedicated 4-lane wide at-grade variants or 2/4-lane elevated BRT system with longer, double-articulated buses can cater to a PHPDT upto 20,000 or more. These systems are operational in some cities of South America like Bogota, Sao Paulo and at Istanbul.

Buses using fossil fuels are now giving way to electric buses due to environmental concerns. Hence, future BRTs are likely to use electric buses too with battery or overhead power supply.

4.1.2.3. METRO NEO

The Metro Neo System has electric coaches that draw power from overhead wires using spring loaded poles. This system is suitable for cities with lesser traffic demand. It is capable of handling PHPDT upto 8000.[2]

The system has low vibration and ensures quieter operation. These coaches have rubber tyres rolling on the road surface, which provides better adhesion than rail-based systems. There are new technologies for charging etc., which enable the coaches to operate over short distances without being connected to an overhead contact line. Modern systems can operate without the overhead contact wire for distances up to 20 km with suitable capacity of battery banks.

2 Standard Specifications of Metro Neo, MoHUA - 2020

4.1.2.4. METROLITE

The MoHUA has issued specifications/guidelines for adopting light urban rail transit system – Metrolite for small cities and towns with a lower estimate of ridership. Metrolite can be developed at-grade or elevated, at a lower cost as compared to the conventional Metro rail system.

In case it is at-grade, the system shall have a dedicated path separating the metro track from the road traffic. In addition to lesser capital cost, the lower operation and maintenance makes this system more financially viable. Metrolite with a maximum axle load of 12T is to be adopted for passenger PHPDT capacity of the order of 15000.[3] The system permits sharper curves of radii up to 25 m.

4.1.2.5. METRO RAIL SYSTEM

A Metro system is a conventional wheel-on-rail railcar running on 1435-mm standard-gauge tracks with modern signalling and associated systems. The Metro systems can be categorized into three (03) types, as mentioned below[4]:

A. Light Metro Rail

Light Metro Systems have a typical capacity of upto 35000 PHPDT. They run on a segregated alignment which can be elevated or underground.

B. Medium Metro Rail

Medium Metro is a system halfway between Light and Heavy Metro. Its capacity lies between 30000 PHPDT and 60000 PHPDT (6 standees/sqm).

C. Heavy Metro Rail

Heavy Metro is a system that can move more than 55000 PHPDT (6 standees/sqm) and runs fully segregated (either elevated or underground).

3 Standard Specifications of Light Urban Rail Transit System “Metrolite”, MoHUA - 2019
4 Standardization & Indigenization of Metro Railways, Systems and Sub-Systems – MoUD, 2013

Table 4-2 summarizes the broad parameters of various mass transit systems:

TABLE 4-2: BROAD PARAMETERS OF VARIOUS MASS TRANSIT SYSTEMS

S.N.	Parameter	BRT	Metro Neo	Metrolite	Metro
1	Typical Axle load	10T	10T	12T	16T/17T
2	PHPDT range	Upto 6000	Upto 8,000	Upto 15,000	30,000 to 80,000
3	Number of cars	1 to 3 with articulation	1 to 3 with articulation	3 to 9 articulated	3 to 8
4	Car dimensions	Width 2.5 m Length 12/18/24 m	Width 2.5 m Length 12/18/24 m	Width 2.65 m Length 33 m	Width 2.9 to 3.2 m Length 22 m/car
5	Car capacity (@8 pax/m^2 standing)	90/170/250 per vehicle	90/170/250 per vehicle	300 for 3-car tram unit of 33m	~ 300
6	Typical platform length	30 m	30 m	50 m for 3-car unit	140 m for 6-car unit
7	Concourse level in elevated mode	Not Required	Not Required	Not Required	Required
8	Capex/km	₹ 50 cr/km	₹ 65 to 80 cr/km	₹ 70 (At-Grade) to 140 (Elevated) cr/km	₹ 250 to 375 cr/km - Elevated
9	O&M costs	Low	Low	Medium	High
10	Operating speed	60-70 kmph	60-70 kmph	60-70 kmph	80-85 kmph
11	Min horizontal curve radius	25 m	20 m	25 m	120 m
12	Power supply for propulsion	Battery / CNG / Fuel cell operated	Overhead wires for part or full length; on-board battery for wire-free running	Overhead wires; on-board battery / super-capacitors for catenary-free running	Overhead wire / third rail

4.1.3 PROJECTED TRAFFIC DEMAND

The projected maximum PHPDT of the proposed Metro corridor is given in Table 4-3.

TABLE 4-3: MAX PHPDT ON LINE 2 IN HORIZON YEARS

S.N.	Name of the Corridor	2027	2037	2047	2057
1	Chandani Chowk – Vanaz – Ramwadi – Wagholi/Vitthalwadi	11,200	17,001	24,255	29,554

4.1.4 RECOMMENDATION

Considering the ridership, characteristics of the corridor, and as Line 2A (Vanaz to Chandani Chowk) and Line 2B (Ramwadi to Wagholi/Vitthalwadi) are the extensions of Line 2 (Vanaz to Ramwadi) of Pune MRTS Phase – 1 (which is a Medium Metro System), Medium Metro is recommended for Line 2A and Line 2B. Detailed recommendations for Medium Metro for these lines are given in the Alternative Analysis Report.

4.2. SYSTEM SPECIFICATIONS ADOPTED FOR THE CORRIDOR

Line 2A and Line 2B are extensions of Line 2 – Vanaz to Ramwadi of Phase – 1, in which the Vanaz to Garware College section has been opened for passenger traffic and the balance section is in an advanced stage of completion. Therefore, considering its existing system characteristics and the same existing depot being utilised, the following specifications for Line 2A and Line 2B are recommended, as mentioned in Table 4-4.

TABLE 4-4: SYSTEM SPECIFICATION CHARACTERISTICS

Parameters		System Specifications
Gauge		1435 mm
Rolling Stock	Coach	Width – 2.9 m Height – 3.9 m Length - 20 to 22 m
	Train Composition	3-Car: DMC+TC+DMC 6-Car: DMC+TC+MC+MC+TC+DMC
	Coach Construction	Aluminium/Stainless Steel
	Axle Load	≤16T
	Max. Design Speed	95 kmph
	Max. Operating Speed	85 kmph
	Max. Acceleration	1.0 m/s^2
	Max. Deceleration	1.1 m/s^2 (Service Brake) 1.3 m/s^2 (Emergency Brake)
	Jerk Limitation	0.75 m/s^3
	Braking System	Regenerative Braking
Traction System		25 kV ac OHE traction system
Propulsion System		3 phase drive system with VVVF control
Signalling System		Communication-Based Train Control System GoA 2 Level
Telecommunication System		IP based min 10G Wide Area Network
Fare Collection System		Computer-based AFC System – Contactless Smart Card & QR Ticket Type 1. EMV (Euro MasterCard Visa & RuPay) 2. PCI-DSS (Payment Card Industry/Data Security Standard) 3. ISO-IEC 14443

CHAPTER 5: CIVIL ENGINEERING AND ALIGNMENT

5.1 SITE APPRECIATION AND RECONNAISSANCE SURVEY

As mentioned in the Preface Table 0-1, seven (07) corridors have been identified for preparation of DPR as part of the Phase-2 of Pune MRTS. Of the seven (07) corridors, two (02) corridors, which are basically extensions of Line 2, Vanaz to Ramwadi of Phase-1 i.e. Line 2A from Vanaz to Chandani Chowk on the west side and Line 2B from Ramwadi to Wagholi/Vitthalwadi on the east side are being taken on priority.

The present report covers the corridors - Line 2A and Line 2B. To finalise the alignment routes for these corridors, station locations, integration with existing and future infrastructure projects, several site visits, reconnaissance surveys and survey by drone have been carried out since November 2021.

The site visits were undertaken by the domain experts which included (but not limited to) Alignment expert, Transport planner, Multi modal planning expert, Station planner, Systems experts, Environmental experts, Social/R&R experts and the Team Leader as well. Several visits were done with Maha-Metro team, which included Executive Director/Civil, Dy. GM/Planning and other team members including the experts from the General Consultants (GC) to Pune Metro Project.

In addition, few visits were undertaken in coordination with the key stakeholders in the city which included Pune Municipal Corporation (PMC) and Pimpri Chinchwad Municipal Corporation (PCMC), Pune Metropolitan Regional Development Authority (PMRDA).

Various boundary conditions like minimum land acquisition, flatter curvatures, heritage/ archaeological structures & sensitive structures i.e. religious buildings, schools, hospitals should not be impacted, minimise environmental impacts, safety issues etc. have been considered.

Several alternative routes based on the Google Earth imagery, traffic data availability from the CMP, several site visits, constraints etc., and the consultant's various proposals, were analysed which are part of the Alternative Analysis Report.

The consultants also presented the critical locations, possible integration opportunities, alternate routes in the review meetings to Maha-Metro. Wherever required, detours, special spans, integrated structures have been planned as part of the geometric design.

Videos and photos of the corridors and special locations have been recorded, which will be handed over to the client on completion of the project.

5.2 ANALYSIS OF THE OPTIONS

5.2.1 LINE 2A: VANAZ TO CHANDANI CHOWK

The corridor starts from the western end of Phase-1 after Vanaz station, which passes through the main arterial along the Mumbai Highway (Katraj-Dehu Bypass Road). The corridor alignment passes through Chandani Chowk, Lonia Jain IT Park along the Paud Road, etc. The Line 2A corridor is shown in Figure 5-1.

FIGURE 5-1: ALIGNMENT OF LINE 2A – VANAZ TO CHANDANI CHOWK

Based on the ground reconnaissance, the alignment from Vanaz to Chandani Chowk looks straight forward alignment. However, the alignment has various challenges and the study team had to evaluate various aspects such as number of stations, location of stations, provision for future extension on National Highway towards Baner, Integration with the under-construction cloverleaf type flyover at Chandani Chowk. As part of the alternative analysis, three (03) main options and seven (07) sub-options have been planned/designed for the Line 2A. The requirement of developing several options arised due to the huge difference in ground levels from Vanaz end of Phase-1 towards the Bengaluru National Highway. The difference in levels is more than 23 m in length of 1100m from Vanaz end of Phase-1 till National Highway 48 and further more 23m from National Highway till NDA Junction. Additionally, there is a road over bridge at Pashan junction which further adds 9-10 m to this level This shows that the level increases drastically as we move forward from National Highway towards NDA Chowk and becomes more restrictive at the Road over Bridge (RoB) crossing the National Highway at NDA Chowk

or Pashan Road junction. The summary of the three main alignment options evaluated for the Line 2A are represented in the Table 5-1.

TABLE 5-1: ALIGNMENT OPTIONS FOR VANAZ TO CHANDANI CHOWK

Option	Description / Features	No. of stations	Future extension	Remarks
1.	Corridor type: Elevated No. of stations: One (Side Platforms) Station location: After the Pashan road bridge near the Triangular region. Uniform gradient of 3.76% from Phase-1 pier P-4 till the crossover start. Future extension: Yes Length: 2.343 km Crossover arrangement before and after the station for usage of platform and reversal. Crossovers on level grade.	1 Elevated Side platforms	Yes	In this option, the alignment is on continuous gradient from the last pier of phase-1, this allows to have clearance of metro viaduct from Pashan road bridge and one station after the bridge which can be integrated with the under-construction flyover.
2.	Corridor type: Elevated (500m), switch over ramp: 250m approx. (RL: +6.5 to -9.0) and underground (1900m). No. of stations: Two (One elevated side platforms with concourse on ground level and one underground island Platform). Stations on level grade (0%) Station location: Elevated station on the Paud Road and underground station near the triangular area after the Pashan road bridge. Future extension: Yes Length: 2.65 km Scissor crossover after the underground station at level gradient i.e. 0.0%	2 1 Elevated and 1 underground (1 side platforms 1 Island platform)	Yes	This option has part underground and part elevated sections. This option allows to plan one elevated and one underground station and also provision for future extension part underground.
3.	Corridor type: Elevated No. of stations: Two (Side Platforms) Station location: One on Paud Road and One before NH. Future extension: No Length: 1.1 km approx Two crossovers before the station-2 for front reversal of trains. Both stations in level grade (0%)	2 Elevated Side Platform	No	In this option, the scissor crossover before station 2 has been replaced with two cross overs. Also, the inter-station distances have been further optimised. The station 1 is at approx. 942 m from the Vanaz station of Phase-1 and station 2 is approx. 815 m from station 1. In order to

Option	Description / Features	No. of stations	Future extension	Remarks
				optimise the station distances, the station 1 has been planned on curve of 1010 m radius.

After review of all the pros and cons of all the main and sub-options, **Option-3** has been recommended, which has been accepted by Maha-Metro. The detailed engineering design has been done on Option-3.

5.2.2 LINE 2B: RAMWADI TO WAGHOLI/VITTHALWADI

For the Line 2B which is an extension on the Eastern side of the Line 2 of Phase 1 (Vanaz-Ramwadi) between Ramwadi to Wagholi/Vitthalwadi, several options were analysed based on site visits, existing infrastructure, stakeholder consultations and proposed future developments. Some of these options are as below:

i. PMC informed that considering the heavy congestion on Nagar Road, **new bypasses** being proposed on North and South side of the Nagar Road. Considering the NHAI flyover from Wagholi to Shikrapur, metro alignment through these bypasses may be considered (Figure 5-2).

Conclusion: Since the ring road is intented to be constructed in wider space and to reduce the volume of traffic using Nagar Road for longer trips, MRTS on the ring road will result in lose the shorter trips. Connectivity to the wider catchment will get impacted. Also, these roads are still in proposal / planning stage.

ii. Corridor alignment on LHS or RHS of the existing BRTS corridor till the existing BRTS and then on centre of the Nagar Road, so as to minimise the disruption of BRTS corridor.

Conclusion: MRTS to follow the centre of the BRTS. The BRTS corridor will be expanded on both sides to maintain the lane widths. The same practice has been followed in the several sections of Phase-1 of the project.

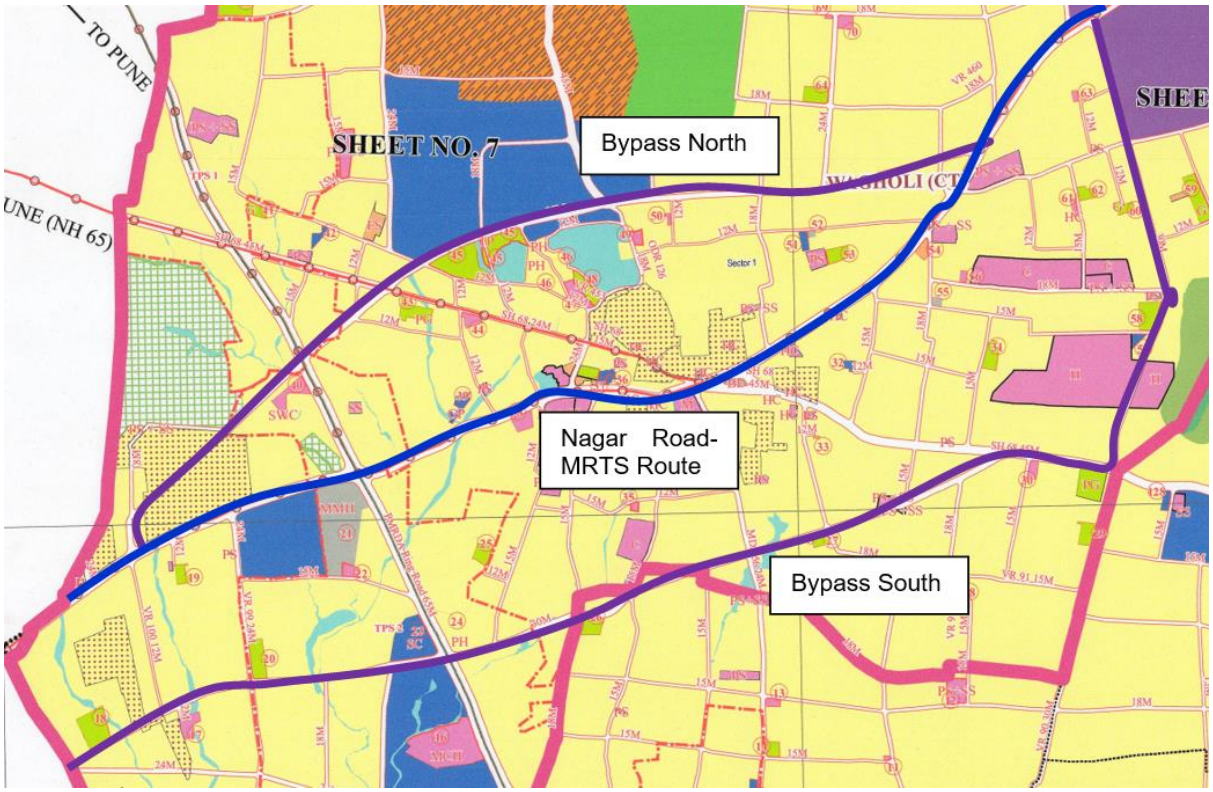


FIGURE 5-2: ALIGNMENT OF LINE 2B – RAMWADI TO WAGHOLI / VITTHALWADI

iii. Interface with NH department of the Public Works Division for integration with the proposed three-tier (Ground plus two) flyover for length of approx. 8kms (Figure 5-3). MRTS to follow road centre and to be planned on tier four (Ground plus three), or MRTS can be planned on RHS or LHS of the Nagar Road as per availability of space.

Conclusion: Since the flyover is in conceptual design stage, the feasibility / viability still not concluded. Also, the rail levels will be in the range of 26-29m from ground level. Access to the stations will have taller escalators, higher staircases etc. Along both side of the Nagar Road, space is available on road for some sections and some sections are under encroachment. Private property acquisition may be required. Therefore, it has been decided that the MRTS should be planned on the centre of the road and the flyover can be integrated later either on ring road or with the MRTS.

After review of the pros and cons of all the above-mentioned options, reviewing the site constraints, integration with future proposals etc. it was recommended that the MRTS alignment should follow the centreline of the Nagar Road, which has been accepted by Maha-Metro. The detailed engineering design has been done on this option.

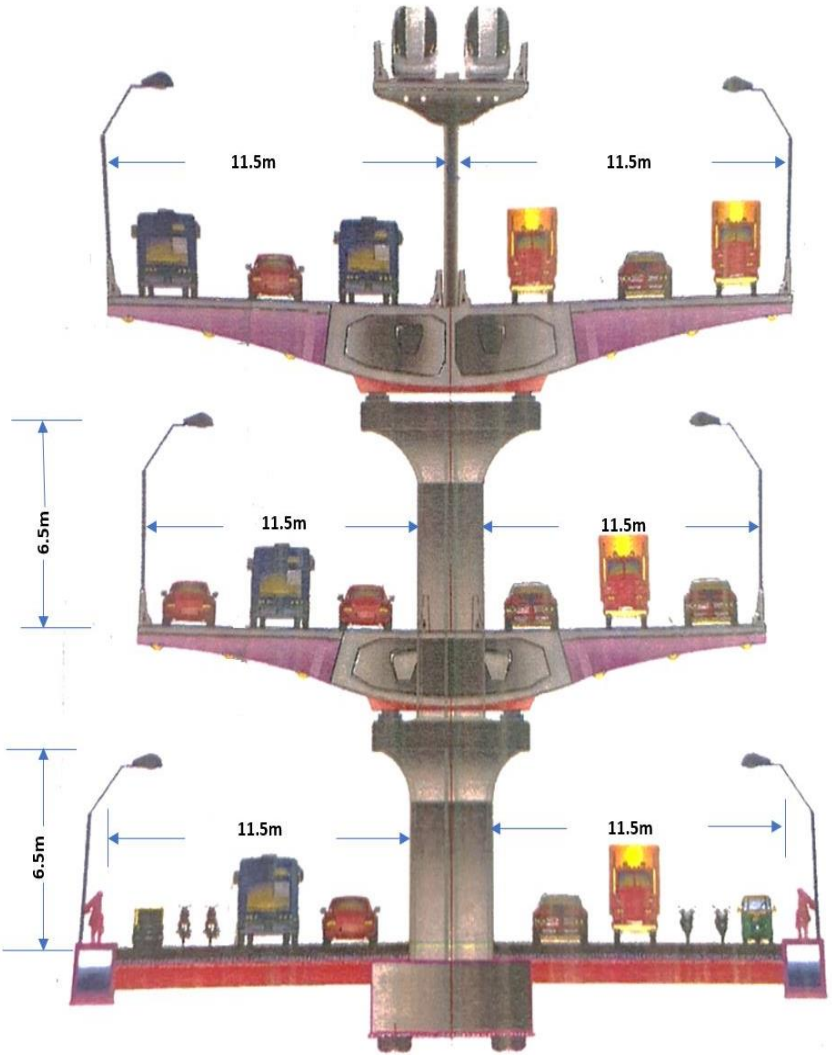


FIGURE 5-3: GROUND LEVEL PLUS TWO LEVELS OF FLYOVER AND MRTS ON TOP

iv. Interface and Integration with the proposed flyover and underpass by Pune Municipal corporation at Kharadi bypass junction. Earlier the alignment was proposed on centre of the existing BRTS corridor. Based on the drawings received from Pune Municipal Corporation (un-coordinated), the alignment drawings were checked with reference to the structures in the survey and superimposed on that. It was realised that, PMC has proposed to widen the road on RHS of the corridor (facing towards Wagholi/Vitthalwadi). The MRTS alignment has been superimposed and planned along with the proposed road development as per PMC (Figure 5-4).

The movement of road traffic from Ramwadi side towards Hadapsar on the flyover and from Hadapsar towards Wagholi/Vitthalwadi through the underpass. The MRTS corridor piers are planned in such a way, that the piers do not infringe the proposed flyover and underpass.

Conclusion: The MRTS follows the centre of the BRTS corridor as per the drawings of Pune Municipal Corporation.

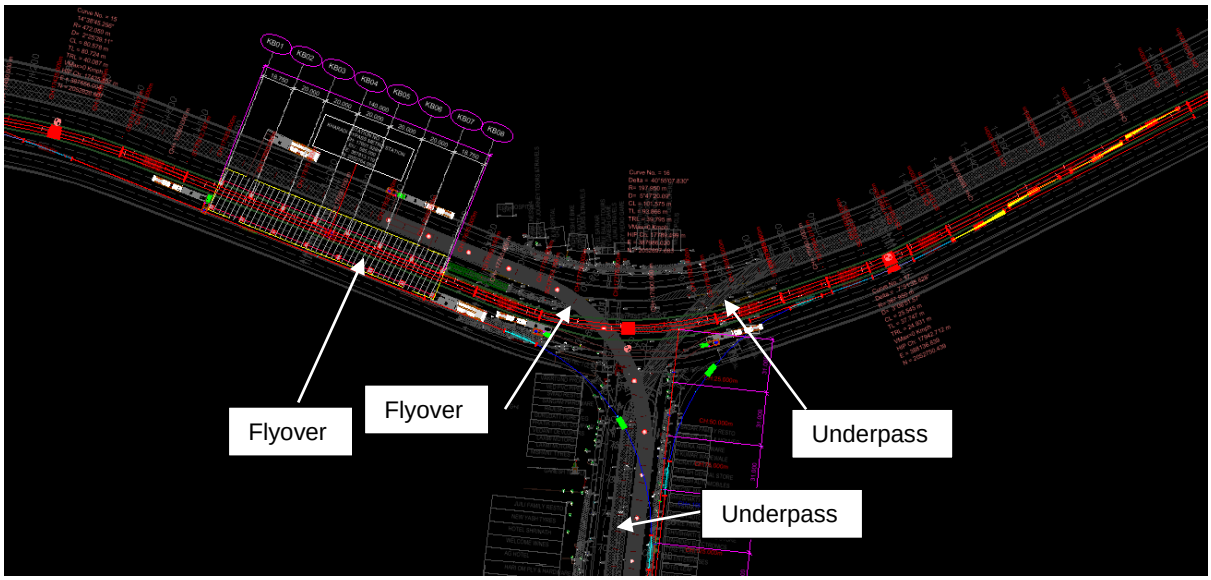


FIGURE 5-4: PROPOSED FLYOVER AND UNDERPASS AT KHARADI JUNCTION

5.3 ENGINEERING SURVEYS

5.3.1 INTRODUCTION

The engineering surveys are conducted for Line 2A and Line 2B, which are extension of Line 2 (Vanaz to Ramwadi – Phase 1).

The Line 2 of the Phase-1 corridor runs from Vanaz on West end to Ramwadi on East end. The West side extension is from Line 2A Vanaz to Chandani Chowk (1.12kms) and the East side extension is from Line 2B from Ramwadi to Wagholi/Vitthalwadi (11.6kms). This system will be similar to the under-construction and partly in operation phase-1 of the Pune Metro system i.e. bi-directional twin tracks with 25kV ac OHE traction system.

Post reconnaissance, planning of the proposed corridors have been undertaken using topographical survey data. The Topographic survey is conducted with the help of Global Positioning System (GPS), Total Station and Auto levels. Based on the survey, details of the existing features along Line 2A and Line 2B were collected, which were further used for designing and planning the alignment and depot for the corridor. Survey details are described in detail in the following sections.

5.3.1.1. TOPOGRAPHICAL SURVEY METHODOLOGY

The Topographic Survey was conducted to collect the details of the existing ground features of Line 2A and Line 2B.

Following procedure has been adopted for undertaking Topographical Survey Work:

i. Establishment of Horizontal Control Points using DGPS

ii. Densification of Horizontal Control Points using Total station
iii. Establishment of Vertical Control Points
iv. Detailed survey of corridors
v. Preparation of Drawings.
vi. Site verification of features and finalization of drawings.
vii. Alignment design on the basis of verified drawings.

Instruments used: Total Station – Leica 06/Leica 02/Leica 03 (Accuracy 1 Second)

i. DGPS – Leica GS14/Leica GS16/Leica GS18
ii. Auto Level/Digital Level – Sokkia/Leica

5.3.1.2. DETAILS OF CONTROL POINTS

In order to ensure correctness of the survey and coordination with the corridors of the Phase-1 of Pune MRTS, information regarding Benchmarks have been taken from the General Consultant's survey team. The Easting and Northing are in "meters", based on UTM coordinate system.

TABLE 5-2: LIST OF GPS ALONG LINE 2A: VANAZ TO CHANDANI CHOWK

GPS No.	Easting	Northing	RL (m)	Remark
D-30	373123.3	2046793	598.259	Near Flying Wheels Showroom
D-31B	372201.5	2046821	614.752	Near Bus Stop in front of Lohia IT Park
D-31A	372195.2	2046819	614.984	Near Bus Stop in front of Lohia IT Park

TABLE 5-3: LIST OF GPS ALONG LINE 2B: RAMWADI – WAGHOLI/VITTHALWADI

GPS No.	Easting	Northing	RL (m)	Remark
MP 86	385253.861	2052352.861	568.033	GPS Provided by GC/Maha-Metro opposite to Ibis Hotel
D-15	387937.143	2052701.992	569.748	Near Tulsi Hotel Kharadi By Pass Junction R/S
D15-NEW	387932.943	2052704.662	569.919	Near Tulsi Hotel Kharadi By Pass Junction R/S (Pillar)
D-16	389789.607	2053811.238	576.103	Hotel Shivsagar Front Ft
D16-NEW	389786.86	2053809.213	576.043	Hotel Shivsagar Front Ft (Pillar)
D17	391304.19	2054393.703	565.445	Opposite Site Of Decathlon
D18	393204.797	2054911.72	581.363	In front Of GHAR-SANSAR Near Petrol Pump At Wagholi Market
D18-NEW	393206.539	2054911.771	581.341	Ghar-Sansar Front Of Ft (Pillar)
D19	394523.41	2056230.894	599.149	Jayraj Executive Lodging Front Of Ft
D21	395703.233	2057142.455	593.447	Near BLUE DART Ware House In Wagholi/Vitthalwadi
D21-NEW	395700.7	2057143.59	593.576	Near BLUE DART Ware House In Wagholi/Vitthalwadi (Pillar)

TABLE 5-4: LIST OF TBMS ALONG CORRIDOR 2B: RAMWADI – WAGHOLI/VITTHALWADI

TBM No	Easting	Northing	Level	Remark
TBM-1	385240.33	2052408.972	569.292	Ashok Plaza Gate Wall
TBM-2	385503.512	2052495.484	571.126	Co-Op Housing Society Temple Gate
TBM-3	386146.637	2052697.292	567.028	Ctr -Gate On
TBM-4	386401.378	2052700.946	568.5	Ctr -On C Wall
TBM-5	386075.911	2052618.708	569.21	Business Chambers Garden on Wall
TBM-6	386401.378	2052700.946	568.5	Mantri Business & Mantri Near Ft
TBM-7	386532.933	2052763.616	569.326	BRT On R/S On Wall Top
TBM-8	386570.769	2052769.039	570.849	BRTOn R/S On Wall Top
TBM-9	386863.506	2052816.857	573.26	9 Base Repair Depot Near Ft
TBM-10	386599.206	2052754.745	570.23	Aganagar Society On Ft
TBM-11	386884.017	2052771.609	572.48	Mundhwa Road Junction
TBM-12	387312.372	2052851.327	572.07	Air Force School Near Ft L/S
TBM-13	387327.411	2052851.352	571.596	Air Force School Near Ft L/S
TBM-14	387684.65	2052856.075	569.054	To Aadesh Creation Junction L/S
TBM-15	387402.439	2052808.041	570.06	Pdc Bank On Step
TBM-1	388102.398	2052716.496	565.312	Bhosale Automobile On Ft
TBM-3	388990.19	2053330.627	569.091	Tedy Toys Near On Wall
TBM-1	391036.824	2054347.113	564.686	Hotel Kaveri opposite Site C Wall
TBM-3	391712.718	2054561.925	568.41	Aarav Enterprises On Wall
TBM-4	391908.705	2054613.772	570.541	Crystal Honda On Wall
TBM-5	392285.57	2054762.819	579.12	Irrigation Department On Wall
TBM-6	392158.401	2054759.386	577.745	Wagheshwar Temple On Wall
TBM-7	392685.507	2054695.015	584.562	Prathamik Aarogya Kendra Wagholi Near
TBM-9	393153.766	2054883.227	582.083	Bharat Pump Garden Wall
TBM-1	393464.176	2055071.208	582.58	Cera Showroom In Front Of
TBM-4	394255.508	2055750.747	591.59	Bakori Fata Chowk
TBM-5	394142.928	2055646.5	590.239	Burger King Front of Wall
TBM-6	394371.947	2056002.658	595.54	Morya Fashion opposite on Permeant Drain Top
TBM-1	395606.262	2057091.879	590.22	Security Cabin Bridge Wall R/S Top
TBM-2	395676.471	2057160.97	592.91	Matoshree Super Market Front Of

5.3.1.3. DETAILED TOPOGRAPHICAL SURVEY

The details of Topographical Survey are provided below (refer Figure 5-5 & Figure 5-6 for activities);

1. Before the commencement of Topographical Survey, Horizontal control grid have been established using Differential Global Positioning System (DGPS) at about 2 km along the alignment on existing Structures/Pavement.
2. After fixing horizontal control points by DGPS at 2 km interval; Vertical control points were transferred from known Ground Control Points (GCPs) to unknown GCPs by means of Auto level/Total Station.

3. Traversing of control points were conducted by Total Station/DGPS (one second accuracy) and intermediate benchmark was marked at regular interval of approx. 500m/1000m.
4. All levels have been taken with respect to benchmarks as supplied by the GC/Maha Metro, which are connected to GTS benchmarks and temporary/permanent benchmarks marked / provided at regular intervals of 250m/500m.
5. After marking of Benchmarks, Topographical Survey work was conducted using Total Station. The survey covered built up line to built up line inclusive of all the road features as directed by Engineer- in charge showing all the bye lanes, footpaths, dividers/central verges, roads, trees, manholes other structures, Over ground drains, H.T., L.T. Transmission lines etc. Spot / Ground levels have been taken at 20-meter Intervals in longitudinal as well as transverse direction (with grid and duly marked on the drawing) and at sudden change of levels and other features etc. as instructed by the Engineer-in-charge. Additional Details includes:
    a. Details of land along the route and their uses such as residential areas, commercial areas, religious, parks, green areas, vacant lands etc.
    b. Details of open Drains, nallahs, with bed levels, LFL's and HFL's
    c. Survey of Level crossings (if any) with their numbers, class, manned or unmanned, Road-Over- Bridges (Robs) Road-Under- Bridges (Rubs) and Foot-Over Bridges (FOBs), Railway bridges with their structural details, angle of crossing and road & rail levels
    d. Details of Religious structures such as temple, Gurudwara, Mosque, Church, Monuments, tombs, etc. Any other structure or details which the consultants may feel important and or as instructed by Engineer-in-charge.
    e. When the proposed alignment is passing along the existing bridges, the topographic details on the either side of the existing bridges have been collected.
    f. After the site data was captured using the topographical survey, survey drawings were prepared.
6. Site verification of features was done to finalize the drawings.
7. The drawings were then submitted to the alignment engineer for Alignment design on basis of verified drawings.

Verification by Maha-Metro/GC:

In addition to the engineers from UMTC, Maha-Metro/GC team on behalf of Maha-Metro verified the instruments, cross checked the GPS benchmarks and drawings etc. on sample basis. On intermediate basis, drawings were also submitted to the GC Engineers for review and feedback.

FIGURE 5-5: TOPOGRAPHIC SURVEY USING TOTAL STATION IN PROGRESS

FIGURE 5-6: TOPOGRAPHIC SURVEY IN PROGRESS

5.4 GEOTECHNICAL INVESTIGATIONS

The geo-technical investigation analysis is conducted with an objective to get factual information on the sub-surface soil condition during the investigation period, along with the laboratory tests results, to obtain strata & type of soil at different depths below the natural ground, so as to arrive at design parameters for the foundations from the recommended safe bearing capacity of foundation soil.

The geotechnical investigation includes the field investigation, the laboratory test results of the soil samples to evaluate the soil parameters and recommendations with regard to capacity of strata for the design of foundations of proposed structures.

5.4.1 GENERAL GEOLOGY & CHARACTERISTICS

5.4.1.1. LOCATION

Pune is the second largest district of Maharashtra State. The district has a geographical area of 15,642 Sqkm, 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 Ahmednagar 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.

Geotechnical investigations have been carried out to determine the strata, depth of foundation and safe bearing capacity of foundations required for the above proposed Metro corridors. i.e. Line 2A Vanaz to Chandani Chowk and Line 2B Ramwadi to Wagholi/Vitthalwadi. The details of these corridors including the alignment, have already been discussed in the previous sections.

The detailed Geo-technical investigation report has been submitted separately as part of the DPR.

5.4.1.2. RAINFALL AND CLIMATE

The climate of the district on the whole is moderate. The winter season is from December to about the middle of February followed by summer season which lasts up to May. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season. The mean minimum temperature is about 12°C and mean maximum temperature is about 39°C. The normal annual rainfall over the district varies from about 468 mm to 4659 mm. It is minimum in the eastern part of the district around Daund (468 mm), Baramati (486 mm) and Jujuri (494 mm).

This increases towards west and reaches a maximum around Khandala (4659 mm) in the Western Ghat. The Chances of receiving normal rainfall are maximum (50 to 55%) in

eastern part around Indapur and Daund, in the central part around Pune city and small area around Junnar in northern part of the district.

Rainfall analysis also indicates occurrence of drought prone area in eastern, southern, southeastern, central and north western part around Indapur, Baramati, Jujuri, Daund, Talegaon, Dhamdhare, Alandi, Shirur and Bhor covering about 50% area of the district. Taluka wise average annual rainfall for the period 2003 to 2012 ranges from about 474 mm (Daund) to 2668 mm (Velhe).

5.4.1.3. PHYSIOGRAPHY

Pimpri-Chinchwad is the extended city limits of Pune, and part of the Pune Metropolitan Region in Maharashtra State. However, it is a separate city from Pune with its own taluka and Municipal Corporation. 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' and falls in parts of Survey of India degree sheets 47-E, 47-F, 47-I, 47-J, 47-K, 47-N and 47-O.

Physiographically, the district can be divided in to three distinct belts i.e.

a. The western belt stretching 6 from 16 to 31 km east of Sahayadri- an extremely rugged country cut by deep valleys, divided and crossed by hill ranges.
b. The central belt extending for about 30 km east of western belt across the tract whose eastern belt is roughly marked by a line drawn from Pabal in the north to south up to Purandar through Pune. In this belt a series of small hills stretch in to valleys and large spurs from Plateaux and
c. The eastern belt with a rolling topography and 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.

5.4.1.4. SEISMICITY

As per the 2002 Bureau of Indian Standards (BIS) map, Maharashtra also falls in Zones II, III & IV. Historically, parts of this state have experienced seismic activity in the M 6.0-6.5 range. The new map includes the central districts of Beed (Bir), Dharashiv (Osmanabad) and Latur, along with eastern sections of Ahmednagar, Pune, Satara and Sangli districts in Zone III. Figure 5-7 shows location of Pune City on the seismic map of Maharashtra state.

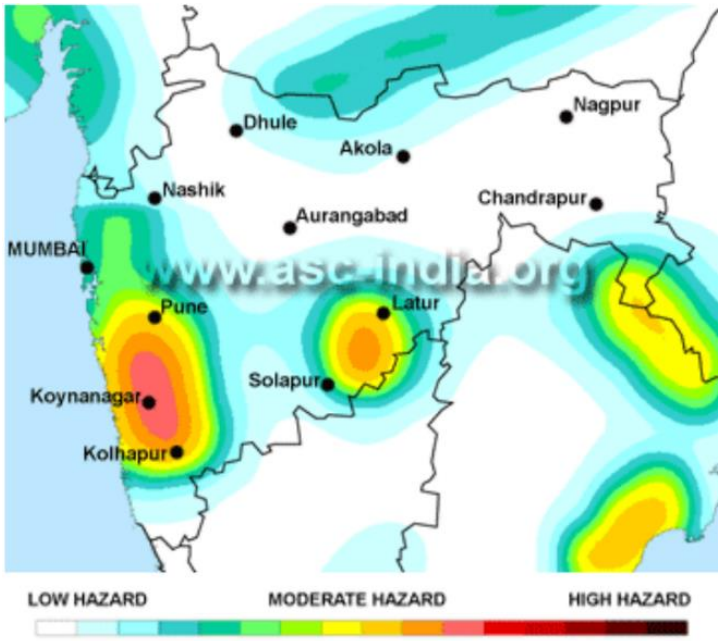


FIGURE 5-7 LOCATION OF PUNE CITY IN SEISMIC MAP OF MAHARASHTRA

Figure 5-8 below represents the seismic map of India, showing the various Seismic zones.

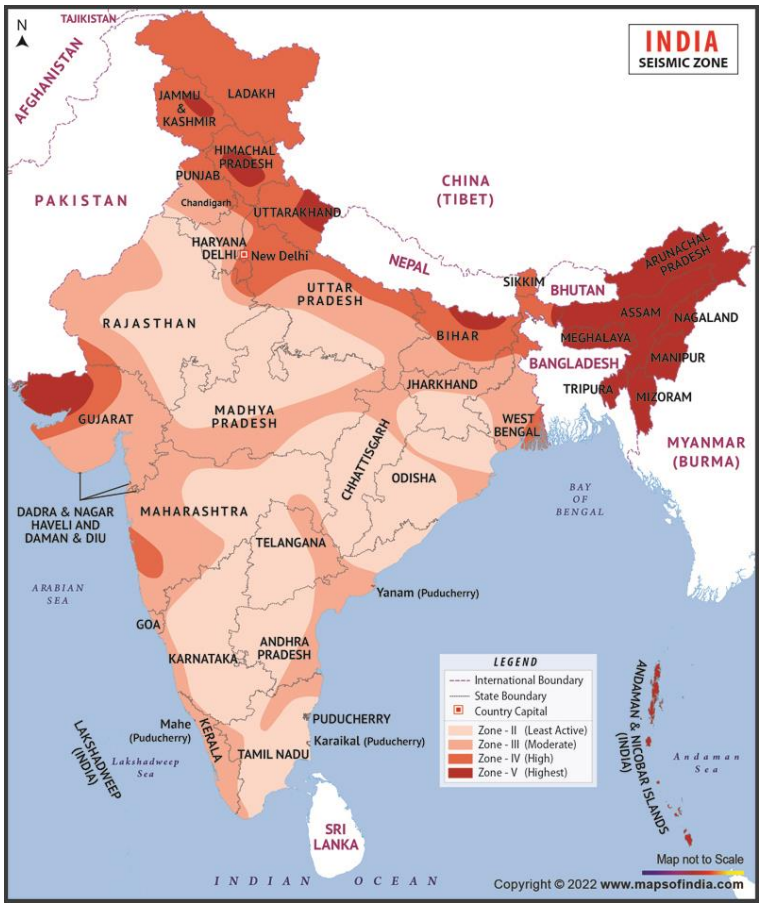


FIGURE 5-8 SEISMIC MAP OF INDIA

5.4.2 FIELD WORK AND TESTS

5.4.2.1. TEST LOCATIONS

The locations of the Boreholes are provided in the below table:

TABLE 5-5: BOREHOLE LOCATIONS

S No.	Test Location	BHL No.	Coordinates	
			Northing	Easting
1	Ramwadi – Wagholi / Vitthalwadi	BHL - 1	2054826	393183
2		BHL - 2	2054710	392185
3		BHL - 3	2054378	391494
4		BHL - 4	2053645	390429
5		BHL - 5	2053645	389509
6		BHL - 6	2053645	389273
7		BHL - 7	2057062	395621
8		BHL - 8	2056583	394784
9		BHL - 9	2055752	394268
10		BHL - 10	2052836	388225
11		BHL - 11	2052770	386842
12		BHL - 12	2052665	386200
13	Chandani Chowk	BHL - 37	2046799	371509

5.4.2.2. ROTARY CORE DRILLING

Rotary Core drilling is done where the formation encountered is too hard to be sampled by any soil sampling methods. Primarily Casing was seated on bedrock or in a firm formation to prevent travelling of the borehole and to prevent loss of drilling fluid. The core drilling was carried out by an Nx-size Triple-tube swivel-type core barrel or any. Core drilling was continued until core blockage occurs or until the net length of the core barrel has been drilled in upto the requirement of engineer in charge. The core samples were obtained at regular interval of 1.5m/3.0m.

At the end of each run, the drill rod string with core barrel is extracted from the Borehole and core is recovered from the core barrel. The percentage of core recovery is recorded and the recovered core pieces were placed in the core box at appropriate spacing, with blocks. Soft or friable cores, or those which change materially upon drying, were wrapped in plastic film. The fractured, bedded and/or jointed pieces of the core were reassembled in the sequential order of their recovery before keeping the same in the core box. If conditions prevent the continued advance of core drilling, the hole were cemented and redrilled, reamed and cased, or cased and advanced with the next smaller-size core barrel. The core drilling observations were done in accordance with IS 5313: 1980, while the drilling information and core description were done in accordance with IS 4464: 1985.

5.4.2.3. DISTURBED AND UNDISTURBED SAMPLE

Disturbed and undisturbed soil samples were obtained depending upon the nature of soil from different depths in the bore hole. The undisturbed samples were collected in sampling tubes. The ends of the tubes are sealed with molten wax to prevent evaporation. These samples were subsequently tested in the laboratory so as to determine the various index and engineering proportion of various sub soil strata met in the bore holes.

5.4.2.4. STANDARD PENETRATION TESTS (SPT)

Standard Penetration Test (SPT) was conducted at different depths in all boreholes where soil was encountered. For shallow depths SPT was conducted at close intervals of 1.5m/3.0m as desired by engineer in charge. The standard split spoon sampler, attached to a string of drill rods was lowered to the bottom of the hole and allowed to rest under self-weight. The drill rods were connected to driving assembly which consisted of a hoisting equipment's, a drive weight (Hammer) of 63.5 Kg, and a guide to ensure a 75 cm free fall of hammer on an anvil. The number of hammer blows that were required to penetrate the sampler through three runs of 15 cm each were recorded as described in IS: 2131 - 1981.

First 15 cm penetration is considered as seating penetration. Initial driving of 15 cm was disregarded and the number of blows required to drive the sampler through the remaining 300 mm is called BLOW COUNT or PENETRATION NUMBER, N. After the bore hole is advanced to desired depth bottom is cleaned Samples from the SPT split spoon sampler were preserved in polythene covers and transported to the laboratory. One more polythene cover was provided to prevent the loss of moisture during the transit. At the end of the test, the sampler is withdrawn and the soil extracted for subsequent testing in the laboratory. When the number of blows exceeded 50 to penetrate the first or second 15 cm length of the Sampler, the SPT 'N' is regarded as more than 100 as described in IS: 2131 - 1981. SPT refusal is recorded when there is no penetration of the sampler at any stage and also when a rebound of the sounding system is recorded.

5.4.2.5. DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic Cone Penetration Tests are carried out in boreholes where Standard penetration test could not be conducted, either due to dense strata or due to presence of Granular Material. DCPT is conducted at required depth at suitable intervals by driving a standard cone of outside diameter 50 mm and having an apex angle of 600 attached to a string of drill rods using a hammer weighing 63.5 kg falling freely through a height of 75.0 cm. The total number of blows required for the 30.0 cm penetration is termed Cone Penetration Resistance or 'Ncd' value. Ncd value is correlated with SPT value, N as under:

Ncd= 1.5 N upto a depth of 4.0 m

Ncd= 1.75 N upto a depth of 4.0 m to 9.0 m

Refusal is deemed to have met if under 35 blows, penetration achieved is less than 10 cms. The above correlation is meant for sandy soils. In boulder deposit / rocky strata evaluation of strength and compressibility characteristics by using elaborate tests is uneconomical for a type of structure proposed to be constructed at site. As a conservative approach, the above correlation can be used such strata to arrive at a safe value of 'N' that takes care of the highly erratic vibrations of properties such strata. Once value of 'N' based on least Ncd value is known, then bearing capacity analysis can be performed as done in case of Sandy deposits.

5.4.2.6. CORRELATION OF 'N' VALUES

In case of sandy/cohesion-less soil, the observed SPT values, designated as 'N', are to be corrected to account for the following two effects:

a) Correction due to effect of overburden pressure: NN = CN X N
   CN' is overburden pressure correction and is calculated as CN = 0.77 $\log_{10}(200/\sigma 0)$.
b) Correction due to submerge effect (in case of fine sand and silt),
   Nc =15 + (NN -15)/2, provided NN>15. Else NC = NN
   Where ' Nc' is the final corrected value.

5.4.2.7. GROUND WATER TABLE

Subsurface explorations were carried out along the length of the proposed corridors. Bore holes were done at regular intervals. Determination of Ground Water Table and water depth from Existing Ground level is done using Steel tape with weigh. The depth of Ground water table is determined as per procedure laid in IS 6935-1973. However, at the time of Investigation at site, Ground Water Table was not encountered in any bore holes upto explored depth in the Month of December-January 2022. The summary of field work conducted is given in Table 5-6.

TABLE 5-6: SUMMARY OF FIELD INVESTIGATION

Borehole No.	Depth Of Borehole (M)	Depth Of Water Table Below Ground Level (M)	Soil/Rock At Termination
Line 2A: Vanaz to Chandani Chowk			
BH-37	5.0	Not Met	Amygdaloidal Basalt Rock
Line 2B: Ramwadi to Wagholi/Vitthalwadi			
BHL-1	7.5	Not Met	Amygdaloidal Basalt Rock
BHL-2	15.0	Not Met	Amygdaloidal Basalt Rock
BHL-3	15.0	Not Met	Amygdaloidal Basalt Rock
BHL-4	12.0	Not Met	Amygdaloidal Basalt Rock
BHL-5	10.5	Not Met	Amygdaloidal Basalt Rock
BHL-6	13.0	Not Met	Amygdaloidal Basalt Rock

Borehole No.	Depth Of Borehole (M)	Depth Of Water Table Below Ground Level (M)	Soil/Rock At Termination
BHL-7	15.0	Not Met	Amygdaloidal Basalt Rock
BHL-8	10.0	Not Met	Amygdaloidal Basalt Rock
BHL-9	12.0	Not Met	Amygdaloidal Basalt Rock
BHL-10	10.0	Not Met	Amygdaloidal Basalt Rock
BHL-11	8.0	Not Met	Amygdaloidal Basalt Rock
BHL-12	9.5	Not Met	Amygdaloidal Basalt Rock

5.4.3 LABORATORY TESTS

5.4.3.1. INDEX PROPERTIES (AS PER SP (PART – 1) – 1987)

All the relevant classification on the samples obtained from the bore holes were carried out in the laboratory. The index properties obtained from such classification tests at different depths in the bore holes are reported in the bore hole log sheets.

5.4.3.2. DISTURBED SOIL SAMPLES

Disturbed soil sample collected in field have been tested in laboratory and preparation of sample for the under mentioned tests have been done in accordance with IS 2720(Part I): 1983 (RA 2015). The following tests were conducted on selected soil:

a) Grain Size Analysis: The grain size analysis of different soil samples was done as per IS 2720 (Part – IV) and 1985 (RA 2015). These analyses of soil are used to classify the soil in various depths of boreholes.
b) Natural Moisture Content: The natural moisture content has been determined from different samples of different boreholes at different depths as per IS 2720 (Part – II) and 1973 (RA 2015).
c) Specific Gravity: The specific gravity of the soil samples has been determined at different levels as per IS 2720 (Part – III) and 1980 (RA 2016). It is used to determining void ratio, porosity, safe bearing capacity & settlement of foundation system as well. The results of specific gravity are shown in borehole sheet separately.

5.4.3.3. UNDISTURBED SOIL SAMPLES

Undisturbed Soil samples have been prepared in accordance with IS 2720(Part- I): 1983 (RA 2015) and tested as follows:

a) Wet and Dry Density: The field of soil samples has been determined by UDS or SPT samples at various depths. Dry density of soil has been determined by Proctor compaction test as per IS 2720 (Part – VII & VIII) and 1980 (RA 2016).

b) Unconfined Compressive Strength Test: The Unconfined compression or compressive strength test comes under IS 2720 (Part – X): 1991 (RA 2015). It determining the strength of clayey soil, UDS, remoulded or compacted, using at controlled rate of strain. It helps in to the calculation of shear parameters for safe bearing capacity.
c) Triaxial Compression Test: The Triaxial compression test under undrained unconsolidated test have been determined by IS 2720 (Part – XI):1993 (RA 2016). It describes the test for determination of compressive strength of a specimen of saturated cohesive soil in Triaxial compression apparatus under cell pressure.

Calculation of bearing capacity is governed generally by I.S. Specification No. 8009- (Part I)- 1976, I.S.No.2720- (Part – II) - 1980, I.S. No 6403-1981, I.S. 1904-1978 and I.S. 1080-1985 and other relevant I.S. Codes as well as based on assessment and latest developments.

5.4.3.4. DESIGN PARAMETERS OF RAIL CORRIDOR

Classification and identification are the pre–requisite of any site investigation report. The sub soil strata are classified on the basis of lab tests as per IS: 1498 -1978. Calculation of bearing capacity is governed generally by I.S. Specification No. 8009- (Part I)- 1976, I.S.No.2720- (Part – II) - 1980, I.S. No 6403-1981, I.S. 1904-1978 and I.S. 1080- 1985 and other relevant I.S. Codes as well as based on assessment and latest developments. The subsoil strata at proposed site on both the corridors is generally rocky. The engineering details (based on field test and laboratory test results) of the sub-soil strata are available separately in Geotechnical Investigation Report.

FOUNDATION PARAMETERS:

Allowable Bearing capacity values are based on the following parameters:

TABLE 5-7: FOUNDATION PARAMETERS

S No.	Type of Footing	Foundation Size	Foundation Depth
1.	Isolated Footing	3.0m x 3.0m 4.0m x 3.0m	1.0m, 2.0m, 3.0m, 4.0m, 5.0m, 6.0m & 7.0m

5.4.4 GEOTECHNICAL ASSESSMENT & FOUNDATION FEASIBILITY

By observing the nature of subsurface strata, the type of foundation for a given proposed structure, expected heavy loads on foundations, the following types of foundations can be recommended.

a) Shallow Foundations

For satisfactory performance of a foundation, the following criteria must be satisfied;

i. **The foundation must not fail in shear.**
Shear failure being catastrophic, an adequate factor of safety is applied to ultimate bearing capacity that can initiate this type of failure. BIS recommends a value of FOS = 2.5 to obtain the net safe bearing capacity qns by using the physical characteristics of the foundation and relevant shear strength parameters of soil.

ii. **The foundation should not settle by an amount more than the permissible settlement.**
Settlement analysis a net loading intensity qn is obtained by using the physical characteristics of the foundation and the relevant compressibility characteristics of the Underlying soil. The value so obtained ensures that the foundation shall not settle more than that which is permissible as per BIS recommendations. The permissible settlement depends upon the type of superstructure and the nature of supporting strata.

The smaller of the bearing pressure values obtained according to above (i) and (ii), is adopted as the allowable bearing capacity.

5.4.4.1. COMPUTATION OF ALLOWABLE BEARING CAPACITY FOR ISOLATED FOOTING IN SOIL SHEARING FAILURE ANALYSIS

Net Ultimate bearing capacity for general shear failure,

$q_{nu} = c\ N_c S_c D_c + q\ (N_q\text{-}1)\ S_q D_q + ½\ B\ \gamma\ N_\gamma S_\gamma D_\gamma\ W'$------- (1)

Net Ultimate bearing capacity for local shear failure,

$q_{nu} = 2/3\ c\ N_c S_c D_c + q\ (N'_q\text{-}1)\ S_q D_q + ½\ B\ \gamma\ N'_\gamma S_\gamma D_\gamma\ W'$ -------- (2)

Shape factors,

For Strip Footing $S_c = 1$; $S_q = 1$; $S_y = 1$

For Rectangle Footing Sc= 1+0.2 B/L; Sq= 1+0.2 B/L; Sy= 1-0.4 B/L

For Square Footing Sc= 1.3; Sq= 1.2; Sy= 0.8

For Circular Footing Sc= 1.3; Sq= 1.2; Sy= 0.6

Depth factors, dc = 1 + 0.2 x D/B Tan (45 + Φ/2); dq = dy = 1 + 0.1 x D/B Tan (45 + Φ/2)

(For Cohesive soil, Φ = 0)

Inclination Factors, $i_c = 1.0$; $i_q = 1.0$; $i_\gamma = 1.0$

OPEN/SHALLOW FOUNDATIONS IN GRAVEL-BOULER DEPOSIT/ROCK

Since in Boulder-Gravel Formation, soil is cohesion less, thereby assuming value of cohesion, c = 0 t/m2.

Net Ultimate bearing capacity for general shear failure,

q_{nu}= q (N_q-1) S_qD_q + ½ B γ $N_\gamma S_\gamma D_\gamma$ W'

As per Indian Railway Standard Code of practice for the Design of Sub-Structures and Foundations of Bridges (Bridge Sub-Structure and Foundation Code), Clause 5.7.1.8 where direct shear tests are nor done, values of ø for granular soil may be assumed as given below:

TABLE 5-8: VALUES OF Ø FOR GRANULAR SOIL

Material	Loose Strata	Dense Strata
Sand Coarse	33˚	45˚
Sandy Gravel	35˚	45˚
Silt and fine Sand	30˚	35˚

BIS recommends a value of FOS = 2.5 to obtain the net safe bearing capacity q_{ns} by using the physical characteristics of the foundation and relevant shear strength parameter of soil.

5.4.4.2. COMPUTATION OF ALLOWABLE BEARING CAPACITY FOR ISOLATED FOOTING ON ROCKY STRATA SHEAR FAILURE ANALYSIS

a) SAFE BEARING CAPACITY BASED ON ROCK MASS RATING (RMR)

Based on average Rock Mass Rating (RMR) below foundation level, net allowable settlement as per Table 3 of IS 12070 - 1987 for Raft foundation up to 6.0 m thickness shall have settlement less than 12 mm.

TABLE 5-9: SAFE BEARING CAPACITY BASED ON ROCK MASS RATING (RMR)

Classification No.	I	II	III	IV	V
Description of Rock	Very Good	Good	Fair	Poor	Very Poor
RMR	100-81	80-61	60-41	40-21	0-20
q_{ns} (t/m^2)	600-448	440-288	280-141	135-48	45-30

b) ALLOWABLE BEARING CAPACITY BASED UPON UNCONFINED COMPRESSIVE STRENGTH (AS PER CLAUSE 6 OF IS: 12070 – 1987)

The allowable bearing pressure based upon unconfined compressive strengths of undisturbed drill core samples for rock strata as per Clause 6 of IS: 12070-1987, using relationship as per equation: $q_a = q_cN_f$

where, q_s = gross safe bearing pressure

q_c = Uniaxial compressive strength of supporting rock strata in kg/cm2

N_f = empirical coefficient depending upon spacing of discontinuities. (Values from Table 4 of IS 12070 – 1987)

c) ALLOWABLE BEARING CAPACITY OF SHALLOW FOUNDATION ON BASES OF SPT 'N' VALUE

$Qs = 0.049\ N_{cor} \times F_{d2} \times S'$ for B < 1.2 m

$Q_s = 0.14\ (N_{cor} - 3) \times [(B + 0.3)/2B]^2 \times R_{W2} \times F_d \times S'$ for B > 1.2 m

where: q_s = net allowable bearing pressure in t/m2,
N_{cor} = corrected standard penetration value
R_{w2} = water table correction factor
F_d = depth factor = $(1 + Df/B) \leq 2$
F_{d2} = depth factor = $(1 + 0.2\ Df/B) \leq 1.2$
B = width of footing in meters
D_f = depth of foundation in meters
S' = Permissible Settlement in mm (From IS 13063– 1991 Table – 1 Clause 5.2.4)

Safe Bearing capacity for each borehole's location has been calculated in **Annexure 5.1.**

5.4.4.3. ESTIMATION OF LOAD CARRYING CAPACITY FOR DEEP FOUNDATION

Depending upon the type of soil, anyone of the following methods shall be used for computing pile capacity:

EVALUATION OF SAFE LOAD OF BORED CAST-IN-SITU PILE

The Safe load capacity Q_s is estimated from the following expression:

$Q_s = Q_u/FOS$ and $Q_u = Q_{pu} + Q_{su}$

Where;

Q_u = Ultimate Load

Q_{pu} = Ultimate Point Resistance

Q_{su} = Ultimate Skin Resistance

Depending upon the nature of strata, the above ultimate resistances are computed as under;

FOR COHESIVE SOIL

The ultimate bearing capacity (Qu) of Bored Cat In-Situ Piles in cohesive soil is given by following formula;

$Q_u = Q_{su} + Q_{pu} = ά\ C_a A_S + A_P\ N_C\ C_P$

The following values of ά (reduction factor) may be taken depending upon the undrained shear strength of clay.

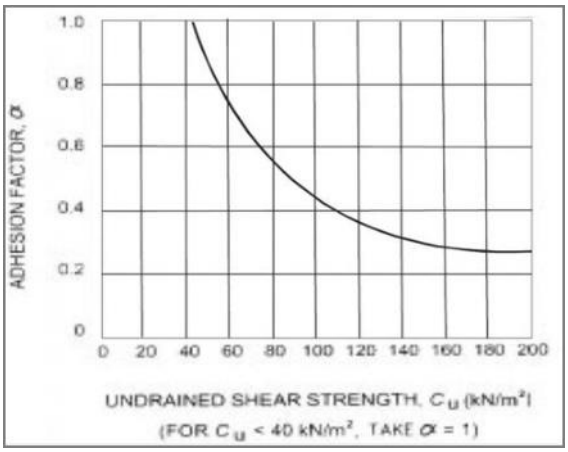
C_a = Average un-drained shear strength along the length of pile

A_s = Surface area of Pile Shaft

A_p = Cross sectional area of pile toe

C_p = Average un-drained shear strength at pile toe

N_c = Bearing capacity factor usually taken as 9



FOR COHESION LESS SOIL

The ultimate bearing capacity (Qu) of piles in granular soil is given by following formula;

$$Q_U = \sum_{i=1}^{n}[KP_{Di} \tan \delta A_{Si}] + [A_P (0.5 \times D \times \gamma N_\gamma + P_D \times N_q)]$$

P_{Di} = Effective overburden pressure for the i^{th} layer where i varies from 1 to n.

K = 1 to 1.5 for Bored piles in loose to dense sands.

δ = Angle of wall friction between Pile and soil, (May be taken equal to Ǿ for Concrete pile)

A_{si} = Surface area of Pile stem in the i^{th} layer where i varies from 1 to n.

A_P = Stem diameter

γ = Effective unit weight of soil at pile toe

P_D = Effective overburden pressure at pile toe

N_γ&N_q= Bearing capacity factors depending upon the angle of Internal friction 'Ǿ' at pile toe.

Note 1: N_γ factor can be taken for general shear failure as per IS: 6403-1981.

Note 2: For bored piles, the value of 'N_q' corresponding to 'Ǿ' are given in IS: 2911-1979.

PILES IN ROCKY STRATA

Based on Uniaxial Compressive Strength,

$Q_s = q_c N_j N_d A_p + q_c \prod D l_s \alpha ß$

where;

Q_u = Safe load capacity of pile, in tonnes

q_c = Uniaxial compressive strength of rock, t/m2

N_j = Values as per IS 12070: 1987 Clause 6.2

N_d = Depth factor = 0.8 + 0.2 ls/D, limited to 2

A_P = Cross sectional area of pile toe, m2

D = Diameter of pile, m

Ls = Socket length into the rock, m

α = Rock socket slide resistance reduction factor

ß = Rock socket correction factor

NET SAFE PILE CAPACITY

$Q_{ns} = Q_u / FOS$

BIS recommends a value of FOS = 2.5 to obtain the net safe bearing capacity q_{ns} by using the physical characteristics of the foundation and relevant shear strength parameters of soil and weathered rock respectively. **However, to be on conservative side in case of rocky strata, FOS = 5.0 is being adopted in present analysis considering Settlement of sub soil, joint orientation and Seepage in rock mass.**

PARAMETERS FOR DEEP FOOTING

Type of Pile = Bored Cast-In-Situ Pile

Diameter of Pile, D = 1000 mm

Rock Socket length of Pile = 2.00 m

Total length of Pile from G.L. = 6.00 m, 6.50 m, 7.50 m, 8.00 & 9.50 m

Rock Level from G.L. = 4.00 m, 4.50 m, 5.50 m, 6.00 m & 7.50 m

5.4.5 RECOMMENDATIONS

Recommended bearing capacity at various depths from NGL for Isolated Footing is as follows:

TABLE 5-10: RECOMMENDATION FOR BEARING CAPACITY

Type of foundation	Sections	Borehole Locations	Depth (m)	$(qa)_{net}$ (t/m²)	$(qa)_{gross}$ (t/m²)
Isolated Footing	Ramwadi – Wagholi / Vitthalwadi	BHL - 1	1	17.6	20.2
			2	27.3	32.46
			3	36.9	44.71
		BHL - 2	2	22.2	26.46
			3	30.1	36.46
			4	36	44.48
		BHL - 3	2	22.9	27.21

Type of foundation	Sections	Borehole Locations	Depth (m)	$(qa)_{net}$ (t/m^2)	$(qa)_{gross}$ (t/m^2)
			3	30.9	37.49
			4	36	44.72
		BHL - 4	3	30	36.6
			4	36	44.8
			5	36	47
		BHL - 5	3	30	36.36
			4	36	44.48
			5	36	46.6
		BHL - 6	2	21.8	25.97
			3	29.5	35.77
			4	37.3	45.58
		BHL - 7	1	14.4	16.35
			2	19.5	23.41
			3	28.1	34.05
		BHL - 8	2	26.9	32.08
			3	36	43.71
			4	36	46.28
		BHL - 9	3	31.1	37.66
			4	36	44.76
			5	36	46.95
		BHL - 10	3	37.5	45.21
			4	37.5	47.78
			5	37.5	50.35
		BHL - 11	3	30.8	37.32
			4	36	44.68
			5	36	46.85
		BHL - 12	4	36	45.96
			5	36	48.45
			6	36	50.94
			3	20	26.22
			4	23.4	31.74
Isolated Footing	Chandani Chowk	BHL - 37	1	31.8	34.4
			2	39.8	45
			3	47.8	55.6

TABLE 5-11: RECOMMENDATION FOR PILE CAPACITIES

Type of foundation	Borehole Locations	Dia of Pile	Rock Socket length of Pile	Total length of Pile from G.L.	Rock Level from G.L.	Net Safe Pile Capacity in Compression (t)	Net Safe Pile Capacity in Uplift (t)
Bored Cast-In-Situ Pile	BHL - 12	1000 mm	2.00 m	6.50	4.5	**588.1**	**272.6**
	BHL - 18	1000 mm	2.00 m	6.00	4.0	**760.8**	**328.8**
	BHL - 21	1000 mm	2.00 m	8.00	6.0	**796.5**	**328.9**

Type of foundation	Borehole Locations	Dia of Pile	Rock Socket length of Pile	Total length of Pile from G.L.	Rock Level from G.L.	Net Safe Pile Capacity in Compression (t)	Net Safe Pile Capacity in Uplift (t)
	BHL - 22	1000 mm	2.00 m	7.50	5.5	**316.1**	**131.5**
	BHL - 25	1000 mm	2.00 m	6.50	4.5	**699.1**	**273.4**
	BHL - 26	1000 mm	2.00 m	6.50	4.5	**538.6**	**213.2**
	BHL - 27	1000 mm	2.00 m	7.50	5.5	**551.3**	**219.7**
	BHL - 28	1000 mm	2.00 m	9.50	7.5	**547.1**	**221.6**
	BHL - 29	1000 mm	2.00 m	6.50	4.5	**453.9**	**181.4**
	BHL - 31	1000 mm	2.00 m	6.50	4.5	**526.3**	**208.6**

NOTE:

1. Sub Soil profile encountered in each borehole at each depth has been shown in Geological Logs attached in Annexure 5.2 in the report.
2. Water table was not encountered in any borehole up to entire explored depth. Exploration work was conducted in Month of December – January 2022.
3. Borehole wise Bearing capacity has been calculated in Annexure 5.1 for Isolated Footing resting on strata encountered.
4. The area under investigation falls under seismic zone – III as per India seismic code.
5. Due to non-availability of ground water, soil is not liable to liquefy.
6. It is recommended to provide minimum socket length 1.0 to 2.0 times the diameter of pile on rocky strata as per Table – 1 of IS 14593: 1998 (RA 2018).
7. Spacing of Piles should be as per IS 2911 for bored cast in-situ piles.
8. Minimum M-35 grade of concrete shall be used for construction of piles.
9. Cover and reinforcement requirement should be made according to IS 2911.
10. It is recommended to conduct pile load test before start of construction work for confirmation of pile capacity as per IS 2911 Part 4.
11. The Safe Bearing Capacity in Soil/Rock is given in Annexure 5.1.

5.5 DESIGN NORMS

5.5.1 ALIGNMENT DEFINITION

This section deals with geometrical standards adopted for design of horizontal and vertical alignments. The proposed corridors under Pune MRTS network will consist of Standard Gauge (SG) lines i.e. 1435 mm. The geometrical design norms are based on the Schedule of Dimension for Pune Metro Project Phase-1 approved by the Ministry of Railways (Railway Board), International practices adopted for similar systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 85 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. The horizontal alignment and vertical alignment are, dictated to a large extent by the geometry of the road and ground levels followed by the alignment.

5.5.2 ROLLING STOCK ASSUMPTION FOR ALIGNMENT STUDY

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

5.5.3 DESIGN INPUT PARAMETERS

General criteria used for the design purpose is given below in Table 5-12.

TABLE 5-12: DESIGN CRITERIA

Sl. No	Criteria	Dimension
1.	Gauge (14mm below top of rail crown)	1435 mm
2.	Spacing of rail lines (between axles of rails)	1510 mm
3.	Distance between centre lines of tracks in tangent sections	4100 mm
4.	Design Speed	95 kmph
5.	Operating Speed	85 kmph
6.	Electric power collection	25kV AC flexible OCS
7	Axle Load	16T

The geometric design has been done on the basis of the design values as given in Table 5-13.

5.5.4 HORIZONTAL ALIGNMENT

As far as possible, the alignment follows the existing roads. This leads to introduction of horizontal curves. In general, the characteristics considered for the designed track geometry are:

- Straight tracks in the horizontal alignment
- Long alignment elements
- Large horizontal radii
- Long transition curves
- Constant and low gradients in the vertical alignment
- Large vertical radii
- Low values of applied cant
- Low cant deficiency
- turnouts located on straight track
- straight track (or large curve radius) along platforms
- Cants of appropriate values, commensurate to operating speed at specific locations have been proposed to counter the effect of centrifugal force.
- Vertical curves & Transition curves of Horizontal Alignment do not overlap.

TABLE 5-13 DESIGN VALUES

S.No	Design Values	Desirable Limit	Exceptional Limit
1	Maximum permissible cant (Ca)	110 mm	NA
2	Maximum permissible cant deficiency (Cd)	85 mm	NA
3	Cant Gradient	≤1:750	≤1:440
4	Rate of change of cant	35 mm/s	56mm/s
5	Rate of change of cant deficiency	35 mm/s	56mm/s
6	Minimum horizontal curve radius on mainline (elevated)	190 m	120 m
7	Minimum horizontal curve radius on mainline (underground)	300 m	200m
8	Minimum length of element (circular curve, tangent, transition curve)	20m or 0m	NA

EQUILIBRIUM CANT:

Cant is the amount by which one rail is raised above the other rail. It is positive when the outer rail on a curved track is raised above inner rail and is negative when the inner rail on a curved track is raised above the outer rail. The equilibrium cant on horizontal curves is calculated from the following formula:

$Ce = G \times V^2 / 127 \times R$

Where,

Ce: Equilibrium cant (mm)

G: Gauge / distance between centre of inner rail to outer rail (~1510mm)

V: Speed (kmph)

R: Radius of curve (m)

Sometimes, the equilibrium cant exceeds the allowable limit of cant that can be applied. In such cases the equilibrium cant is reduced by certain amount to meet the design criteria (allowable limit). This reduction in the value is called Cant deficiency i.e. Cd. The amount of cant applied is called Cant Applied i.e. Ca.

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

5.5.4.1. TANGENT (STRAIGHT) SECTION

The horizontal alignment shall be on tangent at all station platforms for the entire length of the platform. The platform length is proposed to be 140m in length, is based on a “full train set” length, which consists of 6 coaches /cars. To maintain constant distance between platform and vehicle, tangent section shall also extend beyond each end of platform.

The minimum desirable un-superelevated tangent length beyond each end of a platform is usually based on length of one coach / car. Wherever straight is not possible at station platform, curve radius should be >= 1000m.

5.5.4.2. CIRCULAR CURVES

Circular curves shall be defined by their radii in meters. Larger radii shall be used whenever possible to improve the riding quality. The minimum lateral radius of curvature for mainline track shall be governed by the design speeds and by the limits for cant but it shall not be less than 120m for mainline.

For dual tracks on curves, the smaller of the two radii shall govern the selection of clearance requirement and minimum spacing of track centres.

5.5.4.3. COMPOUND CURVES

Compound curves will normally not be required between two different radii of the circular curves where the change of radius of the larger curve does not exceed 15% of the radius of the smaller curve and provided cant deficiency and/or cant excess criteria are not exceeded for either circular curve. Where a compound circular curve is employed with a change of radius greater than 15% of the smaller radius, or where the cant deficiency or cant excess criteria necessitate a change in cant between the circular curves, a suitable transition curve shall be interposed between two parts of the curve.

The length of such a transition curve shall be equal to the difference between the required transition lengths at each end of the curve.

5.5.4.4. REVERSE CURVES

The use of reverse curves is discouraged but where necessary, the two curves shall be separated by a length equal to the sum of the two spiral curve lengths. When it is not possible to provide a straight portion of 20m, 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. If restricted by physical constraints, the cant can vary continuously from one direction to the other.

5.5.4.5. TRANSITION CURVES

Transition curve is an easement curve, in which the change of radius is progressive throughout its length and is usually provided in a shape of a cubic parabola at each end of the circular curve. It affords a gradual increase of curvature from zero at the tangent point to the specified radius of circular curve and permits a gradual increase of super elevation, so that the full superelevation is attained simultaneously with the curvature of the circular arc.

It is necessary to provide transition curves at both ends of the circular curves for smooth riding on the curves and to counteract 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.

In addition to the above, the proposed speed on individual curves and transition lengths are checked for various design parameters including rate of change of cant, rate of change of cant deficiency, cant gradient, lateral jerk and lateral acceleration.

- Overlap between transition curves and vertical curves not permitted;
- Minimum straight between two transition curves: either 20 or nil
- Minimum curve length between two transitions curves: 20m.

The transition curve lengths are also checked based on the design criteria such as:

- Cant gradient = Cant (mm) / Transition length (mm)
  Cant gradient indicate the amount by which cant is increased or reduced in a given length of transition e.g., 1 in 750 means that cant of 1 mm is gained or lost in every 750mm of transition length.
- Rate of change of cant (mm/sec)
  Rate of change of cant is the rate at which cant is increased or reduced per second, at the maximum permissible speed of the vehicle passing over the transition curve, e.g., 35 mm. per second means that a vehicle when traveling at a maximum speed permitted will experience a change in cant or deficiency of cant of 35mm. in each second of travel over the transition.
- Rate of change of cant deficiency (mm/sec).
  Rate of change of cant deficiency is the rate at which cant deficiency is increased or reduced per second, at the maximum permissible speed of the vehicle passing over the transition curve, e.g., 35 mm. per second means that a vehicle when traveling at a maximum speed permitted will experience a change in deficiency of cant of 35mm. in each second of travel over the transition.

5.5.5 VERTICAL ALIGNMENT

The purpose of this section is to establish criteria for use in all design stages of the vertical alignment of the viaduct, station and depot area.

Vertical curves in main lines shall wherever possible be positioned such that coincidence with both transition curves and canted portions is avoided. Where such coincidence is unavoidable the largest practicable vertical curve radius shall be employed, and the cant gradient shall be the minimum.

In all such cases the resultant geometry shall be verified as being compatible with safe passage at the design speeds by the proposed rolling stock.

5.5.5.1. GRADIENTS

STATION TRACKS

Gradient of track in station platform length shall be as under:

- Desirable: Level
- Maximum gradient: 1 in 400

There should be no change in gradient in platform line.

INTER-STATION TRACKS

It is desirable that, the grade on the sections between the stations shall not be steeper than 2.0%. However, there are a few situations, where steeper gradients are unavoidable, such as

a) Switch over ramp between underground and elevated sections where a grade of up to 4% is adopted to minimise the length of ramp. However, desirable gradient is 2%.
b) In case, if the alignment follows road surface and where the existing road gradient is more than 2% as the elevated section is kept parallel to the road surface to minimise the rail level (to reduce the pier height).

So, the maximum grade shall be 4% (compensated). A flat (0.0%) grade is accepted, if adequate drainage can be provided.

However, in practice alternating longitudinal grades of 0.5% with drains at the low point, being the most effective way of assuring proper drainage.

Drainage provisions in tunnel sections shall require the profile to have:

- A desirable minimum grade of 0.5% and
- An absolute minimum of 0.25%.

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

There should be no change of gradient in transition portion of curves.

DEPOT TRACKS

In case of depots the desirable grade on storage tracks is 0.0% but the maximum grade shall not exceed 0.3%.

Adequate track drainage shall be designed to suit the actual grade. All shop tracks be 0.0% grade.

ON TURNOUTS

(a) On Ballasted Track : 0.25%
(b) On Ballastless Track : 3%

There shall be no change of gradient (i.e. Vertical curve) on and within 15.0m (desirable)/3.0 m (minimum) of any turnout on Ballastless track. In case of ballasted track, there shall be no change of grade on and within 30 meters of any turnout.

There shall be no horizontal curve within 15.0m (desirable)/3.0 m (minimum) of any turnout on Ballastless track and 30 meters of any Turnout on Ballasted Track.

5.5.5.2. VERTICAL CURVES

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

parabolic curve. 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: 2500m
- Absolute minimum radius: 1500m

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

- Desirable minimum: 50m
- Absolute minimum: 25m

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.

5.5.6 POINTS AND CROSSINGS

Points & Crossings/Turnouts are used to divert the trains from one track to other. Turnouts are also used to provide disabled siding also. A turnout consists of a pair of switches and a crossing, connected by closure rails.

Whenever possible, points and crossing work shall not coincide with vertically or horizontally curved track, but instead on straight and levelled tracks.

Turnout shall normally be installed on straight track. In exceptional situations, turnout may take off from curve provided that the radius of lead curve (main line as well as diverging line) is not less than 190m. The negotiability of rolling stocks on such turnout must be certified by rolling stock supplier and confirmed through oscillation trial and a suitable speed restriction should be imposed on main and/or diverging track based on track geometry and other considerations, if required. In case of turnout installed on curved track, the minimum distance from commencement of vertical curve or another horizontal curve shall be 15m for Ballastless track. Turnout shall not be laid on transition curve.

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

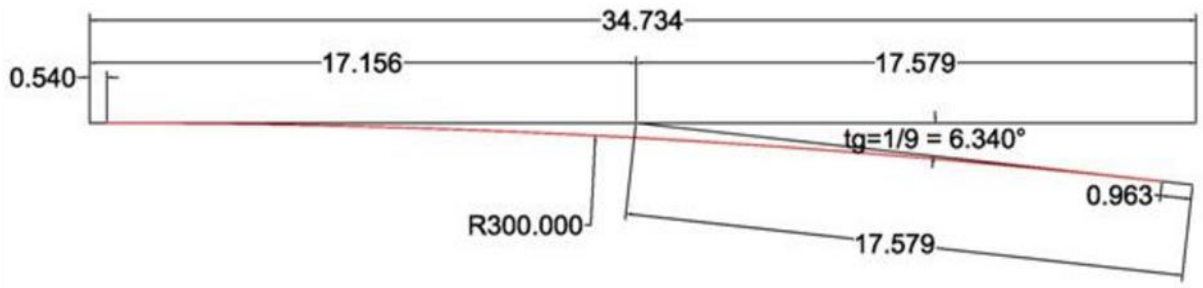


FIGURE 5-9: 1 IN 9, 300MR TURNOUT (ALL DIMENSIONS IN METRE)

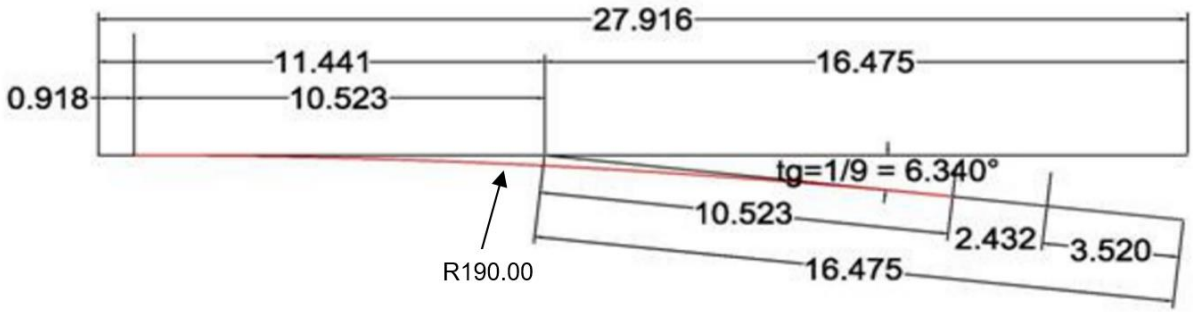


FIGURE 5-10: 1 IN 9, 190MR TURNOUT (ALL DIMENSIONS IN METRE)

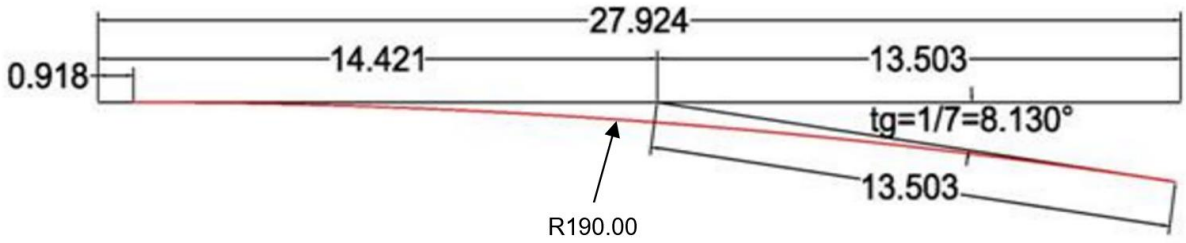


FIGURE 5-11: 1 IN 7, 190MR TURNOUT (ALL DIMENSIONS IN METRE)

5.5.7 SCISSOR 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 45 km/hr.

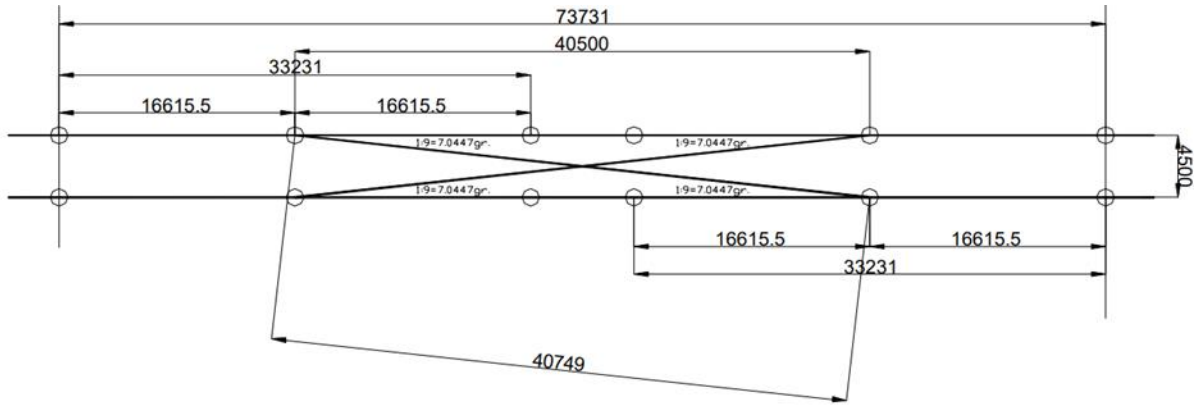


FIGURE 5-12: SCISSOR CROSSOVER – 1 IN 9, 300MR – TRACK CENTRE – 4.5M

5.5.8 TRACK STRUCTURE

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

General

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

From considerations of maintainability, riding comfort and also to contain vibrations and noise levels, the complete track is proposed to be joint-less and for this purpose even the turnouts will have to be incorporated in LWR/CWR. The track will be laid with 1 in 20 canted rails and the wheel profile of Rolling Stock should be compatible with the rail cant and rail profile.

Rail Section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since main lines will have sharp curves and steep gradients, the grade of rail on main lines should be 1080 Head Hardened as per IRS-T-12-2009. As these rails are not manufactured in India at present, these are to be imported. For the Depot lines, the grade of rails should be 880, which can be easily manufactured indigenously.

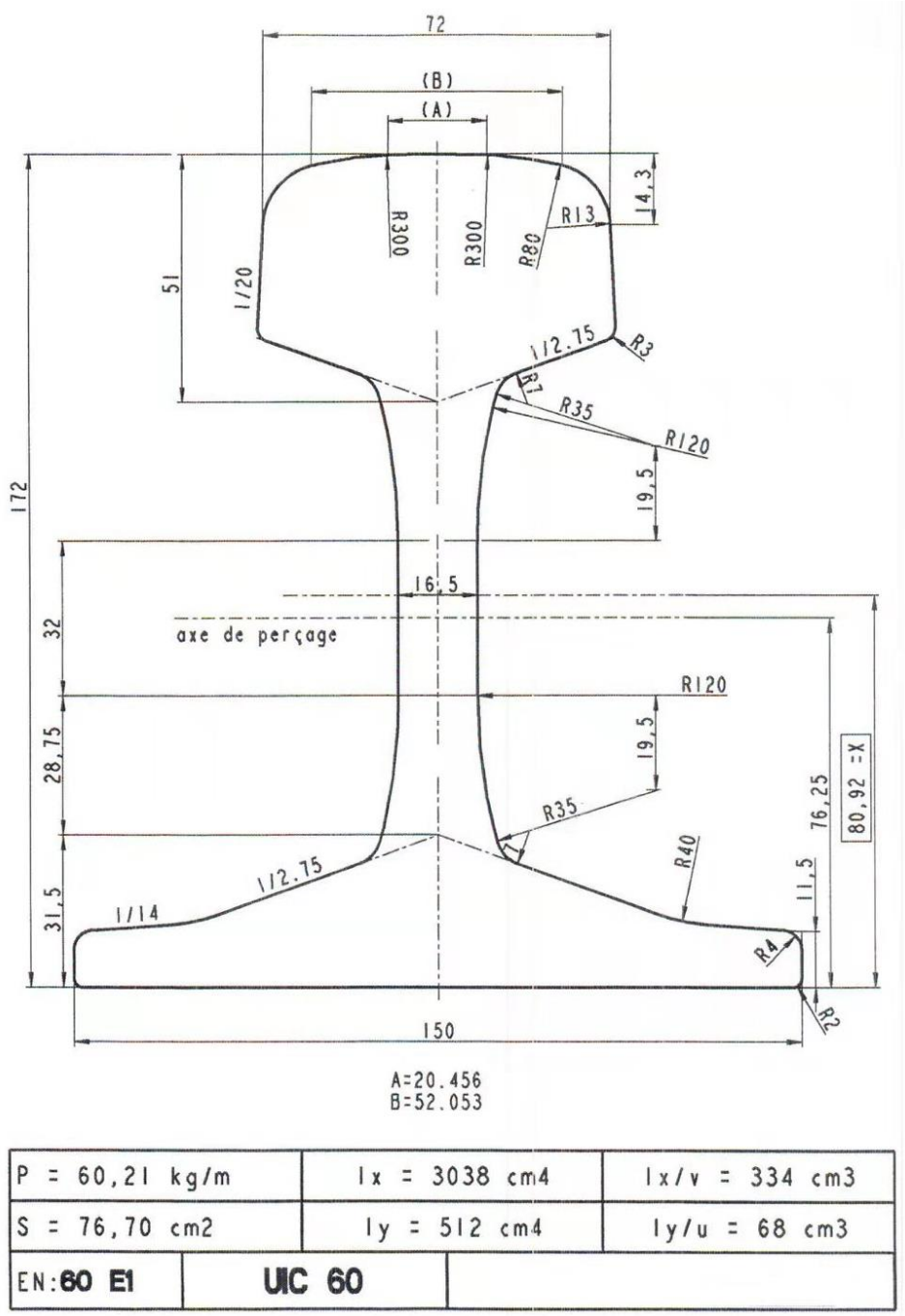
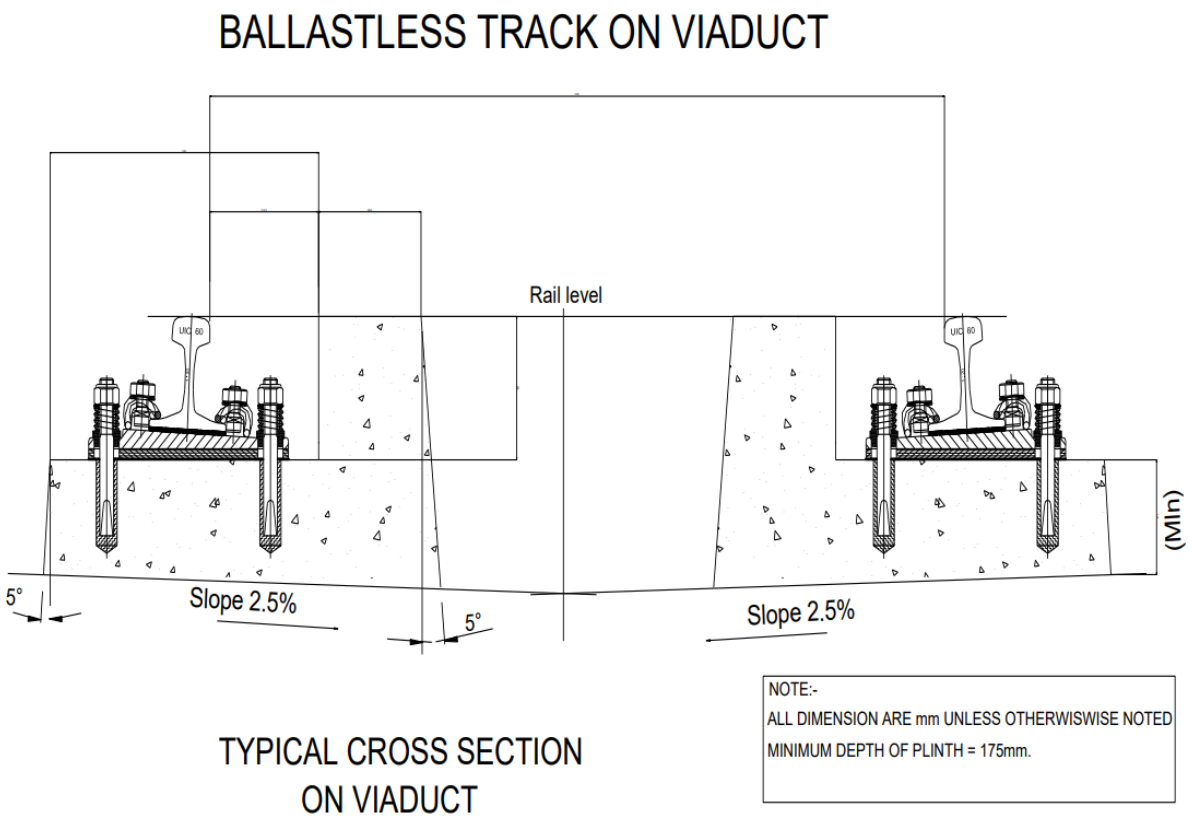


FIGURE 5-13: SCISSOR CROSSOVER – 1 IN 9, 300MR – TRACK CENTRE – 4.5M

Ballastless Track on Viaducts On the viaducts, it is proposed to adopt plinth type ballastless track structure with RCC derailment guards integrated with the plinths. It is proposed to adopt suitable Fastenings System with a base-plate to base-plate spacing of 60-65 cm (Double Resilient Base plate fasting system with e2007 Clips manufactured by Pendrol is being used in Phase-1 of Pune Metro Project), on viaducts complying of performance criteria laid down by Railway Board vide letter Circular No. 2009/Proj/InAs/9/2, dated 02.05.2010.



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

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

5.6 ROUTE ALIGNMENT

As mentioned in the previous sections, two (02) corridors which are extensions of the Line 2 of Phase - 1 Pune Metro have been prioritized and discussed in this Detailed Project Report (DPR).

The two (02) corridors are West Extension and East Extension to the Line 2, i.e. Line 2A Vanaz-Chandani Chowk is West extension and Line 2B Ramwadi-Wagholi/Vitthalwadi is East extension as represented in the Figure 5-14. Both the corridors are elevated.

The alignment design for the project has been undertaken using the state-of-art rail design software i.e. Bentley Open Rail. The elevated alignment is mostly located on the central median of the roads. The requirement of pocket tracks in case of emergency siding has also been reviewed and concluded that, the existing pocket tracks of Phase-1 at

Mangalwar Peth will suffice the operational requirements. No additional pocket tracks are required. The details of length and no. of stations in the two corridors is given below Table 5-14.

TABLE 5-14: PROPOSED MRTS CORRIDORS FOR DPR PART-1

Corridors	Total Length	Elevated	Ramp	Underground	Stations
Line 2A: Vanaz-Chandani Chowk	1122.071 m	1122.07 m	NA	NA	2
Line 2B: Ramwadi-Wagholi/Vitthalwadi	11633.281 m	11633.281 m	NA	NA	11

FIGURE 5-14: PROPOSED LINE 2A AND LINE 2B MRTS ROUTES FOR PUNE METRO PHASE-2 (DPR PART-1)

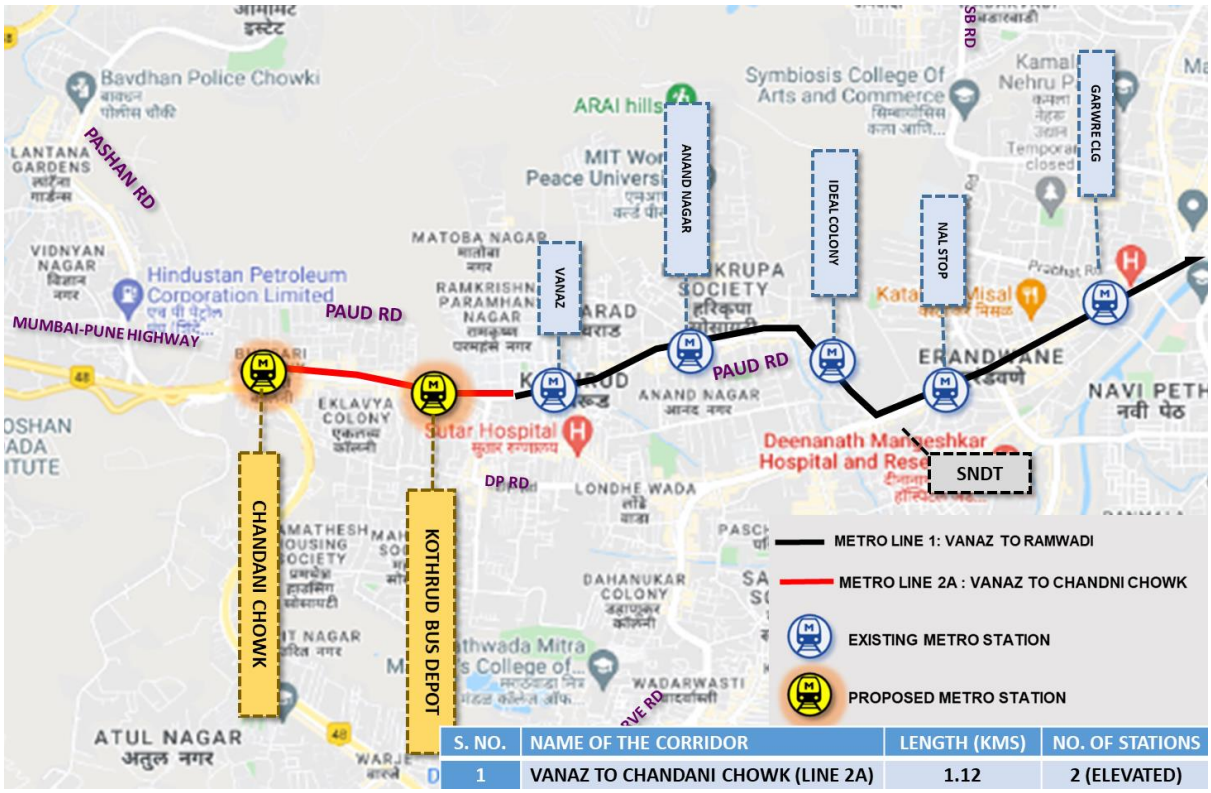
5.6.1 LINE 2A: VANAZ TO CHANDANI CHOWK

5.6.1.1. GENERAL DESCRIPTION OF THE CORRIDOR

Length of this corridor is **1122.071 m** and is **FULLY ELEVATED**. The corridor originates from the dead-end of Phase-1 (pier no. P-4) on Vanaz side at Chainage (-) 757.929. In the design, the chainage reference has been taken from Phase-1, so as to maintain the consistency.

FROM DEAD END OF PHASE-1 (CH -757.929M) TO KOTHRUD BUS DEPOT METRO STATION (CH -964.048 M)

As mentioned in previous sections, the proposed Line 2A is an extension of Phase-1 of the Line 2 (i.e. East West line) on West end. The dead end of phase-1 corridor is at chainage (-) 757.929 and on pier no. P-4. The dead-end is partly on curve of radius 4200.0m which has been curtailed. The Line 2A follows the same horizontal alignment and extends towards Chandani Chowk on Paud Road.



S. NO.	NAME OF THE CORRIDOR	LENGTH (KMS)	NO. OF STATIONS
1	VANAZ TO CHANDANI CHOWK (LINE 2A)	1.12	2 (ELEVATED)

FIGURE 5-15: PROPOSED LINE 2A WITH STATIONS

The first station on this extension is Kothrud bus depot is proposed on centre of the road near the Kothrud Bus Depot. In order to cater to the dense commercial area and maintain the inter station distances, the station has been proposed on curved alignment of radius 1010m. There are commercial properties on both sides of the road.

FROM KOTHRUD BUS DEPOT METRO STATION (CH -964.048 M) TO CHANDANI CHOWK METRO STATION (CH -1779.227 M)

After the Kothrud bus depot metro station, the alignment takes left turn with curve radius of 1000m to follow the centre of Paud Road and continues straight for a length of approx. 334m. Then the alignment takes left turn following the road centre and the second station Chandani Chowk station is proposed at chainage -1779.227. The corridor terminates at chainage -1880m. The length available after end of platform of Chandani Chowk station is 30.7 m. However, in this length the viaduct will touch the flyover.

Therefore, only length of 10-15 m has been considered for construction purpose, keep some length in design for adjustments. Because of non-availability of length of corridor after terminal station, the reversal has been proposed from front side. For this purpose, two crossovers have been proposed between -1334.060 and -1507.178. The length of 30.7 m at the end is sufficient to accommodate friction-based buffer stop. However, considering the usable length of 10-15m, it is proposed and recommended to use fixed hydraulic buffer stops at the end of the corridor.

The corridor terminates at the National Highway-48 (Mumbai Highway) near the underpass. As mentioned in previous section, because of huge level differences between the Paud Road and Bangalore - Mumbai National Highway, the safe clearance of viaduct structure could not be achieved and therefore, the corridor cannot be extended further.

TABLE 5-15: PROPOSED STATIONS ON VANAZ – CHANDANI CHOWK CORRIDOR

SN	Station Name	Platform Type	Chainage (m)	Inter station Distance (m)
	Vanaz Phase 1		**-22**	
	End of Phase 1		-757.929	
1	Kothrud Bus Depot	Side	-964.048	942.048
2	Chandani Chowk	Side	-1779.227	815.179
	Dead End Phase 2		-1880	100.773
	CORRIDOR LENGTH		**-1122.071**	

5.6.1.2. VERTICAL PROFILE OF LINE 2A

The topology of this corridor is varying with huge level differences. However, continuous gradients have been applied so as to manage stations and crossovers. In-order to maintain consistency in design from phase-1 corridor, the vertical alignment design starts from chainage -679.00. The overlap length with phase-1 corridor is between Chainage 679.00 to -757.929m). Therefore, the design length is 1201m and the corridor length is 1122.071m.

The alignment report has been generated from Dead End Side; therefore, the gradient shows Fall instead of Rise. The Vertical Alignment Report table is presented as the Table 5-16 below.

TABLE 5-16: VERTICAL PROFILE (GRADE TABLE) – PROPOSED LINE 2A

SN	Chainage		Length	Rail Level		Gradient	Remarks	Element Type
	From	To		From	To			
1	-1880.000	-1681.444	198.556	632.500	632.500	0.000%	LEVEL	Tangent
2	-1681.444	-1638.565	42.879	632.500	631.887	-1.430%	FALLING	Vertical Curve
3	-1638.565	-1139.435	499.130	631.887	617.613	-2.860%	FALLING	Tangent
4	-1139.435	-1096.556	42.879	617.613	617.000	-1.430%	FALLING	Vertical Curve
5	-1096.556	-891.551	205.006	617.000	617.000	0.000%	LEVEL	Tangent
6	-891.551	-844.461	47.090	617.000	616.261	-1.570%	FALLING	Vertical Curve
7	-844.461	-765.777	78.684	616.261	613.789	-3.141%	FALLING	Tangent
8	-765.777	-718.687	47.090	613.789	613.050	-1.570%	FALLING	Vertical Curve
9	-718.687	-679.000	39.687	613.050	613.050	0.000%	LEVEL	Tangent

5.6.1.3. ABSTRACT OF VERTICAL GRADIENTS

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

Efforts have been made to provide the gradients as flat as possible, subject to ground profile. Total of 15% of the alignment is on curve (179.927m), remaining length is tangent /straight. The abstract is as below:

TABLE 5-17: ABSTRACT OF VERTICAL GRADIENTS

SN	Description	No of Occurrences	Length (m)	Percentage (%) of corridor
1	Level (0%)	3	443.25	36.91%
2	>0% to 1%	0	-	-
3	>1% to 2%	0	-	-
4	>2% to 3%	1	499.13	41.56%
5	>3%	1	78.684	6.55%
6.	Vertical Curve	4	179.94	14.98%

5.6.1.4. CURVATURE OF LINE 2A

The proposed alignment is of short length and with four horizontal curves only. It negotiates to follow the existing road median. At some places there are sharp turns and curves along the road and this necessitates provision of sharp curves on metro alignment also.

The details of curves planned on the proposed Corridor are presented in Table 5-18.

TABLE 5-18: HORIZONTAL REPORT (CURVE SUMMARY) OF LINE 2A

SN	Chainage		Direction	Radius (m)	Deflection Angle	Transition Length (m)		Tangent Length (m)	Circular Curve Length (m)	Total Curve Length (m)	Straight Length (m)
	From	To				Leading	Trailing				
	1880.00	1704.23									175.77
1	-1704.23	-1529.82	Right	330	26°48'34.2009"	20	20	88.6577	134.4116	174.41	334.29
2	-1195.52	-1065.78	Left	1000	5°42'52.2304"	30	30	64.9116	69.737	129.74	31.23
3	-1034.55	-893.54	Right	1010	6°34'51.6416"	25	25	70.5697	91.0089	141.01	101.20
4	-792.35	-692.27	Left	4200	1°01'26.8507"	25	25	50.0372	50.0723	100.07	
	-692.27	-679.0									13.27

5.6.1.5. ABSTRACT OF HORIZONTAL CURVES

The proposed phase-2 alignment (Line 2A) has been designed with overlap length of 301.20m with phase-1 alignment (Design length 1423.27m and actual viaduct will be 1122.071m). However, total length considered for all practical purposes like cost estimate etc. actual viaduct length of phase-2 has been considered. The alignment negotiates frequent horizontal curves to follow the existing road median.

At some places there are sharp turns along the road which necessitated provision of sharp curves on the alignment. Moreover, these sharp turns are negotiated by taking the alignment on one side of both the road legs to minimize land acquisition at the corner of the turn.

Since this corridor is smaller in length, total 4 nos. horizontal curves have been provided on the entire length of the alignment. The minimum radius of curves is 330 m. About 78.25% alignment is on straight & about 21.76 % of alignment is on curves.

The abstract and details of curves are indicated in the tables below.

TABLE 5-19: THE ABSTRACT AND DETAILS OF CURVES

SN	Curve Radius (m)	No. of Occurrences	Length (m)	Percentage (%) of corridor
1	<190	0	-	-
2	>190 <300	0	-	-
3	≥300 ≤500	1	134.4	9.44%
4	>500 ≤800	0		
5	>800 ≤1000	1	69.737	4.90%
6	>1000	2	141.0812	9.91%
7	Straight		878.0433	61.69%
8	Transition curves		200	14.05%
	TOTAL	**4**	**1423.27**	**100%**

5.6.1.6. MAJOR ROADS ALONG THE CORRIDOR

Some of the Major Roads along/across the Line 2A are discussed in the Table 5-20 and Table 5-21.

TABLE 5-20: MAJOR ROADS ALONG LINE 2A

Sl. No.	Road	Chainage (m)	Direction (LHS/RHS)	Name of road along the alignment	Road width (m)
1	Paud Road	-757.929 to -1880	Centre	Paud Road	36

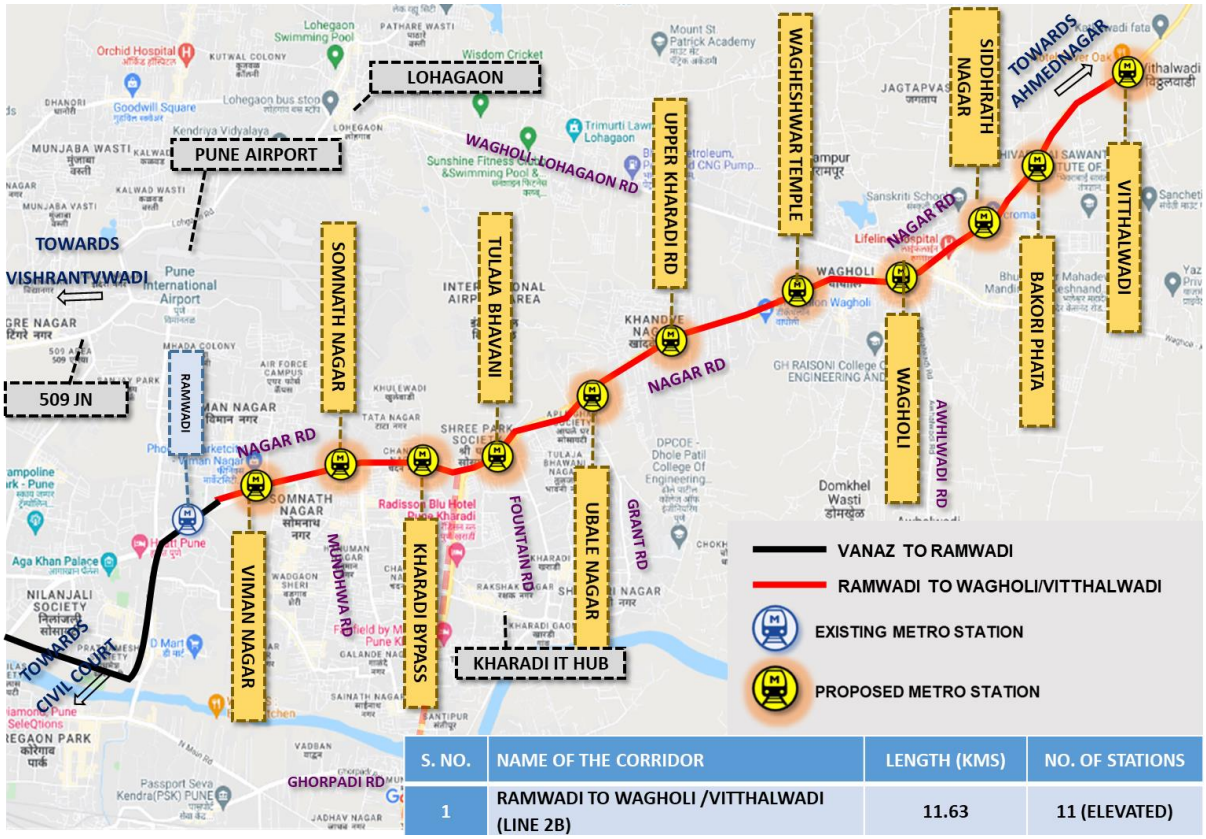
TABLE 5-21: MAJOR ROADS ACROSS LINE 2A

Sl. No.	Road	Chainage (m)	Direction (LHS/RHS)	Name of road along the alignment	Road width (m)
1	Suraj Nagar Road	-841.3955	LHS	Paud Road	6
2	Towards Kothrud Bus Depot	-1147.0414	LHS	Paud Road	8
3	Paud Road	-1155	LHS	Kothrud Depot Road	8

5.6.2 LINE 2B: RAMWADI TO WAGHOLI/VITTHALWADI

5.6.2.1. GENERAL DESCRIPTION OF THE CORRIDOR

The length of this corridor is 11.633 km with 11 stations and is completely elevated. This corridor is very important from traffic and integration point of view. This corridor will integrate with the line 4C - Kharadi - Hadapsar of Phase - 2 MRTS corridor at Kharadi Bypass. The same line 4C continues from Hadapsar to Swargate as line 4B from Hadapsar to Swargate and further as line 4A from Swargate to Khadakwasla. The corridor has been planned on centre of the BRTS corridor till the extent BRTS is available and further on the centre of the State Highway.



S. NO.	NAME OF THE CORRIDOR	LENGTH (KMS)	NO. OF STATIONS
1	RAMWADI TO WAGHOLI /VITTHALWADI (LINE 2B)	11.63	11 (ELEVATED)

FIGURE 5-16: PROPOSED LINE 2B WITH STATIONS

There are several interfaces and integrations on this corridor which have been discussed in the previous section. These are:

a. Integration with HCMTR corridor near Phoenix Mall;

b. Interface with Pune Municipal Corporation (PMC) at Kharadi Bypass for the proposed flyover and underpass by PMC.

c. Interface with NH division of PMC for the 18 lanes three tier flyover (6 lanes each including ground level) proposed.

FROM END OF PHASE-1 (CH 14991.719 M) TO VIMAN NAGAR (CH 15464.618 M)

The Line 2B starts from the end of Phase-1 at Chainage: 14991.719 m (Pier No. P433). The dead end is on a curve of radius 850m. The Line 2B of Phase-2 alignment has been designed following the same geometry for proper superimposition of the geometry.

The alignment follows the centre of the Nagar Road. Most of the stations on the corridor 2B are island stations, however the first station Viman Nagar is a side platform station with 4.1m track centres.

The Viman Nagar station is proposed at Ch: 15464.618 m besides the Phoenix mall on State Highway 27 also called as Nagar Road. In between, there are commercial properties on both sides of the road. Entry / Exit facilities to the station have been planned on the footpath on both sides of the roads. The same station will integrate with the HCMTR corridor in future at the Viman Nagar junction at Ch 15600.819 m.

FROM VIMAN NAGAR (CH 15464.618 M) TO SOMNATH NAGAR (CH 16700.889 M)

From Viman Nagar station, the alignment again tapers towards right by 4.1m from the median to achieve track centre at Ch15700.00 m. The geometry has curve radius of the scale of 500m to 1700m, in order to continue to follow the BRTS / road centreline. There are commercial properties including banks, hotels etc. on both sides of the corridor. At Ch 15909.904 m, the alignment passes through the Ahilyabai Holkar Chowk. Considering the next station i.e. Somnath Nagar at 16700.889 m and limited space for flaring of the tracks, the tracks have been flared from 4.1m track centre to 12.6m starting from Ch 16225.00 m.

From Ch 16250m onwards, there is defence (Air Force) facility on the LHS of the corridor. The station Somnath Nagar has been proposed just after the entry / exit gate to / from the Air Force station. This will allow access to the station for residents of the Air Force area. The Old Mundhwa road is on RHS of the corridor at Ch 16650.00 m.

FROM SOMNATH NAGAR (CH 16700.889 M) TO KHARADI BYPASS (CH 17601.929 M)

From Somnath Nagar, the alignment continues straight on the Nagar Road till the curve at Ch 17250.00 m. Considering the Interchange station at Kharadi Bypass at Ch

17601.929 m, which is planned to be a Two platform station with three lines, crossovers have been planned between Ch 17048.200 m to Ch17195.123m for movement of trains from UP line i.e. Ramwadi to Wagholi/Vitthalwadi to DN Line and also to and from the Hadapsar Kharadi line. One platform will be side platform for the line from Ramwadi towards Wagholi/Vitthalwadi and as Island platform for the lines from Wagholi/Vitthalwadi towards Ramwadi and Kharadi to Hadapsar.

There is a single train length track available on the third line, which can be used as emergency stabling in mid-section in case of breakdown of rolling stock. On the LHS is Air Force campus which is continuing from Ch 16250 m and ends at Ch 17325 m. The alignment is also integrated with the proposed road widening proposal by Pune Municipal Corporation including a flyover and underpass at the junction. Because of the integration, the alignment has been planned on RHS of the existing BRTS and on centre of the future BRTS corridor. The drawings have to be validated by Pune Municipal corporation also for correctness and seamless integration.

FROM KHARADI BYPASS (CH 17601.929 M) TO TULAJA BHAVANI (CH 18843.676 M)

After the Kharadi bypass station, the alignment takes sharp left turn with curve radius of 200m to follow the proposed BRTS centreline as per Pune Municipal Corporation drawing. After this curve, two crossovers have been planned between Ch 18222.707 m and Ch 18131.262 m for interchange between the UP and DN Lines as well as with the Hadapsar line. The alignment further takes left turn with radius of 600m to follow the proposed road / BRTS centreline. From the station till Ch 18050m there are commercial properties on the LHS and then open space till the next station i.e. Tulaja Bhavani at Ch 18843.676 m.

After Ch 18575.00 m, the alignment again takes sharp right turn with radius of 200m to follow the road centre and place station on straight. There are some smaller cross roads on both side of the corridor. Major roads along the corridor have been identified and summarised separately.

FIGURE 5-17: PROPOSED LINE 2B WITH RSS LOCATION

The Blue box is the proposed RSS location and the yellow line is the mainline corridor in Figure 5-17. One RSS has been planned for the corridor 2B. The RSS has been proposed in the open land belonging to government near to the existing 132 kV substation.

FROM TULAJA BHAVANI (CH 18843.676 M) TO UBALE NAGAR (CH 19888.269 M)

After Tulaja Bhavani station, the alignment takes left turn with radius of 270m and continues straight on centre of the road for a length of approx. 230m and then curves of radius 1100m, 600m and 1750m in order to follow the road centre with island station at Ch 19888.269 m. Just after the Tulaja Bhavani station, the BRTS corridor ends at the Aaple Ghar BRTS station. Integration of the BRTS with MRTS systems are being planned as part of Multi Modal Integration. Mostly there are commercial properties on both sides of the corridor. On RHS there are some open plots from Ch 19500.00m till Ch 19750.00 m. There are few cross roads on both sides of the corridor. The Ubale Nagar station has been planned in a way to integrate with road junctions and commercial spaces.

FROM UBALE NAGAR (CH 19888.269M) TO UPPER KHARADI ROAD (CH 20930.634 M)

Further after Ubale Nagar station, the alignment continues to follow the centreline. There is a right-hand curve of radius 1400m after the station then straight alignment of length 175m approx. In order to continue follow the centreline, three curves of 600m RHS, 530m LHS and 1000m RHS have been proposed before the station.

There are commercial properties on both sides of the MRTS corridor. Most of the stations including Upper Kharadi road station provides access to the upcoming residential developments along the corridor.

FROM UPPER KHARADI ROAD (CH 20930.634 M) TO WAGHESHWAR TEMPLE (CH 22312.06 M)

After Upper Kharadi Road station the alignment continues to follow the centreline of the Nagar Road. There are few smaller curve radii of 210m in order to continue to follow the centreline. There are few cross roads and some nallahs along the corridor. The piers have been planned considering all these physical features.

Wagheshwar Temple station has been planned before the temple in order to avoid Visual impact on the temple. The temple has huge footfall. So, station with side platforms has been proposed. The station can be easily accessed through footpaths. At Ch 21625.00m, there is Decathlon store on the RHS.

FROM WAGHESHWAR TEMPLE (CH 22312.06 M) TO WAGHOLI (CH 23269.317 M)

After Wagheshwar temple, the alignment takes right turn with curve radius of 330m following the road geometry. The alignment passes besides the Wagheshwar Temple. At 22575 m is the wide road on LHS towards the temple. The temple is on the LHS at 22700.00 m. There is open space near the temple area.

The alignment then takes right turn of 730m radius and sharp left turn with 135m radius to reach Wagholi station. The Wagholi station has been proposed in front of the Wagholi market (Baji Mandi) and between two junctions. This station will provide access to commercial establishments. Considering the huge footfall at this station, this station was proposed to be side platform station having a full-length concourse with four number of entry and exit facilities.

An emergency crossover has been proposed at chainage 22607.804m, after Wagheshwar Temple.

FROM WAGHOLI (CH 23269.317 M) TO SIDDHARTH NAGAR (CH 24087.658 M)

The alignment continues on the centreline of the Nagar Road after the Wagholi station with left hand curve radius of 280m. There are commercial establishments on both sides of the corridor. After this curve, there is one left hand curve of radius 500m and then straight till the next station i.e. Siddharth Nagar at Ch 24087.658 m. The station has been planned near commercial complex with two entry exits, one each on either side of the corridor.

FROM SIDDHARTH NAGAR (CH 24087.658 M) TO BAKORI PHATA (CH 24948.286 M)

Between the Siddharth Nagar Station and Bakori Phata station, there are only two curves. One after the Siddharth nagar station and one just before the Bakori Phata station. After the Siddharth Nagar Station, the alignment continues to follow the road centreline. There are commercial establishments on both sides of the corridor.

FROM BAKORI PHATA (CH 24948.286 M) TO VITTHALWADI (CH 26232.966 M)

After the Bakori Phata Station, the alignment takes left turn with radius of 200m and continue to follow the road centreline for length of approx. 55m and then right turn with radius of 500m.

Then the alignment continues straight on centre of road for a length of approx. 328m and then right-hand curve of radius 705m to continue to follow the road centre till the last station i.e. Vitthalwadi at Ch 26232.966m.

Since this is a terminal station, crossovers are required on front and rear of the station. Considering the construction difficulty of wider and continuous deck for crossovers, required for Island platform stations, it has been proposed to have side platform station. The crossover in front of the station has been planned between Ch 26071.285 m and Ch 26142.817m.

FROM VITTHALWADI (CH 26232.966M) TO DEAD END (CH 26625.000 M)

The end is proposed at chainage 26625.00 m. Between the end of station and the dead-end, reversal of trains can take place with two sets of crossovers, one before and one after the station. The crossovers after the station have been proposed between Ch 26325.213 m and Ch 26395.137 m. The length beyond the crossovers allows reversal of 6 coach train i.e. 140m long including space for buffer stop.

Since the alignment is planned on the road centre, no such property acquisition is required except at the entry/exit structures for stations. The list of stations with chainage is as below in Table 5-22.

TABLE 5-22: PROPOSED STATIONS ON LINE 2B RAMWADI - WAGHOLI/VITTHALWADI CORRIDOR

SN	Station Name	Platform type	Chainage (m)	Inter station Distance (m)
	Ramwadi- Phase 1	Side	14484.469	
	End of Phase 1		**14991.719**	
1	Viman Nagar	Side	15464.618	980.149
2	Somnath Nagar	Island	16700.889	1236.271
3	Kharadi Bypass	1-side 1-Island	17601.929	901.04
4	Tulaja Bhavani	Island	18843.676	1241.747
5	Ubale Nagar	Island	19888.269	1044.593

SN	Station Name	Platform type	Chainage (m)	Inter station Distance (m)
6	Upper Kharadi Road	Island	20930.634	1042.365
7	Wagheshwar Temple Station	Side	22312.06	1381.426
8	Wagholi	Side	23269.317	957.257
9	Siddharth Nagar	Island	24087.658	818.341
10	Bakori Phata	Island	24948.286	860.628
11	Wagholi/Vitthalwadi	Side	26232.966	1284.68
	End of PH 2		26625.00	392.034
	CORRIDOR LENGTH (m)		**11633.281**	

5.6.2.2. VERTICAL PROFILE OF LINE 2B

The gradients in this stretch are given in the Table 5-23.

Although, the ground is not very undulating, however considering several integration projects, there are several vertical gradients proposed. Also, at some locations, difference in levels have been observed.

TABLE 5-23: VERTICAL PROFILE OF RAMWADI - WAGHOLI/VITTHALWADI CORRIDOR

SN	Chainage From	Chainage To	Length	Rail Level From	Rail Level To	Gradient	Remarks	Element
1	14370.00	14589.08	219.08	577.00	577.00	0.00%	LEVEL	Linear
2	14589.08	14610.92	21.83	577.00	577.16	0.73%	RISE	Vertical Curve
3	14610.92	14815.78	204.87	577.16	580.14	1.46%	RISE	Linear
4	14815.78	14837.62	21.83	580.14	580.30	0.73%	RISE	Vertical Curve
5	14837.62	15013.88	176.27	580.30	580.30	0.00%	LEVEL	Linear
6	15013.88	15036.12	22.23	580.30	580.41	0.48%	RISE	Vertical Curve
7	15036.12	15344.88	308.77	580.41	583.39	0.97%	RISE	Linear
8	15344.88	15367.12	22.23	583.39	583.50	0.48%	RISE	Vertical Curve
9	15367.12	15989.76	622.64	583.50	583.50	0.00%	LEVEL	Linear
10	15989.76	16012.24	22.48	583.50	583.62	0.54%	RISE	Vertical Curve
11	16012.24	16317.30	305.06	583.62	586.89	1.07%	RISE	Linear
12	16317.30	16338.70	21.41	586.89	587.00	0.54%	RISE	Vertical Curve
13	16338.70	16837.32	498.62	587.00	587.00	0.00%	LEVEL	Linear
14	16837.32	16866.68	29.35	587.00	586.88	-0.42%	FALL	Vertical Curve
15	16866.68	16996.29	129.62	586.88	585.79	-0.84%	FALL	Linear
16	16996.29	17017.71	21.41	585.79	585.76	-0.12%	FALL	Vertical Curve
17	17017.71	17414.40	396.70	585.76	588.10	0.59%	RISE	Linear
18	17414.40	17435.60	21.19	588.10	588.16	0.29%	RISE	Vertical Curve
19	17435.60	17778.03	342.44	588.16	588.16	0.00%	LEVEL	Linear

SN	Chainage From	To	Length	Rail Level From	To	Gradient	Remarks	Element
20	17778.03	17821.96	43.93	588.16	587.52	-1.46%	FALL	Vertical Curve
21	17821.96	18236.72	414.76	587.52	575.37	-2.93%	FALL	Linear
22	18236.72	18302.73	66.01	575.37	574.89	-0.73%	FALL	Vertical Curve
23	18302.73	18638.96	336.22	574.89	579.84	1.47%	RISE	Linear
24	18638.96	18661.04	22.09	579.84	580.00	0.74%	RISE	Vertical Curve
25	18661.04	19068.46	407.42	580.00	580.00	0.00%	LEVEL	Linear
26	19068.46	19099.53	31.07	580.00	580.32	1.04%	RISE	Vertical Curve
27	19099.53	19599.47	499.94	580.32	590.68	2.07%	RISE	Linear
28	19599.47	19630.54	31.07	590.68	591.00	1.04%	RISE	Vertical Curve
29	19630.54	20067.64	437.11	591.00	591.00	0.00%	LEVEL	Linear
30	20067.64	20088.36	20.72	591.00	590.97	-0.14%	FALL	Vertical Curve
31	20088.36	20791.64	703.28	590.97	589.03	-0.28%	FALL	Linear
32	20791.64	20812.36	20.72	589.03	589.00	-0.14%	FALL	Vertical Curve
33	20812.36	21082.65	270.29	589.00	589.00	0.00%	LEVEL	Linear
34	21082.65	21117.35	34.70	589.00	588.60	-1.16%	FALL	Vertical Curve
35	21117.35	21467.57	350.22	588.60	580.49	-2.31%	FALL	Linear
36	21467.57	21510.29	42.72	580.49	580.11	-0.89%	FALL	Vertical Curve
37	21510.29	21851.32	341.04	580.11	581.94	0.53%	RISE	Linear
38	21851.32	21874.66	23.33	581.94	582.24	1.31%	RISE	Vertical Curve
39	21874.66	22134.33	259.67	582.24	587.67	2.09%	RISE	Linear
40	22134.33	22165.68	31.35	587.67	588.00	1.05%	RISE	Vertical Curve
41	22165.68	22470.47	304.79	588.00	588.00	0.00%	LEVEL	Linear
42	22470.47	22499.53	29.06	588.00	588.28	0.97%	RISE	Vertical Curve
43	22499.53	22883.32	383.79	588.28	595.72	1.94%	RISE	Linear
44	22883.32	22912.38	29.06	595.72	596.00	0.97%	RISE	Vertical Curve
45	22912.38	23393.18	480.79	596.00	596.00	0.00%	LEVEL	Linear
46	23393.18	23414.82	21.64	596.00	596.09	0.43%	RISE	Vertical Curve
47	23414.82	23622.01	207.19	596.09	597.89	0.87%	RISE	Linear
48	23622.01	23647.99	25.97	597.89	598.00	0.43%	RISE	Vertical Curve
49	23647.99	24378.45	730.46	598.00	598.00	0.00%	LEVEL	Linear
50	24378.45	24401.55	23.11	598.00	598.17	0.72%	RISE	Vertical Curve
51	24401.55	24829.17	427.61	598.17	604.34	1.44%	RISE	Linear

SN	Chainage From	To	Length	Rail Level From	To	Gradient	Remarks	Element
52	24829.17	24850.83	21.66	604.34	604.50	0.72%	RISE	Vertical Curve
53	24850.83	25177.39	326.56	604.50	604.50	0.00%	LEVEL	Linear
54	25177.39	25202.61	25.22	604.50	604.70	0.79%	RISE	Vertical Curve
55	25202.61	25836.47	633.86	604.70	614.69	1.58%	RISE	Linear
56	25836.47	25875.87	39.40	614.69	615.00	0.79%	RISE	Vertical Curve
57	25875.87	26740.00	864.13	615.00	615.00	0.00%	LEVEL	Linear

5.6.2.3. ABSTRACT OF VERTICAL GRADIENTS

While designing vertical alignment, a length of 671.72m of overlap has been kept with phase-1 corridor (Design length-12255m, Actual viaduct length- 11633.281m). Efforts have been made to avoid frequent gradients. The number of gradients has been kept to minimum, however, due to ground profile, difference in Road level of viaduct over mid-section and station location, horizontal alignment, gradients are inevitable. Efforts have been made to provide the gradients as flat as possible, subject to ground profile. About 93.58 % of the total alignment is on gradient / straight and remaining 6.42% alignment is on curve. While 45.41% of the alignment is on level gradient. The abstract is as below:

TABLE 5-24: ABSTRACT OF VERTICAL GRADIENTS

SN	Description	No of Occurrences	Length (m)	Percentage (%) of corridor
1	Level (0%)	13	5565.6	45.41%
2	>0% to 1%	5	2086.59	17.03%
3	>1% to 2%	7	2291.42	18.70%
4	>2% to 3%	5	1524.59	12.44%
5	>3%	0		0%
	Curves	28	786.80	6.42%
	TOTAL		**12255.00**	100%

5.6.2.4. CURVATURE – LINE 2B

Since the full corridor follows the road centreline, there are several horizontal curves. Some curves are of sharp radius and some are flatter. The details of curves on this Corridor are given in Table 5-25.

TABLE 5-25: DETAILS OF HORIZONTAL CURVES (CURVE SUMMARY) – LINE 2B

Curve No.	Chainage		Direction	Radius (m)	Deflection Angle	Transition Length (m)		Tangent Length (m)	Circular curve length (m)	Total curve length (m)	Straight Length (m)
	From	To				Leading	Trailing				
1	14561.13	14636.42	Right	455	6°19'56.7028"	25	25	37.67	25.29	75.29	152.34
2	14788.76	14864.55	Right	255	11°24'41.3497"	25	25	37.99	25.79	75.79	116.39
3	14980.94	15072.15	Left	850	4°27'46.6708"	25	25	45.62	41.21	91.21	193.32
4	15265.47	15340.37	Right	1050	2°59'44.9332"	20	20	37.46	34.9	74.9	214.85
5	15555.22	15620.82	Right	720	3°37'44.3783"	20	20	32.81	25.6	65.6	177.97
6	15798.79	15862.23	Left	600	4°08'53.9400"	20	20	31.73	23.44	63.44	47.71
7	15909.94	15983.24	Right	550	5°01'52.5621"	25	25	36.67	23.3	73.3	35.15
8	16018.39	16089.57	Left	1700	1°33'22.8922"	25	25	35.59	21.18	71.18	157.96
9	16247.53	16395.76	Right	500	14°07'14.9249"	25	25	74.43	98.23	148.23	70.68
10	16466.44	16529.17	Left	700	3°29'53.0598"	20	20	31.38	22.74	62.74	444.72
11	16973.89	17039.83	Left	2500	1°03'09.7746"	20	20	32.97	25.93	65.93	166.11
12	17205.94	17308.41	Right	350	12°40'53.3730"	25	25	51.4	52.47	102.47	44.22
13	17352.63	17512.77	Right	470	14°38'45.2563"	40	40	80.42	80.14	160.14	180.39
14	17693.16	17875.99	Left	200	40°55'07.8301"	40	40	94.73	102.83	182.83	28.03
15	17904.02	17979.78	Left	370	7°51'35.8276"	25	25	37.92	25.76	75.76	156.84
16	18136.62	18402.98	Left	600	22°05'34.0858"	35	35	134.65	196.36	266.36	176.84
17	18579.82	18722.02	Right	200	29°16'44.8606"	40	40	72.32	62.2	142.2	244.34
18	18966.36	19046.53	Left	270	11°42'24.9935"	25	25	40.19	30.17	80.17	238.87
19	19285.4	19348.85	Right	1100	2°15'47.8184"	20	20	31.73	23.45	63.45	31.72

Curve No.	Chainage		Direction	Radius (m)	Deflection Angle	Transition Length (m)		Tangent Length (m)	Circular curve length (m)	Total curve length (m)	Straight Length (m)
	From	To				Leading	Trailing				
20	19380.57	19447.65	Left	600	4°29'43.8052"	20	20	33.55	27.08	67.08	21.82
21	19469.47	19595.79	Left	1750	3°28'51.7204"	20	20	63.18	86.32	126.32	134.31
22	19730.1	19803.13	Right	1200	2°17'36.0386"	25	25	36.52	23.03	73.03	172.57
23	19975.7	20232.28	Right	1400	9°40'55.8190"	20	20	128.57	216.58	256.58	180.69
24	20412.97	20492.93	Right	600	5°14'51.6151"	25	25	40	29.95	79.95	105.51
25	20598.44	20659.56	Left	530	4°26'44.3321"	20	20	30.57	21.12	61.12	31.58
26	20691.14	20850.15	Right	1000	7°57'52.2812"	20	20	79.62	119.01	159.01	158.88
27	21009.03	21072.07	Right	1400	1°45'41.1592"	20	20	31.52	23.04	63.04	87.58
28	21159.65	21377.54	Right	1050	10°31'32.4814"	25	25	109.22	167.89	217.89	23.16
29	21400.7	21577.37	Left	375	21°38'47.8304"	35	35	89.22	106.68	176.68	54.69
30	21632.06	21708.96	Right	650	4°34'32.3098"	25	25	38.47	26.91	76.91	113.11
31	21822.07	21899.46	Left	210	15°39'26.8289"	20	20	38.88	37.39	77.39	23.31
32	21922.77	22050.31	Right	210	25°14'56.7255"	35	35	64.59	57.54	127.54	30.92
33	22081.23	22224.34	Left	500	11°48'55.0836"	40	40	71.75	63.11	143.11	175.44
34	22399.78	22572.23	Right	330	22°59'43.9485"	40	40	87.16	92.44	172.44	184.06
35	22756.29	22959.21	Right	730	14°21'25.7994"	20	20	101.95	162.92	202.92	21.12
36	22980.33	23073.07	Left	135	30°52'22.6628"	20	20	47.31	52.74	92.74	299.38
37	23372.45	23437.25	Left	280	9°10'06.5381"	20	20	32.46	24.81	64.81	84.39
38	23521.64	23597.35	Left	500	5°48'37.7180"	25	25	37.88	25.71	75.71	82.05
39	23679.4	23752.69	Right	10000	0°16'36.0665"	25	25	36.65	23.29	73.29	420.88
40	24173.57	24336.83	Left	760	10°25'22.4261"	25	25	81.82	113.25	163.25	119.22
41	24456.05	24536.18	Left	500	6°19'03.3677"	25	25	40.1	30.13	80.13	262.56

Curve No.	Chainage		Direction	Radius (m)	Deflection Angle	Transition Length (m)		Tangent Length (m)	Circular curve length (m)	Total curve length (m)	Straight Length (m)
	From	To				Leading	Trailing				
42	24798.74	24873.29	Left	480	5°54'49.6480"	25	25	37.3	24.54	74.54	157.4
43	25030.69	25094.94	Left	200	12°40'35.4166"	20	20	32.22	24.25	64.25	0.00
44	25094.94	25163.27	Right	500	5°32'18.1426"	20	20	34.19	28.33	68.33	59.14
45	25222.41	25293.88	Right	500	5°53'53.9190"	20	20	35.76	31.47	71.47	328.85
46	25622.73	25958.26	Right	705	24°01'05.4812"	40	40	169.99	255.53	335.53	446.72
47	26404.98	26523.71	Right	610	7°51'53.5424"	35	35	59.44	48.73	118.73	21.8
48	26545.51	26704.19	Left	370	20°42'04.4329"	25	25	80.09	108.68	158.68	0.00

5.6.2.5. ABSTRACT OF HORIZONTAL CURVES

The proposed phase-2 alignment has been designed with overlap length of 638.11m with phase-1 alignment (Design length 12271.29m and actual viaduct will be 11633.381m). However, total length considered for all practical purposes like cost estimate etc. actual viaduct length of phase-2 has been considered. The proposed alignment negotiates frequent horizontal curves to follow the existing road median. At some places there are sharp turns along the road which necessitated provision of sharp curves on the alignment. Moreover, these sharp turns are negotiated by taking the alignment on one side of both the road legs to minimize land acquisition at the corner of the turn.

There are total of 48 nos. horizontal curves have been provided on the entire length of the alignment. The minimum radius of curves is 135 m. About 55.68% alignment is on straight & remaining 44.32% of alignment is on curves.

The abstract and details of curves are indicated in the table below;

TABLE 5-26: ABSTRACT OF HORIZONTAL CURVES

SN	Curve Radius (m)	No. of Occurrences	Length (m)	Percentage (%) of corridor
1	<190	1	52.75	0.43%
2	>190 <300	8	364.98	2.97%
3	≥300 ≤500	14	792.98	6.46%
4	>500 ≤800	13	976.94	7.96%
5	>800 ≤1000	2	160.22	1.31%
6	>1000	10	645.62	5.26%
7	Straight	47	6832.91	55.68%
8	Transition curves		2445	19.92%
	TOTAL		12271.4	100%

5.6.2.6. MAJOR ROADS ALONG THE CORRIDOR

Some of the Major Roads along/across the Line 2B are discussed in the Table 5-27.

TABLE 5-27: MAJOR ROADS ALONG LINE 2B

Sl. No.	Road	Chainage (m)	Direction (LHS/RHS)	Name of road along the alignment	Road width (m)
1	Pune Ahmednagar Highway	14991.719 to 26740.514	Centre	Pune Ahmednagar Highway	30-60

TABLE 5-28: MAJOR ROADS ACROSS LINE 2B

Sl. No.	Road	Chainage (m)	Direction (LHS/RHS)	Name of road along the alignment	Road width (m)
1	Viman Nagar Road	15600	LHS	Pune Ahmednagar Highway	21
2	Old Mundhwa Road	16655	RHS	Pune Ahmednagar Highway	15
3	Niwas Road	17275	RHS	Pune Ahmednagar Highway	5-6
4	Beed Ahmednagar Pune Road	17775	RHS	Pune Ahmednagar Highway	30
5	Fountain Road	14414	RHS	Pune Ahmednagar Highway	22
6	Wagholi Road	22575	LHS	Pune Ahmednagar Highway	18
7	Kesnand - Wadegaon Road	23450	RHS	Pune Ahmednagar Highway	22
8	Towards Kharadi Gaon	18412	RHS	Pune Ahmednagar Highway	24
9	Patil Road B	19200	LHS	Pune Ahmednagar Highway	16
10	Khandve Nagar	19888	LHS	Pune Ahmednagar Highway	5-6
11	Upper Kharadi Main Road	20407	RHS	Pune Ahmednagar Highway	12
12	Lohagaon Road	23225	LHS	Pune Ahmednagar Highway	7-8
13	Awalwadi Road	23200	RHS	Pune Ahmednagar Highway	10-12
14	Sanskrit School Road	24636	LHS	Pune Ahmednagar Highway	5-6

5.7 CIVIL STRUCTURES

5.7.1 ELEVATED VIADUCT STRUCTURE

5.7.1.1. SUPERSTRUCTURE TYPE

The superstructure of a large part of the viaduct comprises of simply supported spans. However, at major crossings over or along existing bridge, special steel or continuous unit will be provided. Following options are available for an elevated viaduct superstructure:

- Precast Segmental Box – Girder for standard viaduct
- Precast double U-girder with internal prestressing.
- Cast-in-situ Segmental Balanced Cantilever
- Special Span as per site requirements– Like Steel composite girder

Precast Segmental Box – Girder

- Span range 13.0 m to 34.0 m; Average span in Phase - 1 is 25 to 28 m.
- Track centre to centre distance 4.1 m;
- Precast segmental – maximum height – one segment – 45T approx. – erection can be done by launching crane;
- Post-tensioned precast concrete – grade 50 MPA to grade 60 MPA.

FIGURE 5-18: METRO VIADUCT ON SEGMENTAL BOX GIRDER, UNDER CONSTRUCTION

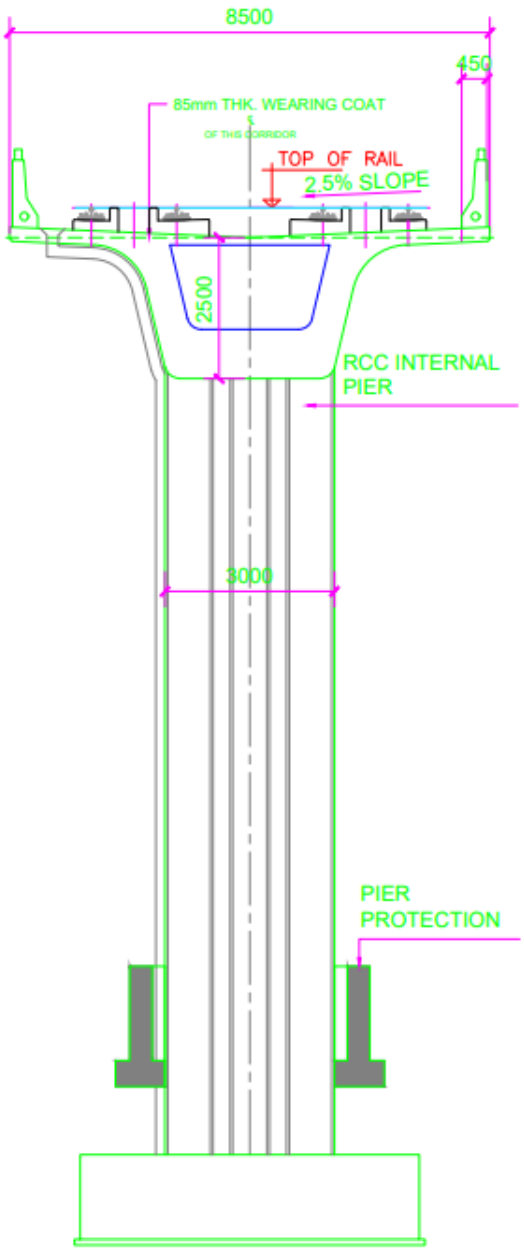


FIGURE 5-19: TYPICAL CROSS SECTION OF A DUAL TRACK METRO VIADUCT ON SEGMENTAL BOX GIRDER

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.

PRE-CAST DOUBLE / TWIN 'U' GIRDER WITH INTERNAL PRESTRESSING

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

- Built-in sound barrier.
- Built-in cable support and system function.
- Possibility to lower the longitudinal profile by approximately 1m compared to conventional design.
- Built-in structural elements capable of maintaining the trains on the bridge in case of derailment (a standard barrier design does not allow this)
- Built-in maintenance and evacuation path on either side of the track.

The schematic arrangement for this is shown in Figure 5-20.

FIGURE 5-20: LAUNCHING OF DOUBLE U GIRDER.

CAST-IN-SITU SEGMENTAL BALANCED CANTILEVER

Balanced cantilever construction is suited to precast segmental and cast-in-place bridges. The deck is erected segmentally on each side of the pier in a balanced sequence to minimize load unbalance and longitudinal bending in piers and foundations. The deck is self-supporting during construction, and it also supports erection equipment and construction materials stored on the cantilever. This construction method is particularly advantageous on long spans, in marine operations, and where access beneath the deck is difficult.

Negative bending governs balanced cantilever construction, and this often requires box sections with a thick bottom slab at the root of the cantilever and many longitudinal tendons in the top slab. For a given span length, balanced cantilever erection of precast segmental bridges is often more expensive than span-by-span erection in terms of quantities of structural materials and associated labour. The advantage of balanced cantilever erection is that the segments are handled individually, and the erection equipment is therefore lighter and less expensive than a self-launching gantry for span-by-span construction, which sustains the weight of an entire span of segments during span assembly and application of post-tensioning.

Balanced cantilever bridges typically have box section. The bottom slab of a box girder lowers the cross-sectional center of gravity, which increases the flexural capacity in the negative bending regions. The torsional strength and stiffness of a hollow section assure stability of the cantilevers on the long spans where this construction method is typically employed. This is particularly true when the deck is curved in plan. Single-cell box girders may reach 18-20m of width; transverse ribs in the top slab, diagonal struts propping the edges of the side wings from the bottom web-slab nodes of the cross-section, and combinations of ribs and struts have been successfully used to further widen the top slab of single-cell box girders.

FIGURE 5-21: CONSTRUCTION OF BALANCED CANTILEVER TYPE VIADUCT

RECOMMENDATION:

After studying all the feasible options and in continuation to the works in Phase-1 of Pune MRTS, Pre-cast segmental box girder using external unbounded tendon is recommended because of the advantages mentioned above.

5.7.1.2. 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 2m to 3.0 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.

5.7.2 CONSTRUCTION METHODOLOGY

5.7.2.1. 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 a wide span range. Following type of superstructures has been considered:

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 prestressing 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 schematic arrangement is shown at Figure 5-22.

FIGURE 5-22: LAUNCHING OF SEGMENTAL BOX ON VIADUCT.

PRECAST DOUBLE 'U' GIRDER WITH INTERNAL PRESTRESSING

The twin U-Girder viaducts incorporating one girder for each track are a popular structural form because it lends itself to quick construction. However, the success of its usage is dependent on the ease of transportation and erection of the girders. Narrow and winding roads for bringing the precast element from the casting yard to the site can cause problems which must be anticipated before selecting this technique. Also, the availability of road space for the two lifting cranes at the time of erection must also be visualized beforehand. The girders are casted in casting yard under all quality control measures, transported and launched using cranes at site.

FIGURE 5-23: SEQUENCING OF ACTIVITIES- PRECAST U GIRDER.

- ***Cast-in-situ Segmental Balanced Cantilever Method***

The formwork is supported from a movable form carrier. The form traveller moves forward on rails attached to the deck of the completed structure and is anchored to the deck at the rear. With the form traveller in place, a new segment is formed, cast and stressed to the previously constructed segment. A covering may be provided on the form carrier so that work may proceed during inclement weather.

Each segment is reinforced with conventional untensioned steel and sometimes by transverse or vertical prestressing or both, while the assembly of segments is achieved by longitudinal post-tensioning. One segment to the left of the pier is first constructed and then stressed against the crosshead, followed by the corresponding unit on the right, which will also be stressed against the crosshead. The sequence is then repeated. Additional prestressing shall be provided for continuity to the overall frame structure.

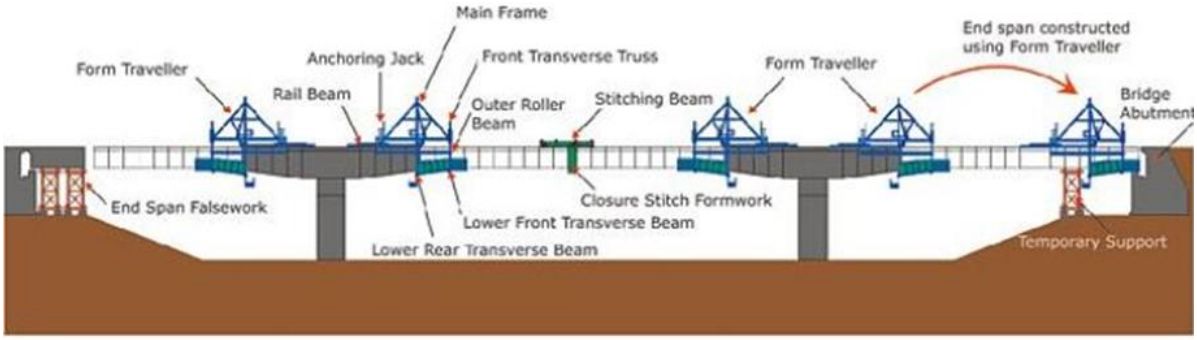


FIGURE 5-24: CONSTRUCTION OF BALANCED CANTILEVER TYPE VIADUCT.

The operation sequence in cast in place balance cantilever construction is as follows:

- Setting up and adjusting carrier
- Setting up and aligning forms
- Placing reinforcement and tendon ducts
- Concreting
- Inserting prestress tendons in the segment and stressing
- Removing the formwork
- Moving the form carrier to the next position and starting a new cycle

The limitation of the method is that the strength of concrete is always on the critical path of construction and it also influences greatly the structure's deformability, particularly during construction.

5.7.2.2. SPAN BY SPAN CONSTRUCTION METHOD

Constructing the typical 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.

- 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.

FIGURE 5-25: SPAN BY SPAN CONSTRUCTION OF VIADUCT

The advantage of the span-by-span method of construction pertains to the pre-stressing 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.

The capital investment in the equipment for this type of construction is considerable.

5.7.2.3. PRE-CAST CONSTRUCTION

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

- Reduction in construction period due to concurrent working for substructure and superstructure.
- For segmental, pre-cast element (of generally 3.0m length), transportation from construction depot to site is easy and economical.
- Minimum inconvenience is caused to the public utilizing 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 2.5 ha to 3 ha is required for each construction depot (one per contract).

FIGURE 5-26: CASTING OF BOX SEGMENTS IN CASTING YARD

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 5-27: TRANSPORTATION OF BOX GIRDER

5.7.2.4. CONSTRUCTION OF VIADUCT BEFORE AND AFTER ISLAND STATIONS

In order to achieve track centres from 4.1m to 12.6m, the track structure need to flare till the full width. Box girders of such width will not be feasible to construct. In case of U girders, the depth reduces by almost 2.5-3m. To manage this depth, either pier heights will need to be increased for some length. Also, U girders are of specific / standard length and non-standard spans will be needed before & after stations. Therefore, it is recommended to use pre-cast I-girders with cast-in-situ deck slab. This will maintain uniform pier height (depth of I-girders nearly same to box-girders).

The I-girders are casted in the casting yard as per the approved drawing and WMS. After attening the desired concrete strength as per the drawing, stressing activity is done. After

24 hours of stressing of the I girder stressing grouting activity can proceed as per the approved mix design.

- Then I girder is transported to the site with the help of suitable trailor.
- The I girder is lifted with the help of two crane, placed as per the lifting plan and the suitable capacity of the crane.
- Bearings are placed on the pedestal and the I-girder are placed over the bearing after the lifting.
- After lifting it is locked with the suitable arrangement, as per the design.
- After all, 4 I-girder placing, casting of the end diaphragm is done.
- The deck slab shuttering will be done and placing of the reinforcement will be done of the deck slab casting.
- During deck slab casting the location of all the conduits for system, signal will be checked and the position of the track reinforcement will be checked accordingly.

FIGURE 5-28 PLACING OF I-GIRDER

FIGURE 5-29 PREPARING OF DECK-BED

FIGURE 5-30 LAUNCHING OF I-GIRDER

5.7.2.5. CONSTRUCTION OF STATIONS

SIDE PLATFORM STATIONS (Viman Nagar, Wagheshwar Temple, Wagholi and Vitthalwadi).

It is proposed to construct the elevated stations with elevated concourse over the road at most of the locations to minimize land acquisition. The viaduct can be continued through the stations also, however, to minimise the rail levels, it is recommended to construct the station on cast in situ slabs. 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.

If the viaduct with continue through the stations, super-structure will consist of precast segmental box Girders for supporting the track structure and I Girder / Double T Girders for supporting the platform and concourse areas. A pre-cast or cast in situ prestressed cross girder will be required over the middle piers for supporting platform structure. Box shaped in situ prestressed cantilever cross girders are planned for supporting the concourse girders and escalators at mezzanine level. Most of the members will be pre-cast in a construction depot and launched at site through cranes.

ISLAND PLATFORM STATIONS (Six stations except above four and Kharadi Bypass)

For Island type platform stations also, the station will be on three levels i.e. Ground, Concourse and Platform. The concourse lengths have been optimised with reduced length of 60-80m and the platform length remains 140m long. The tracks will be constructed on deck slab after the I-girders are placed on the bearings/piers.

The platforms will be constructed further supported on I girders on the slab. The typology is single pier with cantilever pier arms, supporting the full structure i.e. rail tracks and platform slab. The entry/ exit structure will have separate support structure.

KHARADI BYPASS STATION

This station will be combination of the Two station types i.e. side platform and Island platform.

5.7.2.6. 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
All precast element for viaduct and station	M -45
Cantilever piers and portals	M – 45/ 60
Other miscellaneous structure	M - 30

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

5.7.2.7. REINFORCEMENT AND PRE-STRESSED STEEL

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

5.7.2.8. ROAD WIDTH REQUIRED DURING CONSTRUCTION

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

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

- Preliminary action for diversion of utility and preparation of estimates thereof.
- Reservation of land along the corridor, identification and survey for acquisition.

5.8 UTILITY DIVERSIONS

5.8.1 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.

5.8.2 UTILITY AND SERVICES

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

TABLE 5-29: ORGANISATIONS / DEPARTMENTS WITH CONCERNED UTILITY SERVICES IN PUNE

SN	Organization / Department	Utility Services corridor)
1.	Pune Municipal Corporation	Surface water drains, nallahs, sewerage and drainage conduits, sewerage treatment plants, pumping stations, electric poles, Road construction & maintenance of Roads, Water supply Line 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.	Electricity Board	OH & underground electric cables
5.	Maharashtra Natural Gas Limited	Gas pipe line

5.8.3 SEWER LINES, STROM WATER DRAINS AND WATER LINES

The sewer/drainage lines generally exist in the service lanes i.e. away from main carriageway. However, in certain stretches, these have come near the central verge or under main carriageway, as a result of subsequent road widening.

The major sewer/drainage lines and water mains running across the alignment and likely to be affected due to location of column foundations are proposed to be taken care of by relocating on column supports of viaduct by change in span or by suitably adjusting the layout of pile foundations.

Where, this is not feasible, lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines. Investigations of underground utilities are in progress and details would be furnished during construction stage.

TABLE 5-30: DETAILS OF AFFECTED STORM WATER PIPE LINES IN LINE 2A (VANAZ – CHANDANI CHOWK)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	-875.8659	-1056.75	180.8826	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
2	-933.3213	-1091.78	158.4599	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
3	-1698.333	-1737.8	39.4656	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
4	-1655	-1733.19	78.1869	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES

TABLE 5-31: DETAILS OF AFFECTED STORM WATER PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	15487.99	15536.81	48.83	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
2	15489.24	15538.15	48.91	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
3	16649.35	16698.45	49.10	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
4	16660.83	16709.93	49.10	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
5	17542.51	17668.05	125.54	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
6	17492.57	17745.25	252.67	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
7	17818.51	17861.69	43.18	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
8	18894.08	18943.99	49.91	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
9	18866.84	18925	58.16	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
10	19805.46	19884.87	79.40	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
11	19839.33	19888.43	49.10	RHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
12	21005.08	21085.9	80.82	RHS	1200 Cast in Situ	Hume Pipe	1.5-2	Parallel	Elevated	YES
13	23175.19	23219.75	44.56	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
14	24085.44	24134.68	49.24	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
15	24080.98	24134.62	53.65	RHS	1200 Cast in Situ	Hume Pipe	1.5-2	Parallel	Elevated	YES
16	24953.65	25011.1	57.46	RHS	1200 Cast in Situ	Hume Pipe	1.5-2	Parallel	Elevated	YES
17	26153.96	26315.53	161.58	LHS	450-1200	Hume Pipe	1.5-2	Parallel	Elevated	YES

TABLE 5-32: DETAILS OF AFFECTED WATER PIPE LINES IN LINE 2A (VANAZ – CHANDANI CHOWK)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA / SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	-875.866	-1056.75	180.8826	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
2	-933.321	-1091.78	158.4599	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
3	-1698.33	-1737.8	39.4656	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
4	-1655	-1733.19	78.1869	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES

TABLE 5-33: DETAILS OF AFFECTED WATER PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	15487.99	15536.81	48.83	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
2	15489.24	15538.15	48.91	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
3	16649.35	16698.45	49.10	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
4	16660.83	16709.93	49.10	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
5	17542.51	17668.05	125.54	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
6	17492.57	17745.25	252.67	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
7	18897.42	18942.42	45.00	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
8	18871.21	8926.21	55.00	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
9	19808.14	19881.65	73.51	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
10	19842.38	19885.48	43.10	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
11	22225	22395	170.00	LHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES
12	22225	22395	170.00	RHS	75-1000	Steel	1-1.5	Parallel	Elevated	YES

TABLE 5-34: DETAILS OF AFFECTED SEWER LINES IN LINE 2A (VANAZ – CHANDANI CHOWK)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	-875.8659	-1056.75	180.8826	LHS	800-1200	RCC	1.5-2	Parallel	Elevated	YES
2	-933.3213	-1091.78	158.4599	RHS	800-1200	RCC	1.5-2	Parallel	Elevated	YES
3	-1698.3334	-1737.8	39.4656	RHS	800-1200	RCC	1.5-2	Parallel	Elevated	YES
4	-1655	-1733.19	78.1869	LHS	800-1200	RCC	1.5-2	Parallel	Elevated	YES

TABLE 5-35 : DETAILS OF AFFECTED SEWER PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	15487.985	15536.81	48.83	LHS	450	Hume Pipe	1.5-2	Parallel	Elevated	YES
2	15489.239	15538.15	48.91	RHS	1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
3	16649.35	16698.45	49.10	LHS	450	Hume Pipe	1.5-2	Parallel	Elevated	YES

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
4	16660.831	16709.93	49.10	RHS	1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
5	17542.508	17668.05	125.54	LHS	1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
7	17492.573	17745.25	252.67	RHS	1200	Hume Pipe	1.5-2	Parallel	Elevated	YES
9	17818.507	17861.69	43.18	RHS	600	Hume Pipe	1.5-2	Parallel	Elevated	YES
10	18894.08	18943.99	49.91	LHS	600	Hume Pipe	1.5-2	Parallel	Elevated	YES
11	18866.843	18925	58.16	RHS	600	Hume Pipe	1.5-2	Parallel	Elevated	YES
12	19805.462	19884.87	79.40	LHS	1200mm Cast in Situ drain	Hume Pipe	1.5-2	Parallel	Elevated	YES
13	19839.327	19888.43	49.10	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
14	20986.682	21046.92	60.23	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
15	21005.078	21085.9	80.82	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
16	22337.409	22386.15	48.74	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
17	22310.912	22360.01	49.10	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
18	23317.04	23355.94	38.90	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
19	23135.32	23174.2	38.88	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
20	23175.189	23219.75	44.56	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
21	23356.814	23400	43.19	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
22	24085.44	24134.68	49.24	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
23	24080.978	24134.62	53.65	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
24	24922.009	25003.15	81.14	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
25	24953.645	25011.1	57.46	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
26	26146.045	26315.53	169.49	LHS		Hume Pipe	1.5-2	Parallel	Elevated	YES
27	26144.434	26318.15	173.71	RHS		Hume Pipe	1.5-2	Parallel	Elevated	YES

5.8.4 DETAILS OF GAS PIPE LINES GETTING AFFECTED

TABLE 5-36: DETAILS OF AFFECTED GAS PIPE LINES IN LINE 2A (VANAZ – CHANDANI CHOWK)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	-875.866	-1056.7485	180.8826	LHS	125	MPDE	**1.5-2**	Parallel	Elevated	YES
2	-933.321	-1091.7812	158.4599	RHS	125	MPDE	**1.5-2**	Parallel	Elevated	YES

TABLE 5-37: DETAILS OF AFFECTED GAS PIPE LINES IN LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (mm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	15487.99	15536.811	48.83	LHS	125	**MPDE**	**1.5-2**	Parallel	Elevated	YES
3	16649.35	16698.45	49.10	LHS	125	**MPDE**	**1.5-2**	Parallel	Elevated	YES
4	17542.51	17668.05	125.54	LHS	125	**MPDE**	**1.5-2**	Parallel	Elevated	YES
5	18894.08	18943.989	49.91	LHS	125	**MPDE**	**1.5-2**	Parallel	Elevated	YES
6	19805.46	19884.865	79.40	LHS	125	**MPDE**	**1.5-2**	Parallel	Elevated	YES

TABLE 5-38: DETAILS OF AFFECTED OPTICAL FIBRES CABLE IN LINE 2A (VANAZ – CHANDANI CHOWK)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA (µm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	-875.866	-1056.75	180.8826	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
2	-933.321	-1091.78	158.4599	RHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
3	-1655	-1733.19	78.1869	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES

TABLE 5-39: DETAILS OF AFFECTED OPTICAL FIBRES CABLE IN 2B (RAMWADI- WAGHOLI/VITTHALWADI)

Sl. No.	Chainage From (m)	Chainage To (m)	Length (m)	LHS / RHS	DIA/SIZE (µm)	Material	Depth (BGL) in m	Position of Alignment	Metro Alignment	Diversion Reqd.
1	15487.99	15536.81	48.83	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
2	15489.24	15538.15	48.91	RHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
3	16649.35	16698.45	49.10	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
4	17542.51	17668.05	125.54	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
5	23135.32	23174.2	38.88	RHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
6	23175.19	23219.75	44.56	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
7	23356.81	23400	43.19	RHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
8	24922.01	25003.15	81.14	LHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES
9	24953.65	25011.1	57.46	RHS	50-60	Silica & Plastic	1-1.5	Parallel	Elevated	YES

TABLE 5-40: DETAILS OF AFFECTED HT LINE 2B (RAMWADI- WAGHOLI/VITTHALWADI)

MSETCL HT LINES:- RAMWADI - VITTHALWADI									
Sl. No.	**Chainage From (m)**	**Length (m)**	**LHS / RHS**	**Power**	**Material**	**Depth (BGL) in m**	**Position of Alignment**	**Metro Alignment**	**Diversion Reqd.**
1	19725	350-400	Across	132KV	Aluminium /Copper	OHE	Perpendicular	Perpendicular	Yes

Figure shows a typical cross section for requirement of clearance for HT line above Metro Rail Corridor.

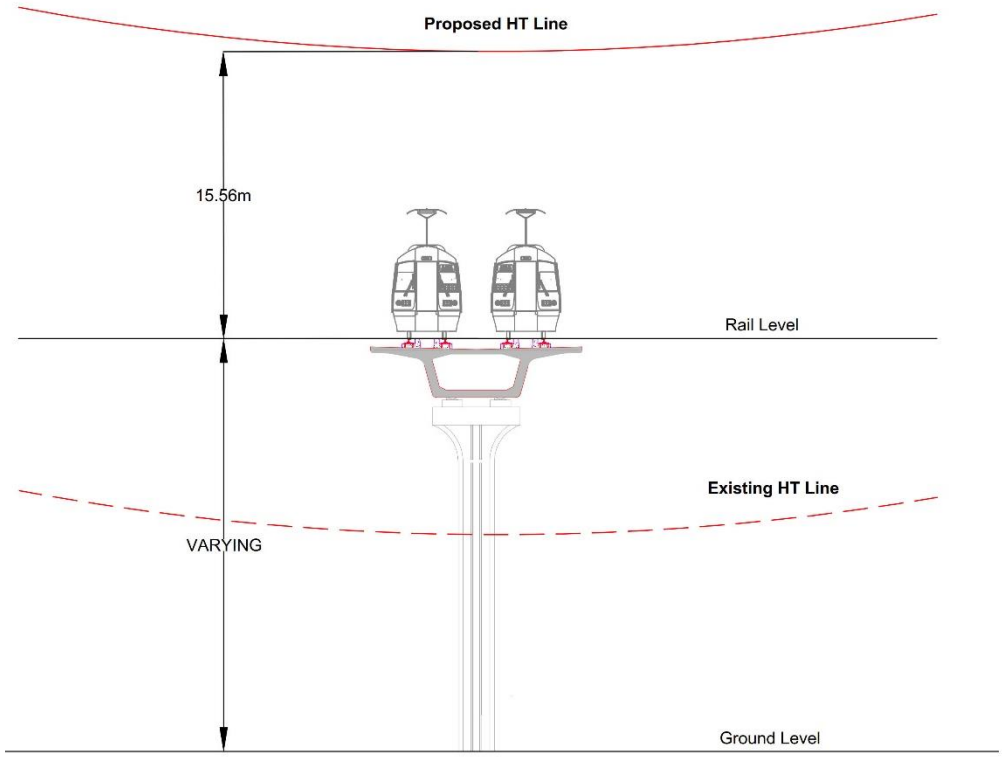


FIGURE 5-31: CLEARANCE REQUIRED FOR HT LINE

5.8.5 DETAILS OF UTILITIES – ABOVE AND UNDER GROUND

Above ground utilities namely street light, poles, traffic signal posts, telecommunication posts, junction boxes, trees etc., are also required to be shifted and relocated suitably during construction of elevated viaduct.

Accordingly, underground utilities will also need to be shifted during construction of structures like piers, stations etc., since these will be interfering with the proposed alignment. Approximate numbers of utilities in Ramwadi - Wagholi & Vanaz – Chandani Chowk corridors are indicated in Table 5-41.

TABLE 5-41: SUMMARY OF AFFECTED UTILITIES

SN	Utility Type	No.s (Line 2A)	No.s (Line 2B)
1.	Electric Pole	1	46
2.	Traffic Signals	6	14
3.	Sign Boards	6	60
4.	Electric Transformers	1	5

SN	Utility Type	No.s (Line 2A)	No.s (Line 2B)
5.	Overhead Transmission	0	1
6.	Chambers	36	79
7.	Trees	27	69
8.	Street Lights	22	265
Total		**99**	**539**

5.9 LAND REQUIREMENT FOR CORRIDORS

5.9.1 LAND REQUIREMENT FOR MAJOR COMPONENTS

Availability of land is one of the major prerequisites for a project in city. As the Metro alignment has to be planned on set standards and parameters, sometimes 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 scarce, costly and acquisition being complex process, the alignment is so planned that land acquisition required is minimum. Land is mainly required for (may or may not be applicable in this project):

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

5.9.2 LAND REQUIREMENT FOR ELEVATED STRETCHES

For elevated section, single pier supporting the viaduct will be located on the middle of road and part on BRTS corridor 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. However, no land acquisition is required for traffic integration aspects.

The existing viaduct structure of elevated Metro for Phase-1 is about 8.5 m (edge to edge) wide. For reasons of safety a clean marginal distance / setback of about 5 m is necessary from either edge of the viaduct (or 10 m on both sides of the centre line) wherein no structures are to be located.

5.9.3 LAND REQUIREMENT - LINE 2A (VANAZ TO CHANDANI CHOWK)

5.9.3.1. LAND REQUIREMENT FOR RUNNING SECTION

The alignment is planned on the median of Road thus no land acquisition required for the running section.

5.9.3.2. LAND REQUIREMENT FOR STATION

The land requirement placing the entry/exit staircases, ancillary building and other structures for the line 2A is presented in Table 5-42.

TABLE 5-42: DETAILS OF LAND TO BE ACQUIRED AT STATION LOCATIONS ON CORRIDOR 2A- VANAZ TO CHANDANI CHOWK

S. No	Station Name	Entry/ Exit	Area (Sqm)			Survey Number	Ownership	Rate (Rs.)	LA Cost[1](Rs. in Cr)			Remark
			PMC	GOM	PVT				PMC	GOM	PVT	
1	Chandani Chowk	EE3			106.26	150	Pvt	82120			2.18	Lohia IT Park

The details of temporary land requirement at the station area during the construction are presented in Table 5-43.

TABLE 5-43: DETAILS TEMPORARILY LAND REQUIREMENT AT STATION LOCATIONS ON CORRIDOR 2A- VANAZ TO CHANDANI CHOWK

S. No	Station Name	Entry/ Exit	Area (Sqm)			Survey Number	Ownership	Rate (Rs.)	LA Cost[2](Rs. in Cr)			Remark
			PMC	GOM	PVT				PMC	GOM	PVT	
1	Kothrud Bus Depot	EE4			52.78	Bavdhan 94	Pvt.	82120			0.04	Mixed Residential
2	Chandani Chowk	EE3			63.2	Bavdhan 150	Pvt	82120			0.06	Commerical
Total					**115.98**						**0.10**	

* Per Year Rental at 2.5% of Ready reckoner rate

The details of land to be utilized within the ROW (Footpath/Carriageway) are presented in Annexure 5.3.

1 Cost of Government land is taken at ready reckoner rate of 2022-23 and Private land at 2.5 times of ready reckoner rate of 2022-23

2 Cost of Government land is taken at ready reckoner rate of 2022-23 and Private land at 2.5 times of ready reckoner rate of 2022-23

5.9.3.3. LAND REQUIREMENT FOR DEPOT

No separate depot has been proposed for the extension and it is proposed that existing depot at Vanaz to be utilized for this extension.

5.9.3.4. LAND REQUIREMENT FOR TRACTION & RECEIVING SUB-STATION

It is proposed that existing RSS to be utilized for Line 2A.

5.9.3.5. SUMMARY OF LAND REQUIREMENT FOR LINE 2A

Summary of Permanent land to be acquired

TABLE 5-44: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2A (VANAZ TO CHANDANI CHOWK)

S. No	Description	Land Requirement (Sqm)				LA Cost (cr.)			
		PMC	GoM (Govt)	Private	Total	PMC	GoM (Govt)	Private	Total
1	Running Section								
2	Stations			106.26	106.26	0.00	0.00	2.18	2.18
3	Depot								
4	RSS/TSS								
Total		**0.00**	**0.00**	**106.26**	**106.26**	**0.00**	**0.00**	**2.18**	**2.18**

Summary of Temporary land to be requirement

TABLE 5-45: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2A (VANAZ TO CHANDANI CHOWK)

S. No	Description	Area (Sqm)				Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	Private	Total	PMC	GoM (Govt)	Private	Total
1	Stations	0.00	0.00	115.98	115.98	0.00	0.00	0.10	0.10
2	Casting Yard		25000.00		25000.00		2.64		2.64
Total		**0.00**	**25000.00**	**115.98**	**25115.98**	**0.00**	**2.64**	**0.10**	**2.74**

5.9.4 LAND REQUIREMENT - LINE 2B (RAMWADI TO WAGHOLI/ VITTHALWADI)

5.9.4.1. LAND REQUIREMENT FOR RUNNING SECTION

The alignment is planned on the median of Road thus no land acquisition required for the running section.

5.9.4.2. LAND REQUIREMENT FOR STATION

The land requirement placing the entry / exit staircases, ancillary building and other structures for the line 2B is presented in Table 5-46.

TABLE 5-46: DETAILS OF LAND TO BE ACQUIRED AT STATION LOCATIONS ON CORRIDOR 2B- RAMWADI TO WAGHOLI/VITTHALWADI

S. No	Station Name	Entry/ Exit	Area (Sqm) PMC	GOM	PVT	Survey Number	Owner ship	Rate (Rs.)	LA Cost[3](Rs. in Cr) PMC	GOM	PVT	Remark
1	Kharadi Bypass	EE4			15	Wadgaon Sheri 51	Pvt.	142450			0.53	Konark Alpha
2	Ubale Nagar	EE2			9.24	Wagholi 1347	Pvt.	92750			0.21	Punjab Spice hotel
3	Upper Kharadi Road	EE1			89.31	Wagholi 1361	Pvt.	92750			2.07	MSN Logistics
4	Wagheshwar Temple	EE1			112.53	Wagholi 1420	Pvt.	92750			2.61	Maruti Showroom
5	Wagholi	EE4	190.35			Wagholi 1121	PMC	10210	0.19			Wagholi Vegetable Market
7	Bakori Phata	EE1			220.78	Wagholi 559	Pvt.	52450			2.89	Mixed Residential
8	Vitthalwadi	EE1			74.13	Wagholi 523	Pvt.	12660			0.23	Industrial
Total			**190.35**		**520.99**				**0.19**		**8.54**	

* Private Land to be acquired at 2.5 times the ready reckoner rate
Government land to be acquired at ready reckoner rate

3 Cost of Government land is taken at ready reckoner rate of 2022-23 and Private land at 2.5 times of ready reckoner rate of 2022-23

The details of temporary land requirement at the station area during the construction are presented in Table 5-47.

TABLE 5-47: DETAILS TEMPORARILY LAND REQUIREMENT AT STATION LOCATIONS ON CORRIDOR 2B- RAMWADI- WAGHOLI/VITTHALWADI

S. No	Station Name	Entry/ Exit	Area (Sqm)			Survey Number	Owner ship	Rate (Rs.)	LA Cost[4](Rs. in Cr)			Remark
			PMC	GOM	PVT				PMC	GOM	PVT	
1	Kharadi Bypass	EE1			55	Wadgaon Sheri 52	Pvt.	75910			0.04	Mixed Residential
		EE2			53.75	Wadgaon Sheri 52	Pvt.	75910			0.04	Mixed Residential
		EE3			68.58	Wadgaon Sheri 43	Pvt.	22580			0.02	EON Hospital Parking
		EE4			25	Wadgaon Sheri 51	Pvt.	142450			0.04	Konark Alpha
2	Ubale Nagar	EE1			25	Wagholi 1348	Pvt.	55210			0.01	Jeevan Rakshak Hospital
		EE2			27.88	Wagholi 1347	Pvt.	92750			0.03	Punjab Spice hotel
3	Upper Kharadi Road	EE1			61.76	Wagholi 1361	Pvt.	92750			0.06	MSN Logistics
4	Wagheshwar Temple	EE2			74.75	Wagholi 1420	Pvt.	92750			0.07	Maruti Showroom
5	Wagholi	EE1			102	Wagholi 1417	Pvt.	55210			0.06	Mixed Residential
		EE2			70	Wagholi 613	Pvt.	55210			0.04	Mixed Residential
		EE3	75.86			Wagholi 1123	PMC	10210	0.01			Wagholi Market

4 Cost of Government land is taken at ready reckoner rate of 2022-23 and Private land at 2.5 times of ready reckoner rate of 2022-23

S. No	Station Name	Entry/ Exit	Area (Sqm)			Survey Number	Owner ship	Rate (Rs.)	LA Cost[4](Rs. in Cr)			Remark
			PMC	GOM	PVT				PMC	GOM	PVT	
		EE4	56.57			Wagholi 1121	PMC	10210	0.01			Wagholi Market
6	Siddharth Nagar	EE1			195.08	Wagholi 638	Pvt.	55210			0.11	ICICI Bank
7	Bakori Phata	EE1			65.42	Wagholi 559	Pvt.	52450			0.03	Mixed Residential
8	Vitthalwadi	EE1			55.76	Wagholi 523	Pvt.	12660			0.01	Industrial
		EE2			68.86	Wagholi 516	Pvt.	12660			0.01	Industrial
Total			**132.43**	**0**	**833.91**				**0.02**	**0**	**0.57**	

The details of land to be utilized within the ROW (Footpath/Carriageway) are presented in Annexure 5.3.

5.9.4.3. LAND REQUIREMENT FOR DEPOT

No separate depot has been proposed for the extension and it is proposed that existing depot at Vanaz to be utilized for this extension. Requirement of a satellite depot is envisaged and discussed in Chapter 14.

5.9.4.4. LAND REQUIREMENT FOR TRACTION & RECEIVING SUB-STATION

A land parcel of 5000 sqm is required for the RSS. Land parcel available near the Kharadi Bypass is proposed for the RSS. The location of the same is presented in Figure 5-32 and cost in Table 5-48

TABLE 5-48: LAND REQUIREMENT FOR THE RSS

S. No	Location Name	Survey No.	Area Sqm	Owner	Ready Reckoner Rate (INR)	Cost of LA Rs In Cr.	Remark
1	Land Near Kharadi Bypass	139	5000	Govt	10540	5.27	LIC

FIGURE 5-32: LAND IDENTIFIED FOR RSS

5.9.4.5. SUMMARY OF LAND REQUIREMENT

Summary of Permanent land to be acquired

TABLE 5-49: SUMMARY OF PERMANENT LAND ACQUISITION FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI)

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. Cr.)			
		PMC	GoM (Govt)	Private	Total	PMC	GoM (Govt)	Private	Total
1	Running Section				0.00				0.00
2	Stations	190.35	0.00	520.99	711.34	0.19	0.00	8.54	8.73
3	Depot				0.00				0.00
4	RSS/TSS		5000.00		5000.00		5.27		5.27
Total		**190.35**	**5000.00**	**520.99**	**5711.34**	**0.19**	**5.27**	**8.54**	**14.00**

Summary of Temporary land to be requirement

TABLE 5-50: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2B (RAMWADI TO WAGHOLI/VITTHALWADI)

S. No	Description	Area (Sqm)				Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	Private	Total	PMC	GoM (Govt)	Private	Total
1	Stations	132.43	0.00	948.84	1081.27	0.02	0.00	0.57	0.59
2	Casting Yard		25000.00		25000.00		2.64		2.64
Total		**132.43**	**25000.00**	**948.84**	**26081.27**	**0.02**	**2.64**	**0.57**	**3.23**

Station-wise land plans are attached in Annexure 5.5.

5.9.4.6. SUMMARY OF AGENCYWISE LAND REQUIREMENT

For purpose of funding, land belonging to PMC has been proposed to be funded/provided by PMC and other land parcels (belonging to GoI, GoM and privately owned) has been proposed to be funded/provided by GoM.

TABLE 5-51: AGENCY WISE LAND REQUIREMENT

	Area (Sqm)		Cost (Rs. in Crore)	
	PMC	GoM	PMC	GoM
Line 2A				
Permanent	0.00	106.26	0.00	2.18
Temporary	0.00	25115.98	0.00	2.74
Line 2B				
Permanent	190.35	5520.99	0.19	13.81
Temporary	132.43	25948.84	0.02	3.21
Total				
Permanent	**190.35**	**5627.25**	**0.19**	**15.99**
Temporary	**132.43**	**51064.82**	**0.02**	**5.95**
		Total	**0.21**	**21.94**
		Grand Total	**22.15**	

The escalation on land cost is considered at 5% per year and total cost towards land requirement is presented in Table 5-52

TABLE 5-52: ESCALATED LAND COST FOR PROJECT

S. No	Perticular	Rs. in Crore	
		July 22 Prices	Escalated Cost
1	Land Cost to PMC	0.21	0.24
2	Land Cost to GoM	21.94	24.86

ANNEXURE 5

ANNEXURE 5.1: SAFE BEARING CAPACITY IN SOIL/ROCK

TABLE 0-1: SAFE BEARING CAPACITY IN SOIL/ROCK – ISOLATED FOOTING (3.0 M X 3.0 M)

CALCULATION SHEET FOR SAFE BEARING CAPACITY IN SOIL/ROCK																																			
Bore Hole Location	Founding Strata	Size of Footing		Depth of Footing	Density	Cohesion Value	Angle of shearing resistance	Mobilized Angle of Shearing Resistance,	Bearing Capacity Factor			Shape Factor			Depth Factor			Water correction factor	Overburden Pressure	Terzaghi Shear Analysis			Based on UCS				Based ON RMR		Settlement Analysis				Safe bearing Capacity	Gross allowable bearing Capacity
																				Net ultimate bearing Capacity	Factor of Safety	Net Safe Bearing Capacity	Rock compressive Strenght, UCS	Empirical coefficient	Gross Bearing Capacity	Net Safe Bearing Capacity	Rock Mass Rating	Safe Bearing Capacity	N-value	Δ for Unit presure (10t/m²)	Net SBC for 40mm settlement	Net SBC for 12mm settlement		
		L	B	D	ϒ	C	Φ	Φ'	N'c	N'q	N'γ	Sc	Sq	Sγ	Dc	Dq	Dγ	W'	q	qnu	FOS	qns	c	N_f	qg	qns	RMR	qns	N		qns	qns	qa	qg
		m	m	m	t/m³	t/m²	°	°	-	-	-	-	-	-	-	-	-	-	t/m²	t/m²	-	t/m²	t/m²		t/m²	t/m²	-	t/m²	-	mm	t/m²	t/m²	t/m²	t/m²
1	SOIL	3.0	3.0	1.0	2.60	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	2.60	57.5	3.0	19.2	4112	0.1	411.2	408.6	15	41	50	-	-	31.8	**19.2**	**21.8**
		3.0	3.0	2.0	2.60	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	5.20	87.7	3.0	29.2	4112	0.1	411.2	406.0	15	41	50	-	-	39.8	**29.2**	**34.4**
		3.0	3.0	3.0	2.60	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	7.80	117.9	3.0	39.3	4112	0.1	411.2	403.4	15	41	50	-	-	47.8	**39.3**	**47.1**
2	SOIL	3.0	3.0	2.0	2.12	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	4.24	71.5	3.0	23.8	0	0.1	0.0	-	0	30	50	-	-	39.8	**23.8**	**28.1**
		3.0	3.0	3.0	2.12	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.36	96.2	3.0	32.1	0	0.1	0.0	-	8	36	50	-	-	47.8	**32.1**	**38.4**
		3.0	3.0	4.0	2.12	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.48	120.8	3.0	40.3	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.5**
3	SOIL	3.0	3.0	2.0	2.18	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	4.36	73.5	3.0	24.5	0	0.1	0.0	-	0	30	50	-	-	39.8	**24.5**	**28.9**
		3.0	3.0	3.0	2.18	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.54	98.9	3.0	33.0	0	0.1	0.0	-	8	36	50	-	-	47.8	**33.0**	**39.5**
		3.0	3.0	4.0	2.18	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.72	124.2	3.0	41.4	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.7**
4	SOIL	3.0	3.0	3.0	2.20	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.60	99.8	3.0	33.3	0	0.1	0.0	-	0	30	50	-	-	47.8	**30.0**	**36.6**
		3.0	3.0	4.0	2.20	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.80	125.4	3.0	41.8	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.8**
		3.0	3.0	5.0	2.20	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	11.00	150.9	3.0	50.3	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**47.0**
5	SOIL	3.0	3.0	3.0	2.12	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.36	96.2	3.0	32.1	0	0.1	0.0	-	0	30	50	-	-	47.8	**30.0**	**36.4**
		3.0	3.0	4.0	2.12	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.48	120.8	3.0	40.3	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.5**
		3.0	3.0	5.0	2.12	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	10.60	145.4	3.0	48.5	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.6**
6	SOIL	3.0	3.0	2.0	2.08	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	4.16	70.2	3.0	23.4	0	0.1	0.0	-	0	30	50	-	-	39.8	**23.4**	**27.5**
		3.0	3.0	3.0	2.08	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.24	94.3	3.0	31.4	0	0.1	0.0	-	0	30	50	-	-	47.8	**30.0**	**36.2**
		3.0	3.0	4.0	2.08	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.32	118.5	3.0	39.5	0	0.1	0.0	-	12	39	50	-	-	47.8	**39.0**	**47.3**
7	SOIL	3.0	3.0	1.0	1.98	1.2	29	20.3	15.1	6.6	5.6	1.30	1.20	0.80	1.00	1.00	1.00	0.8	1.98	39.6	2.5	15.8	0	0.1	0.0	-	0	30	50	-	-	31.8	**15.8**	**17.8**
		3.0	3.0	2.0	1.98	1.2	29	20.3	15.1	6.6	5.6	1.30	1.20	0.80	1.00	1.00	1.00	0.8	3.96	52.9	2.5	21.2	0	0.1	0.0	-	0	30	50	-	-	39.8	**21.2**	**25.1**
		3.0	3.0	3.0	1.98	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	5.94	89.8	3.0	29.9	0	0.1	0.0	-	8	36	50	-	-	47.8	**29.9**	**35.9**
8	SOIL	3.0	3.0	2.0	2.57	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	5.14	86.7	3.0	28.9	0	0.1	0.0	-	8	36	50	-	-	39.8	**28.9**	**34.0**
		3.0	3.0	3.0	2.57	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	7.71	116.6	3.0	38.9	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**43.7**
		3.0	3.0	4.0	2.57	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	10.28	146.4	3.0	48.8	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.3**
9	SOIL	3.0	3.0	3.0	2.19	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.57	99.3	3.0	33.1	0	0.1	0.0	-	8	36	50	-	-	47.8	**33.1**	**39.7**

CALCULATION SHEET FOR SAFE BEARING CAPACITY IN SOIL/ROCK																																		
Bore Hole Location	Founding Strata	Size of Footing		Depth of Footing	Density	Cohesion Value	Angle of shearing resistance	Mobilized Angle of Shearing Resistance,	Bearing Capacity Factor			Shape Factor			Depth Factor			Water correction factor	Overburden Pressure	Terzaghi Shear Analysis			Based on UCS				Based ON RMR		Settlement Analysis				Safe bearing Capacity	Gross allowable bearing Capacity
																				Net ultimate bearing Capacity	Factor of Safety	Net Safe Bearing Capacity	Rock compressive Strenght, UCS	Empirical coefficient	Gross Bearing Capacity	Net Safe Bearing Capacity	Rock Mass Rating	Safe Bearing Capacity	N-value	Δ for Unit presure (10t/m²)	Net SBC for 40mm settlement	Net SBC for 12mm settlement		
		L	B	D	ϒ	C	Φ	Φ'	N'c	N'q	N'y	Sc	Sq	Sy	Dc	Dq	Dy	W'	q	qnu	FOS	qns	c	N_f	qg	qns	RMR	qns	N		qns	qns	qa	qg
		m	m	m	t/m³	t/m²	°	°	-	-	-	-	-	-	-	-	-	-	t/m²	t/m²	-	t/m²	t/m²		t/m²	t/m²	-	t/m²	-	mm	t/m²	t/m²	t/m²	t/m²
		3.0	3.0	4.0	2.19	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.76	124.8	3.0	41.6	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.8**
		3.0	3.0	5.0	2.19	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	10.95	150.2	3.0	50.1	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**47.0**
10	ROCK	3.0	3.0	3.0	2.57	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	7.71	854.6	5.0	170.9	1956	0.1	195.6	187.9	10	38	50	-	-	47.8	**37.5**	**45.2**
		3.0	3.0	4.0	2.57	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	10.28	1049.5	5.0	209.9	1956	0.1	195.6	185.3	10	38	50	-	-	47.8	**37.5**	**47.8**
		3.0	3.0	5.0	2.57	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	12.85	1244.4	5.0	248.9	1956	0.1	195.6	182.8	10	38	50	-	-	47.8	**37.5**	**50.4**
11	SOIL	3.0	3.0	3.0	2.17	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	6.51	98.4	3.0	32.8	0	0.1	0.0	-	8	36	50	-	-	47.8	**32.8**	**39.3**
		3.0	3.0	4.0	2.17	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	8.68	123.6	3.0	41.2	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.7**
		3.0	3.0	5.0	2.17	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	10.85	148.9	3.0	49.6	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.9**
12	SOIL+ROCK	3.0	3.0	4.0	2.49	0	35	25.0	20.8	10.7	10.9	1.30	1.20	0.80	1.00	1.00	1.00	0.8	9.96	141.9	3.0	47.3	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.0**
		3.0	3.0	5.0	2.49	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	12.45	1205.7	5.0	241.1	2311	0.1	231.1	218.7	8	36	50	-	-	47.8	**36.0**	**48.5**
		3.0	3.0	6.0	2.49	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	14.94	1394.5	5.0	278.9	2311	0.1	231.1	216.2	8	36	50	-	-	47.8	**36.0**	**50.9**
37	ROCK	3.0	3.0	1.0	2.60	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	2.60	470.3	5.0	94.1	1588	0.1	158.8	156.2	24	48	50	-	-	31.8	**31.8**	**34.4**
		3.0	3.0	2.0	2.60	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	5.20	667.4	5.0	133.5	1588	0.1	158.8	153.6	24	48	50	-	-	39.8	**39.8**	**45.0**
		3.0	3.0	3.0	2.60	0	40	40.0	75.3	64.2	109.4	1.30	1.20	0.80	1.00	1.00	1.00	0.8	7.80	864.6	5.0	172.9	1588	0.1	158.8	151.0	24	48	50	-	-	47.8	**47.8**	**55.6**

TABLE 0-2: SAFE BEARING CAPACITY IN SOIL/ROCK – ISOLATED FOOTING (4.0 M X 3.0 M)

CALCULATION SHEET FOR SAFE BEARING CAPACITY IN SOIL/ROCK																																		
Bore Hole Location	Founding Strata	Size of Footing		Depth of Footing	Density	Cohesion Value	Angle of shearing resistance	Mobilized Angle of Shearing Resistance,	Bearing Capacity Factor			Shape Factor			Depth Factor			Water correction factor	Overburden Pressure	Terzaghi Shear Analysis			Based on UCS				Based ON RMR		Settlement Analysis				Safe bearing Capacity	Gross allowable bearing Capacity
																				Net ultimate bearing Capacity	Factor of Safety	Net Safe Bearing Capacity	Rock compressive Strenght, UCS	Empirical coefficient	Gross Bearing Capacity	Net Safe Bearing Capacity	Rock Mass Rating	Safe Bearing Capacity	N-value	Δ for Unit presure (10t/m²)	Net SBC for 40mm settlement	Net SBC for 12mm settlement		
		L	B	D	ϒ	C	Φ	Φ'	N'c	N'q	N'y	Sc	Sq	Sy	Dc	Dq	Dy	W'	q	qnu	FOS	qns	c	N_f	qg	qns	RMR	qns	N		qns	qns	qa	qg
		m	m	m	t/m³	t/m²	°	°	-	-	-	-	-	-	-	-	-	-	t/m²	t/m²	-	t/m²	t/m²		t/m²	t/m²	-	t/m²	-	mm	t/m²	t/m²	t/m²	t/m²
1	SOIL	4.0	3.0	1.0	2.60	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	2.60	52.8	3.0	17.6	4112	0.1	411.2	408.6	15	41	50	-	-	31.8	**17.6**	**20.2**
		4.0	3.0	2.0	2.60	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	5.20	81.8	3.0	27.3	4112	0.1	411.2	406.0	15	41	50	-	-	39.8	**27.3**	**32.5**
		4.0	3.0	3.0	2.60	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	7.80	110.7	3.0	36.9	4112	0.1	411.2	403.4	15	41	50	-	-	47.8	**36.9**	**44.7**

CALCULATION SHEET FOR SAFE BEARING CAPACITY IN SOIL/ROCK

Bore Hole Location	Founding Strata	Size of Footing		Depth of Footing	Density	Cohesion Value	Angle of shearing resistance	Mobilized Angle of Shearing Resistance,	Bearing Capacity Factor			Shape Factor			Depth Factor			Water correction factor	Overburden Pressure	Terzaghi Shear Analysis			Based on UCS				Based ON RMR		Settlement Analysis				Safe bearing Capacity	Gross allowable bearing Capacity
																				Net ultimate bearing Capacity	Factor of Safety	Net Safe Bearing Capacity	Rock compressive Strenght, UCS	Empirical coefficient	Gross Bearing Capacity	Net Safe Bearing Capacity	Rock Mass Rating	Safe Bearing Capacity	N-value	Δ for Unit presure (10t/m²)	Net SBC for 40mm settlement	Net SBC for 12mm settlement		
		L	B	D	ϒ	C	Φ	Φ'	N'c	N'q	N'y	Sc	Sq	Sy	Dc	Dq	Dy	W'	q	qnu	FOS	qns	c	N_f	qg	qns	RMR	qns	N		qns	qns	qa	qg
		m	m	m	t/m³	t/m²	°	°	-	-	-	-	-	-	-	-	-	-	t/m²	t/m²	-	t/m²	t/m²		t/m²	t/m²	-	t/m²	-	mm	t/m²	t/m²	t/m²	t/m²
2	SOIL	4.0	3.0	2.0	2.12	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	4.24	66.7	3.0	22.2	0	0.1	0.0	-	0	30	50	-	-	39.8	**22.2**	**26.5**
		4.0	3.0	3.0	2.12	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.36	90.3	3.0	30.1	0	0.1	0.0	-	8	36	50	-	-	47.8	**30.1**	**36.5**
		4.0	3.0	4.0	2.12	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.48	113.9	3.0	38.0	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.5**
3	SOIL	4.0	3.0	2.0	2.18	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	4.36	68.6	3.0	22.9	0	0.1	0.0	-	0	30	50	-	-	39.8	**22.9**	**27.2**
		4.0	3.0	3.0	2.18	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.54	92.8	3.0	30.9	0	0.1	0.0	-	8	36	50	-	-	47.8	**30.9**	**37.5**
		4.0	3.0	4.0	2.18	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.72	117.1	3.0	39.0	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.7**
4	SOIL	4.0	3.0	3.0	2.20	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.60	93.7	3.0	31.2	0	0.1	0.0	-	0	30	50	-	-	47.8	**30.0**	**36.6**
		4.0	3.0	4.0	2.20	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.80	118.2	3.0	39.4	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.8**
		4.0	3.0	5.0	2.20	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	11.00	142.7	3.0	47.6	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**47.0**
5	SOIL	4.0	3.0	3.0	2.12	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.36	90.3	3.0	30.1	0	0.1	0.0	-	0	30	50	-	-	47.8	**30.0**	**36.4**
		4.0	3.0	4.0	2.12	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.48	113.9	3.0	38.0	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.5**
		4.0	3.0	5.0	2.12	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	10.60	137.5	3.0	45.8	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.6**
6	SOIL	4.0	3.0	2.0	2.08	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	4.16	65.4	3.0	21.8	0	0.1	0.0	-	0	30	50	-	-	39.8	**21.8**	**26.0**
		4.0	3.0	3.0	2.08	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.24	88.6	3.0	29.5	0	0.1	0.0	-	0	30	50	-	-	47.8	**29.5**	**35.8**
		4.0	3.0	4.0	2.08	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.32	111.8	3.0	37.3	0	0.1	0.0	-	12	39	50	-	-	47.8	**37.3**	**45.6**
7	SOIL	4.0	3.0	1.0	1.98	1.2	29	20.3	15.1	6.6	5.6	1.15	1.15	0.70	1.00	1.00	1.00	0.8	1.98	35.9	2.5	14.4	0	0.1	0.0	-	0	30	50	-	-	31.8	**14.4**	**16.3**
		4.0	3.0	2.0	1.98	1.2	29	20.3	15.1	6.6	5.6	1.15	1.15	0.70	1.00	1.00	1.00	0.8	3.96	48.6	2.5	19.5	0	0.1	0.0	-	0	30	50	-	-	39.8	**19.5**	**23.4**
		4.0	3.0	3.0	1.98	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	5.94	84.3	3.0	28.1	0	0.1	0.0	-	8	36	50	-	-	47.8	**28.1**	**34.1**
8	SOIL	4.0	3.0	2.0	2.57	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	5.14	80.8	3.0	26.9	0	0.1	0.0	-	8	36	50	-	-	39.8	**26.9**	**32.1**
		4.0	3.0	3.0	2.57	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	7.71	109.5	3.0	36.5	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**43.7**
		4.0	3.0	4.0	2.57	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	10.28	138.1	3.0	46.0	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.3**
9	SOIL	4.0	3.0	3.0	2.19	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.57	93.3	3.0	31.1	0	0.1	0.0	-	8	36	50	-	-	47.8	**31.1**	**37.7**
		4.0	3.0	4.0	2.19	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.76	117.7	3.0	39.2	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.8**
		4.0	3.0	5.0	2.19	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	10.95	142.1	3.0	47.4	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**47.0**
10	ROCK	4.0	3.0	3.0	2.57	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	7.71	796.5	5.0	159.3	1956	0.1	195.6	187.9	10	38	50	-	-	47.8	**37.5**	**45.2**
		4.0	3.0	4.0	2.57	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	10.28	983.3	5.0	196.7	1956	0.1	195.6	185.3	10	38	50	-	-	47.8	**37.5**	**47.8**
		4.0	3.0	5.0	2.57	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	12.85	1170.1	5.0	234.0	1956	0.1	195.6	182.8	10	38	50	-	-	47.8	**37.5**	**50.4**
11	SOIL	4.0	3.0	3.0	2.17	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	6.51	92.4	3.0	30.8	0	0.1	0.0	-	8	36	50	-	-	47.8	**30.8**	**37.3**
		4.0	3.0	4.0	2.17	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	8.68	116.6	3.0	38.9	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**44.7**
		4.0	3.0	5.0	2.17	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	10.85	140.8	3.0	46.9	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.9**
12	SOIL ±ROCK	4.0	3.0	4.0	2.49	0	35	25.0	20.8	10.7	10.9	1.15	1.15	0.70	1.00	1.00	1.00	0.8	9.96	133.8	3.0	44.6	0	0.1	0.0	-	8	36	50	-	-	47.8	**36.0**	**46.0**

CALCULATION SHEET FOR SAFE BEARING CAPACITY IN SOIL/ROCK

Bore Hole Location	Founding Strata	Size of Footing		Depth of Footing	Density	Cohesion Value	Angle of shearing resistance	Mobilized Angle of Shearing Resistance,	Bearing Capacity Factor			Shape Factor			Depth Factor			Water correction factor	Overburden Pressure	Terzaghi Shear Analysis			Based on UCS				Based ON RMR		Settlement Analysis				Safe bearing Capacity	Gross allowable bearing Capacity
																				Net ultimate bearing Capacity	Factor of Safety	Net Safe Bearing Capacity	Rock compressive Strenght, UCS	Empirical coefficient	Gross Bearing Capacity	Net Safe Bearing Capacity	Rock Mass Rating	Safe Bearing Capacity	N-value	Δ for Unit presure (10t/m²)	Net SBC for 40mm settlement	Net SBC for 12mm settlement		
		L	B	D	ϒ	C	Φ	Φ'	N'c	N'q	N'y	Sc	Sq	Sy	Dc	Dq	Dy	W'	q	qnu	FOS	qns	c	N_f	qg	qns	RMR	qns	N		qns	qns	qa	qg
		m	m	m	t/m³	t/m²	°	°	-	-	-	-	-	-	-	-	-	-	t/m²	t/m²	-	t/m²	t/m²		t/m²	t/m²	-	t/m²	-	mm	t/m²	t/m²	t/m²	t/m²
		4.0	3.0	5.0	2.49	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	12.45	1133.6	5.0	226.7	2311	0.1	231.1	218.7	8	36	50	-	-	47.8	**36.0**	**48.5**
		4.0	3.0	6.0	2.49	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	14.94	1314.6	5.0	262.9	2311	0.1	231.1	216.2	8	36	50	-	-	47.8	**36.0**	**50.9**
37	ROCK	4.0	3.0	1.0	2.60	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	2.60	427.9	5.0	85.6	1588	0.1	158.8	156.2	24	48	50	-	-	31.8	**31.8**	**34.4**
		4.0	3.0	2.0	2.60	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	5.20	616.9	5.0	123.4	1588	0.1	158.8	153.6	24	48	50	-	-	39.8	**39.8**	**45.0**
		4.0	3.0	3.0	2.60	0	40	40.0	75.3	64.2	109.4	1.15	1.15	0.70	1.00	1.00	1.00	0.8	7.80	805.8	5.0	161.2	1588	0.1	158.8	151.0	24	48	50	-	-	47.8	**47.8**	**55.6**

ANNEXURE 5.2: GEOLOGICAL LOG OF DRILL HOLE

TABLE 0-1: GEOLOGICAL LOG OF DRILL HOLE – BH 1

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/13/2021	**COMPLETED**	12/15/2021	**TOTAL DEPTH (M)**	7.5 m

Depth,m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	FILLING MATERIAL 0.00 M - 0.50 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	SPT	>100	BROWNISH GREY COLORED FILLED UP MATERIAL
1.5	AMYGDALOIDAL BASALT ROCK		MODERATELY WEATHERED/FRESH							41		0.0				-	-	GREYISH BROWN COLORED ROCK
3.0										49		0.0						
4.5			SLIGHTLY WEATHERED							77		21.3						
6.0										91		73.7						
7.5										86		53.0						

TABLE 0-2: GEOLOGICAL LOG OF DRILL HOLE – BH 2

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/17/2021	**COMPLETED**	12/18/2021	**TOTAL DEPTH (M)**	15.0 m

Depth, m	Lithology: Description	Lithology: Log	Structural Conditions: Structural Description	Structural Conditions: Log	Core Recovery: 20	40	60	80	100	% Core Recovery	Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm: Test Section	SPT/DCPT Blows per cm: Value	Special Observation and Interpretation
0.0	FILLING MATERIAL 0.00 M-1.50 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	BROWNISH GREY COLORED FILLED UP MATERIAL
1.5										0		0.0				SPT	>100	
3.0	SOIL & BASALT ROCK MIXTURE 1.50 M - 6.00 M		COMPLETELY WEATHERED/ RESIDUAL SOIL							0		0.0				SPT	>100	GREYISH BROWN COLORED SOIL & ROCK MIXTURE
4.5										0		0.0						
6.0										0		0.0						
7.5	AMYGDALOIDAL BASALT ROCK 6.0 M - 15.0 M		HIGHLY WEATHERED/FRESH							<10		0.0						GREYISH BROWN COLORED ROCK
9.0										<10		0.0						
10.5										<10		0.0						
12.0			MODERATELY WEATHERED/FRESH							15		0.0						
13.5										18		0.0						
15.0										23		10.0						

TABLE 0-3: GEOLOGICAL LOG OF DRILL HOLE – BH 3

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/19/2021	**COMPLETED**	12/21/2021	**TOTAL DEPTH (M)**	15.0 m

Depth,m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	FILLING MATERIAL 0.00 M -1.50 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	REDDISH BROWN COLORED FILLED UP MATERIAL
1.5										0		0.0				SPT	>100	
3.0	SOIL & BASALT ROCK MIXTURE 1.50 M - 6.00 M		COMPLETELY WEATHERED/ RESIDUAL SOIL							0		0.0				SPT	>100	GREYISH BROWN COLORED SOIL & ROCK MIXTURE
4.5										0		0.0						
6.0										0		0.0						
7.5	AMYGDALOIDAL BASALT ROCK 6.0 M - 15.0 M		HIGHLY WEATHERED/FRESH							<10		0.0						GREYISH BROWN COLORED ROCK
9.0										<10		0.0						
10.5										<10		0.0						
12.0			MODERATELY WEATHERED/FRESH							10		0.0						
13.5										14		0.0						
15.0										30		0.0						

TABLE 0-4: GEOLOGICAL LOG OF DRILL HOLE – BH 4

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/23/2021	**COMPLETED**	12/23/2021	**TOTAL DEPTH (M)**	12.0 M

Depth,m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	FILLED UP SOIL & BOULDER MIXTURE 0.00 M - 3.00 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	REDDISH BROWN COLORED FILLED UP MATERIAL
1.5										0		0.0				SPT	>100	
3.0										0		0.0				SPT	>100	
4.5	AMYGDALOIDAL BASALT ROCK 3.0 M - 12.0 M		HIGHLY WEATHERED/FRESH							0		0.0						GREYISH BROWN COLORED ROCK
6.0										0		0.0						
7.5										<10		0.0						
9.0			MODERATELY WEATHERED/FRESH							9		0.0						
10.5										25		0.0						
12.0										19		0.0						

TABLE 0-5: GEOLOGICAL LOG OF DRILL HOLE – BH 5

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/24/2021	**COMPLETED**	12/26/2021	**TOTAL DEPTH (M)**	10.5 M

Depth, m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	MOORAM SOIL & BOULDER MIXTURE 0.00 M - 3.00 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	
1.5										0		0.0				SPT	>100	REDDISH BROWN COLORED SOIL & COBBLE MIXTURE
3.0										0		0.0				SPT	>100	
4.5	AMYGDALOIDAL BASALT ROCK 3.0 M - 10.5 M		HIGHLY WEATHE RED/FR							22		0.0						GREYISH BROWN COLORED ROCK
6.0			SLIGHTLY WEATHERED							53		0.0						
7.5										58		32.0						
9.0										59		20.3						
10.5										55		18.0						

TABLE 0-6: GEOLOGICAL LOG OF DRILL HOLE – BH 6

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/26/2021	**COMPLETED**	12/27/2021	**TOTAL DEPTH (M)**	13.0 M

Depth, m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	MOORAM SOIL & BOULDER MIXTURE 0.00 M - 1.50 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	REDDISH BROWN COLORED SOIL & COBBLE MIXTURE
1.5										0		0.0				SPT	>100	
3.0	AMYGDALOIDAL BASALT ROCK 3.0 M - 13.5 M		HIGHLY WEATHERED/FRESH							13		0.0						GREYISH BROWN COLORED ROCK
4.5										26		0.0						
6.0										22		0.0						
7.5										25		12.0						
9.0										23		0.0						
10.5			MODERATELY WEATHERED/FRESH							33		19.7						
12.0										53		34.0						
13.0										84		71.0						

TABLE 0-7: GEOLOGICAL LOG OF DRILL HOLE – BH 7

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/27/2021	**COMPLETED**	12/29/2021	**TOTAL DEPTH (M)**	15.0 M

Depth, m	Lithology: Description	Lithology: Log	Structural Conditions: Structural Description	Structural Conditions: Log	Core Recovery: 20	40	60	80	100	% Core Recovery	Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm: Test Section	Value	Special Observation and Interpretation
0.0	SAND & GRAVEL MIXTURE 0.00 M - 3.00 M		MEDIUM DENSE								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	BROWNISH COLORED SOIL & FINE GRAVEL MIXTURE
1.5												-				SPT	8 10 12	
3.0												-				SPT	>100	
4.5	AMYGDALOIDAL BASALT ROCK 3.0 M - 15.0 M		HIGHLY WEATHERED/FRESH							16		0.0						GREYISH BROWN COLORED ROCK
6.0										14		8.0						
7.5										13		0.0						
9.0										26		20.7						
10.5			MODERATELY WEATHERED/FRESH							23		10.0						
12.0										21		10.7						
13.5										25		17.3						
15.0										41		35.3						

TABLE 0-8: GEOLOGICAL LOG OF DRILL HOLE – BH 8

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	12/31/2021	**COMPLETED**	1/1/2022	**TOTAL DEPTH (M)**	10.0 M

Depth,m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	AMYGDALOIDAL BASALT ROCK 0.0 M - 10.0 M		MODERATELY WEATHERED/FRESH							-	IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED			GREYISH BROWN COLORED DISINTEGRATED ROCK
1.5										60		0.0						
3.0										52		0.0						
4.5										42		8.7						
6.0			SLIGHTLY WEATHERED							48		27.0						GREYISH BROWN COLORED ROCK
7.5										51		34.0						
9.0										38		38.7						
10.0										56		42.0						

TABLE 0-9: GEOLOGICAL LOG OF DRILL HOLE – BH 9

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	1/2/2022	**COMPLETED**	1/2/2022	**TOTAL DEPTH (M)**	12.0 M

Depth,m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core Recovery						Test Section	Value	
0.0	MOORAM SOIL & BOULDER MIXTURE 0.00 M - 3.00 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	REDDISH BROWN COLORED SOIL & COBBLE MIXTURE
1.5										0		0.0				SPT	>100	
3.0										0		0.0						
4.5	AMYGDALOIDAL BASALT ROCK 3.0 M - 12.0 M		HIGHLY WEATHERED/FRESH							0		0.0						GREYISH BROWN COLORED ROCK
6.0										17		0.0						
7.5										17		7.3						
9.0			MODERATELY WEATHERED/FRESH							21		16.0						
10.5										27		10.7						
12.0										47		16.0						

TABLE 0-10: GEOLOGICAL LOG OF DRILL HOLE – BH 10

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	1/14/2021	**COMPLETED**	1/16/2021	**TOTAL DEPTH (M)**	10.0 M

Depth, m	Lithology: Description	Lithology: Log	Structural Conditions: Structural Description	Structural Conditions: Log	Core Recovery: 20	40	60	80	100	% Core Recovery	Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm: Test Section	SPT/DCPT Blows per cm: Value	Special Observation and Interpretation
0.0	MOORAM SOIL & COBBLE MIXTURE 0.00 M - 3.00 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	
1.5										0		0.0				SPT	>100	REDDISH BROWN COLORED SOIL & COBBLE MIXTURE
3.0										0		0.0						
4.5	AMYGDALOIDAL BASALT ROCK 3.0 M - 10.0 M		HIGHLY WEATHERED/FRESH							36		6.7						GREYISH BROWN COLORED ROCK
6.0										49		12.7						
7.5			MODERATELY WEATHERED/FRESH							48		30.7						
9.0										55		30.7						
10.0										65		41.0						

TABLE 0-11: GEOLOGICAL LOG OF DRILL HOLE – BH 11

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	1/30/2022	**COMPLETED**	1/30/2022	**TOTAL DEPTH (M)**	8.0 M

Depth, m	Lithology: Description	Lithology: Log	Structural Conditions: Structural Description	Structural Conditions: Log	Core Recovery: 20	40	60	80	100	% Core	Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm: Test Section	SPT/DCPT Blows per cm: Value	Special Observation and Interpretation
0.0	MOORAM SOIL & COBBLE MIXTURE 0.00 M - 3.00 M	FILLING	CRUSHED								IMPREGNATED DIAMOND CORE BIT	-	HX	HX	NOT ENCOUNTERED	-	-	REDDISH BROWN COLORED SOIL & COBBLE MIXTURE
1.5										0		0.0				SPT	>100	
3.0										0		0.0						
4.5	AMYGDALOIDAL BASALT ROCK 3.0 M - 8.0 M		HIGHLY WEATHERED/FRESH							21		0.0						GREYISH BROWN COLORED ROCK
6.0										33		16.0						
7.5			MODERATELY WEATHERED/FRESH							37		26.7						
8.0										50		23.3						

TABLE 0-12: GEOLOGICAL LOG OF DRILL HOLE – BH 12

GEOLOGICAL LOG OF DRILL HOLE

PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.

BEARING OF HOLE	VERTICAL	**DRILLING METHOD**	ROTARY CORE DRILLING	**LOCATION**	WAGHOLI - RAMWADI ROAD
STARTED	1/30/2022	**COMPLETED**	1/30/2022	**TOTAL DEPTH (M)**	9.5 M

Depth, m	Lithology: Description	Lithology: Log	Structural Conditions: Structural Description	Structural Conditions: Log	Core Recovery: 20	40	60	80	100	% Core	Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm: Test Section	SPT/DCPT Blows per cm: Value	Special Observation and Interpretation
0.0												-				-	-	
1.5	MOORAM SOIL & COBBLE MIXTURE 0.00 M - 4.50 M	FILLING	CRUSHED							0		0.0				SPT	>100	REDDISH BROWN COLORED SOIL & COBBLE MIXTURE
3.0										0		0.0						
4.5										0		0.0						
6.0	AMYGDALOIDAL BASALT ROCK 4.50 M - 9.50 M		HIGHLY WEATHERED/FRESH							35		0.0						GREYISH BROWN COLORED ROCK
7.5										48		0.0						
9.0			MODERATELY WEATHERED/FRESH							62		30.7						
9.5										70		9.3						

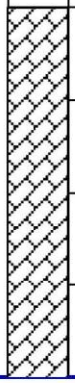
IMPREGNATED DIAMOND CORE BIT

HX

HX

NOT ENCOUNTERED

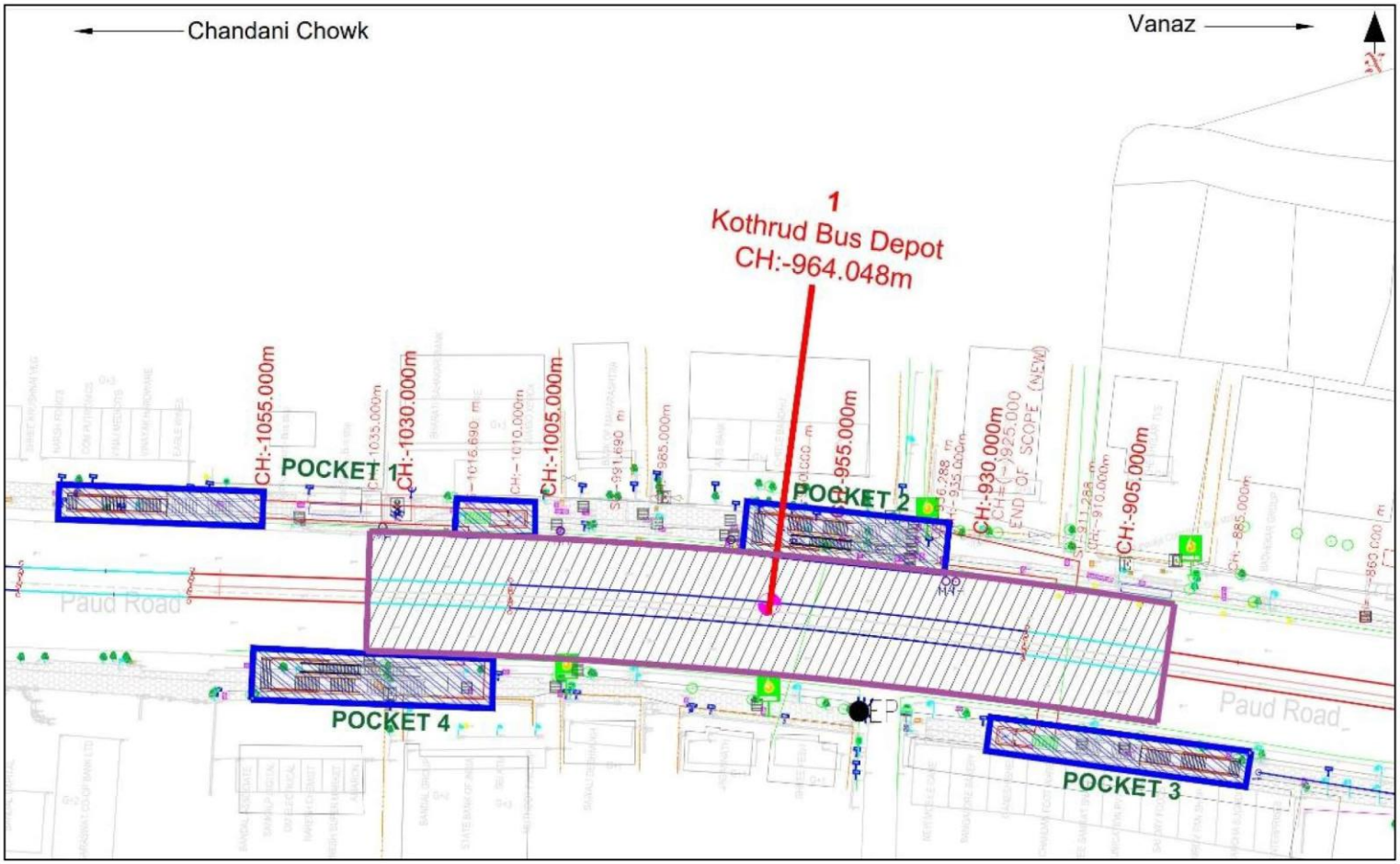
TABLE 0-13: GEOLOGICAL LOG OF DRILL HOLE – BH 37

GEOLOGICAL LOG OF DRILL HOLE																				
PROJECT : GEOTECHNICAL INVESTIGATION FOR PREPARATION OF ALTERNATIVE ANALYSIS REPORT (AAR) AND DETAILED PROJECT REPORT (DPR) FOR PUNE MRTS PHASE 2.																				
BEARING OF HOLE		VERTICAL			DRILLING METHOD						ROTARY CORE DRILLING			LOCATION			CHANDNI CHOWK		
STARTED		1/3/2022			COMPLETED						1/4/2022			TOTAL DEPTH (M)			5.0 M		
Depth,m	Lithology		Structural Conditions		Core Recovery						Type of Bit	R.Q.D. (%)	Size of Hole	Casing	Depth of Water Table	SPT/DCPT Blows per cm		Special Observation and Interpretation
	Description	Log	Structural Description	Log	20	40	60	80	100	% Core						Test Section	Value	
0.0	AMYGDALOIDAL BASALT ROCK 0.0 M - 5.0 M		SLIGHTLY WEATHERED								IMPREGNATED DIAMOND CORE BIT		HX	HX	NOT ENCOUNTERED			GREYISH BROWN COLORED HARD ROCK
1.5										59		16.0						
3.0										75		70.7						
4.5										83		80.0						
5.0										90		80.0						

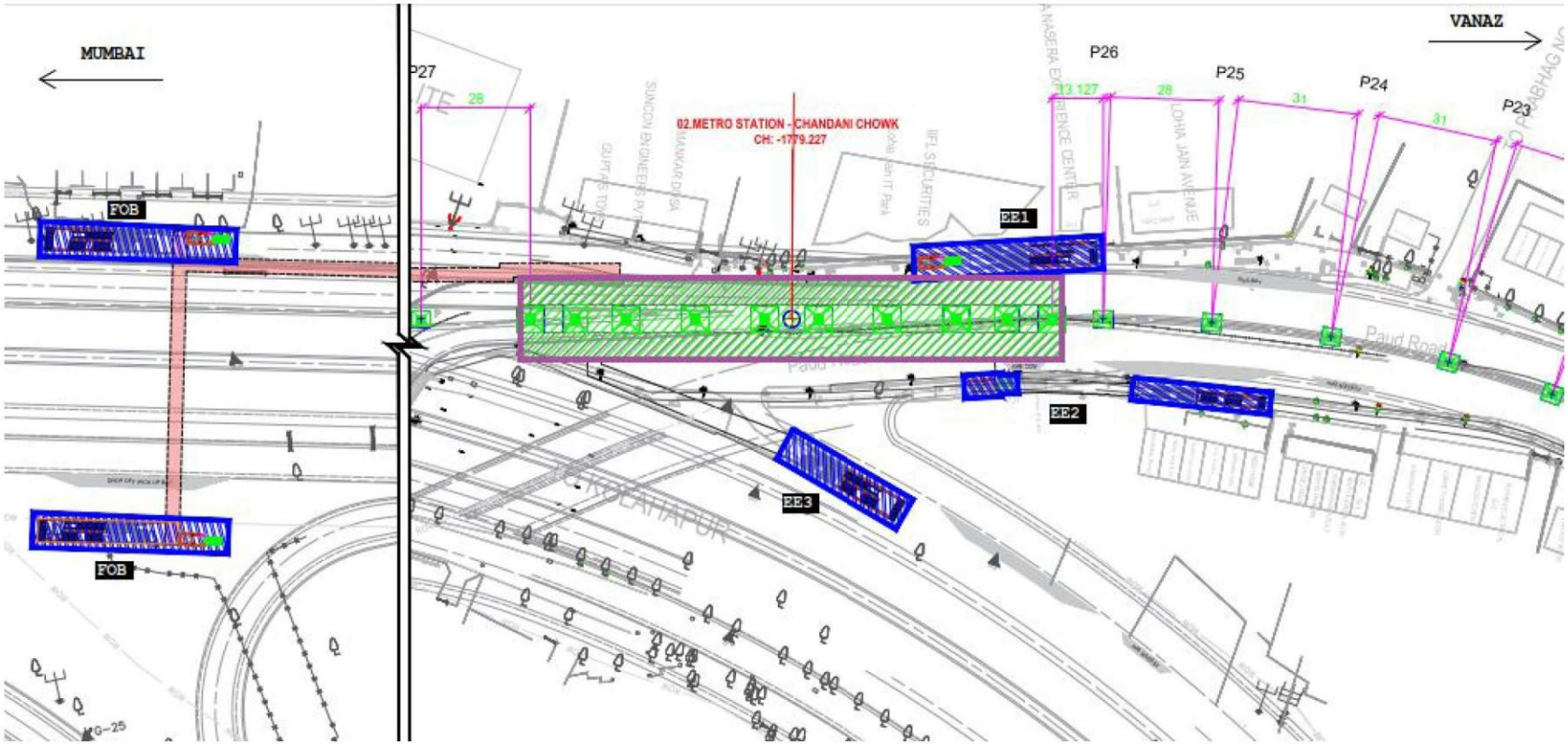
ANNEXURE 5.5: LAND PLANS FOR STATIONS

Line 2A: Vanaz to Chandani Chowk

1. Kothrud Bus Depot

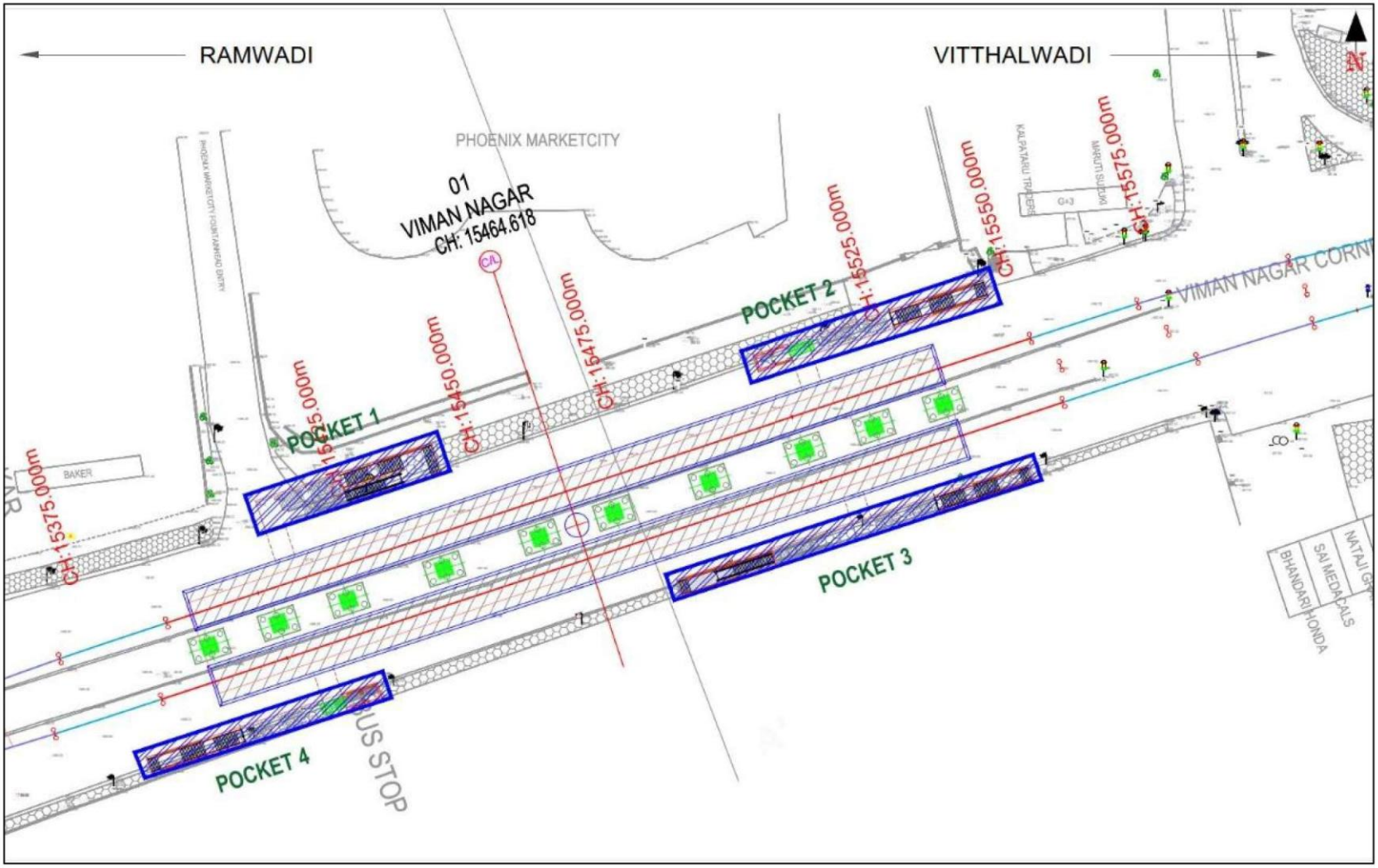


2. Chandani Chowk

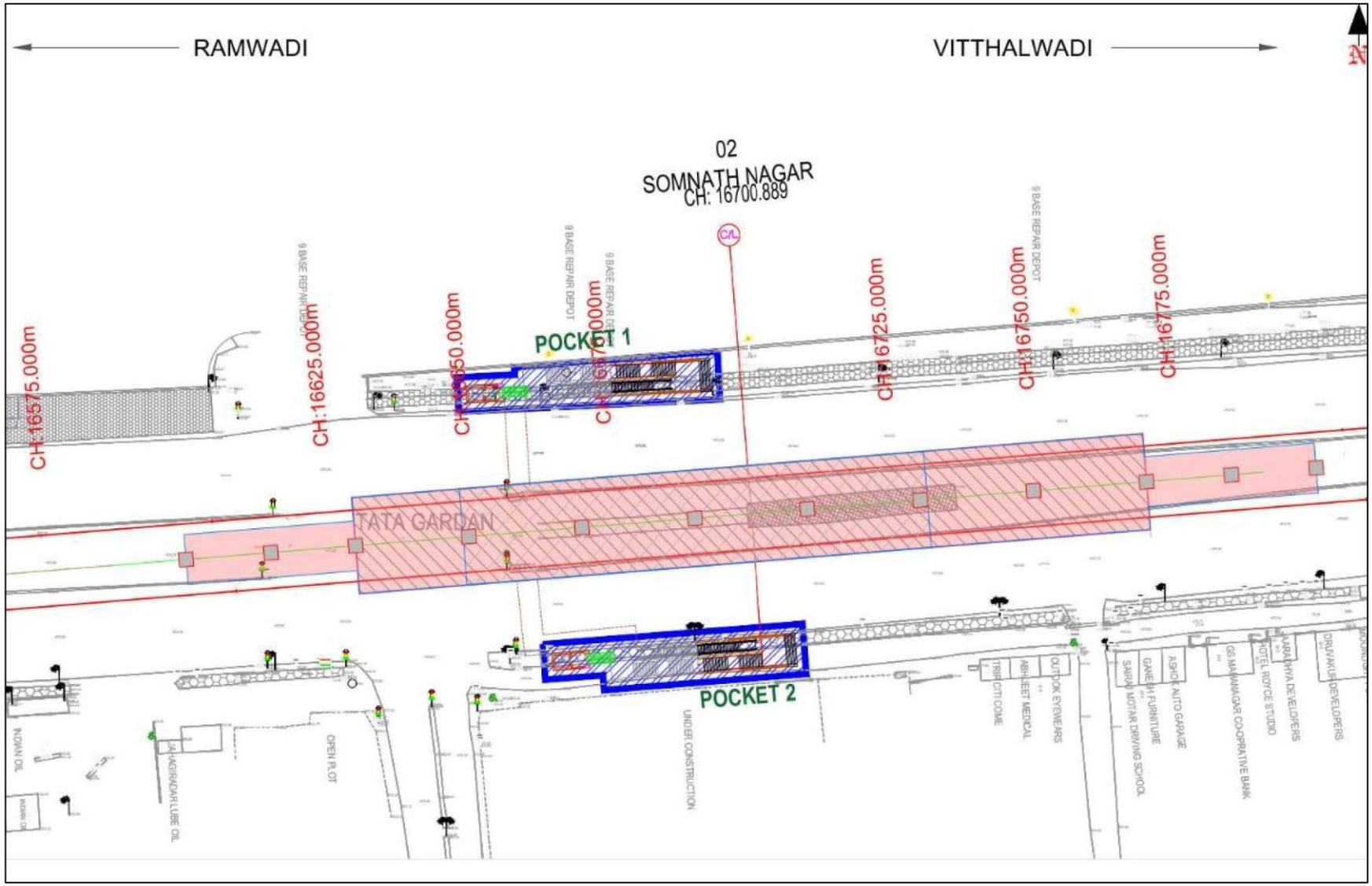


Line 2B: Ramwadi to Wagholi/Vitthalwadi

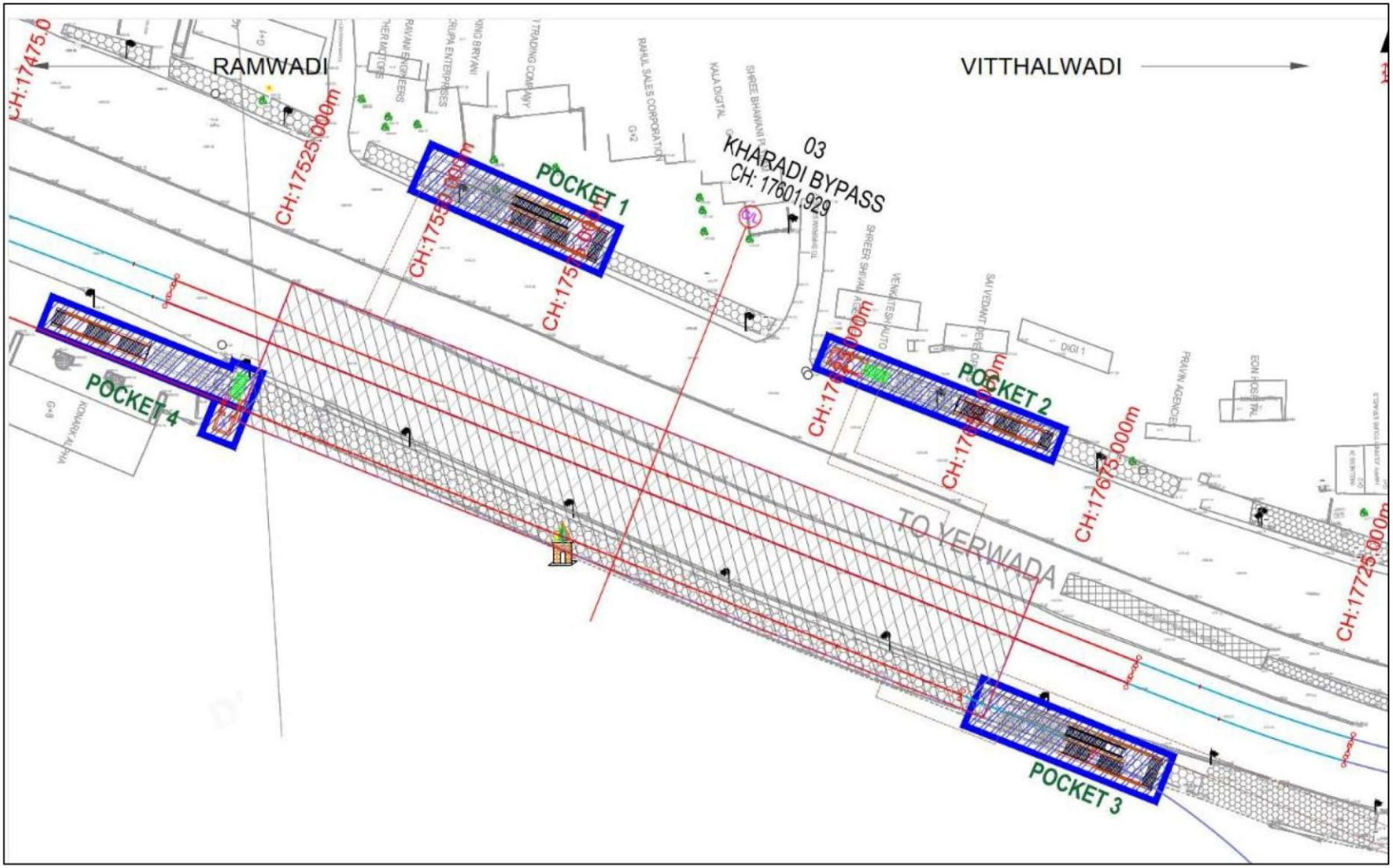
1. Viman Nagar



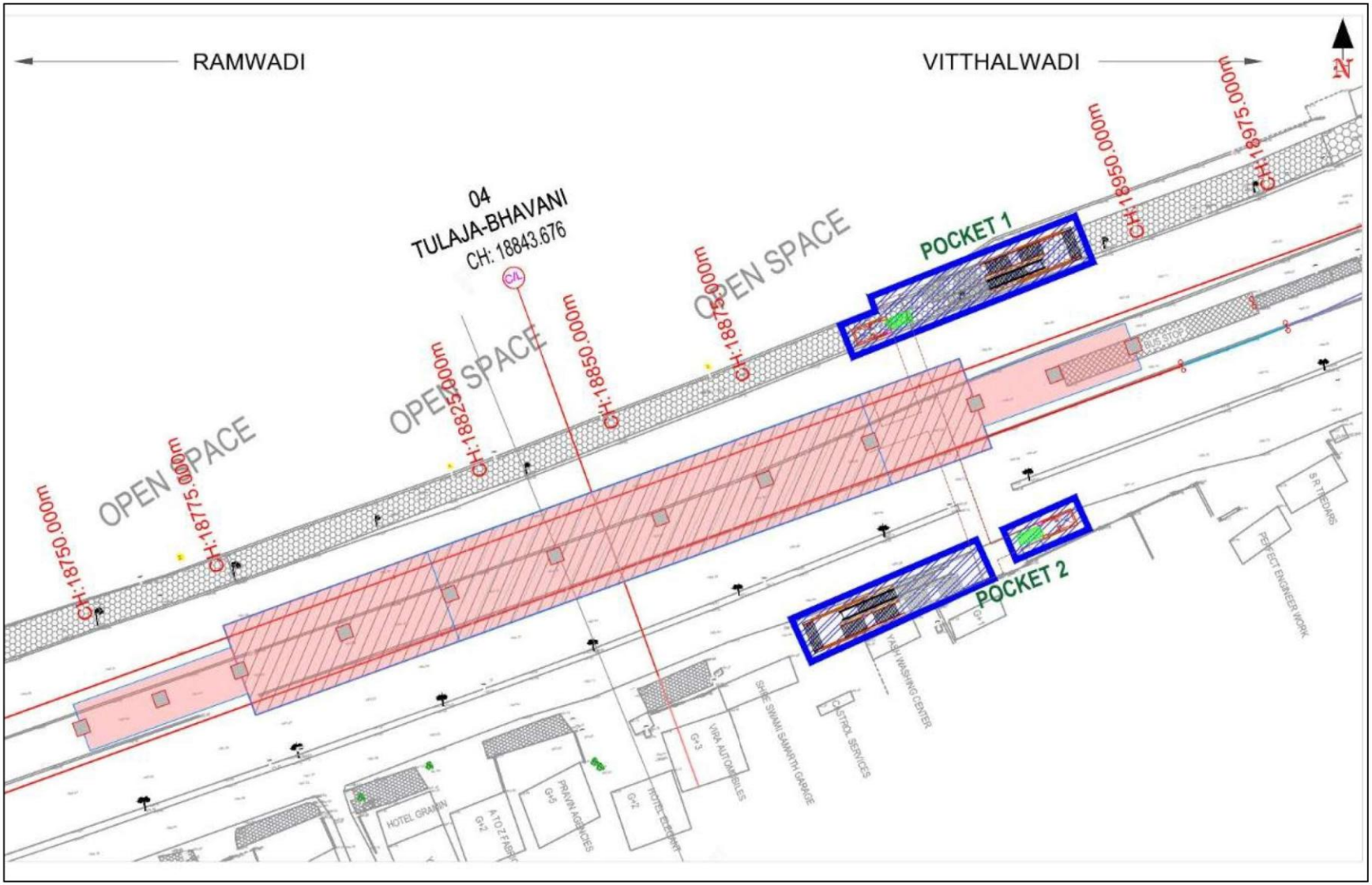
2. Somnath Nagar



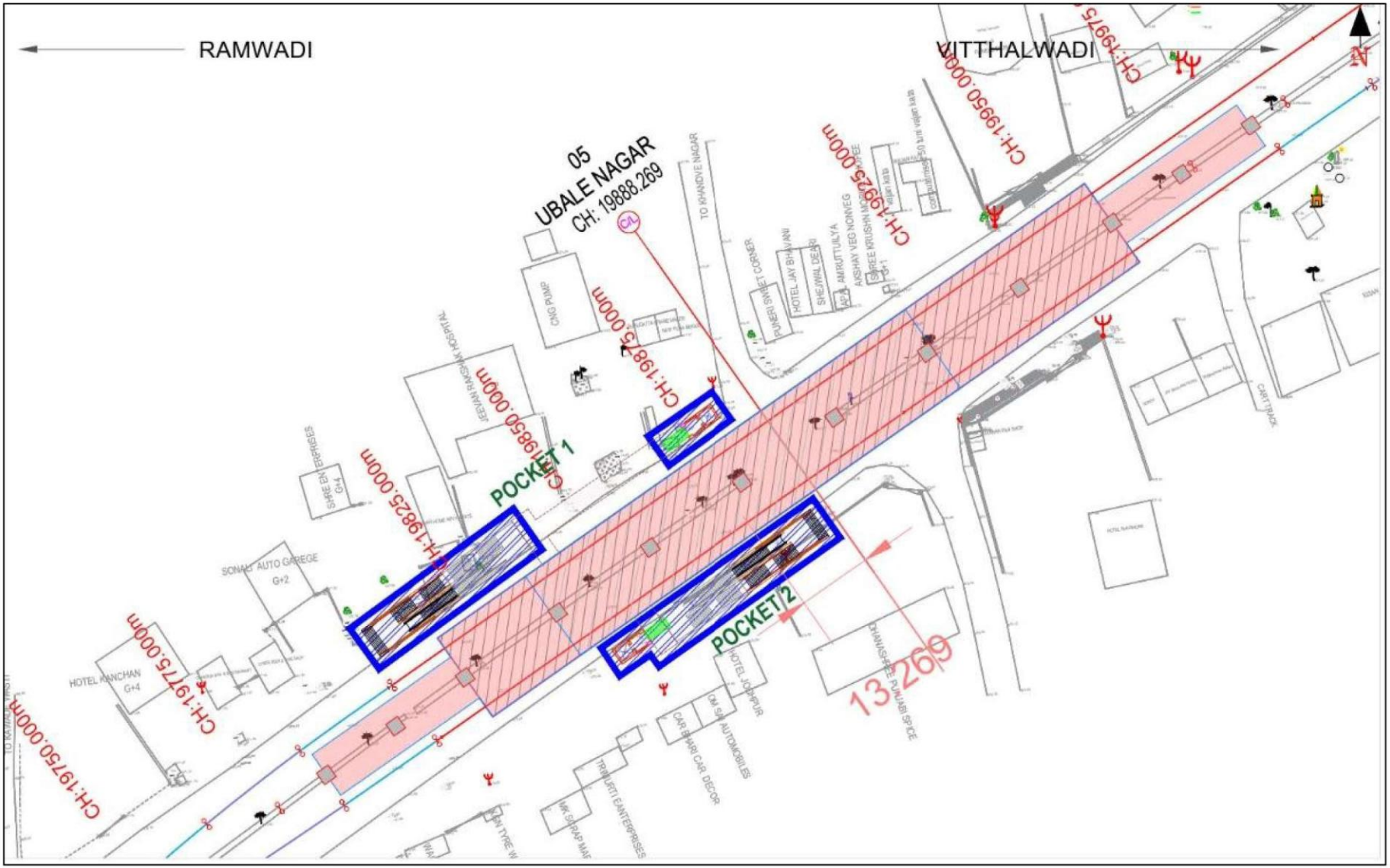
3. Kharadi Bypass



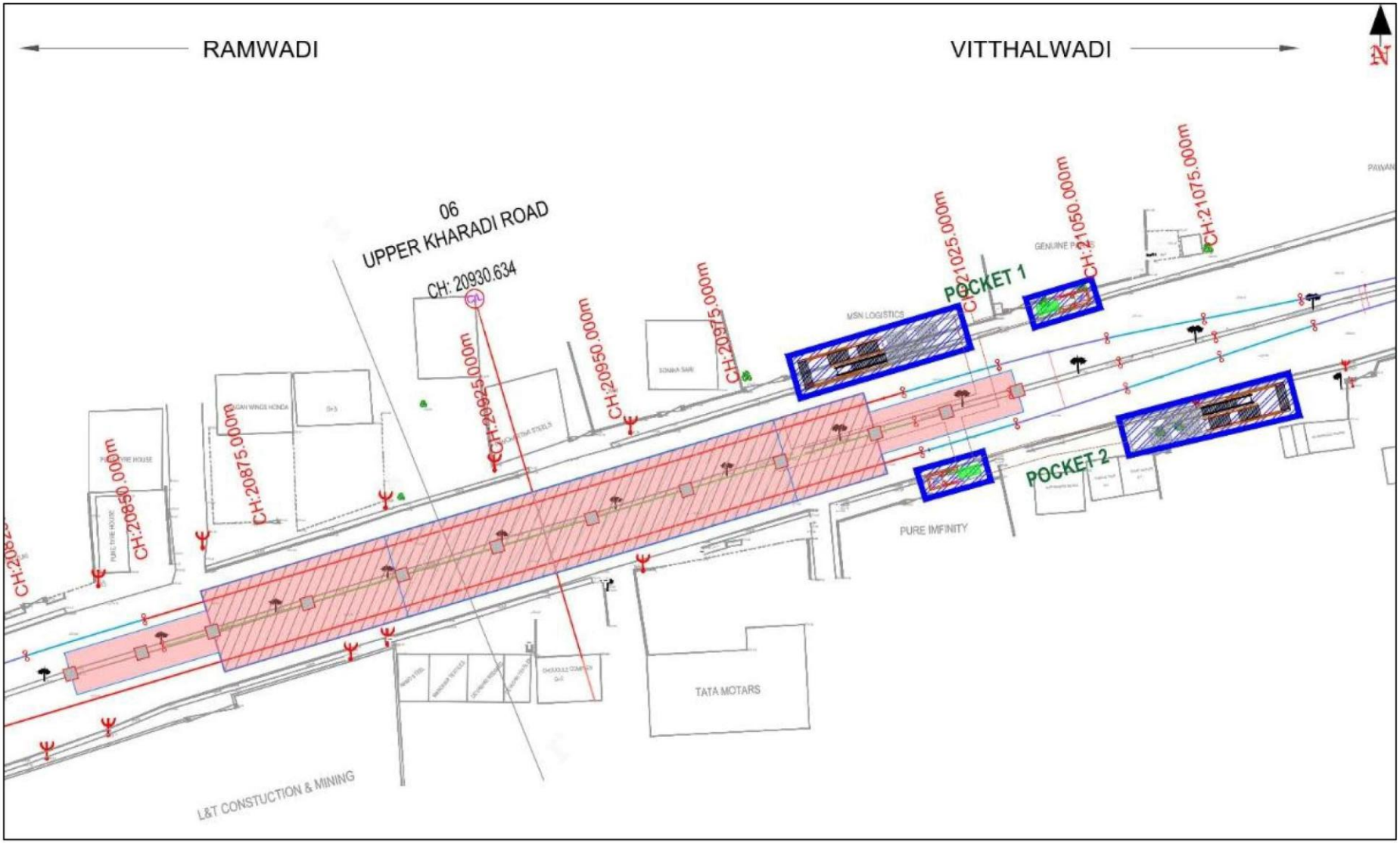
4. Tulaja Bhavani



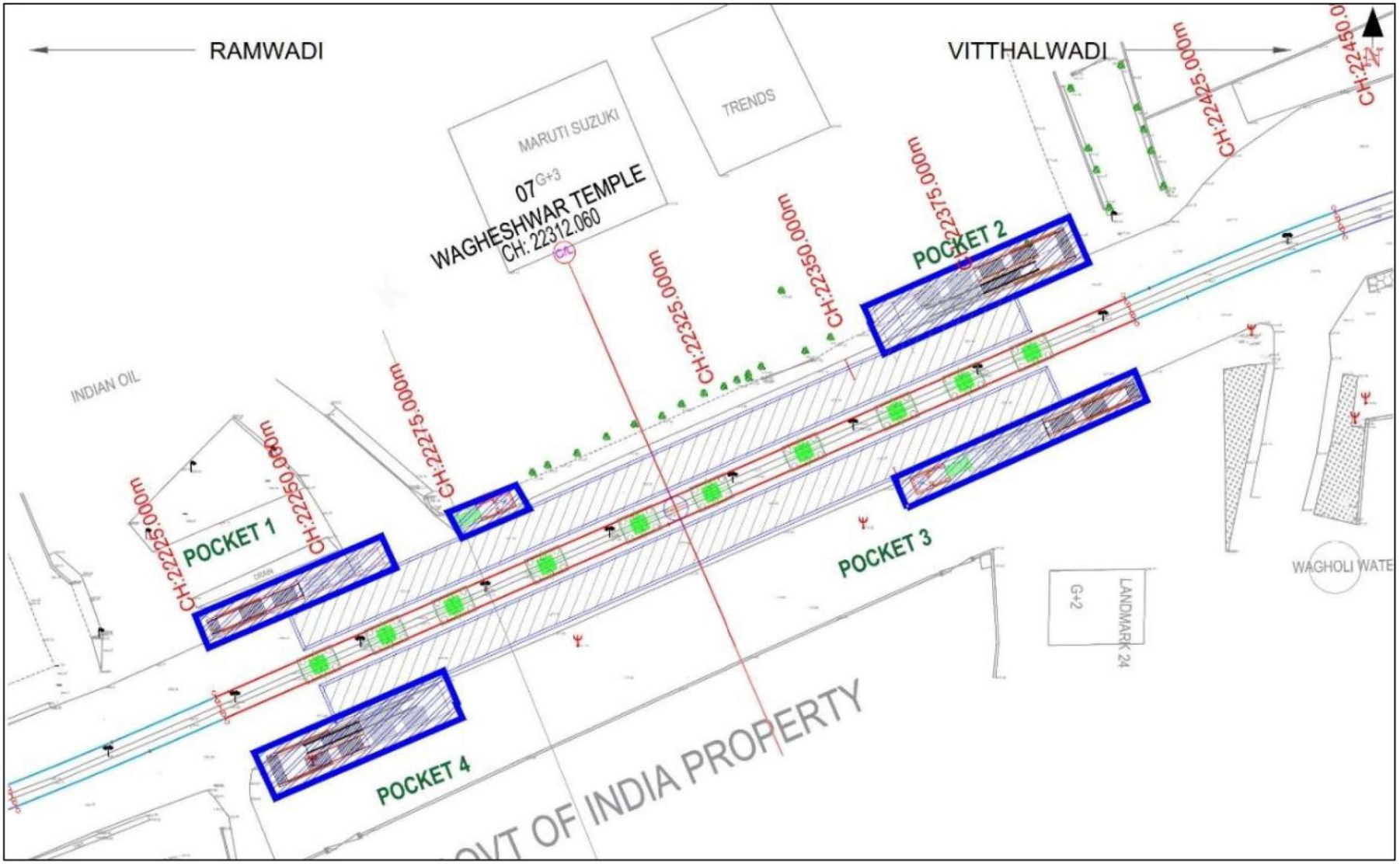
5. Ubale Nagar



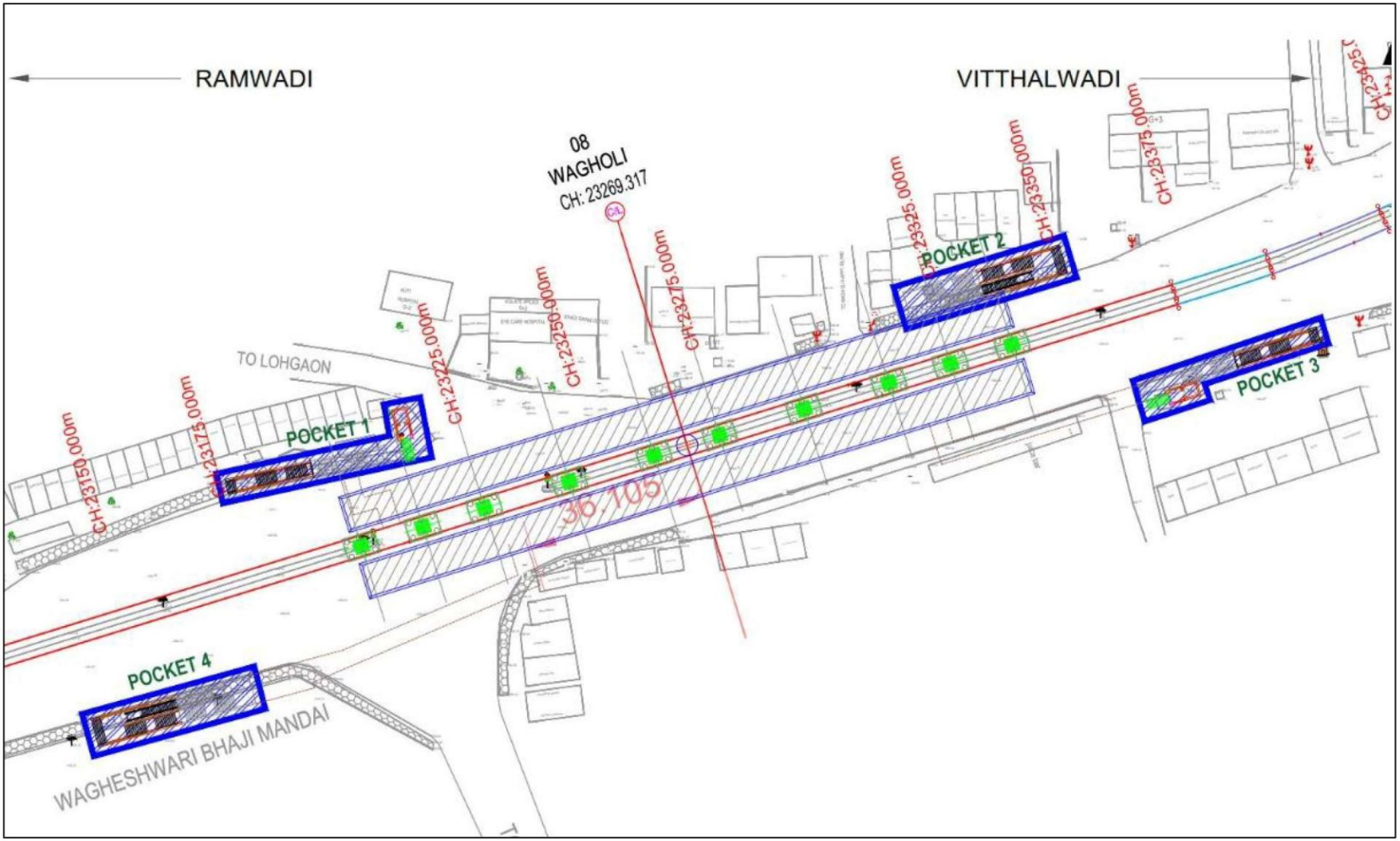
6. Uppar Kharadi Road



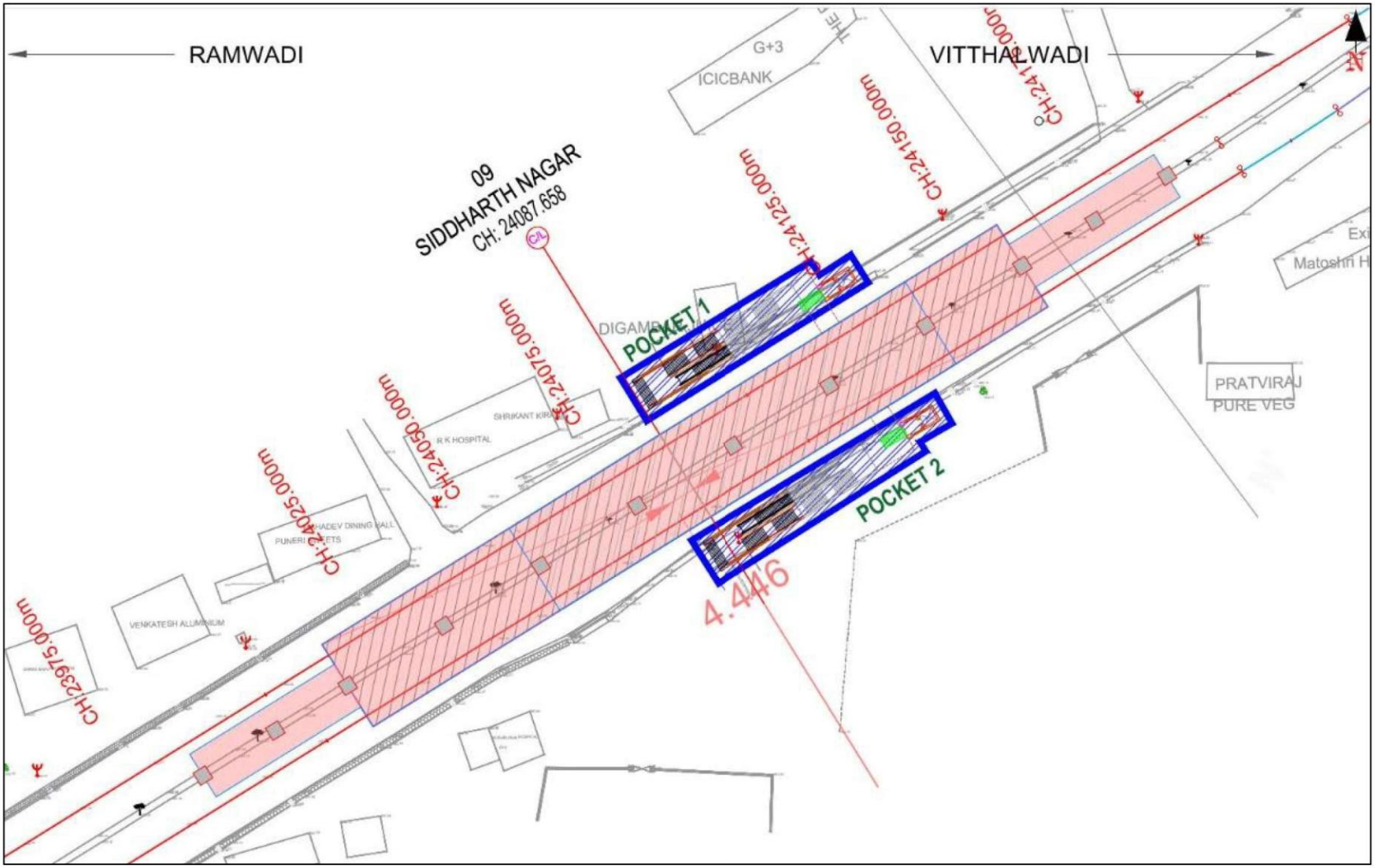
7. Wagheshwar Temple



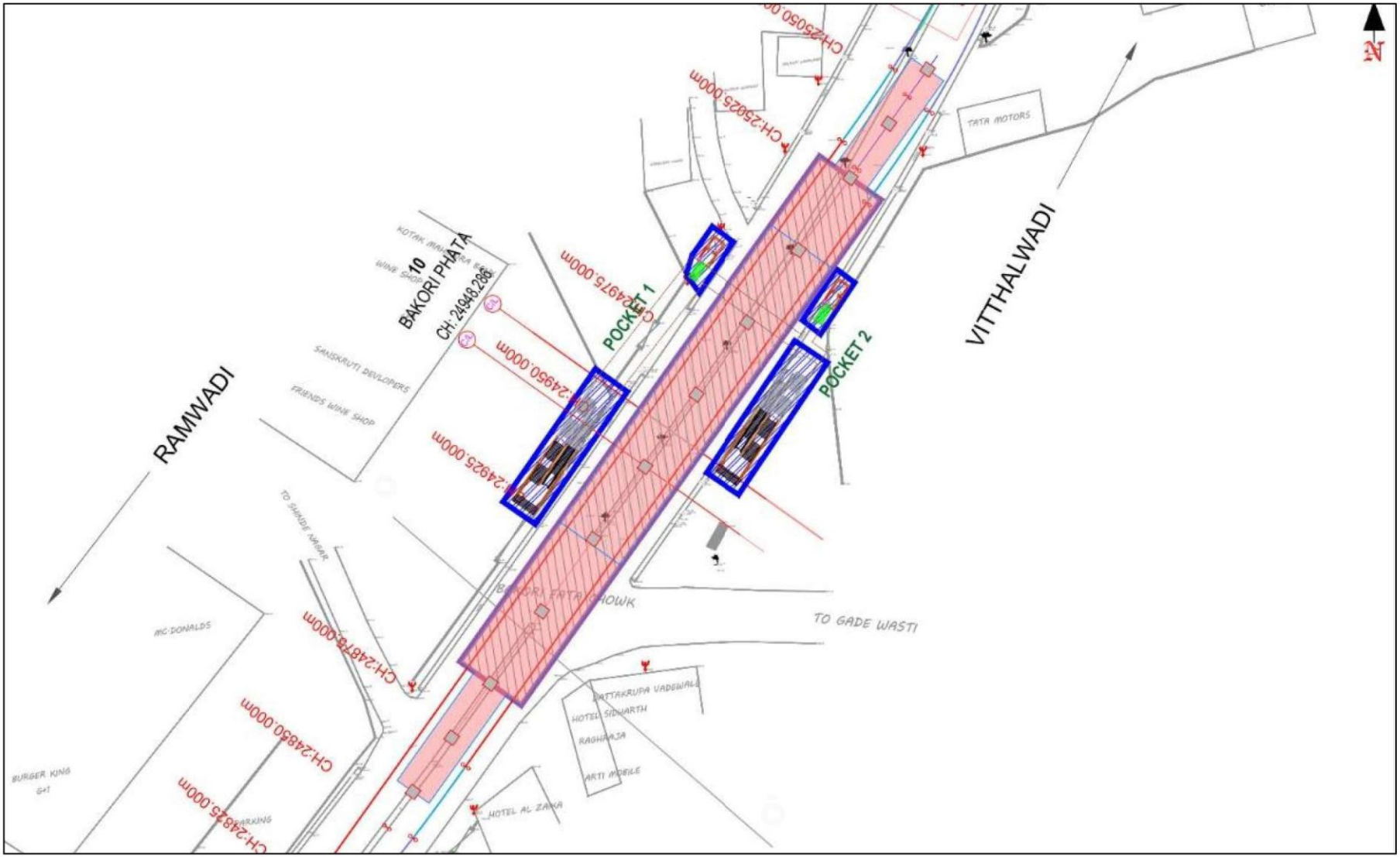
8. Wagholi


RAMWADI
VITTHALWADI
08
WAGHOLI
CH: 23269.317
TO LOHGAON
CH:23150.000m
CH:23175.000m
CH:23225.000m
CH:23250.000m
CH:23275.000m
CH:23325.000m
CH:23350.000m
CH:23375.000m
POCKET 1
POCKET 2
POCKET 3
POCKET 4
36.105
WAGHESHWARI BHAJI MANDAI

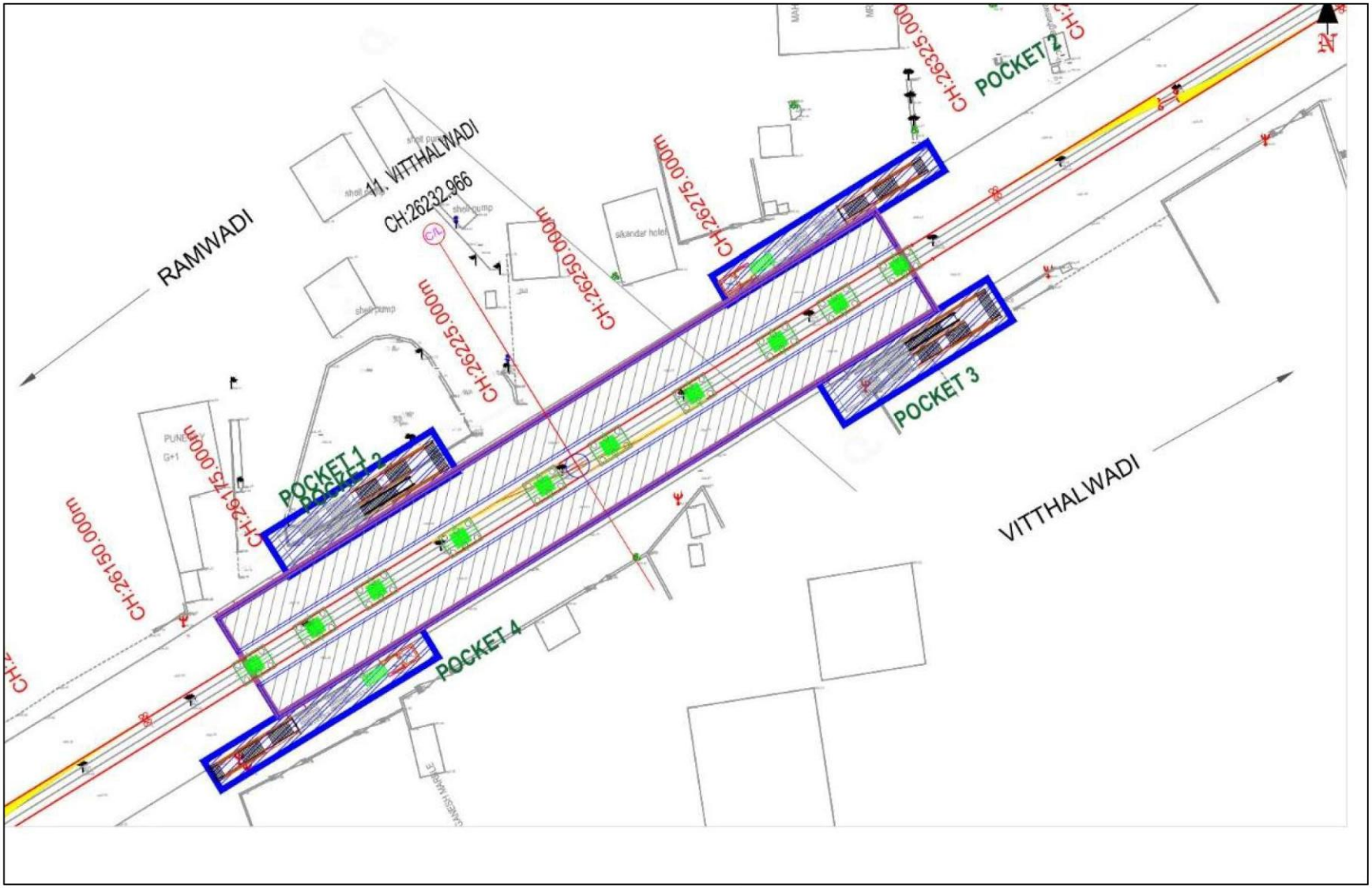
9. Siddharth Nagar



10. Bakori Phata



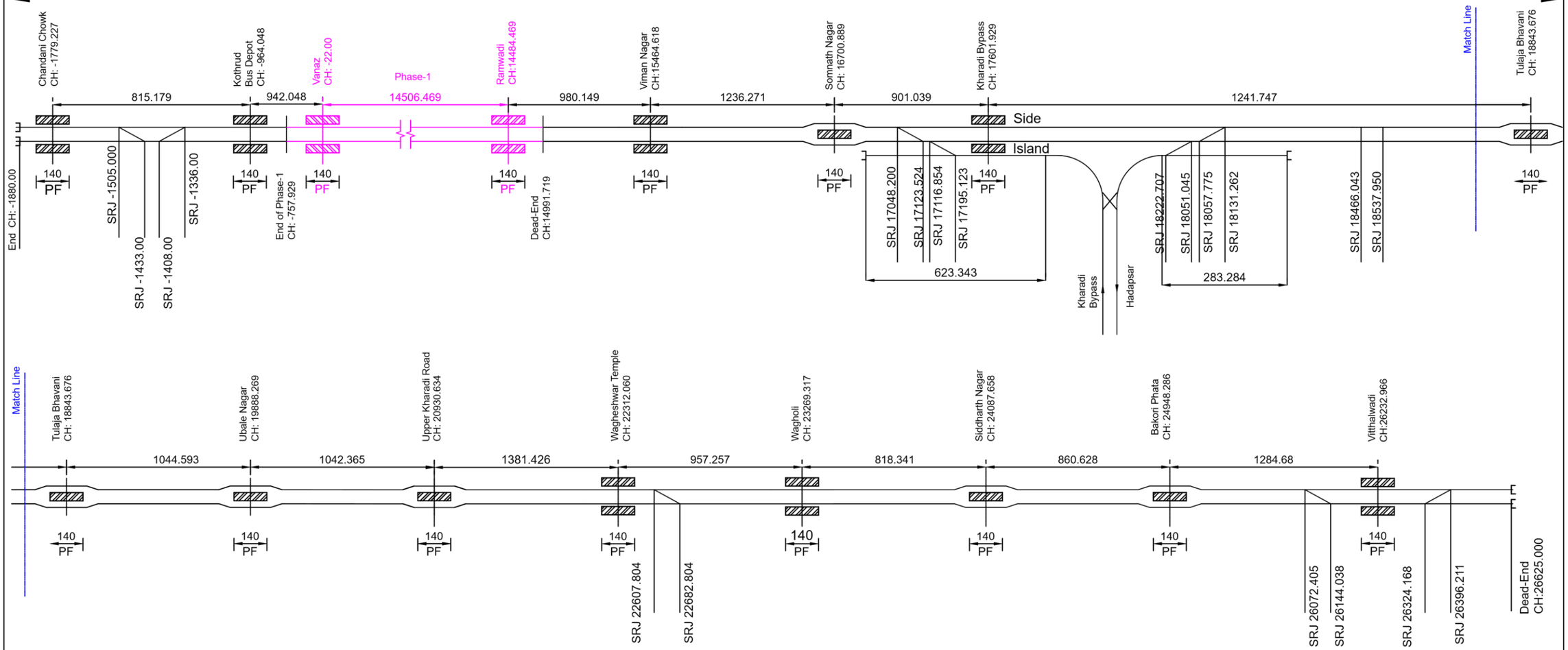
11. Vitthalwadi



PUNE MRTS PROJECT SCHEMATIC ROUTE MAP OF PHASE-2 CHANDNI CHOWK TO VITHALWADI

TO CHANDNI CHOWK

TO VITTHALWADI



REVISIONS			
Sr. NO.	DESCRIPTION OF REVISION	REVISION NO.	DATE

THE RESPONSIBILITY OF CONTROL, CHECK & VERIFICATION OF ACCURACY, CORRECTNESS, COMPLETENESS, INTEGRATION & FULL COMPLIANCE OF THE CONTRACT PROVISIONS IN RESPECT OF DESIGN, ANALYSIS AND DRAWINGS RESTS WITH THE DETAILED DESIGN CONSULTANT / DETAILED DESIGN CONSULTANT & CONTRACTOR.

CONSULTANT / CONTRACTOR	
SIGN:	SIGN:
DATE: 29.06.2022	DATE: 29.06.2022
NAME: Prakash Kumar	NAME: Rajneesh Porwal
DESIGN BY	APPROVED BY

Urban Mass Transit Company Ltd.

in association with

LEAP Infraasys Pvt. Ltd.

COUNTER SIGNED BY MAHARASHTRA METRO RAIL CORPORATION LTD.

DY. HOD

HOD

CLIENT : Maharashtra Metro Rail Corporation Limited

DPR PROJECT :
PUNE METRO RAIL PROJECT
PHASE-2 RAMWADI - WAGHOLI SECTION NEAR SINHAGAD ROAD FLYOVER.

PMC REFERENCE DRAWING:
PROPOSED FLYOVER AT RAJARAM BRIDGE SINHAGAD ROAD GENERAL ARRANGEMENT DETAILS
CH. 225 TO CH. 3100
DWG. NO. KE1161_GB_101, REV NO. 00, DATED 20.01.2021

TITLE :
TRACK SCHEMATIC
CHANDNI CHOWK to VITHALWADI
Phase-2 of Pune MRTS

DRG. No:				SHEET NO.
DPR / PHASE - II / TRKSCM / 01				01/01
SCALE: NTS	STATUS DPR	REVISION 01	SIZE A3	DATE 30.06.2022

CHAPTER 6. STATION PLANNING

6.1. STATION PLANNING

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

The list of proposed stations are presented in Table 6-1.

TABLE 6-1: LIST OF STATIONS FOR LINE 2A AND LINE 2B

S.N.	Station Name	Chainage (m)	Interstation Distance (m)	Ground Level (m)	Rail Level (m)	Station Type (Elevated/At-Grade)
Pune Metro Line 2A (Vanaz to Chandani Chowk)						
1	Kothrud Bus Depot	-964.048	942.048*	598.75	617.00	Elevated
2	Chandani Chowk	-1779.227	815.179	616.88	632.50	Elevated
Pune Metro Line 2B (Ramwadi to Wagholi/Vitthalwadi)						
1	Viman Nagar	15464.618	980.149**	567.09	586.2	Elevated
2	Somnath Nagar	16700.889	1236.271	573.78	587.00	Elevated
3	Kharadi Bypass	17601.929	901.04	571.06	585.50	Elevated (Interchange)
4	Tulaja Bhavani	18843.676	1241.747	564.15	580.00	Elevated
5	Ubale Nagar	19888.269	1044.593	575.48	591.00	Elevated
6	Upper Kharadi Road	20930.634	1042.365	574.31	589.00	Elevated
7	Wagheshwar Temple	22312.06	1381.426	572.03	588.00	Elevated
8	Wagholi	23269.317	957.257	581.02	596.00	Elevated

S.N.	Station Name	Chainage (m)	Interstation Distance (m)	Ground Level (m)	Rail Level (m)	Station Type (Elevated/At-Grade)
9	Siddharth Nagar	24087.658	818.341	583.05	598.00	Elevated
10	Bakori Phata	24948.286	860.628	591.33	604.5	Elevated
11	Vitthalwadi	26232.966	1284.68	595.21	615.00	Elevated
*From Vanaz Metro Station of Phase 1 **From Ramwadi Metro Station of Phase 1						

The average interstation distance for Vanaz to Chandani Chowk (Line 2A) and Ramwadi to Wagholi/Vitthalwadi (Line 2B) is is worked out to be 878.614m and 1068.045m respectively, thus reduction in overall cost of metro system (excluding rolling stock) vis a vis interstation distance is not required as per Report on “Benchmarking for Cost Estimation of Metro Rail Projects”, published by MoHUA.

6.1.1 DESCRIPTION OF THE ROUTE ALIGNMENT

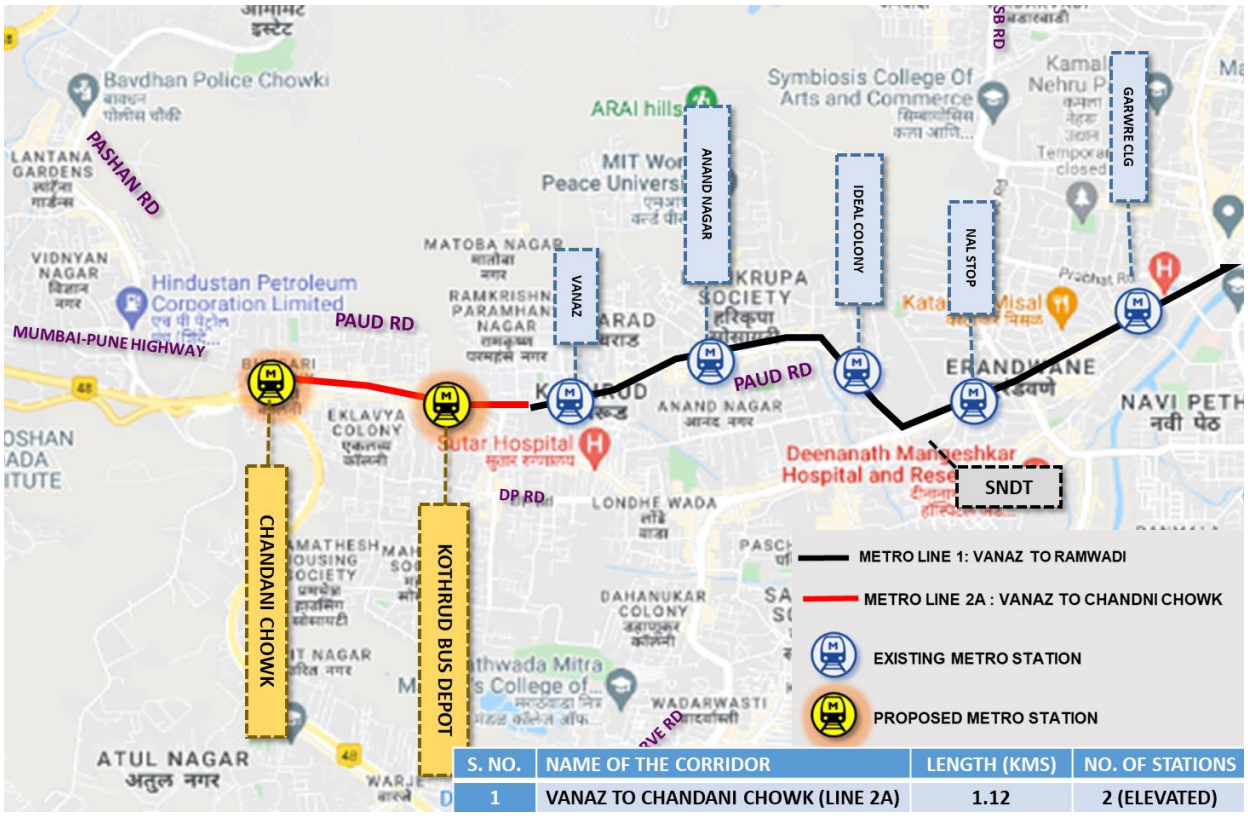
The proposed metro rail system has been planned to serve major passenger catchment areas/destinations and to enable convenient integration with other modes of transport. The proposed corridors are planned as extensions to the existing Line 2 of Pune Metro i.e. Vanaz to Ramwadi running East-West. Two extensions are proposed for the line as given in Table 6-2.

TABLE 6-2: CORRIDOR DESCRIPTION

S. No.	Name of the Corridor	Length (Kms)	No. of Stations
1	Vanaz to Chandani Chowk (Line 2A)	1.12	2
2	Ramwadi to Vitthalwadi (Line 2B)	11.63	11
	Total	**12.75**	**13**

6.1.1.1. DESCRIPTION OF THE ROUTE AIGNMENT – LINE 2A

As mentioned in the Table 6-2 the Line 2A is 1.12 Km in length and planned as extension to Line 2 of Pune Metro towards west. The extension is proposed along the Paud Road and passes through the main arterial connecting the Mumbai Highway (Katraj-Dehu Bypass Road) at Chandani Chowk. The Line 2A is shown in Figure 6-1.

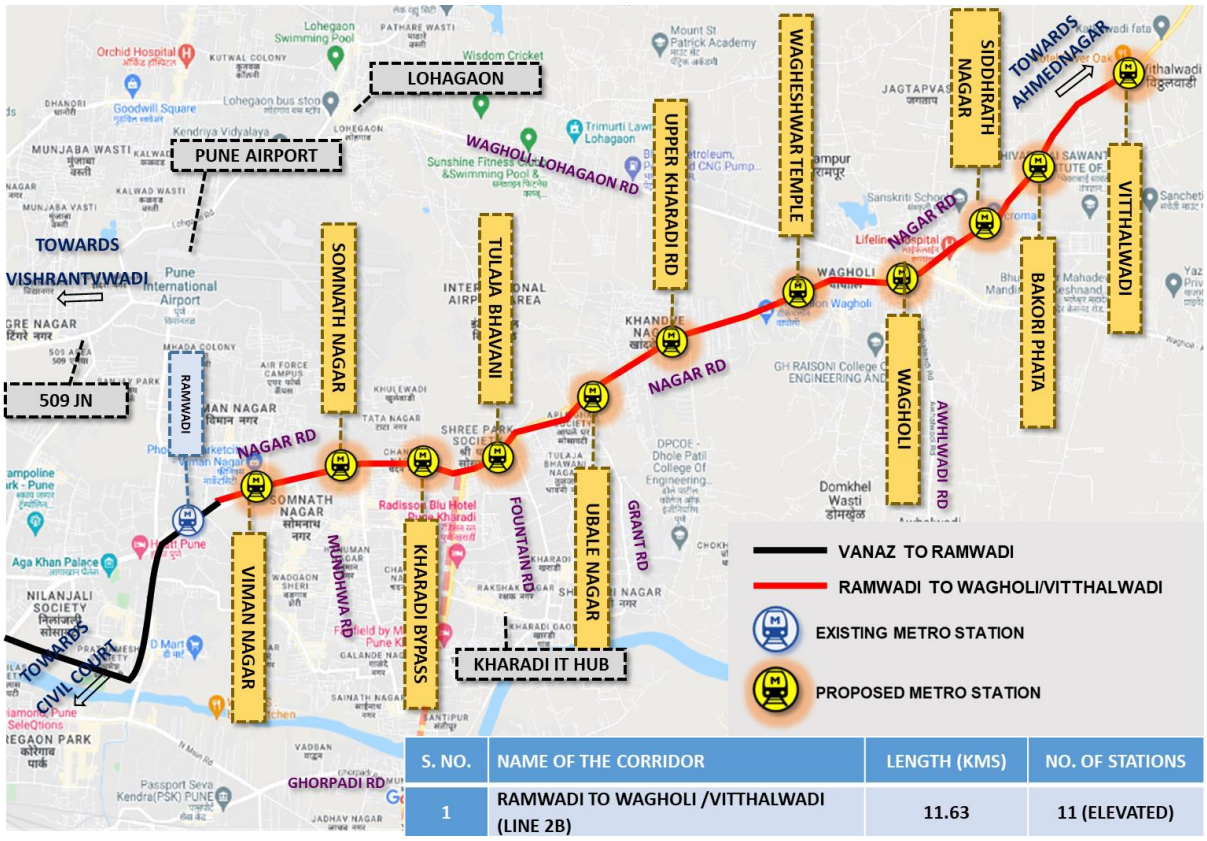


S. NO.	NAME OF THE CORRIDOR	LENGTH (KMS)	NO. OF STATIONS
1	VANAZ TO CHANDANI CHOWK (LINE 2A)	1.12	2 (ELEVATED)

FIGURE 6-1: PUNE METRO LINE 2A – VANAZ TO CHANDANI CHOWK ALIGNMENT

6.1.1.2. DESCRIPTION OF THE ROUTE AIGNMENT – LINE 2B

The Line 2B is 11.63 Km in length, which passes along Pune-Ahmednagar Highway (Nagar Road) – NH27. The corridor alignment is an extension for Line 2 – Vanaz to Ramwadi of Phase I and it passes along Weikfield IT Citi Info Park, Ahilyabai Holkar Chowk, Tata Guard Room, Chandan Nagar, Hadapsar Bypass Stop, Kharadi Bypass ST Stop, Aaple Ghar, Khandve Nagar, Wagheshwar Temple, Wagholi Weekly Bazaar etc. The Line 2B alignment is shown in Figure 6-2.



S. NO.	NAME OF THE CORRIDOR	LENGTH (KMS)	NO. OF STATIONS
1	RAMWADI TO WAGHOLI /VITTHALWADI (LINE 2B)	11.63	11 (ELEVATED)

FIGURE 6-2: PUNE METRO LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI ALIGNMENT

6.1.2 PLANNING AND DESIGN CRITERIA FOR STATIONS

The standards/recommendations for planning and design criteria for stations are:

1. The stations are divided into public and non-public areas (those areas where access is restricted). The public areas can be further subdivided into paid and unpaid areas.
2. The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario.
3. The platform level at elevated type stations is determined by a critical clearance of 5.5 m under the concourse above the road intersection, allowing 3.55 m for the concourse height, about 1.85 m for structure of concourse floor and 1.8 m for structure of tracks above the concourse. Further, the platforms are 1.09 m above the tracks. This would make the rail level in an elevated situation at least 13.5 meters above ground.
4. The concourse contains automatic fare collection system in a manner that divides the concourse in two distinct areas. The “Unpaid Area” is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the “Paid Area”, which includes access to the platforms.

5. The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space.
6. Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.
7. Station entrances are located with particular reference to passenger catchment points and physical site constraints allowing for 30-meter or 42-meter right-of-way proposed by the local authorities.
8. Office accommodation, operational areas and plant room space is required in the non-public areas at each station.
9. The DG set, Bore Well, Pump House and Underground Water Tanks would be located generally under one entry/exit on the ground.
10. The system is being designed to maximize its attraction to potential passengers and the following criteria have been observed:
    a. Minimum distance of travel to and from the platform and between platforms for transfer between lines.
    b. Adequate capacity for passenger movements.
    c. Convenience, including good signage relating to circulation and orientation.
    d. Safety and security, including a high level of protection against accidents.
11. Following requirements have been considered:
    a. Minimum capital cost is incurred consistent with maximizing passenger attraction.
    b. Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
    c. Flexibility of operation including the ability to adapt to different traffic conditions changes in fare collection methods and provision for the continuity of operation during any extended maintenance, repair period, etc.
    d. Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
    e. Provision of display of passenger information and advertising.
12. The numbers and sizes of staircases/escalators are determined by checking the capacity against AM and PM peak flow rates for both normal and emergency conditions such as delayed train service, emergency evacuation in case of train fire etc.
13. In order to transfer passengers efficiently from street to platforms and vice versa, station planning has been based on established principles of pedestrian flow and arranged to minimize unnecessary walking distances and cross-flows between incoming and outgoing passengers.

14. Passenger handling facilities comprise of stairs/escalators, lifts and ticket gates required to process the peak traffic from street to platform and vice-versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit).

6.1.3 NORMS FOR STATION PLANNING AND DESIGN

1. The stations are generally located on the road median. Total length of the station is 140 m. All the stations are two-level stations. The concourse is planned along the part or whole length of the platform with staircases leading from either side of the road. The maximum width of the station at concourse is 17 m. in case of island platform and 21 m in case of side platforms.
1. Typically, the concourse is divided into public and restricted zones. The restricted zone contains station operational areas such as Station Control Room, Waiting Room, Meeting Room, UPS & Battery Room, Auxiliary Service Station, Signal and Telecom Rooms, Train Crew Room, Security Room, Station Store Room, Staff Toilets. The public zone is further divided into paid and unpaid areas which consists of circulation areas, public toilets, retail areas etc. Water Tanks, Pump Room and DG room is provided on the ground under the entry/ exit structure

2. Since the station is in the middle of the road, minimum vertical clearance of 5.5 m has been provided under the concourse. Platforms are at a level of around 14.6 meters above the road. To reduce physical and visual impact of the elevated station, stations have been proposed as cantilevered structures with single column located at the central verge of the road.
3. 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 tracks. Structures that afford maximum transparency and are light looking have been envisaged. A slim and ultra-modern concrete form is proposed, as they would look both compatible and modern high-rise environment as well as the lesser-built, low-rise developments along some parts of the corridor.
4. Platform roofs, that can invariably make a structure look heavy, have been proposed to be of steel frame with Galvalume Sheets and aluminium louvers to achieve a light look. Platforms would be protected from the heat and rains by providing an overhang of the roof and sidewalls are avoided, thereby enhancing the transparent character of the station building.

The required station accommodations are;

1. Station Control Room
2. Cleaners Room
3. Security Room

4. First Aid Room
5. Ticket Office
6. Miscellaneous Operations Room
7. Ticket Hall Supervisor and Excess Fare
8. Platform Supervisors Booth
9. Ticket Room
10. Auxiliary Substation
11. DG Room
12. Staff Room
13. Fire Tank and Pump Room
14. Toilets
15. Commercial Outlets and Kiosks
16. Station Store Room
17. UPS and Battery Room
18. Refuse Store
19. Signalling/Communication Room

The description of the required station accommodations is given in below sections;

6.1.3.1. PASSENGER AMENITIES

Passenger amenities such as ticketing counters/automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Uniform numbers of these facilities have been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station. The same applies to provision of platform widths and staircase/escalators. Maximum capacity required at any station in the year 2027, 2037, 2047, and 2057 have been calculated and the most critical year for emergency operation has been adopted for all stations.

For this purpose, peak minute traffic is assumed to be 2% of the peak hour traffic. For checking the adequacy of platform area, stair widths and requirement additional of emergency evacuation stairs, a maximum accumulation of passengers in the station has been considered to be comprising waiting passengers at the platform (including two missed headways) and section load expected to be evacuated at the station in case of an emergency.

6.1.3.2. CONCOURSE

Concourse forms the interface between street and platforms. In elevated stations, this is contained along the full length of the station. This is where all the passenger amenities are provided. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct paid and unpaid areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms.

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

6.1.3.3. ENTRY/EXIT

- Entrances to stations have adequate capacity to satisfy predicted passenger flows and emergency evacuation requirement.
- The position of entrances is determined by the juxtaposition of building location of Roadway footpath width, space availability and flow directions of passenger traffic.
- The numbers and width of staircases/ escalators are determined by checking the capacity/available width against peak passenger flows rates for both normal and emergency conditions such as delayed train service, fire etc.
- d. All entrances extending to street level are proposed to be protected against flooding. This protection is done by the provision of a minimum of 3 steps up to a landing (+450 mm minimum)

6.1.3.4. WALKWAYS/RAMPWAYS

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

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

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

d. The walkways, ramps, platform width etc. have been planned for a minimum Level of Service (LOS) E. The pedestrian Flow Analogy with respect to Level of Service is detailed below in Figure 6.3 and Table 6.3.

FIGURE 6-3 PEDESTRIAN FLOW ANALOGY

TABLE 6-3: LOS GUIDELINES FOR THE PEDESTRIANS

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

6.1.3.5. TICKETING GATES (AFC GATES)

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

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

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

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

e. Special gates are designed for;
   - Widened ticket gates for Disabled persons' access,
   - Customers with luggage,
   - Customers with strollers

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

   Ticketing gates' requirement has been calculated taking the gate capacity as 28 persons per minute per gate. Passenger forecast for the horizon year has been used to compute the maximum design capacity. At least two ticketing gates shall be provided at any station even if the design requirement is satisfied with only one gate. Uniform space has been provided in all stations where gates can be installed as and when required.

FIGURE 6-4: AFC GATES AT STATIONS

6.1.3.6. TICKET COUNTERS AND VENDING MACHINES (TVMS)

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

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

the requirement of ticket counters has been calculated and the same provided for in the plans.

b. The number of TVMs required is governed by the peak hour passenger traffic, the fare policy and the ticketing. Depending on the composition of monthly pass/smart card users and single ticket users, the number of TVMs could change.
c. Adequate provision has been kept at the stations for the TVM and ticket counters in the unpaid area of the concourse and is suitably located for the ease of usability of the passengers. As a general thumb rule, it is proposed to provide 5 to 7 TVMs for stations with high traffic and 2 to 5 TVMs for other stations. Interchange stations may be provided with 7 to 10 TVMs. The ticket vending machines at stations is presented in Figure 6.5.

FIGURE 6-5: TICKET VENDING MACHINES

6.1.3.7. TICKET OFFICE

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

A minimum of 2 ticket office per station in the stations with high traffic, and 1 ticket office per station in the stations with low traffic have been planned (Figure 6.6).

FIGURE 6-6: TICKET COUNTER

6.1.3.8. STAIRS, ESCALATORS AND LIFTS

Provision has been made for escalators and lifts in the paid area i.e. from concourse to platforms. In addition, staircases with 3.6 m or 2.4 m width, depending on the type of station are provided on platform connecting to the concourse.

These stairs and escalator together provide an escape capacity adequate to evacuate maximum accumulated passengers in emergency from platforms to concourse in 5.5 minutes. Lifts have been provided one each on platform, to provide access for elderly and disabled. Since the rise to road from the concourse is about 8 m, it is proposed to provide escalators and lifts in addition to stairs for vertical movement of passengers from Road to Concourse level also.

Entry structures are divided into two categories based on the composition of staircase, escalator and lift with or without integration of ancillary building and multi-modal integration. Provision of entry structure type is based on land availability.

Entry structure with combined multi-modal integration would help in facilitating last mile connectivity. Also, entry structure with combined ancillary would reduce ground footprint.

- E1 – 01 Staircase (2.4 m), 01 Escalator
- E2 – 01 Staircase (2.4 m), 01 Lift

S. No	Station Name	No. of Lifts	No. of Escalators
Pune Metro Line 2A (Vanaz to Chandani Chowk)			
1	Kothrud Bus Depot	2	2
2	Chandani Chowk*	4	2
Pune Metro Line 2B (Ramwadi to Wagholi/Vitthalwadi)			
1	Viman Nagar	2	2
2	Somnath Nagar	2	2
3	Kharadi Bypass*	3	2
4	Tulaja Bhavani	2	2
5	Ubale Nagar	2	2
6	Upper Kharadi Road	2	2
7	Wagheshwar Temple	2	2
8	Wagholi	2	2
9	Siddharth Nagar	2	2
10	Bakori Phata	2	2
11	Vitthalwadi	2	2
* Includes the lifts in FOB connected to the Metro Station Concourse			

6.1.4 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 NBC 2016 Clause J-5.1cstates that the station also shall be designed to permit evacuation from the most remote point on the platform to a point of safety in 8 minutes or less. The maximum travel distance on the platform to a point at which a means of egress route leaves the platform shall not exceed 100 m (300 ft.).
- For enclosed stations equipped with an emergency ventilation system, that concourse is permitted to be defined as a point of safety.
- NBC 2016 Clause J-5.1b, the maximum time to evacuate a platform should not be more than 5.5 minutes. Considering, that for the maximum occupant load, the last person takes 5.5 minute to reach the nearest staircase/escalator/ fire escape staircase.
- For ensuring adequacy of platform area, stair widths and requirement of additional emergency evacuation stairs, a maximum accumulation of passengers in the station has been considered to be comprising waiting passengers at the platform (including two missed headways) and section load (or full train load if the section load exceeds a full train load) expected to be evacuated from the peak direction at the station in case of an emergency. Also, waiting passengers congregated during this disrupted time of service (two missed headways) in the off-peak direction to be

added in the evacuation from the platform to concourse in case of underground stations and concourse to ground in both underground as well as elevated stations.

- The egress time calculations for each station type enclosed in Annexure 6.1

Evacuation Time	Min
On Platform T1	1.18
Platform to Concourse T2	1.20
Concourse to safe area T3	1.05
Total walking time T=T1+T2+T3	3.44

6.1.4.1. FIRE FIGHTING MEASURES

Firefighting provisions in Elevated metro stations are in accordance with the National Building Code of India 2016. National Building Code (clause 6.4.4) - Fire protection and firefighting system for metro stations stipulates:

1. Wet Riser System

Main and diesel pump of 2280 Litres/min capacity to support 3 to 4 hydrant at a time [station building is split into two halves]. It is presumed that fire will not break out in the two parts simultaneously. There are minimum 2 hydrants in one part. Therefore, pump capacity as above is proposed. Jockey pump 180 l/min shall also have DG back up.

2. Internal Hydrant

The internal hydrant is provided with 2 no. RRL hose pipes of 38 mm Ø with 63 mm standard instantaneous coupling along with associated branch pipe and cabinet and a first aid hose reel of 25 mm Ø length 45m fitted with 6.5 mm nozzle. One hydrant each at Ground Level, Passage Level and Platform Level in each half of the station building is also provided and so located that every part of station is within 30 m radius.

a. Sprinklers are provided in the property development area only. Additional sprinkler pump is not provided as these are not required being the integral part of the station. The two pumps already provided will take care of sprinkler flow requirements.
b. Detectors are provided in the operational areas only, and above false ceiling if the gap is 750 mm.
c. One manual call box at each level in each half of the station building is provided.
d. The HT panels, LT panels, main LT distribution board and essential power panels shall be provided with linear heat sensing tubes with CO2 cylinder.
e. A two-way fire brigade inlet at ground level on each rising main for hydrants is provided.
f. Draw off connection is provided on the fire water tank for fire brigade.
g. Water tank of 75,000 litres capacity if planned since commercial development is restricted to 250 sum.
h. Portable fire extinguishers (CO2) a set of two is provided in each of the equipment room.

6.1.5 STATION TYPOLOGY

Three (03) types of stations have been considered. The station typology has been represented in Table 6-4 and discussed in subsequent sections.

TABLE 6-4: STATION TYPES

Station Type	Platform Type	Concourse	Platform
Type A Station	Island Platform with Short Concourse	62.7 X 17 m	140 x 17 m
Type B Station	Side Platform (Full Concourse)	140 x 21 m	140 x 21 m
Type C Station	Interchange Station	140 X 26 m	140 X 26 m

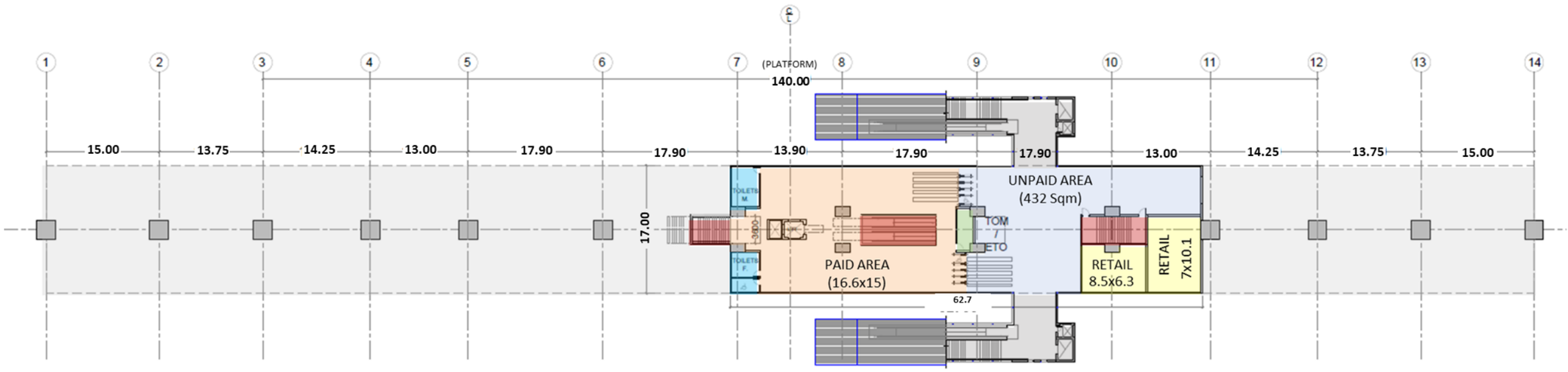
Majority of the stations have been planned as island platforms with short concourse for optimizing the station area. However, considering the specific requirements, at the station, full concourse and side platform stations have also been proposed.

6.1.5.1. TYPE A STATION – ISLAND PLATFORM WITH SHORTER CONCOURSE

Type A station is planned with Island platform and shorter concourse. Two (02) entries/exits have been planned on either side of the station. Connectivity between both the entries/entries have been provided in the unpaid concourse.

TABLE 6-5: ROOM SCHEDULE FOR STATION TYPE A – CONCOURSE LEVEL

ROOM NAME	ROOM SIZE (m)		AREA PROVIDED (SQM)
PAID AREA	16.6	15	249
UNPAID AREA			432
TOILETS	3.6	10.6	38
TOM/ETO	2.1	5.6	12
RETAIL 1	8.5	6.3	54
RETAIL 2	7	10.1	71
UPS 1	8	5.8	46
CER	8.2	5.8	48
SER	8.2	5.8	48
STAFF ROOM	3.8	5.8	22
SCR	12.7	3.5	44
DB	3.5	3.5	12
UPS 2	11.25	3.1	35
ASS	30	5.8	174



All Dimensions in Meter

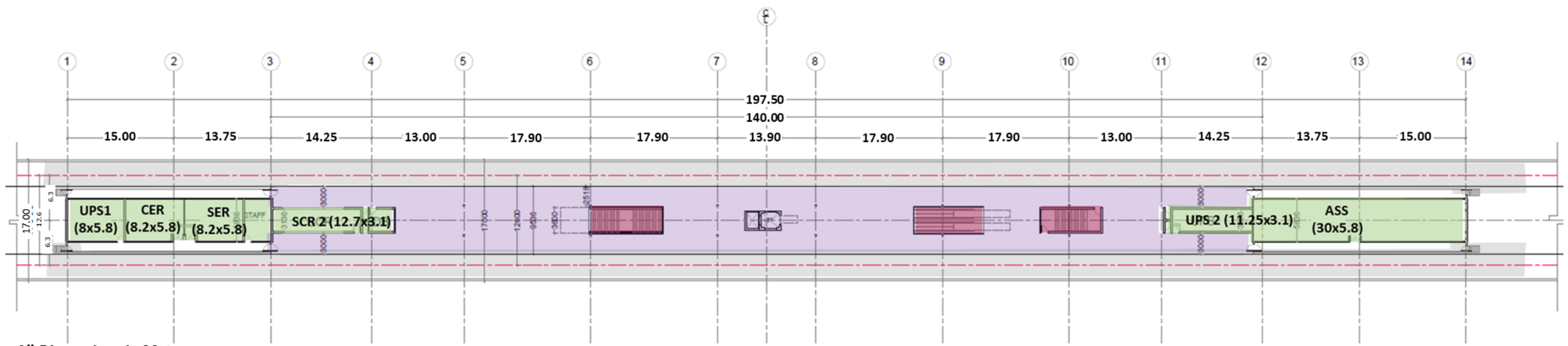
PAID AREA | ENTRY/EXITS | OPERATION ROOMS | RETAIL

UNPAID AREA | STRICASE / ESCALATOR | TOILETS | PLATFORM

RoomSchedule for Type A Station			
Room Name	**Room Size**		**Area Provided (Sqm)**
PAID AREA	16.6	15	249
UNPAID AREA			432
TOILETS	3.6	10.6	38
TOM/ETO	2.1	5.6	12
RETAIL 1	8.5	6.3	54
RETAIL 2	7	10.1	71
UPS 1	8	5.8	46
CER	8.2	5.8	48
SER	8.2	5.8	48
STAFF ROOM	3.8	5.8	22
SCR	12.7	3.1	39
DB	3.5	3.5	12
UPS 2	11.25	3.1	35
ASS	30	5.8	174

TOM	TICKET OFFICE MACHINE
ETO	EXCESS TICKET OFFICE
SCR	STATION CONTROL ROOM
CER	CENTRAL EQUIPMENT ROOM
SER	SIGNALLING EQUIPMENT ROOM
ASS	AUXILLIARY SUB STATION

FIGURE 6-7: TYPE A – CONCOURSE LEVEL



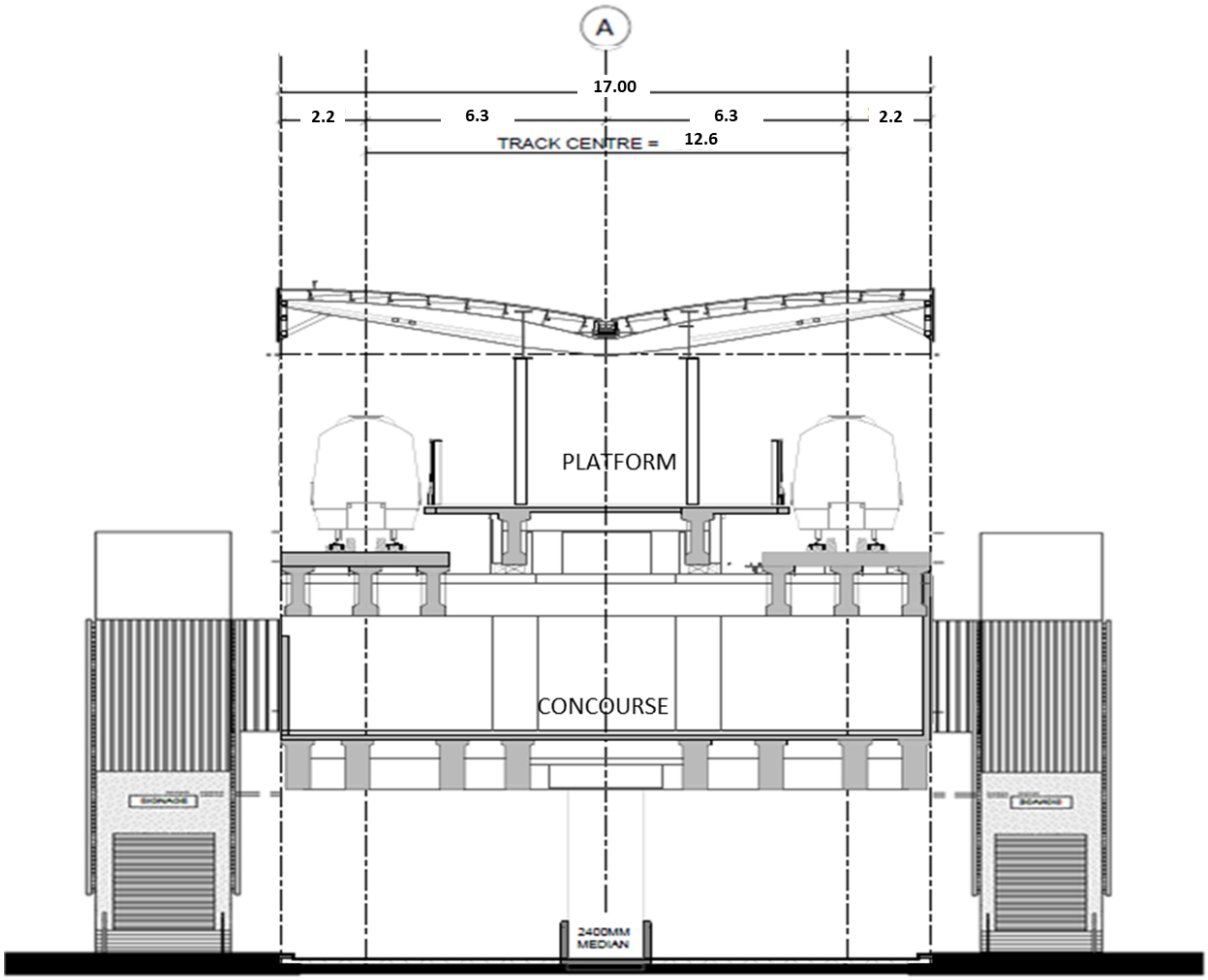
All Dimensions in Meter

PAID AREA
UNPAID AREA
TRACKS
STRICASE / ESCALATOR
OPERATION ROOMS
TOILETS
RETAIL
PLATFORM

RoomSchedule for Type A Station			
Room Name	Room Size		Area Provided (Sqm)
PAID AREA	16.6	15	249
UNPAID AREA			432
TOILETS	3.6	10.6	38
TOM/ETO	2.1	5.6	12
RETAIL 1	8.5	6.3	54
RETAIL 2	7	10.1	71
UPS 1	8	5.8	46
CER	8.2	5.8	48
SER	8.2	5.8	48
STAFF ROOM	3.8	5.8	22
SCR	12.7	3.1	39
DB	3.5	3.5	12
UPS 2	11.25	3.1	35
ASS	30	5.8	174

TOM	TICKET OFFICE MACHINE
ETO	EXCESS TICKET OFFICE
SCR	STATION CONTROL ROOM
CER	CENTRAL EQUIPMENT ROOM
SER	SIGNALLING EQUIPMENT ROOM
ASS	AUXILLIARY SUB STATION

FIGURE 6-8: TYPE A – PLATFORM LEVEL



All Dimensions in Meter

CROSS SECTION

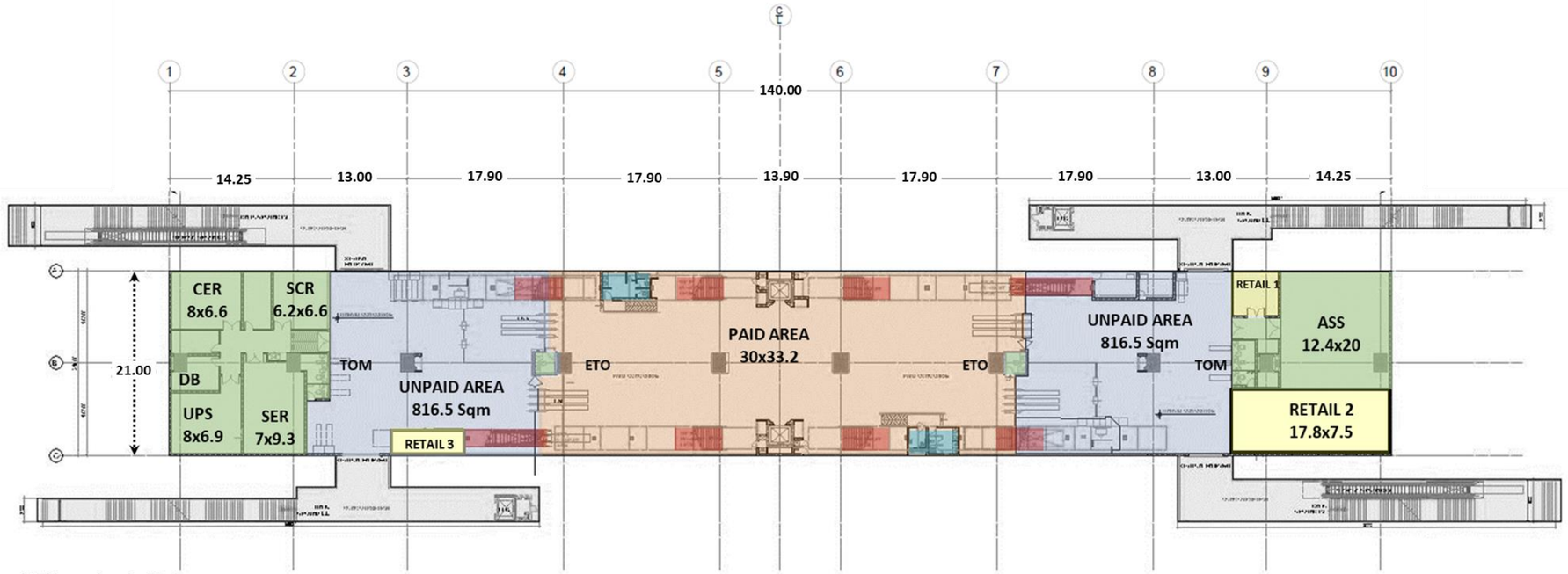
FIGURE 6-9: TYPE A – CROSS SECTION

6.1.5.2. TYPE B STATION – SIDE PLATFORMS WITH FULL CONCOURSE

Type B Station is planned as Station having side platforms with full concourse. The station type is planned at terminal stations and has four (04) entry/exit structures.

TABLE 6-6: ROOM SCHEDULE FOR TYPE B STATION

ROOM NAME	ROOM SIZE (m)		AREA PROVIDED (SQM)
PAID AREA	30	33.2	996
UNPAID AREA			1633
TOILETS	10.8	5.8	63
TOM 1	2.4	5.1	12
TOM 2	2.5	5.1	13
ETO 1	3.8	2.1	8
ETO 2	3.8	2.1	8
SCR	6.2	6.4	40
UPS 1	8	6.9	55
CER	8	6.6	53
SER	7	9.3	65
STAFF ROOM	3	6.4	19
UPS 2	7.4	6	44
DB	5.5	4	22
ASS	12.4	20	248
RETAIL 1	5.2	5	26
RETAIL 2	17.8	7.5	134
RETAIL 3	8	2.6	21



Room Schedule for Type B Station			
Room Name	Room Size		Area (Sqm)
PAID AREA	30	33.2	996
UNPAID AREA			1633
TOILETS	10.8	5.8	63
TOM 1	2.4	5.1	12
TOM 2	2.5	5.1	13
ETO 1	3.8	2.1	8
ETO 2	3.8	2.1	8
SCR	6.2	6.6	41
UPS	8	6.9	55
CER	8	6.6	53
SER	7	9.3	65
DB	5.5	4	22
ASS	12.4	20	248
RETAIL_1	5.2	5	26
RETAIL_2	17.8	7.5	134
RETAIL-3	8	2.6	21

TOM	TICKET OFFICE MACHINE
ETO	EXCESS TICKET OFFICE
SCR	STATION CONTROL ROOM
CER	CENTRAL EQUIPMENT ROOM
SER	SIGNALLING EQUIPMENT ROOM
ASS	AUXILLIARY SUB STATION

FIGURE 6-10: TYPE B - CONCOURSE LEVEL

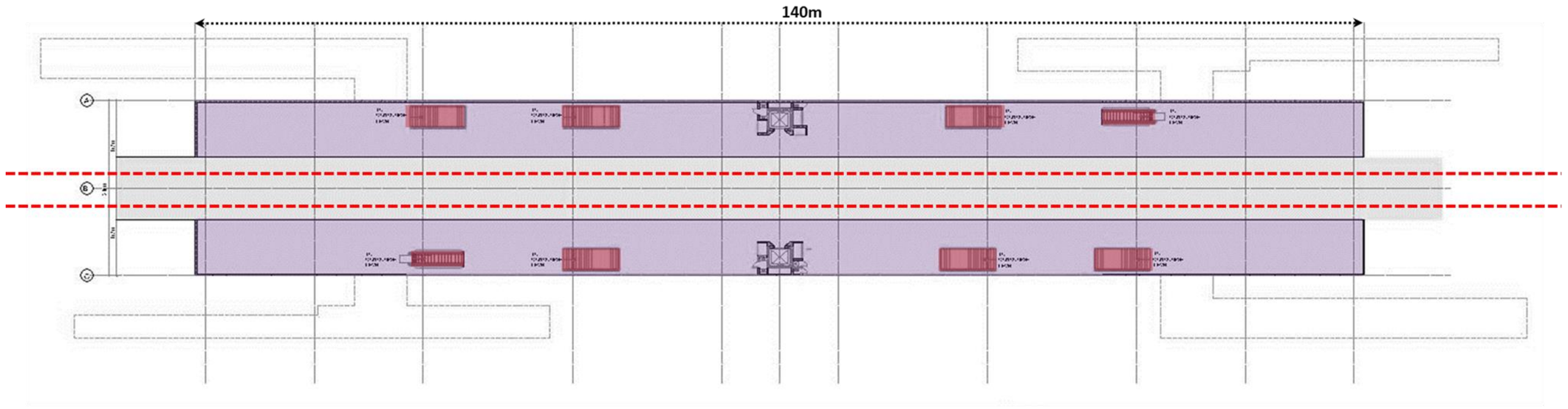


FIGURE 6-11: TYPE B - PLATFORM LEVEL

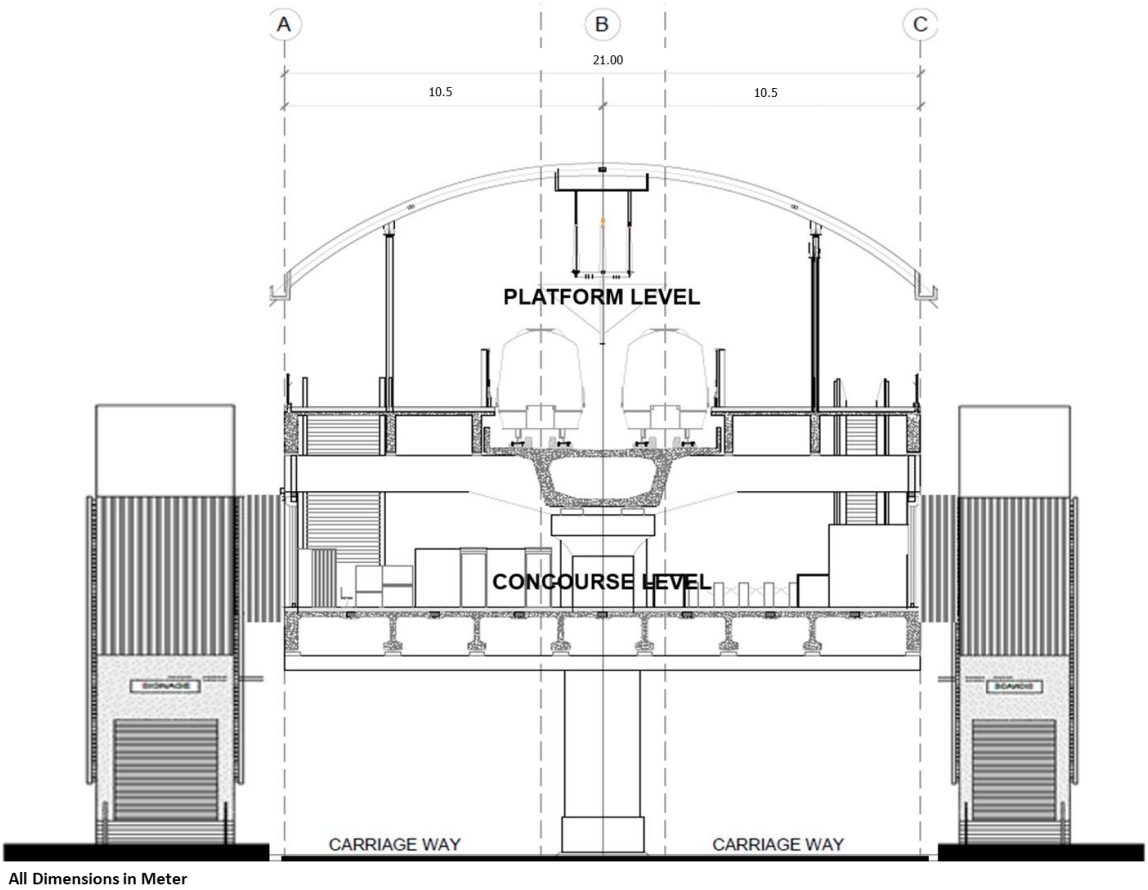


FIGURE 6-12: TYPE B - CROSS SECTION

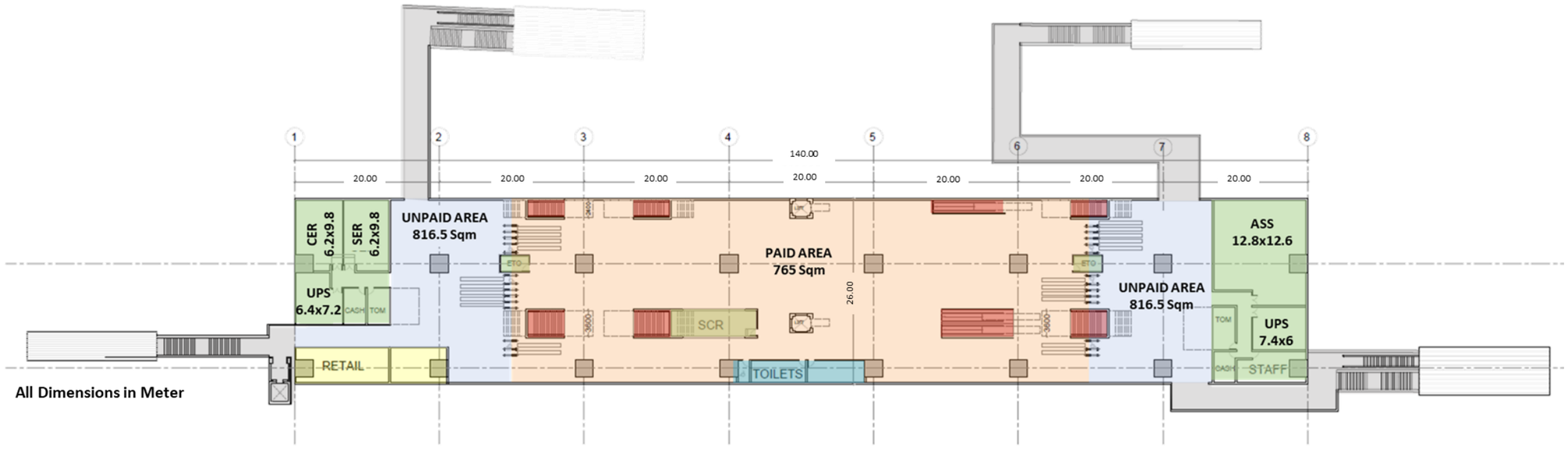
6.1.5.3. TYPE C STATION – INTERCHANGE STATION

An interchange is a station where two or more lines cross each other and the passenger has the option to transfer from one line to the other within the system. A seamless transfer of passenger and smooth flow of movement is essential for an interchange station. An interchange station provides a greater utility and flexibility for the system as a whole, and it decreases the time required for travel within the city since it is located at the intersection of two or more lines, and many passengers will change from one line to the other. The interchange passenger movements require larger areas for circulation than normal stations, because it is important to save time in transfer of passengers between the lines. An Interchange station also has special provisions of paid to paid connection between two stations.

An interchange is planned at Line 2B (Ramwadi- Vitthalwadi) and Line 4C (Hadapsar- Kharadi) with Line 4C terminating at the Kharadi Bypass Metro Station. Station is planned to have three platforms, having one common platform for both the corridors. Kharadi Bypass Station is proposed to be used as Interchange station/terminal station which connects the two lines; Ramwadi to Wagholi Corridor and Hadapsar corridor

TABLE 6-7: ROOM SCHEDULE FOR TYPE C STATION

ROOM NAME	ROOM SIZE (m)		AREA PROVIDED (SQM)
PAID AREA			765
UNPAID AREA			1633
TOILETS	17.5	3	53
TOM 1	3.1	5	16
TOM 2	3.1	6	19
ETO 1	3.8	2.1	8
ETO 2	3.8	2.1	8
RETAIL 1	10.5	4.9	51
RETAIL 2	5.5	4.9	27
UPS 1	6.4	7.2	46
CER	6.2	9.8	61
SER	6.2	9.8	61
STAFF ROOM	7.3	4.2	31
SCR	11.8	3.6	42
DB	3.5	3.5	12
UPS 2	7.4	6	44
ASS	12.8	12.6	161



RoomSchedule for Type C Station			
Room Name	**Room Size**		**Area Provided (Sqm)**
PAID AREA			765
UNPAID AREA			1633
TOILETS	17.5	3	53
TOM 1	3.1	5	16
TOM 2	3.1	6	19
ETO 1	3.8	2.1	8
ETO 2	3.8	2.1	8
RETAIL 1	10.5	4.9	51
RETAIL 2	5.5	4.9	27
UPS 1	6.4	7.2	46
CER	6.2	9.8	61
SER	6.2	9.8	61
STAFF ROOM	7.3	4.2	31
SCR	11.8	3.6	42
DB	3.5	3.5	12
UPS 2	7.4	6	44
ASS	12.8	12.6	161

CKET OFFICE MACHINE
CCESS TICKET OFFICE
ATION CONTROL ROOM
NTRAL EQUIPMENT ROOM
GNALLING EQUIPMENT ROOM
UXILLIARY SUB STATION

FIGURE 6-13: TYPE C - CONCOURSE LEVEL

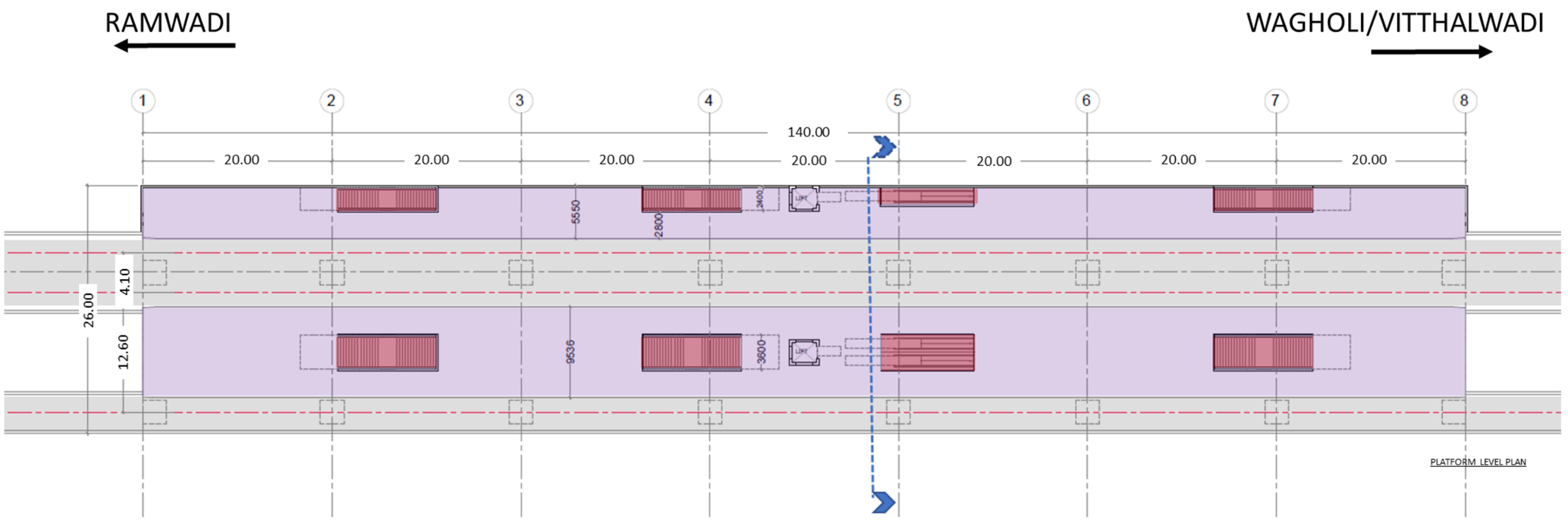
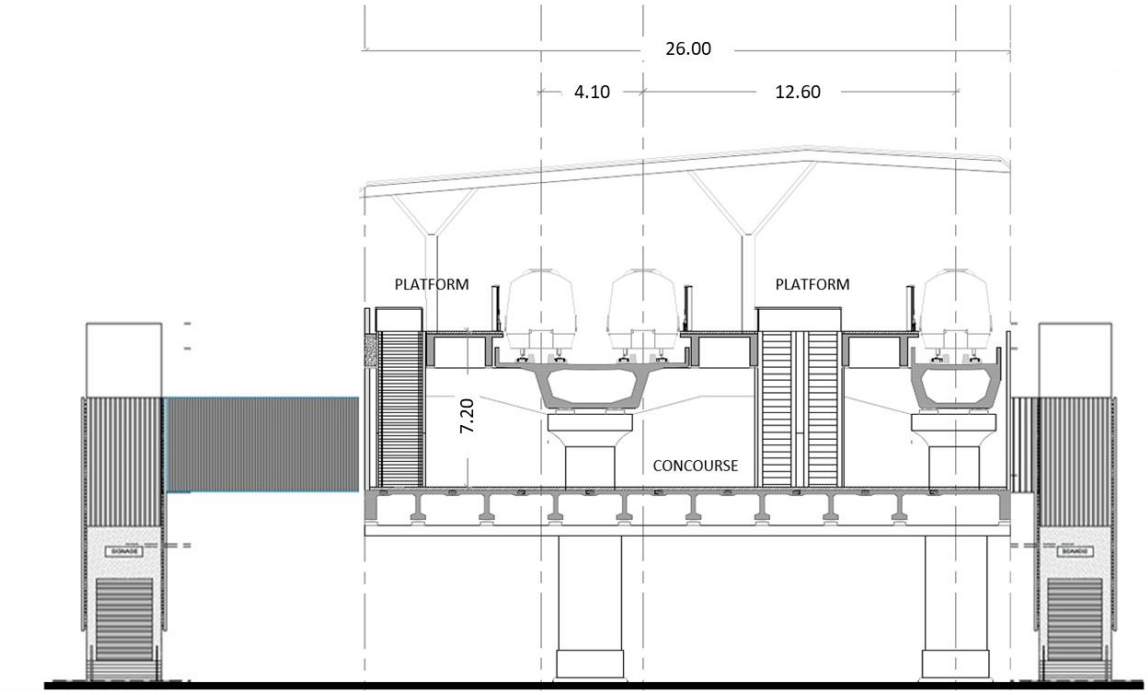


FIGURE 6-14: TYPE C - PLATFORM LEVEL



All Dimensions in Meter

CROSS SECTION

FIGURE 6-15: TYPE C - CROSS SECTION

The typology proposed for each station is presented in Table 6-8.

TABLE 6-8: PROPOSED STATION TYPOLOGIES FOR LINE 2A AND LINE 2B

S.No	Station Name	Chainage (m)	Interstation Distance (m)	No. of Entry / Exit	Station Typology#
Pune Metro Line 2A (Vanaz to Chandani Chowk)					
1	Kothrud Bus Depot	-964.048	942.048*	4	Type B
2	Chandani Chowk•	-1779.227	815.179	5	Type B
Pune Metro Line 2B (Ramwadi to Vitthalwadi)					
1	Viman Nagar	15464.618	980.149**	4	Type B
2	Somnath Nagar	16700.889	1236.271	2	Type A
3	Kharadi Bypass•	17601.929	901.04	5	Type C
4	Tulaja Bhavani	18843.676	1241.747	2	Type A
5	Ubale Nagar	19888.269	1044.593	2	Type A
6	Upper Kharadi Road	20930.634	1042.365	2	Type A
7	Wagheshwar Temple	22312.06	1381.426	4	Type B
8	Wagholi	23269.317	957.257	4	Type B
9	Siddharth Nagar	24087.658	818.341	2	Type A
10	Bakori Phata	24948.286	860.628	2	Type A
11	Vitthalwadi	26232.966	1284.68	4	Type B

*****From Vanaz Metro Station of Phase 1
**From Ramwadi Metro Station of Phase 1
Type A- Island Platform Short Concourse
Type B- Side Platform full concourse
Type C- Interchange Station
• Includes Entry Structures of FOB connected to Station Concourse. Two (02) for Chandani Chowk and One (01) for Kharadi Bypass

6.1.6 STATION DESCRIPTION

6.1.6.1. LINE 2A – VANAZ TO CHANDANI CHOWK

The proposed extension between Vanaz and Chandani Chowk is 1.12 km in length and has 02 stations planned. The description for all the proposed stations along Corridor are summarized below;

1. KOTHRUD BUS DEPOT METRO STATION

TABLE 6-9: DETAILS OF KOTHRUD BUS DEPOT METRO STATION

Kothrud Bus Depot Station			
Chainage (m)	-964.048		
Ground Level (m)	598.75		
Rail Level (m)	617.00		
Interstation Distance (m)	Vanaz	Kothrud Bus Depot	Chandani Chowk
	942	0	815
Station Type	Elevated – Type B		
Location	Station is located on Paud Road near Kothrud Bus Depot		
Catchment Area	The major source of passenger trip generation around this residential and commercial establishment along the Paud Road.		
Surrounding Land use	The surrounding area is a mix of residential, commercial & Industrial uses.		
Landmarks	Station is located near the Kothrud Bus Depot		
Connectivity	Connectivity through PT and IPT		
Entry Exit	Four (04) Entry Structures are proposed for the station		

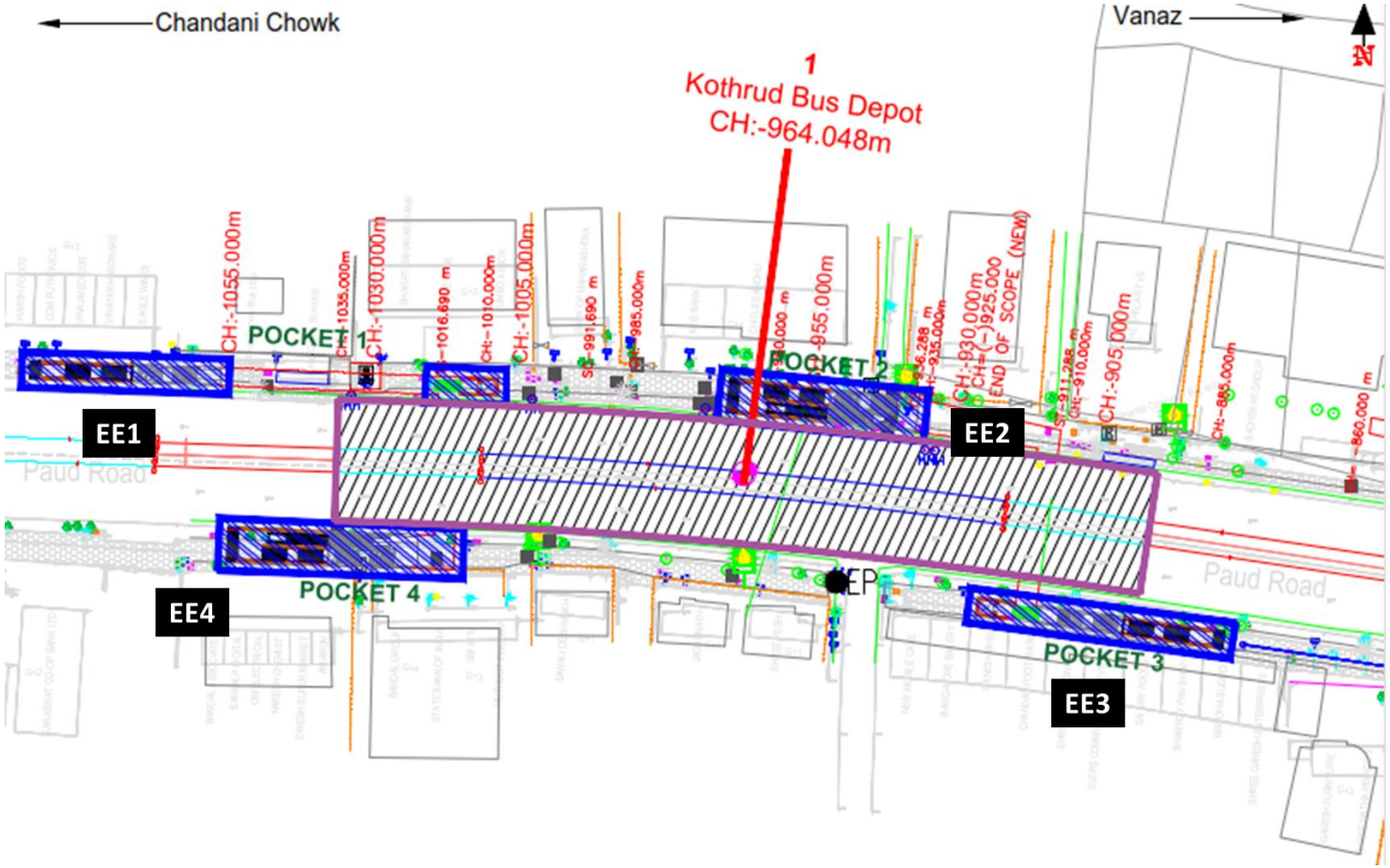


FIGURE 6-16: METRO ALIGNMENT THROUGH KOTHRUD DEPOT METRO STATION

2. CHANDANI CHOWK METRO STATION

TABLE 6-10: DETAILS OF CHANDANI CHOWK METRO STATION

Chandani Chowk Metro Station			
Chainage (m)	-1779.227		
Ground Level (m)	616.881		
Rail Level (m)	632.50		
Interstation Distance (m)	Kothrud Bus Depot	Chandani Chowk	End Chainage
	815	0	100.77
Station Type	Elevated – Type B		
Location	Station is located on Paud Road near Chandani Chowk		
Catchment Area	The major source of passenger trip generation residential and commercial areas. Station is also located near to the Chandani Chowk which is a pick up and drop off location for commuters travelling to Mumbai.		
Surrounding Land use	The surrounding area is predominantly residential with a mix of commercial uses		
Landmarks	Station is located near the Chandani Chowk, Lohia IT park near the Paud road and Mumbai Highway intersection.		
Connectivity	• MSRTC Stop on Mumbai Highway • PT and IPT connectivity		
Entry/Exit	Three (03) Entry Structures are proposed near the station whereas Two (02) Entry Structures for FOB on either side of Mumbai Highway at MSRTC Bus Stop are proposed for the connectivity to station at Concourse.		
Issue	• Steep gradient between Paud Road and Mumbai Highway • Located near Chandani Chowk		

Chandani Chowk Metro Station

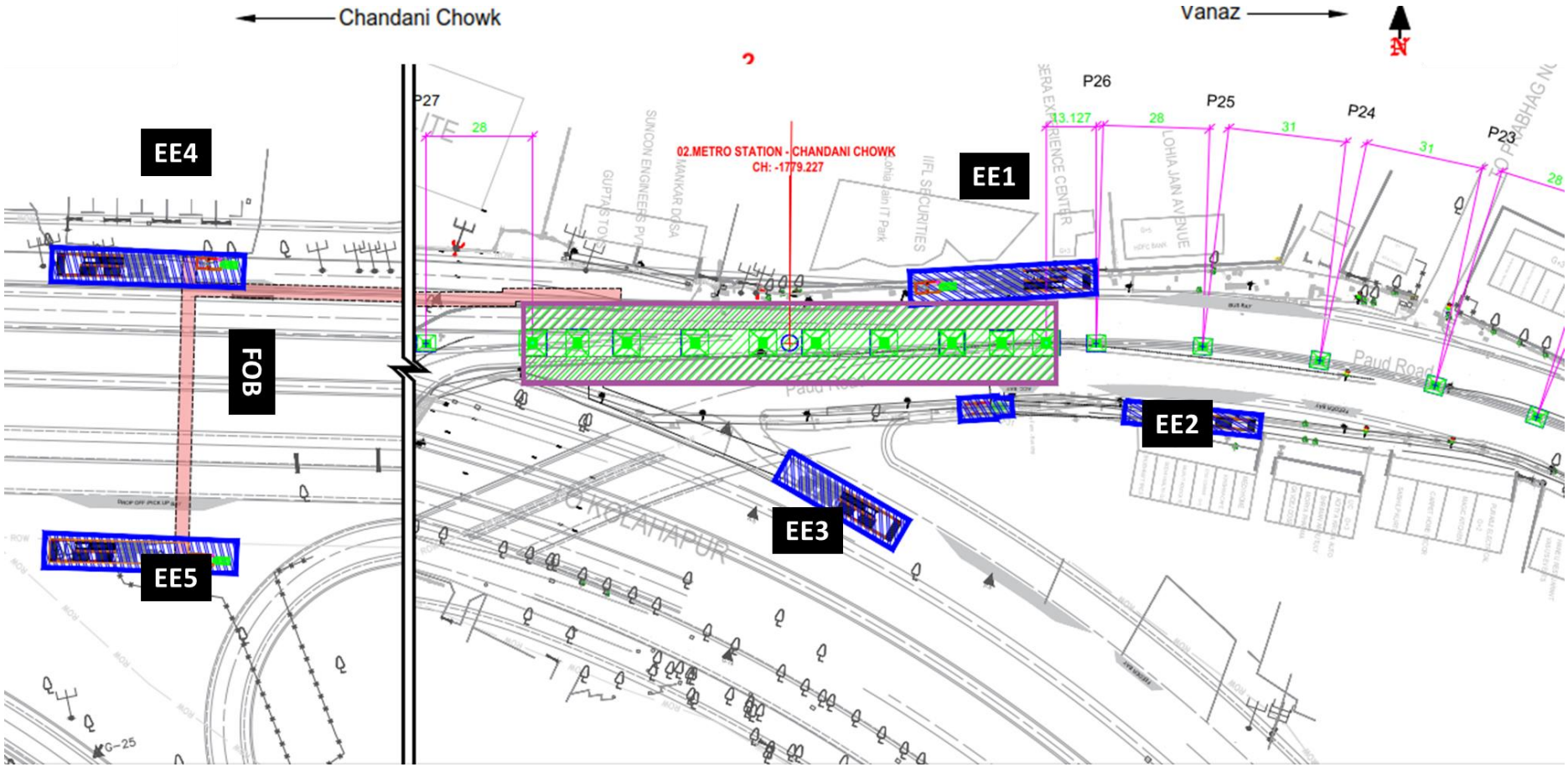


FIGURE 6-17: METRO ALIGNMENT THROUGH CHANDANI CHOWK METRO STATION

6.1.6.2. LINE 2B – RAMWADI TO VITTHALWADI

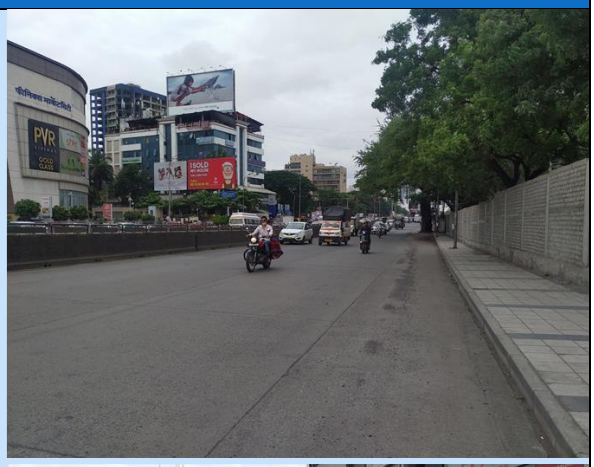
The proposed extension between Ramwadi and Vitthalwadi is about 12 km in length and has 11 stations planned. The description for all the proposed stations along Corridor are summarized below;

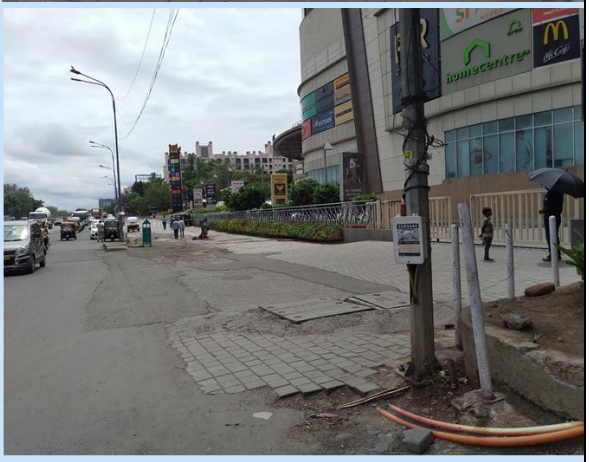
1. Viman Nagar Metro Station

TABLE 6-11: DETAILS OF VIMAN NAGAR METRO STATION

Viman Nagar Metro Station			
Chainage (m)	15464.618		
Ground Level (m)	567.09		
Rail Level (m)	586.2		
Interstation Distance (m)	Ramwadi	Viman Nagar	Somnath Nagar
	980	0	1236
Station Type	Elevated – Type B		
Location	On Nagar Road (Viman Nagar Junction)		
Catchment Area	The major source of passenger trip generation around this station are residential and commercial establishment along the Nagar Road.		
Surrounding Land use	The surrounding area is a mix of residential, commercial.		
Landmarks	Station is adjacent to Malls, office spaces and Hospitality establishments. Pune International Airport is located about 3km from the station.		
Connectivity	• Station is located along important corridor, i.e. Nagar Road. • Airport is located at about 3km from station. • Connectivity to nearby catchment by, IPT and PT • Connectivity with proposed PMC HCMTR		
Entry/Exit	Four (04) entries are planned on either side of station		
Issue	• Station is located near Viman Nagar Junction and a Mall. • Dead wall and Defense area along EE2 • Narrow footpath along EE2		
Challenges	• Land requirement at EE2 • Traffic Management at Viman Nagar Junction		

Viman Nagar Metro Station





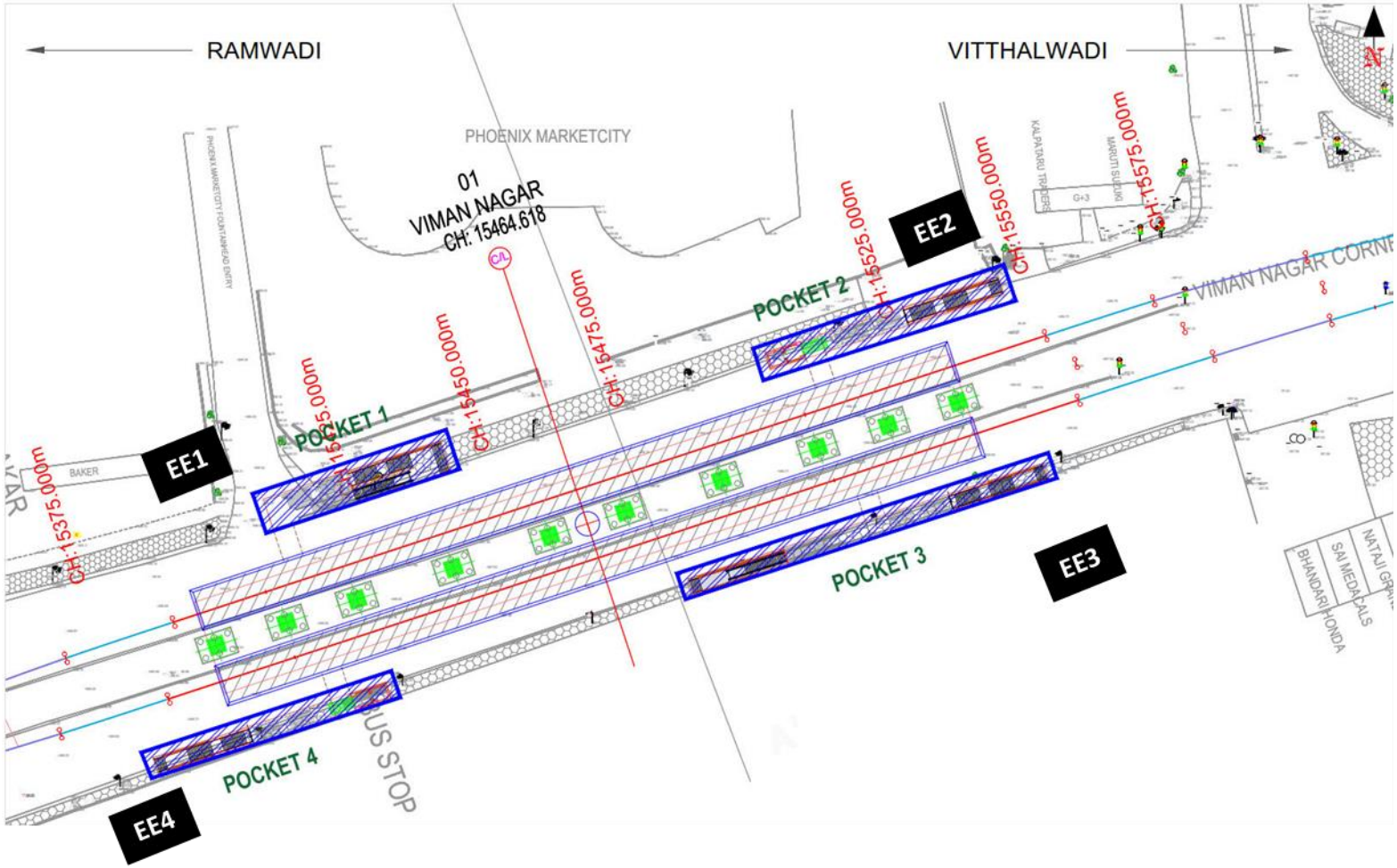


FIGURE 6-18: METRO ALIGNMENT THROUGH VIMAN NAGAR METRO STATION

2. Somnath Nagar Station

TABLE 6-12: DETAILS OF SOMNATH NAGAR METRO STATION

Somnath Nagar Metro Station			
Chainage (m)	16700.889		
Ground Level (m)	573.78		
Rail Level (m)	587.00		
Interstation Distance (m)	Viman Nagar	Somnath Nagar	Kharadi Bypass
	1236	0	901
Station Type	Elevated – Type A		
Location	On Nagar Road (Tata Guard Room BRT Station)		
Catchment Area	The major source of passenger trip generation around this station are residential areas of Somnath Nagar, Chandan Nagar, Wadgaon Sheri etc. along the Nagar Road.		
Surrounding Land use	The surrounding area is a predominantly Residential		
Landmarks	Station is located near the Air Force Station and Tata Guard Room BRTS Station		
Connectivity	• Connectivity to nearby catchment through PT and IPT • Wider Footpath and cycle track for NMT connectivity • Interchange between Somnath nagar and Tata Guard Room.		
Entry/Exit	Two (02) Entry structures have been planned		
Issue	• Dead wall of defense land along EE1 • Integration/ Interchange with BRTS		

Somnath Nagar Metro Station

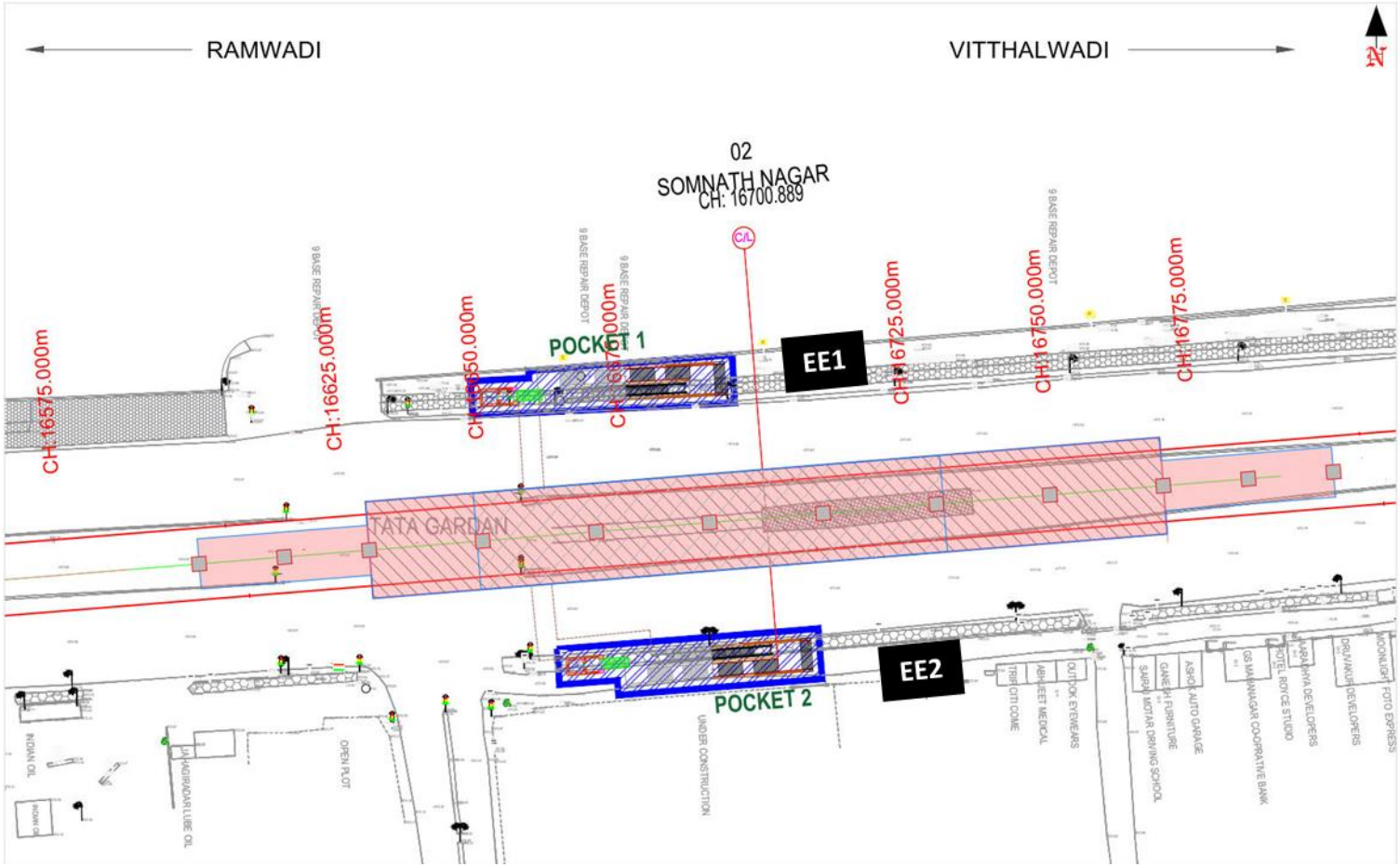
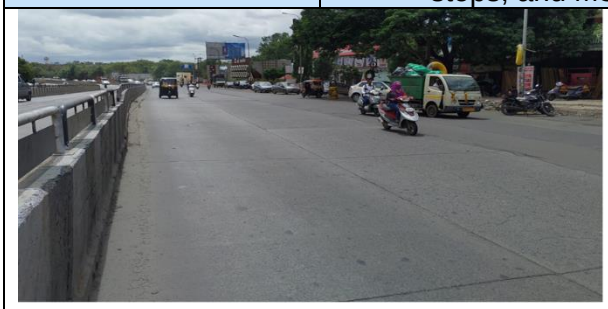
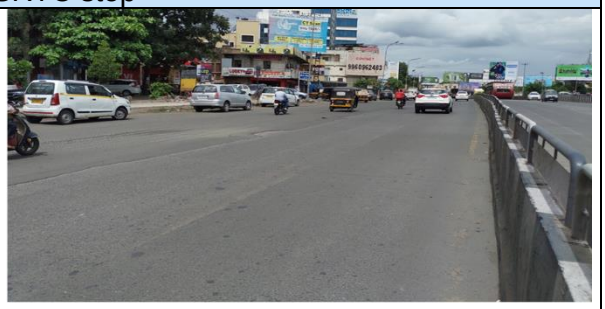


FIGURE 6-19: METRO ALIGNMENT THROUGH SOMNATH NAGAR METRO STATION

3. Kharadi Bypass Metro Station

TABLE 6-13: DETAILS OF KHARADI BYPASS METRO STATION

Kharadi Bypass Station			
Chainage (m)	17601.929		
Ground Level (m)	571.06		
Rail Level (m)	585.500		
Interstation Distance (m)	Somnath Nagar	Kharadi Bypass	Tulaja Bhavani
	901	0	1241
Station Type	Elevated (Interchange) – Type C		
Location	On Nagar Road (Kharadi Bypass)		
Catchment Area	The major source of passenger trip generation around this station are residential and commercial establishments along Nagar road and Mundhwa-Kharadi Road.		
Surrounding Land use	The surrounding area is a predominantly Residential and Commercial along with few institutional land uses comprising of hospitals.		
Landmarks	Station is located near the Kharadi Bypass, EON Hospital, MSRTC Bus Stop		
Connectivity	• Station is located near Kharadi bypass BRTS Station • Bus Stop for Regional Bus (MSRTC) • Connectivity to Kharadi Area		
Entry-Exit	Four (04) Entry-Exit Structures are planned for the station along with One (01) Entry-Exit structure for FOB connected to Station Concourse.		
Issues	• Located near Kharadi Bypass • Proposed Flyover • Parking at the intersection due to presence of shops, bus stops, and MSRTC stop		

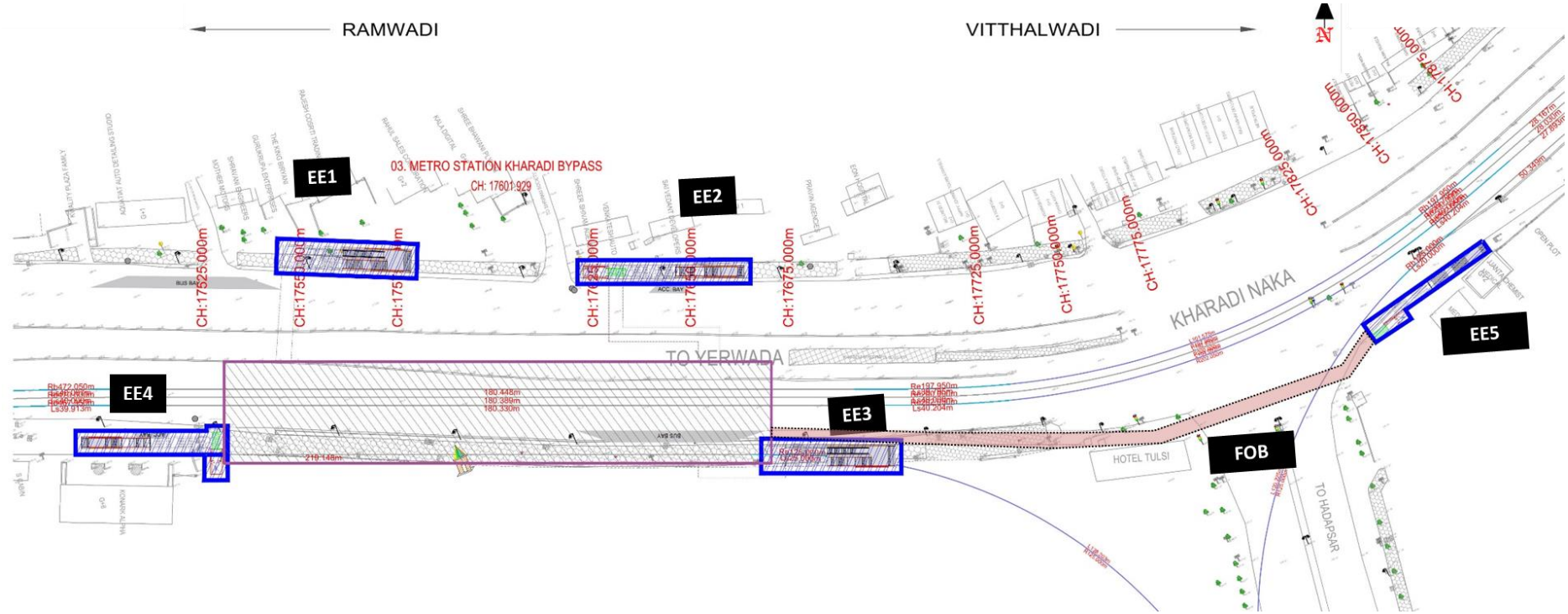


FIGURE 6-20: METRO ALIGNMENT THROUGH KHARADI BYPASS METRO STATION

4. Tulaja Bhavani Metro Station

TABLE 6-14: DETAILS OF TULAJA BHAVANI METRO STATION

Tulaja Bhavani Metro Station			
Chainage (m)	18843.676		
Ground Level (m)	564.15		
Rail Level (m)	580.00		
Interstation Distance (m)	Kharadi Bypass	Tulaja Bhavani	Ubale Nagar
	1241	0	1044
Station Type	Elevated – Type A		
Location	On Nagar Road (Aaple Ghar BRT Station)		
Catchment Area	The major source of passenger trip generation around this station are residential areas of Tulaja Bhavani Nagar located on south side of Nagar Road.		
Surrounding Land use	The surrounding area is a predominantly Residential		
Landmarks	Station is located near the Aaple Ghar Society, Private Bus Parking and Mahalaxmi Lawns.		
Connectivity	• Tulaja Bhavani Nagar • Bus Parking (Wagheshwar Parking) for Private Regional Buses • Aaple Ghar BRTS Station		
Entry-Exit	Two (02) Entry Structures are planned on either side of station		
Issues	Lack of Pedestrian and NMT Facilities on Tulaja Bhavani Nagar Side		

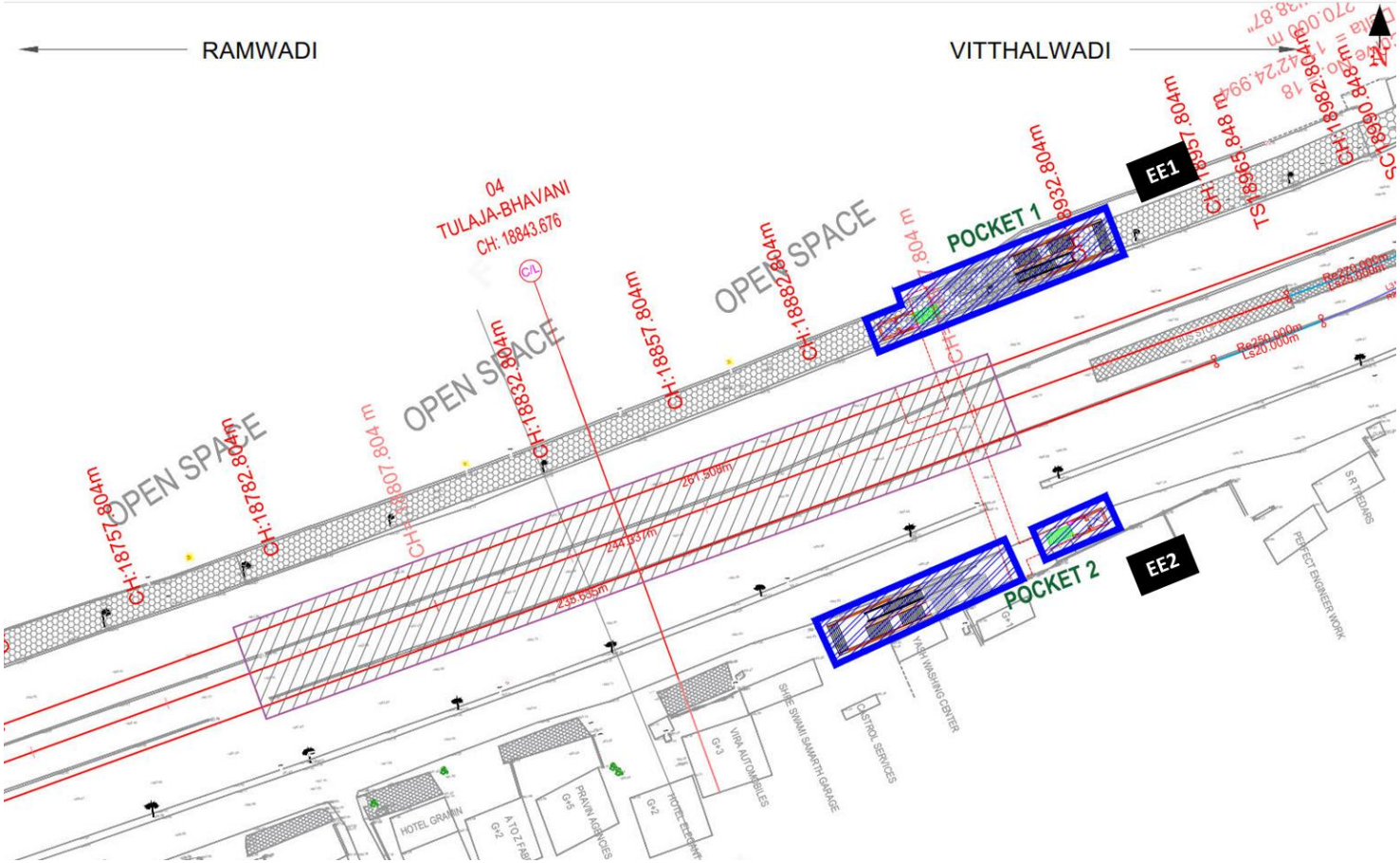


FIGURE 6-21: METRO ALIGNMENT THROUGH TULAJA BHAVANI METRO STATION

5. Ubale Nagar Metro Station

TABLE 6-15: DETAILS OF UBALE NAGAR METRO STATION

Ubale Nagar Metro Station			
Chainage (m)	19888.269		
Ground Level (m)	575.48		
Rail Level (m)	591.00		
Interstation Distance (m)	Tulaja Bhavani	Ubale Nagar	Upper Kharadi Road
	1044	0	1042
Station Type	Elevated – Type A		
Location	On Nagar Road (Ubale Nagar)		
Catchment Area	The major source of passenger trip generation around this station are residential areas of Ubale Nagar, Khandve and surrounding Industrial establishments.		
Surrounding Land use	The surrounding area is a mix of Residential and commercial.		
Connectivity	• Connectivity to the catchment through PT and IPT. • NMT facilities proposed for development		
Entry-Exit	Two (02) Entry Structures are planned		
Issues	• Lack of Pedestrian and NMT Facilities		

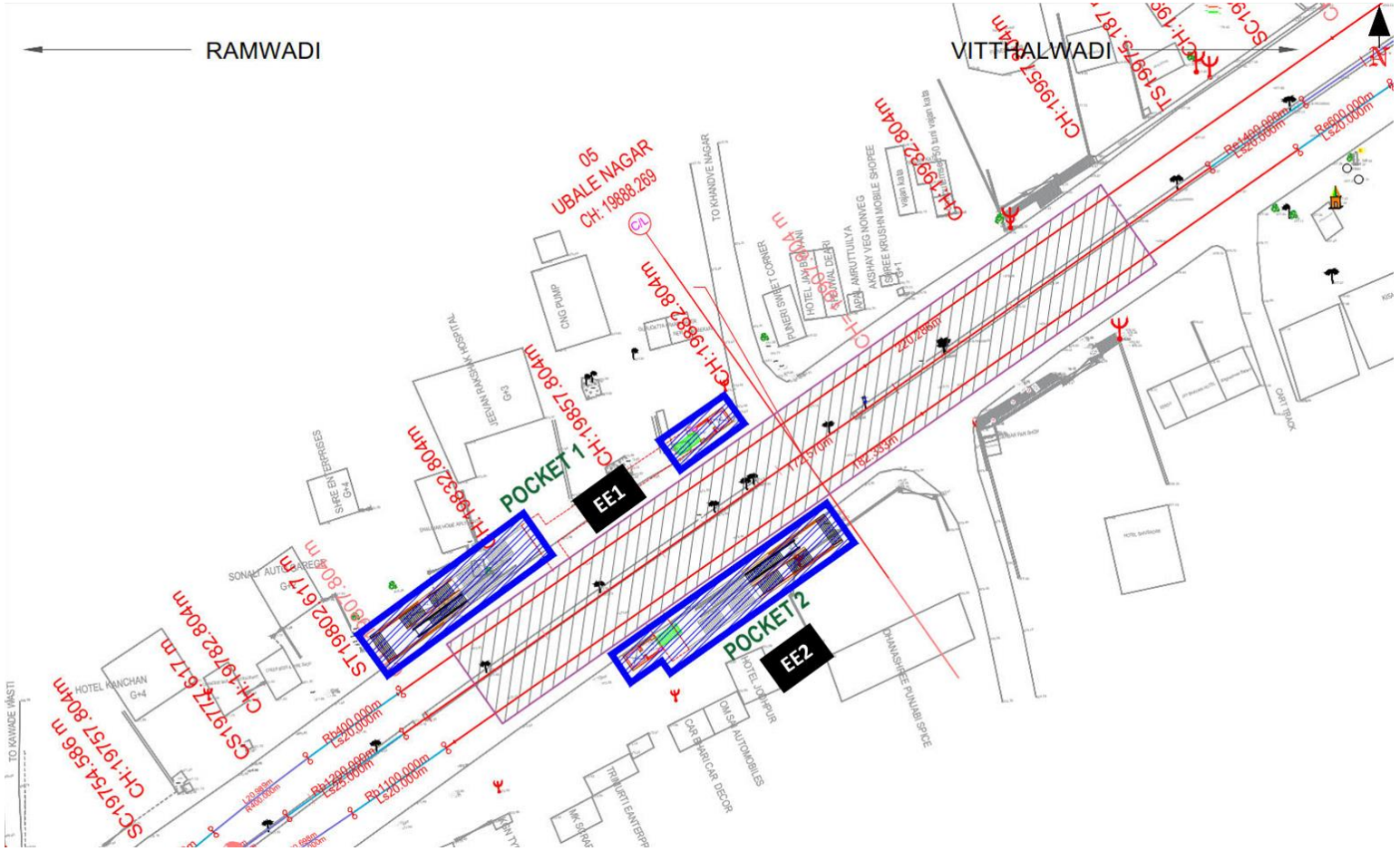


FIGURE 6-22: METRO ALIGNMENT THROUGH UBALE NAGAR METRO STATION

6. Upper Kharadi Road Metro Station

TABLE 6-16: DETAILS OF UPPER KHARADI ROAD METRO STATION

Upper Kharadi Road Metro Station			
Chainage (m)	20930.634		
Ground Level (m)	574.31		
Rail Level (m)	589.00		
Interstation Distance (m)	Ubale Nagar	Upper Kharadi Road	Wagheshwar Temple
	1042	0	1381
Station Type	Elevated – Type A		
Location	On Nagar Road		
Catchment Area	The major source of passenger trip generation around this station are upcoming nearby residential areas and industrial/warehouse establishments		
Surrounding Land use	The surrounding area is a predominantly Residential.		
Landmarks	Gagan Honda, Talera Warehouse, Reliance Mart		
Connectivity	• Connectivity to the catchment through PT and IPT. • NMT facilities proposed for development		
Entry-Exit	• Two (02) Entry Structures are planned		
Issues	• Lack of Pedestrian and NMT Facilities		

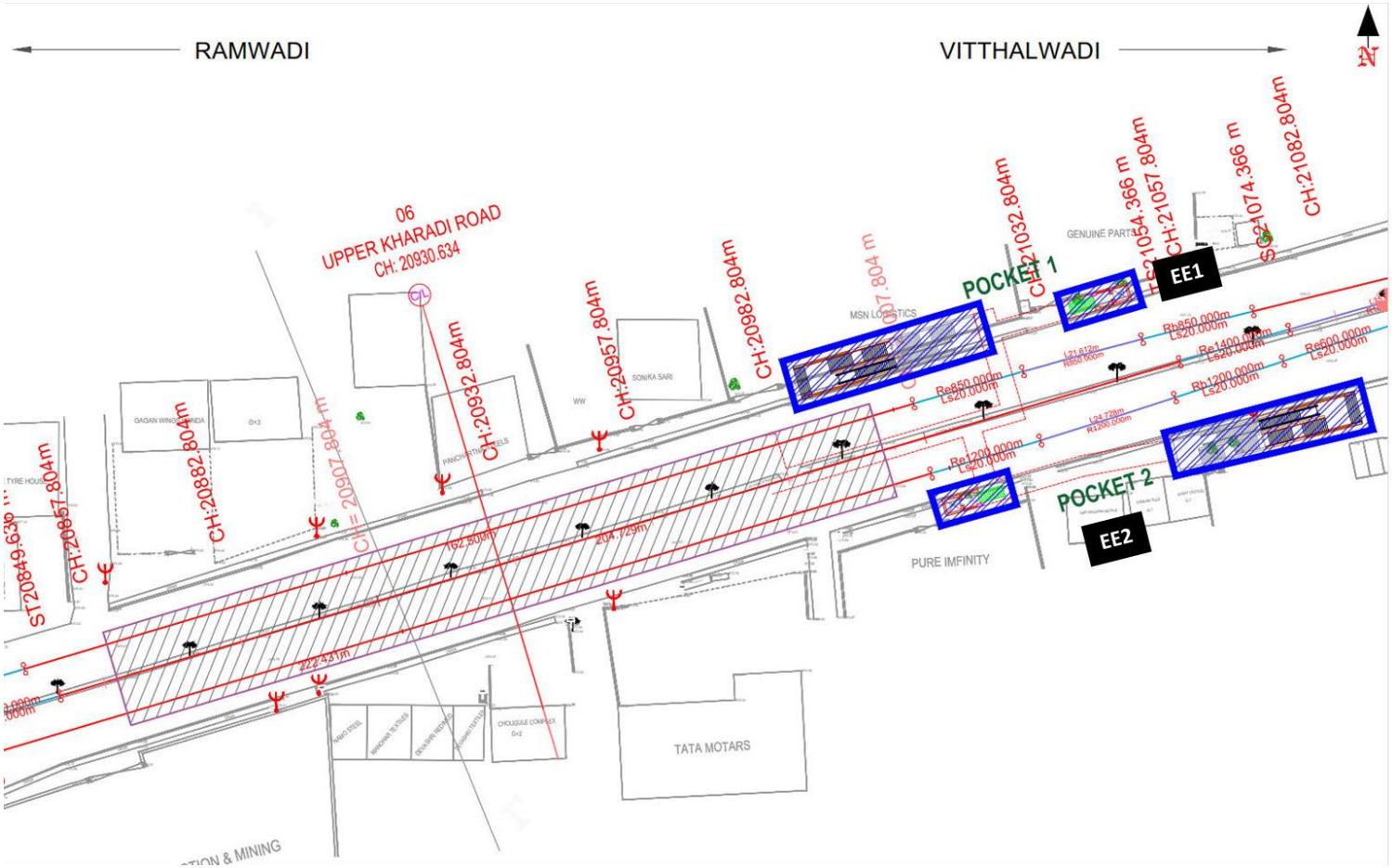
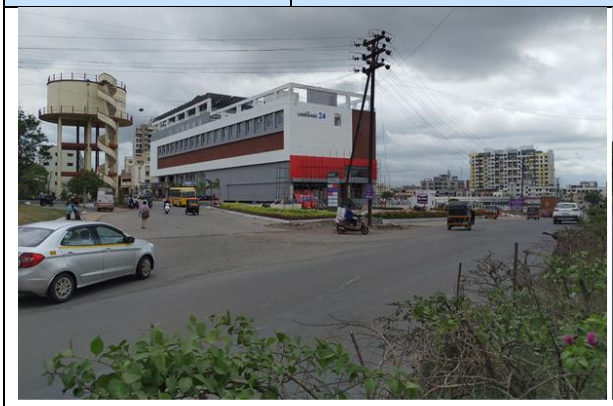
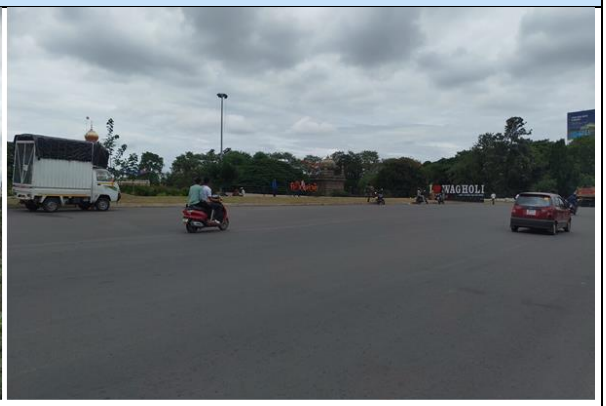


FIGURE 6-23: METRO ALIGNMENT THROUGH UPPER KHARADI ROAD METRO STATION

7. Wagheshwar Temple Metro Station

TABLE 6-17: DETAILS OF WAGHESHWAR TEMPLE METRO STATION

Wagheshwar Temple Metro Station			
Chainage (m)	22312.06		
Ground Level (m)	572.03		
Rail Level (m)	588.00		
Interstation Distance (m)	Upper Kharadi Road	Wagheshwar Temple	Wagholi
	1381	0	957
Station Type	Elevated – Type B		
Location	On Nagar Road (Wagheshwar Temple)		
Catchment Area	The major source of passenger trip generation around this station are residential areas, Institutional and commercial establishments in the catchment. Station is also located near The Wagheshwar Temple		
Surrounding Land use	The surrounding area is a predominantly Residential, Institutional and commercial		
Landmarks	Station is located near the Wagheshwar Temple, Satav High School and Moze College.		
Connectivity	Through PT and IPT		
Entry-Exit	Four (04) Entry Structures are planned for station		
Issues	• Located near the intersection of Nagar road and Wagholi-Lohagaon Road • Lack of pedestrian and NMT facilities • On Street Parking on Nagar Road		

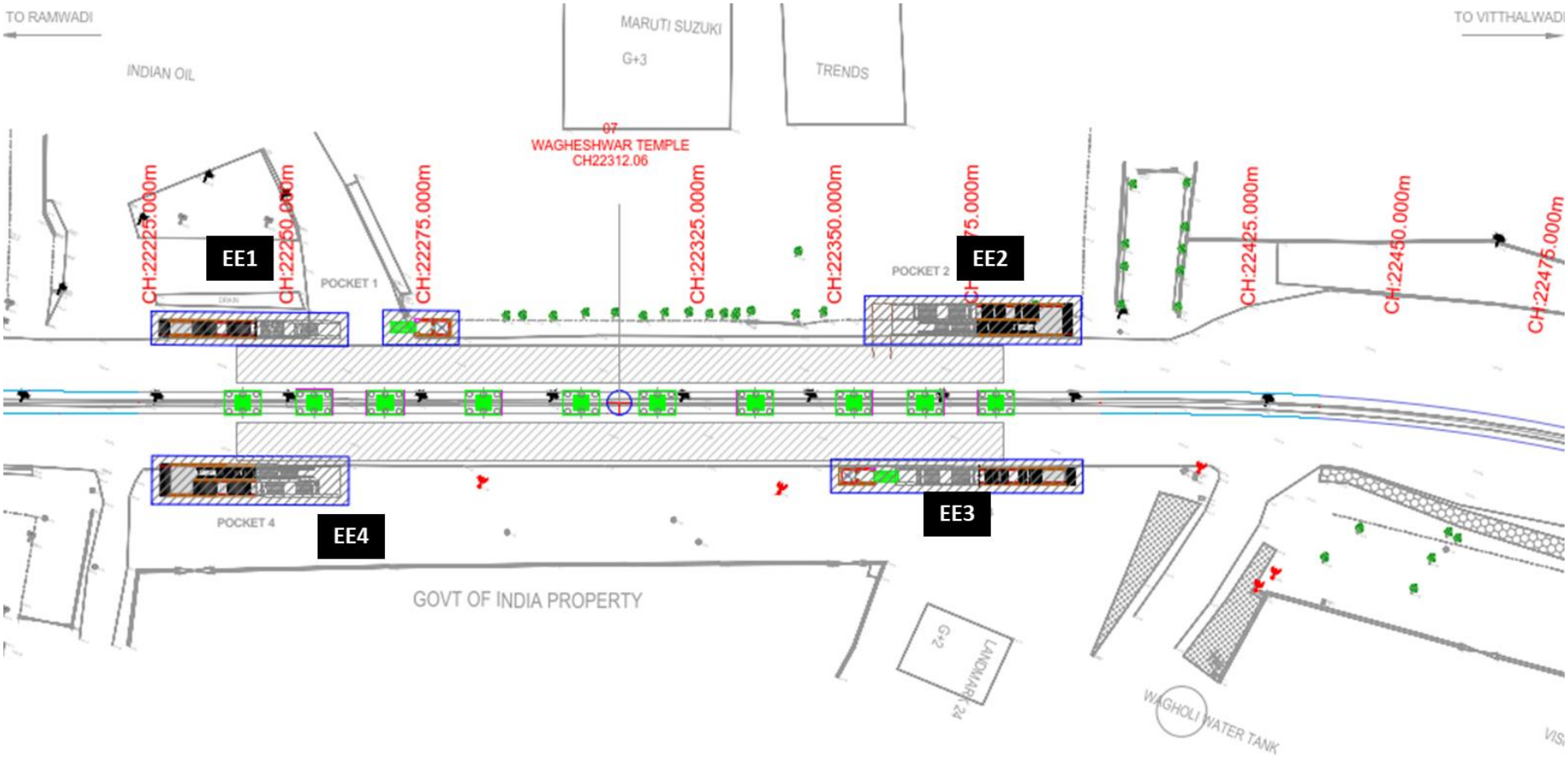


FIGURE 6-24: METRO ALIGNMENT THROUGH WAGHESHWAR TEMPLE METRO STATION

8. Wagholi Metro Station

TABLE 6-18: DETAILS OF WAGHOLI METRO STATION

Wagholi Metro Station			
Chainage (m)	23269.317		
Ground Level (m)	581.02		
Rail Level (m)	596.00		
Interstation Distance (m)	Wagheshwar Temple	Wagholi	Siddharth Nagar
	957	0	818
Station Type	Elevated – Type B		
Location	On Nagar Road (Wagholi Market)		
Catchment Area	The major source of passenger trip generation around this station are residential areas of Wagholi and commercial establishments along the Nagar Road. Station catchment also includes the institutions such as Raisoni College of Engineering, Vegetable Market, PMPML Stop etc.		
Surrounding Land use	The surrounding area is a predominantly Residential and Commercial		
Landmarks	Station is located near the Wagholi Vegetable Market.		
Connectivity	• PT and IPT connectivity to catchment • PMPML Depot located near the station		
Entry-Exit	Four (04) Entry Structures planned for the station		
Issues	• Located in the congested area of Wagholi • LCV and Freight traffic due to presence of Vegetable Market • Lack of Pedestrian and NMT Facilities		

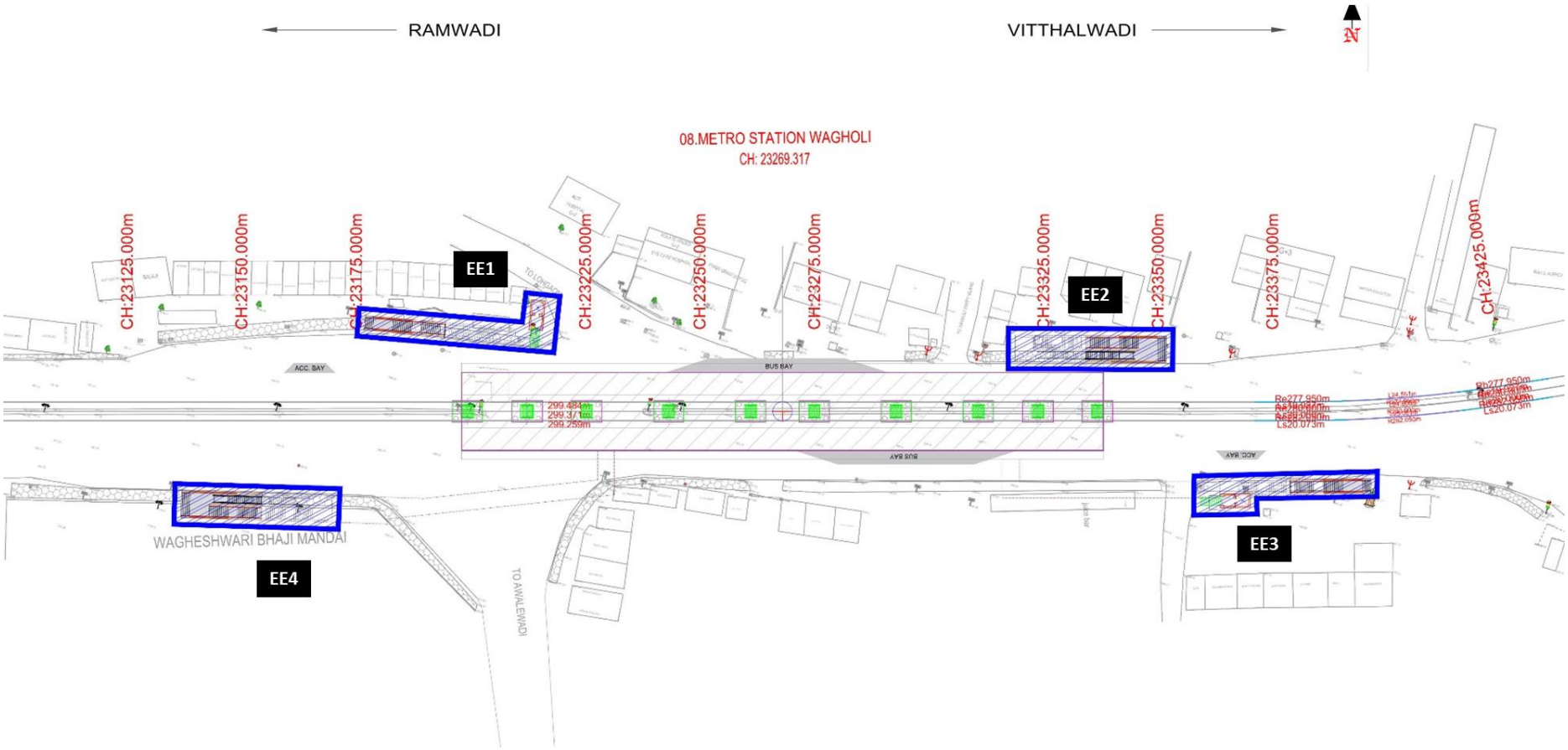


FIGURE 6-25: METRO ALIGNMENT THROUGH WAGHOLI METRO STATION

9. Siddharth Nagar Metro Station

TABLE 6-19: DETAILS OF SIDDHARTH NAGAR METRO STATION

Siddharth Nagar Metro Station			
Chainage (m)	24087.658		
Ground Level (m)	583.05		
Rail Level (m)	598.00		
Interstation Distance (m)	Wagholi	Siddharth Nagar	Bakori Phata
	818	0	860
Station Type	Elevated – Type A		
Location	On Nagar Road (Silver Crest)		
Catchment Area	The major source of passenger trip generation around this station are residential areas of along the Nagar Road. Catchment also includes the JSPM college and Bhivarabai Sawant Institute Of Technology And Research		
Surrounding Land use	The surrounding area is a predominantly Residential		
Landmarks	Station is located near the Silver Crest Apartment		
Connectivity	Connectivity through PT and IPT		
Entry-Exit	Two (02) Entry Structures proposed for the station		
Issues	Lack of Pedestrian and NMT Facility		

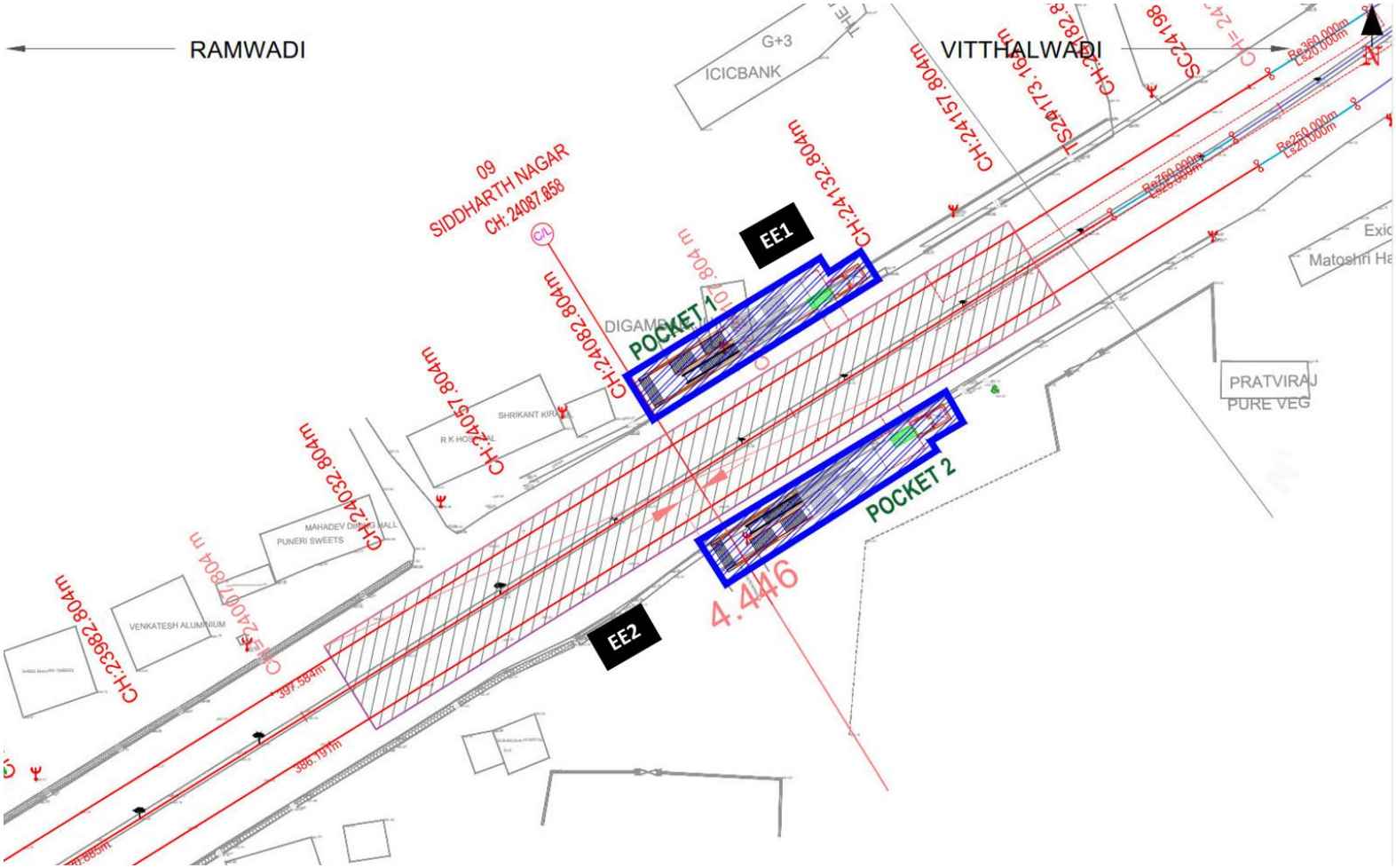
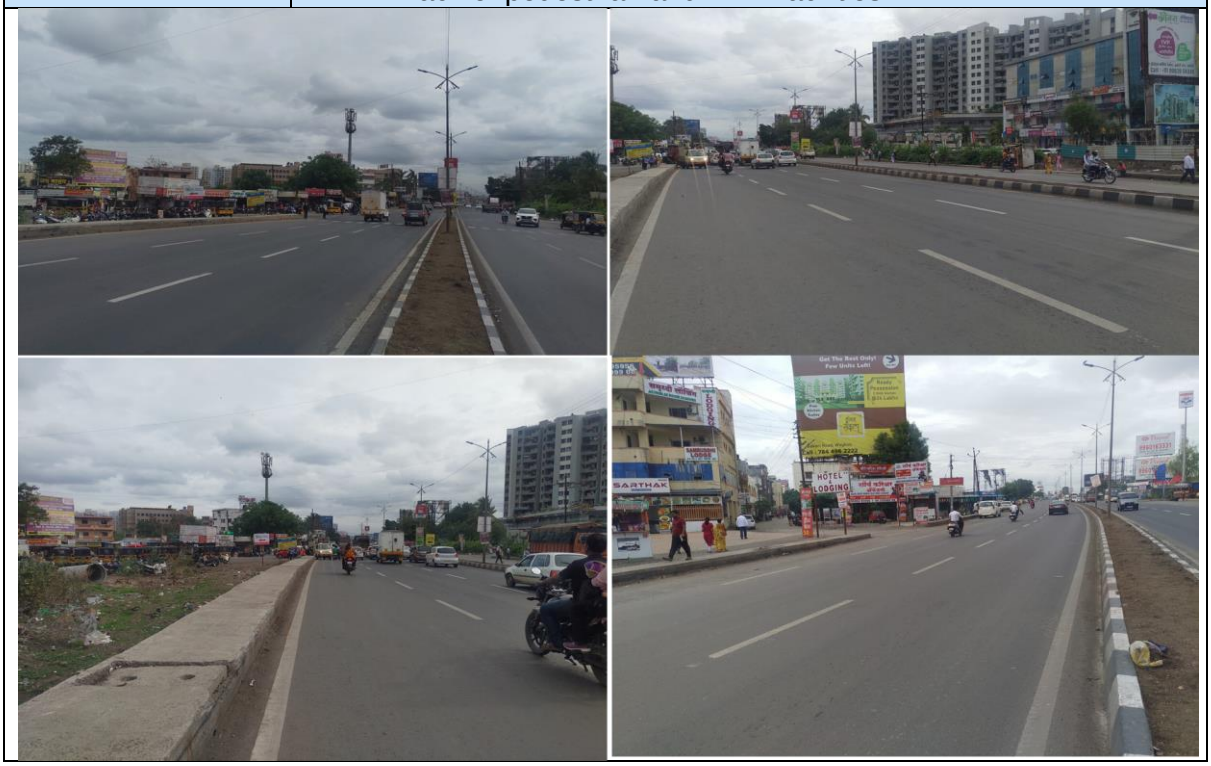


FIGURE 6-26: METRO ALIGNMENT THROUGH SIDDHARTH NAGAR METRO STATION

10. Bakori Phata Metro Station

TABLE 6-20: DETAILS OF BAKORI PHATA METRO STATION

Bakori Phata Metro Station			
Chainage (m)	24948.286		
Ground Level (m)	591.33		
Rail Level (m)	604.5		
Interstation Distance (m)	Siddharth Nagar	Bakori Phata	Vitthalwadi
	860	0	1284
Station Type	Elevated – Type A		
Location	On Nagar Road (Bakori Phata)		
Catchment Area	The major source of passenger trip generation around this station are residential, commercial and Institutional areas of along the Nagar Road. Catchment includes the Bharatiya Jain Sanghatana's Arts, Commerce & Science College, Lexicon School etc.		
Surrounding Land use	The surrounding area is a predominantly Residential		
Landmarks	Station is located near the Bakori Phata, Bharatiya Jain Sanghatana's Arts, Commerce & Science College, Lexicon School etc.		
Connectivity	Connectivity through PT and IPT		
Entry-Exit	Two (02) Entry Structures are planned for the station		
Issues	• Located near Institutional Landuse, thus road safety concerns during construction. • Lack of pedestrian and NMT facilities		



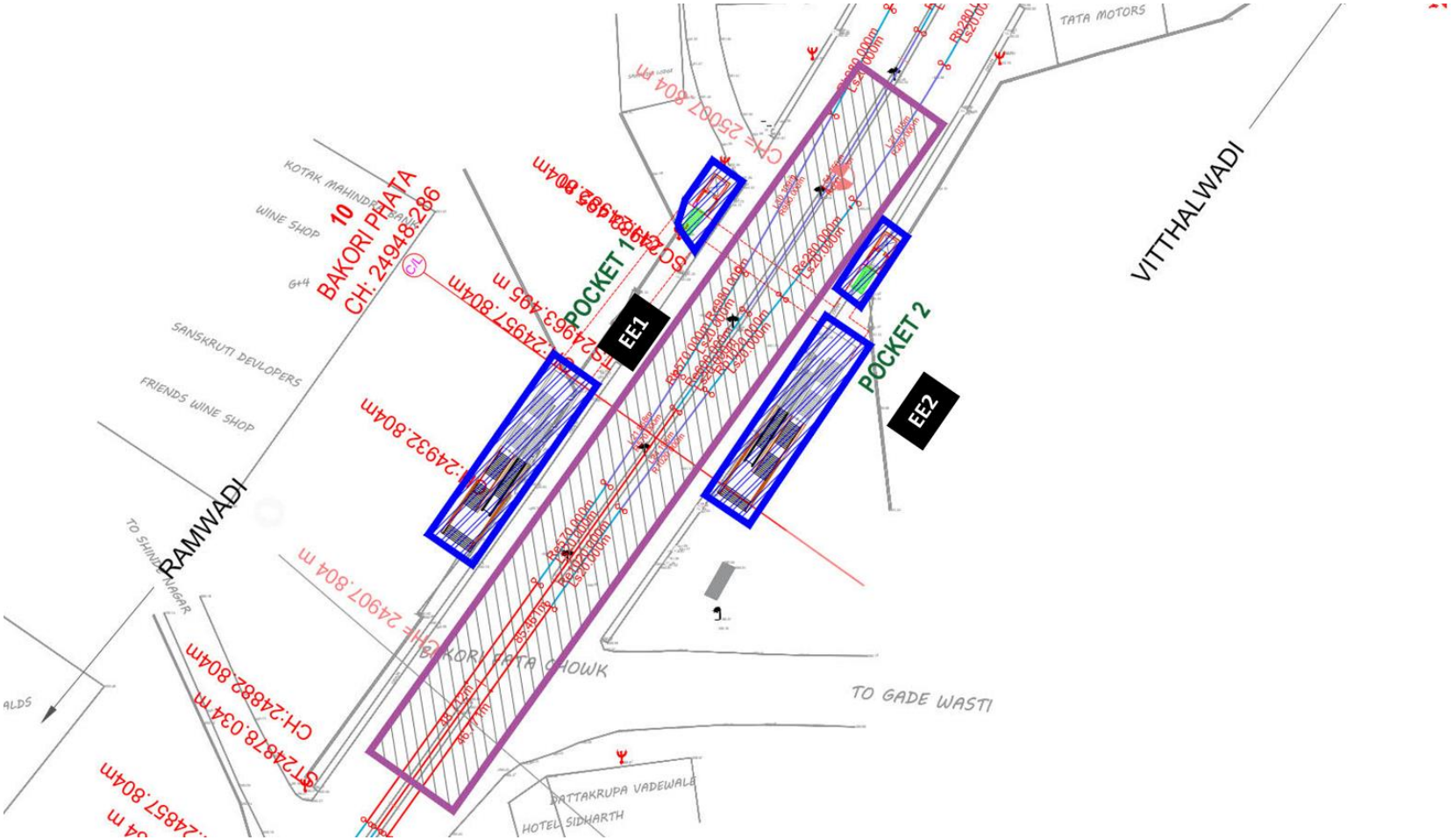


FIGURE 6-27: METRO ALIGNMENT THROUGH BAKORI PHATA METRO STATION

11. Vitthalwadi Metro Station

TABLE 6-21: DETAILS OF VITTHALWADI METRO STATION

Vitthalwadi Station			
Chainage (m)	26232.966		
Ground Level (m)	595.21		
Rail Level (m)	615.00		
Interstation Distance (m)	Bakori Phata	Vitthalwadi	End Chainage
	1284	0	392
Station Type	Elevated – Type B		
Location	On Nagar Road (Shell Petrol Pump)		
Catchment Area	The major source of passenger trip generation around this station are Industrial areas.		
Surrounding Land use	The surrounding area is a predominantly Industrial areas which includes warehouses followed by mix of residential and commercial establishments		
Landmarks	Station is located near the Shell Petrol Pump, Wagheshwar Warehouse.		
Connectivity	Connectivity through PT and IPT		
Entry-Exit	Four (04) Entry Structures are planned for the station		
Issues	• Located near Industrial Landuse and open space • Lack of pedestrian and NMT facilities		

FIGURE 6-28: METRO ALIGNMENT THROUGH VITTHALWADI METRO STATION

6.2. STATION AREA PLANNING FOR NON-MOTORIZED VEHICLE AND PEDESTRIANS FACILITIES:

Non-Motorised Transport (NMT) and Pedestrians have been given priority while designing the station areas. following facilities have been proposed near the station.

- Adequate footpath (min. 1.8m to 2m) at all entries to accommodate the faster dispersal of commuters.
- Dedicated Cycle track of 2.2m along the corridor.
- Drop off bays for Specially-abled Commuters, Feeder buses, City Buses, IPT as well as private vehicles have been proposed near all entry exits.
- Specially-abled drop offs are planned close to the elevators. PT and Feeder bus drop offs have been given priority and planned nearest to the station followed by IPT and private vehicles.
- The facilities planned and implemented in Phase 1 of Pune Metro have been presented in Figure 6-29.

FIGURE 6-29: PLANNING FOR NON-MOTORIZED VEHICLE AND PEDESTRIAN FACILITIES

- All the footpaths in station influence zone have been planned to be upgraded to desired level of comfort and also proposed new within the stations vicinity areas. The existing road shoulder areas and service lanes also have been augmented/ strengthened in the design wherever possible to utilize the complete ROW to cater to the future traffic volume.

- Junction improvement is also proposed for the nearest major junctions of the station.
- The details of the planning for Non-Motorized Vehicle and pedestrian facilities have been presented in detail in Chapter 7.3 in Intermodal Integration.

6.3. ACCESSIBILITY FOR SPECIALLY-ABLED

It is essential that all facilities planned at the station are to be Universally Accessible. Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons-1998 and revised in 2013 by Ministry of Home and Urban Affairs and IRC SP 117-2018 provide the Guidelines Universal Accessibility Designs.

Signage planning considering clear, concise, and consistent fonts to be adopted. All travellers need clear information about the purpose and layout of stations to maintain a sense of direction and independent use of all facilities. Using internationally and nationally established symbols and pictograms with clear lettering and 'Braille' ensures universal accessibility cutting across regional/cultural and language barriers. A cohesive information and signage system can provide visual (e.g. signs, notice boards), audible (e.g. public address and security systems, induction loops, telephones, and infrared devices), and/ or tactile information (e.g. signs with embossed lettering or Braille). The international symbol of accessibility is shown in Figure 6-30.

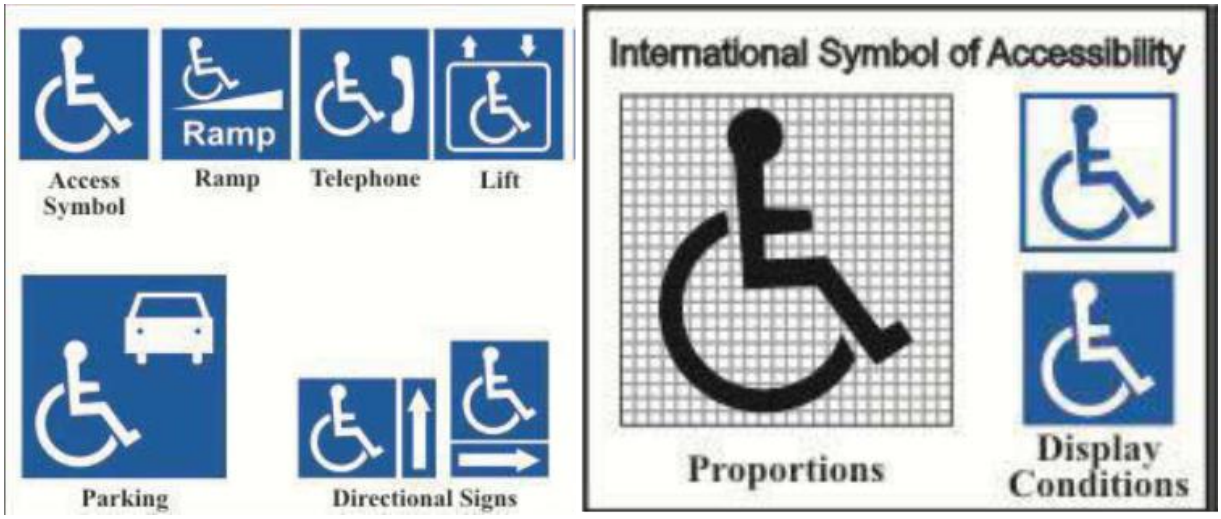


FIGURE 6-30: DISABLED FRIENDLY FEATURES

6.3.1. TACTILE PAVING- GUIDING & WARNING

a) Tactile Guiding Paver (Line-Type)

It is recommended to install a row of tactile guidance paver along the entire length of the proposed accessible route for visual impaired persons. Care must be taken to ensure that there are no obstacles, such as wall, pillar, uneven surfaces, Soffit (underside /open area under the stairs etc. along the route traversed by the

guidance paver. Also, there should be clear headroom of at least 2.1 m height above the tactile guidance paver, free of protruding objects such as overhanging advertisement panel and signage, along the entire length of the walk.

b) Tactile Warning Paver (Dot-Type)

These pavers indicate an approaching potential hazard or a change in direction of the walkway and serve as a warning of the approaching danger to persons with visual impairments, preparing them to tread cautiously and expect obstacles along the travel path, traffic intersections, doorways, stairs, etc. They are used to screen off obstacles, drop-offs or other hazards, to discourage movement in an incorrect direction and to warn of a corner or junction. Two rows of tactile warning paver should be installed across the entire width of the designated accessible passenger pathway at appropriate places such as before intersections, terminal entrances, obstacles such as signage, and each time the walkway changes direction.

6.3.2. PLACES TO INSTALL WARNING PAVER

- In front of an area where traffic is present.
- In front of an entrance/exit to and from a staircase or multi-level crossing facility.
- Entrances/exits metro stations or boarding areas.
- Guiding & warning tactile paving for metro systems are shown in the Figure 6-31.

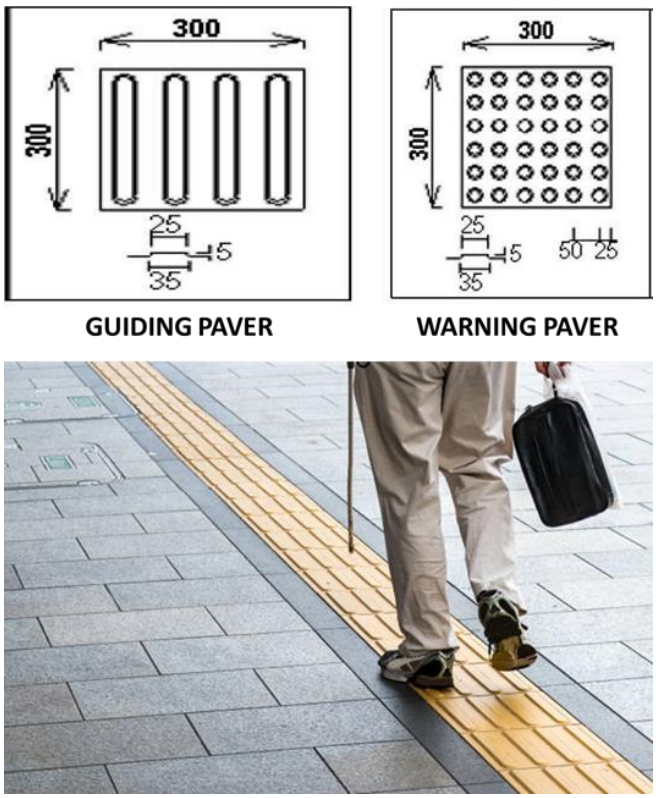


FIGURE 6-31: TACTILE FLOORING

Universally accessible designs are also proposed in the station area at the road level. Dedicated Drop off bays for Specially-abled commuters have been planned near to the Elevators and access ramps are proposed for the wheelchair access. Tactile is proposed on the footpath for the visually impaired commuters for way finding. Table top crossings have been proposed at the smaller cross roads and property entrances to maintain the continuity in footpath where as rams are proposed at the major intersection.

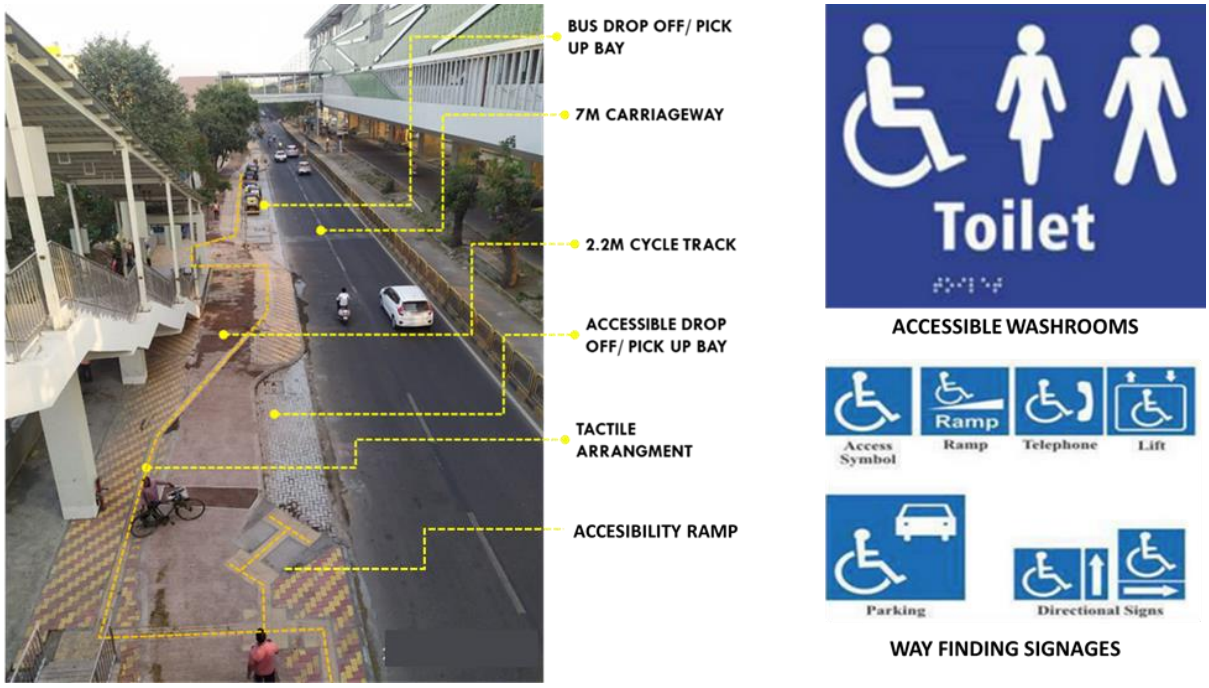


FIGURE 6-32: ACCESSIBILITY FOR SPECIALLY-ABLED

6.4. PARKING AT STATION

Commuters are expected to utilize various modes to reach metro stations. Parking is one of the essential component of the station area. It is however noted that Private Parking is discouraged and use of PT, IPT, Cycle is encouraged. Drop off bays are proposed at every station for city buses and IPT to cater the last mile connectivity to the station. In addition to the existing PT services feeder systems are also proposed to provide the connectivity within 2.5 km radius of Station catchment.

These arrangements can reduce the parking needs at the station. Limited parking for private vehicles can be provided subject to the availability of spaces.

Cross roads can also be utilized for providing On-street parking along the proposed corridors.

Open land parcels belonging to the Government Agencies are identified along the corridor and proposed to be developed under TOD for Non-Fare box revenues. It is proposed that

part of area should be reserved for parking of Metro Commuters. Details of the same are presented in Table 6-22.

TABLE 6-22: DETAILS OF LAND IDENTIFIED FOR THE TOD

S. No	Station Name	Area Name	Area (Ha)	Parking Area (sqm)	Survey Number	Ownership	Rate
1	Wagheshwar Temple	Wagheshwar Garden	5.5	1560	1415	Govt	15600
2	Wagholi	Talathi Office	1.8	1040	1123	Govt	10210
3	Wagholi	Vegetable Market	14	2600	1123	Govt	10210
Total			21.3				

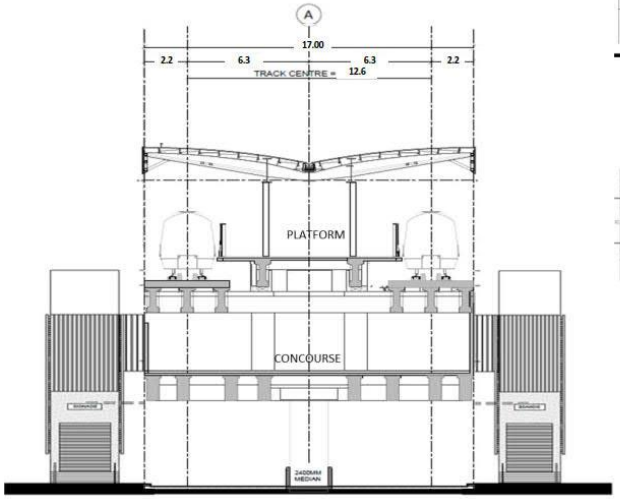
ANNEXURE 6.1: EGRESS CALCULATIONS

Emergency Evacuation Requirements_Type A (Siddharth Nagar)			Peak Hr. (2057)		
Emergency Egress from Platform to Concourse			Boarding	Alighting	
Type A (Island Platform)			2228	142	
System Interval (SI)	4	min			
F= peak minute flow	35	passengers			
Train crush Load	1574	passengers			
Egress Element	**Number**	**Width**	**Total width in mm**	**p/mm-min**	**p/min**
Platform to Concourse (Upwards)					
Public Area stairs (2)	1.00	3600.00	3600.00	0.055	198.00
Escalators (4) - *One escaltor out of service*	1.00	1000.00	1000.00	0.135	135.00
Knock Down Staircase	0.00	0.00	0.00	0.055	0.00
Emergency Stairs (2)	1.00	1500.00	1500.00	0.055	82.50
					415.50
Throughfare barriers					
Entry/Exit Gates (Capacity 50 persons)	8		0.00	50.00	400.00
Disabled Gates (Capacity 50 persons)	2		0.00	50.00	100.00
Service Gates (Capacity 60 persons)	0	1200.00	0.00	60.00	0.00
					500.00
Fare Barriers to safe area (Downwards)					
Stairs	2	2400.00	4800.00	0.060	288.00
Escalators	2	1000.00	2000.00	0.135	270.00
Emergency Stairs	0	1800.00	0.00	0.060	0.00
					558.00
Walking time for longest distance route					
Platform to safe area			**Meter**	**m/min**	***min***
On Platform T1			45.00	38.00	1.18
Platform to Concourse T2			17.53	14.60	1.20
Concourse to safe area T3			40.00	38.00	1.05
Total walking time T=T1+T2+T3					3.44
(NBC 2016 Clause J-5.1b)					
TEST 1 - Evacuate platform occupant load to concourse in *5.5 minutes or less*					
Evacuating Passengers in Emergency = (3 x SI x F)+TL					
Emergency Platform Occupant Load	**1991.08**	**Persons**			
Total time to evacuate the passengers	5.50	**Minutes**			
Platform exit capacity=	**415.50**				
Fp (Time to clear Platform) =	Platform Ocupant load / Platform exit capacity				
Fp	4.79				
(NBC 2016 Clause J-5.1c)					
TEST 2 - Evacuate Platform occupant load from most remote point on platform to point of safety in *8 minutes or less*					
Wp (waiting time at platform exits) = Fp-T1	3.61	**minutes**			
Concourse occupant load = Platform occupant load - (Fp x emergency stairs capacity)	1595.74	**persons**			
Ffb (Fare barrier flow time) = Concourse occupant load / Fare barrier exit capacity	3.19				
Wf (Waiting time at fare barrier) = Ffb - Fp (cannot be less than zero)	0.00	**minutes**	-1.60		
Fc (Concourse exit flow time) = Concourse Occupant load / Concourse exit capacity	2.86	**minutes**			
Wc (waiting time at concourse exits) = [Fc - max(Ffb or Fp)]	0.00	**minutes**	-0.33		
Total Exit time = T+ Wp + Wf + Wc	7.05	**OK**			

Emergency Evacuation Requirements_Type B			Peak Hr. (2057)		
Emergency Egress from Platform to Concourse			Boarding	Alighting	
Type B (Side Platform)			5281	4347	
System Interval (SI)	4	min			
F= peak minute flow	82	passengers			
Train crush Load	1574	passengers			
Egress Element	**Number**	**Width**	**Total width in mm**	**p/mm-min**	**p/min**
Platform to Concourse (Upwards)					
Public Area stairs (2)	3.00	2400.00	7200.00	0.055	396.00
Escalators (4) - *One escaltor out of service*	1.00	1000.00	1000.00	0.135	135.00
Knock Down Staircase	0.00	0.00	0.00	0.055	0.00
Emergency Stairs (2)		1800.00	0.00	0.055	0.00
					531.00
Throughfare barriers					
Entry/Exit Gates (Capacity 50 persons)	6		0.00	50.00	300.00
Disabled Gates (Capacity 50 persons)	2		0.00	50.00	100.00
Service Gates (Capacity 60 persons)	2	1200.00	2400.00	60.00	120.00
					520.00
Fare Barriers to safe area (Downwards)					
Stairs	4	2400.00	9600.00	0.060	576.00
Escalators	2	1000.00	2000.00	0.135	270.00
Emergency Stairs	0	1800.00	0.00	0.060	0.00
					846.00
Walking time for longest distance route					
Platform to safe area			**Meter**	**m/min**	***min***
On Platform T1			45.00	38.00	1.18
Platform to Concourse T2			17.53	14.60	1.20
Concourse to safe area T3			40.00	38.00	1.05
Total walking time T=T1+T2+T3					3.44
(NBC 2016 Clause J-5.1b)					
TEST 1 - Evacuate platform occupant load to concourse in *5.5 minutes or less*					
Evacuating Passengers in Emergency = (3 x SI x F)+TL					
Emergency Platform Occupant Load	**2562.60**	**Persons**			
Total time to evacuate the passengers	5.50	**Minutes**			
Platform exit capacity=	**531.00**				
Fp (Time to clear Platform) =	Platform Ocupant load / Platform exit capacity				
Fp	4.83				
(NBC 2016 Clause J-5.1c)					
TEST 2 - Evacuate Platform occupant load from most remote point on platform to point of safety in *8 minutes or less*					
Wp (waiting time at platform exits) = Fp-T1	3.64	**minutes**			
Concourse occupant load = Platform occupant load - (Fp x emergency stairs capacity)	2562.60	**persons**			
Ffb (Fare barrier flow time) = Concourse occupant load / Fare barrier exit capacity	4.93				
Wf (Waiting time at fare barrier) = Ffb - Fp (cannot be less than zero)	0.00	**minutes**	0.10		
Fc (Concourse exit flow time) = Concourse Occupant load / Concourse exit capacity	3.03	**minutes**			
Wc (waiting time at concourse exits) = [Fc - max(Ffb or Fp)]	0.00	**minutes**	-1.90		
Total Exit time = T+ Wp + Wf + Wc	7.08	**OK**			

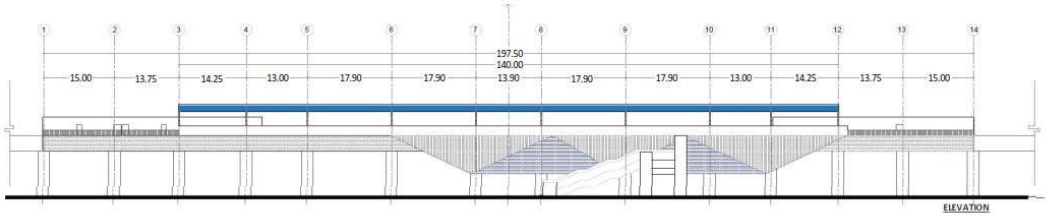
Emergency Evacuation Requirements_Type C (KHARADI BYPASS)			Peak Hr. (2057)		
Emergency Egress from Platform to Concourse			Boarding	Alighting	
Type C (Interchange Station)			7214.00	5642.00	
System Interval (SI)	4	min			
F= peak minute flow	188	passengers			
Train crush Load	1574	passengers			
Egress Element	**Number**	**Width**	**Total width in mm**	**p/mm-min**	**p/min**
Platform to Concourse (Upwards)					
Public Area stairs (2)	3.00	3600.00	10800.00	0.055	594.00
Escalators (4) - *One escaltor out of service*	1.00	1000.00	1000.00	0.135	135.00
Knock Down Staircase	0.00	0.00	0.00	0.055	0.00
Emergency Stairs (2)	0.00	1800.00	0.00	0.055	0.00
					729.00
Throughfare barriers					
Entry/Exit Gates (Capacity 50 persons)	8		0.00	50.00	400.00
Disabled Gates (Capacity 50 persons)	2		0.00	50.00	100.00
Service Gates (Capacity 60 persons)	1	1200.00	1200.00	60.00	60.00
					560.00
Fare Barriers to safe area (Downwards)					
Stairs	4	2400.00	9600.00	0.060	576.00
Escalators	2	1000.00	2000.00	0.135	270.00
Emergency Stairs	0	1800.00	0.00	0.060	0.00
					846.00
Walking time for longest distance route					
Platform to safe area			**Meter**	**m/min**	***min***
On Platform T1			45.00	38.00	1.18
Platform to Concourse T2			17.53	14.60	1.20
Concourse to safe area T3			40.00	38.00	1.05
Total walking time T=T1+T2+T3					3.44
(NBC 2016 Clause J-5.1b)					
TEST 1 - Evacuate platform occupant load to concourse in *5.5 minutes or less*					
Evacuating Passengers in Emergency = (3 x SI x F)+TL					
Emergency Platform Occupant Load	**3824.77**	**Persons**			
Total time to evacuate the passengers	5.50	**Minutes**			
Platform exit capacity=	**729.00**				
Fp (Time to clear Platform) =	Platform Ocupant load / Platform exit capacity				
Fp	5.25				
(NBC 2016 Clause J-5.1c)					
TEST 2 - Evacuate Platform occupant load from most remote point on platform to point of safety in *8 minutes or less*					
Wp (waiting time at platform exits) = Fp-T1	4.06	**minutes**			
Concourse occupant load = Platform occupant load - (Fp x emergency stairs capacity)	3824.77	**persons**			
Ffb (Fare barrier flow time) = Concourse occupant load / Fare barrier exit capacity	6.83				
Wf (Waiting time at fare barrier) = Ffb - Fp (cannot be less than zero)	0.00	**minutes**	1.58		
Fc (Concourse exit flow time) = Concourse Occupant load / Concourse exit capacity	4.52	**minutes**			
Wc (waiting time at concourse exits) = [Fc - max(Ffb or Fp)]	0.00	**minutes**	-2.31		
Total Exit time = T+ Wp + Wf + Wc	7.50	**OK**			

Annexure 6.2- Station Layouts

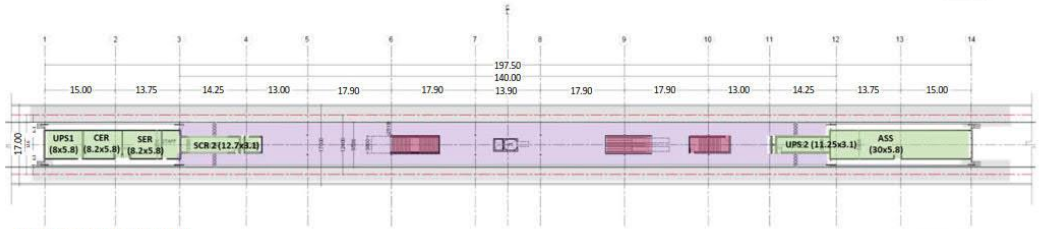


All Dimensions in Meter

CROSS SECTION



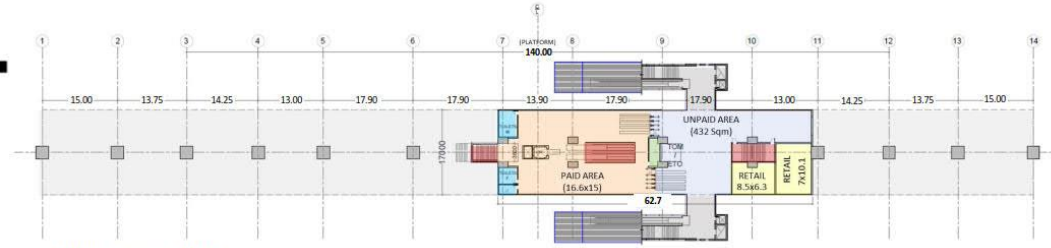
ELEVATION



All Dimensions in Meter

PLATFORM LEVEL PLAN

PAID AREA | TRACKS | OPERATION ROOMS | RETAIL
UNPAID AREA | STRICASE / ESCALATOR | TOILETS | PLATFORM



All Dimensions in Meter

PAID AREA | ENTRY/EXITS | OPERATION ROOMS | RETAIL
UNPAID AREA | STRICASE / ESCALATOR | TOILETS | PLATFORM

RoomSchedule for Type A Station			
Room Name	**Room Size**		**Area Provided (Sqm)**
PAID AREA	16.6	15	249
UNPAID AREA			432
TOILETS	3.6	10.6	38
TOM/ETO	2.1	5.6	12
RETAIL 1	8.5	6.3	54
RETAIL 2	7	10.1	71
UPS 1	8	5.8	46
CER	8.2	5.8	48
SER	8.2	5.8	48
STAFF ROOM	3.8	5.8	22
SCR	12.7	3.1	39
DB	3.5	3.5	12
UPS 2	11.25	3.1	35
ASS	30	5.8	174

TOM	TICKET OFFICE MACHINE
ETO	EXCESS TICKET OFFICE
SCR	STATION CONTROL ROOM
CER	CENTRAL EQUIPMENT ROOM
SER	SIGNALLING EQUIPMENT ROOM
ASS	AUXILLIARY SUB STATION

THE RESPONSIBILITY OF CONTROL, CHECK & VERIFICATION OF ACCURACY, CORRECTNESS, COMPLETENESS, INTEGRATION & FULL COMPLIANCE OF THE CONTRACT PROVISIONS IN RESPECT OF DESIGN, ANALYSIS AND DRAWINGS RESTS WITH THE DETAILED DESIGN CONSULTANT / DETAILED DESIGN CONSULTANT & CONTRACTOR.

CONSULTANT / CONTRACTOR

SIGN: | SIGN:
DATE: | DATE:
NAME: | NAME:
DESIGN BY | APPROVED BY

Urban Mass Transit Company Ltd.

COUNTER SIGNED BY MAHARASHTRA METRO RAIL CORPORATION LTD.

DY. HOD

HOD

NOTE:

- All dimensions, Levels and Chainages are in Meters unless otherwise mentioned.
- Dimensions shall not be scaled from the drawing. Only written dimensions shall be followed.
- The span arrangement shown may change at certain locations depending on site constraints.
- This is design stage and normally there are changes during construction considering uncharted utilities, modifications required in road spaces, interface with the road's contractor, critical obstructions etc.

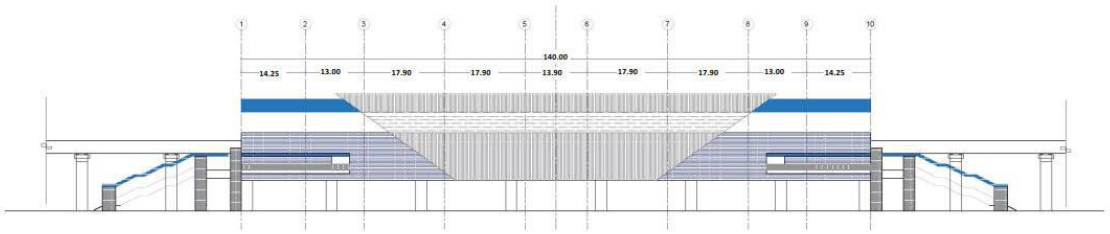
CLIENT : Maharashtra Metro Rail Corporation Limited

DPR PROJECT : PUNE METRO RAIL PROJECT PHASE-2

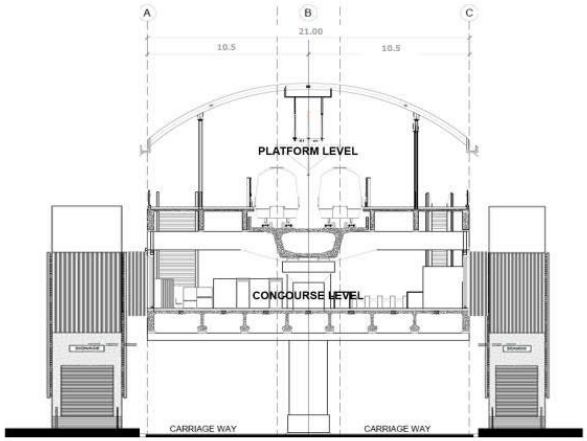
TITLE : TYPE A (ISLAND PLATFORM) PLANS, SECTION AND ELEVATION

DRG. No: | SHEET No

SCALE: HOR. NTS	STATUS PRELIMINARY	REVISION	SIZE A3	DATE

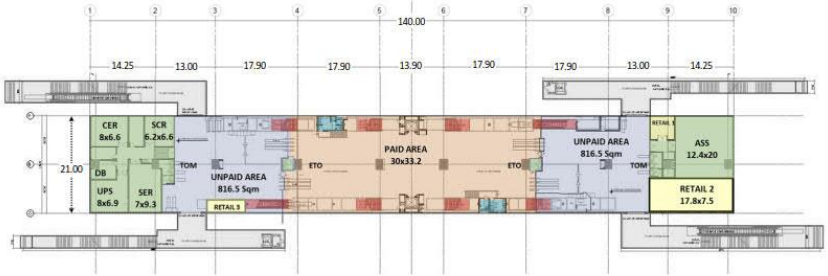


ELEVATION



ELEVATION

PLATFORM LEVEL PLAN



CROSS SECTION

PAID AREA
UNPAID AREA
ENTRY/EXITS
STRICASE / ESCALATOR
OPERATION ROOMS
TOILETS
RETAIL
PLATFORM

CONCOURSE LEVEL PLAN

ALL DIMENSIONS IN MTR.

Room Schedule for Type B Station

Room Name	Room Size		Area (Sqm)
PAID AREA	30	33.2	996
UNPAID AREA			1633
TOILETS	10.8	5.8	63
TOM 1	2.4	5.1	12
TOM 2	2.5	5.1	13
ETO 1	3.8	2.1	8
ETO 2	3.8	2.1	8
SCR	6.2	6.6	41
UPS	8	6.9	55
CER	8	6.6	53
SER	7	9.3	65
DB	5.5	4	22
ASS	12.4	20	248
RETAIL_1	5.2	5	26
RETAIL_2	17.8	7.5	134
RETAIL-3	8	2.6	21

TOM	TICKET OFFICE MACHINE
ETO	EXCESS TICKET OFFICE
SCR	STATION CONTROL ROOM
CER	CENTRAL EQUIPMENT ROOM
SER	SIGNALLING EQUIPMENT ROOM
ASS	AUXILLIARY SUB STATION

THE RESPONSIBILITY OF CONTROL, CHECK & VERIFICATION OF ACCURACY, CORRECTNESS, COMPLETENESS, INTEGRATION & FULL COMPLIANCE OF THE CONTRACT PROVISIONS IN RESPECT OF DESIGN, ANALYSIS AND DRAWINGS RESTS WITH THE DETAILED DESIGN CONSULTANT / DETAILED DESIGN CONSULTANT & CONTRACTOR.

CONSULTANT / CONTRACTOR

SIGN:	SIGN:
DATE:	DATE:
NAME:	NAME:
DESIGN BY	APPROVED BY

Urban Mass Transit Company Ltd.

COUNTER SIGNED BY MAHARASHTRA METRO RAIL CORPORATION LTD.

DY. HOD

HOD

NOTE:

- All dimensions, Levels and Chainages are in Meters unless otherwise mentioned.
- Dimensions shall not be scaled from the drawing. Only written dimensions shall be followed.
- The span arrangement shown may change at certain locations depending on site constraints.
- This is design stage and normally there are changes during construction considering uncharted utilities, modifications required in road spaces, interface with the road's contractor, critical obstructions etc.

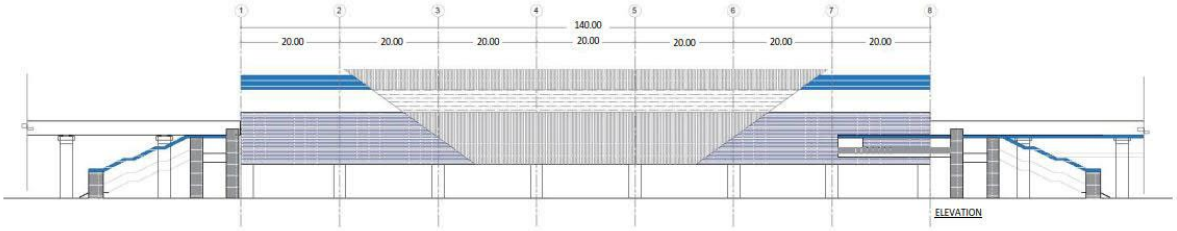
CLIENT : Maharashtra Metro Rail Corporation Limited

DPR PROJECT : PUNE METRO RAIL PROJECT PHASE-2

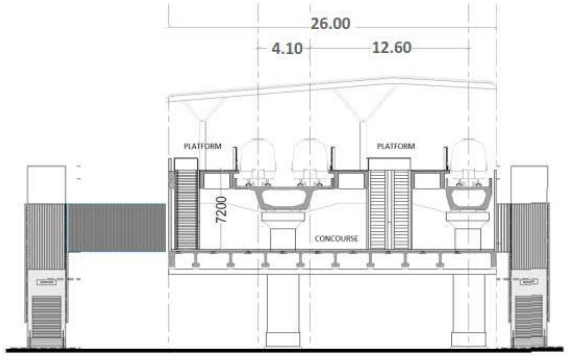
TITLE : TYPE B (SIDE PLATFORM) PLANS, SECTION AND ELEVATION

DRG. No: SHEET NO.

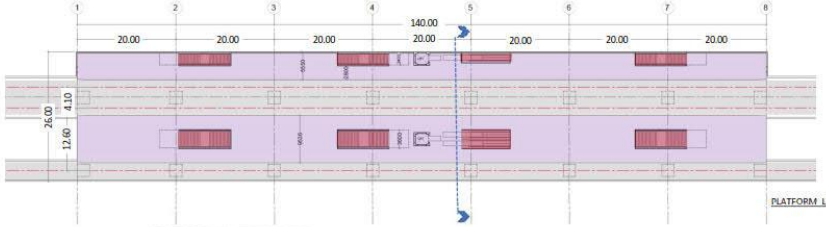
SCALE: HOR. NTS	STATUS PRELIMINARY	REVISION	SIZE A3	DATE



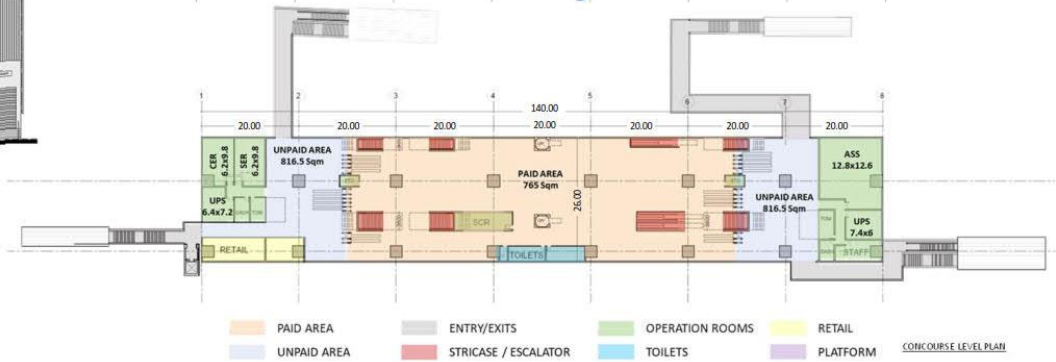
ELEVATION



CROSS SECTION



PLATFORM LEVEL PLAN



CONCOURSE LEVEL PLAN

ALL DIMENSIONS IN MTR.

RoomSchedule for Type D Station

Room Name	Room Size		Area Provided (Sqm)
PAID AREA			765
UNPAID AREA			1633
TOILETS	17.5	3	53
TOM 1	3.1	5	16
TOM 2	3.1	6	19
ETO 1	3.8	2.1	8
ETO 2	3.8	2.1	8
RETAIL 1	10.5	4.9	51
RETAIL 2	5.5	4.9	27
UPS 1	6.4	7.2	46
CER	6.2	9.8	61
SER	6.2	9.8	61
STAFF ROOM	7.3	4.2	31
SCR	11.8	3.6	42
DB	3.5	3.5	12
UPS 2	7.4	6	44
ASS	12.8	12.6	161

TOM	TICKET OFFICE MACHINE
ETO	EXCESS TICKET OFFICE
SCR	STATION CONTROL ROOM
CER	CENTRAL EQUIPMENT ROOM
SER	SIGNALLING EQUIPMENT ROOM
ASS	AUXILLIARY SUB STATION

THE RESPONSIBILITY OF CONTROL, CHECK & VERIFICATION OF ACCURACY, CORRECTNESS, COMPLETENESS, INTEGRATION & FULL COMPLIANCE OF THE CONTRACT PROVISIONS IN RESPECT OF DESIGN, ANALYSIS AND DRAWINGS RESTS WITH THE DETAILED DESIGN CONSULTANT / DETAILED DESIGN CONSULTANT & CONTRACTOR.

CONSULTANT / CONTRACTOR

SIGN:	SIGN:
DATE:	DATE:
NAME:	NAME:
DESIGN BY	APPROVED BY

Urban Mass Transit Company Ltd.

COUNTER SIGNED BY MAHARASHTRA METRO RAIL CORPORATION LTD.

DY. HOD

HOD

NOTE:

- All dimensions, Levels and Chainages are in Meters unless otherwise mentioned.
- Dimensions shall not be scaled from the drawing. Only written dimensions shall be followed.
- The span arrangement shown may change at certain locations depending on site constraints.
- This is design stage and normally there are changes during construction considering uncharted utilities, modifications required in road spaces, interface with the road's contractor, critical obstructions etc.

CLIENT : Maharashtra Metro Rail Corporation Limited

DPR PROJECT : PUNE METRO RAIL PROJECT PHASE-2

TITLE : TYPE C (INTERCHANGE STATION) PLANS, SECTION AND ELEVATION

DRG. No: MM-UMTC-DPR2- ST-AR-C-001 | SHEET NO.

SCALE: HOR. NTS	STATUS PRELIMINARY	REVISION	SIZE A3	DATE

CHAPTER 7. INTERMODAL INTEGRATION

7.1. INTERMODAL INTEGRATION

7.1.1 INTRODUCTION

With the vision of providing seamless connectivity to the Pune Metro commuters, it is essential to provide interconnectivity of Metro with other available transport modes. Ease of multi-model connectivity to commuters help in promoting sustainable mobility in the city and region.

It has been observed in many cities that at Metro Stations, due to the large number of commuters and the confluence of multiple modes of transit including private vehicles and two wheelers, buses, intermediate public transport (IPTs), non-motorized vehicles and pedestrians, the station areas tend to be very congested with all these modes of transport converging at a single point. It needs to be ensured that commuters can access the Metro Stations using all modes of transport in a safe and efficient manner.

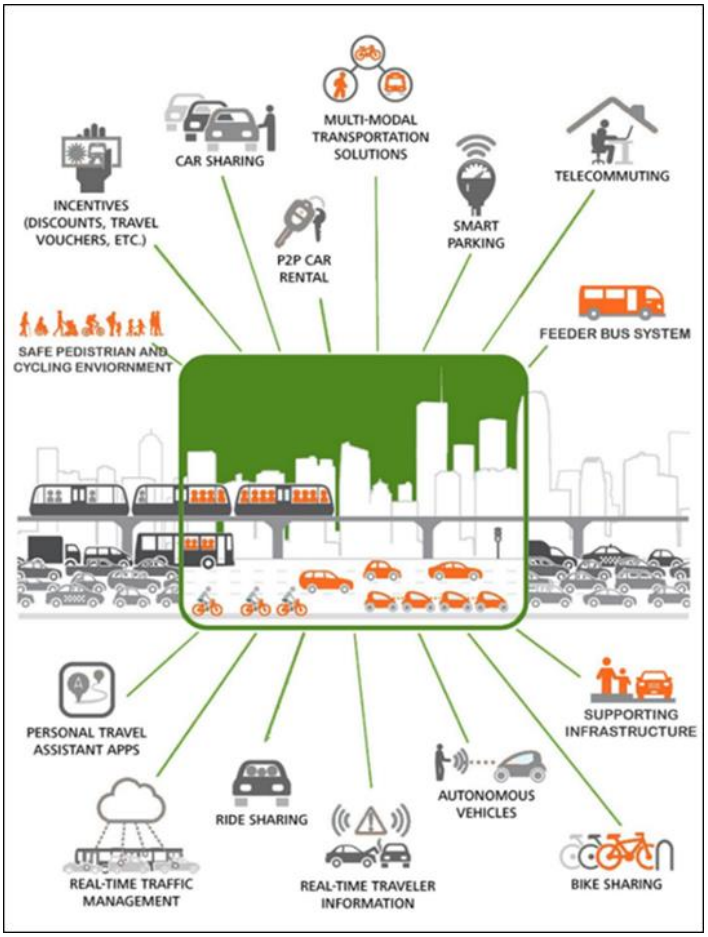


FIGURE 7-1: VARIOUS LINKAGES OF MULTI-MODAL TRANSPORTATION SYSTEM

The Metro Rail Policy was formulated by Ministry of Housing and Urban Affairs (MoHUA) in 2017, emphasises on provision infrastructure for integration of all Public Transport (PT), Intermediate Public Transport (IPT) and private modes in DPR's for the metro systems. This connectivity would provide better accessibility to the Metro Station by walk, cycle, Auto-rickshaws and bus services. Multimodal integration is planned to provide first and last mile connectivity for commuters.

A holistic approach to Multi Modal Transport for effective movement of people rather than vehicle is essential, as suggested by NUTP, to attain a sustainable transport system.

Generally, Multi Modal Integrated Transportation System has been characterized by increased capacity and efficient access. Public transport is an important constituent of multi–modal transportation system and hence local and regional public transportation systems must be an integral part of the same.

However, a seamless travel in the city would require integration of various modes to the mass transit system as well as at various levels starting from physical and operational integration of various modes, information integration and fare integration. A strong institutional framework is also vital to plan, execute and monitor the implementation of these levels.

The five pillars of integration in order to provide seamless mobility, is to have Institutional, Operational, Physical, Fare and Information integration in a city. Figure 7-2 shows five pillars of Multi-Modal Integration Planning.

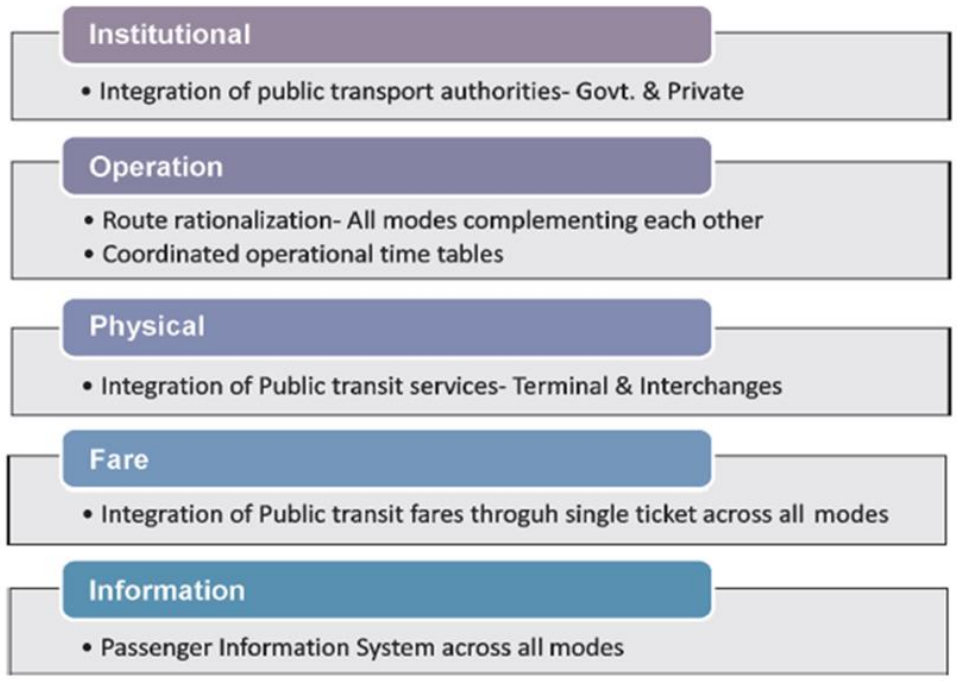


FIGURE 7-2: FIVE PILLARS OF MULTI-MODAL INTEGRATION

The Multi-modal Integration planning is to provide seamless integration between Metro Station and other transport modes like walking, bicycling, public transport, feeder services and IPT and private transport.

Based on National Urban Transport Policy (NUTP), Sustainable Urban Transport Project (SUTP) has divided the pillars of integration into three major components as follows:

- Public Transport
- Transport Network
- Non-Motorized Transport

Each component is further divided into sub component for physical integration as given in Table 7-1.

TABLE 7-1: COMPONENTS FOR MULTI-MODAL INTEGRATION

Components	Institutional Integration	Operational Integration	Physical Integration	Fare Integration	Information Integration
Public Transport	Setting up of UMTA	Route Network Planning	Bus Stop	One ticket for all means of transport	Inter-modal time passenger information systems
			Bus Terminal		
		Service Plan	Metro Station		
			Intermediate Public Transport (IPT) Stop		
			Multi-Modal Hub		
Transport Network		N/A	Road Network		
			Intersection		
			Parking		
Non-Motorized Transport (NMT)		N/A	Cycle Track		
			Cycle Stop		
			Footpath		

The benefits of Multimodal Integration include:

- **Streets for all** – Equitable allocation of street space to strengthen space share for NMT & pedestrians
- **Improving Walkability, Non-Motorized Facilities and Infrastructure** – Junction improvements, pedestrianization of high-density activity zones, creating segregated bicycle infrastructure, parking facilities etc.
- **Public Realm Enhancement** – Reconfiguration of RoW gives an opportunity for place making and social gathering space.
- **Ease of Commuting** – Due to integration, the transport system seems very attractive to commuters and thus derives a range of benefits

  - Reduce Travel Time
  - Reduce hassle of Interchange
  - Saving in money
  - Assured door to door travel using PT system
- **Increase in Public Transport Use** – An integration of public transport with synchronized time tables, integrated physical infrastructure, common fare collection system and Passenger Information System will increase convenience and comfort and once the customers are satisfied with the built image of the transport system, the shift to the public transport system is easier.
- Sustain and increase ridership of main transport system (Metro System) of regular usage by existing commuters as well as introduction of new commuters to the system. This in turn provides benefits to service provider:
  - Reduce Travel Time
  - Reduce hassle of Interchange
  - Saving in money
  - Assured door to door travel using PT system
- **Accessibility to all** – Providing priority access to specially-abled to use the Metro system, universal design for access to all.
- **Pedestrian and Bicycle Convenience, Safety & Comfort** – Improving the safety, convenience and comfort of the NMT users by the way of traffic calming measures, location of pedestrian crossings, creating pedestrian priority areas, pedestrian linkages, Barrier Free Access for elderly and specially-abled, Safe Mobility for Women and Children etc.

The benefits for the commuters include reduced travel time, reduced hassle of interchange, savings in money and assured door to door travel after integration of first and last mile connectivity. All four modes of Walking, Cycling, Public Transport and Private Transport together will provide a citywide multimodal integrated framework for travel.

7.1.2 INTEGRATED MULTI-MODAL URBAN TRANSPORT SYSTEM

Multimodal integration depends on many factors such as nature of station terminal (terminal or wayside), its catchment, availability of access/dispersal modes, and interchange with other mass transport, distance from station, other available/ planned transport modes, trip length and destination. This includes planning for roads, footpaths/pedestrian facilities, bus stops, IPT stands, parking for different modes, pick and drop areas etc.

Intermodal integration explores the coordinated use of two or more modes of transport for efficient, speedy, sage, pleasant and comfortable movement of passengers in urban areas in the station catchment. It provides convenient and economical connection of various modes to make complete journey from origin to destination.

Some of the essential features of an integrated multi-modal urban transport system are the physical integration by means of 'station accessibility plan', integration with public transport services and other feeder systems, integration of fares & ticketing of different systems, integration of infrastructure provisions, operational integration for management, pricing and integration of transport authorities.

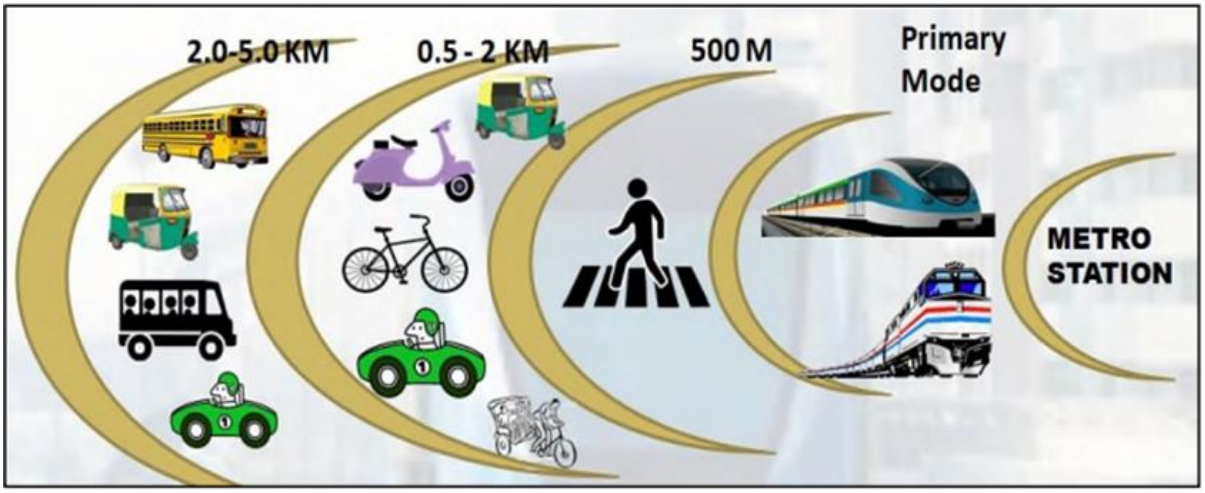


FIGURE 7-3: METRO MULTI-MODAL INTEGRATION IN THE CATCHMENT AREA

7.1.3 PLANNING FOR INTEGRATION

7.1.3.1. LOCAL AREA MAPPING

Local area mapping is a preliminary exercise done for planning of Multimodal Integration. It includes identification of large residential population, commercial establishments, government offices, educational institutions, large hospitals, universities, industrial zones, IT parks, SEZSs, tourist attractions, popular religious destinations and places like Civil Courts, RTO, Defence Establishments and Camps within the catchment area of stations and provision of comfortable and seamless (at-grade or grade separated) connectivity for NMT users to those spaces.

Mapping of existing activities like existing PT, IPT stops, vendor spaces, pedestrian and bicycle infrastructure, service/utilities, etc., is important for preparation of multimodal integration plans for stations.

The planning principles taken into account for intermodal integration at the station locations are as follows:

- Seamless connectivity to and from catchment area of the station
- Integration with all possible modes including other mass transport systems
- Priority to be given to pedestrians followed by public transport
- Parking facilities for all modes including non-motorized transport (NMT)
- Minimal land acquisition

- Accommodate ground constraints

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

- Minimizing pedestrian/vehicle conflicts and effective passenger interchange with feeder modes. Proper design of circulation area adjoining the station building to ensure rapid/ efficient dispersal of the passengers and avoiding conflicts between pedestrian and vehicular traffic.
- Pedestrians require a convenient and safe access to the proposed metro station. For smooth movement of pedestrians, the footpaths in the metro station primary influence zone/ catchment area will be considered to be upgraded to desired level of comfort and also proposed new footpaths in the stations vicinity areas.
- High quality pedestrian access will be accomplished through design factors such as directness and connectivity, ease of movement, safety and security. The vendors if any on the footpaths shall be removed and desired accessibility to metro stations will be provided. The facilities (footpaths/ walkways) will be directly integrated with the metro system.
- Facilitating passenger interchange with other transit systems: Dedicated linkages proposed like skywalks, covered walkways etc. which will reduce the passenger travel time and pedestrian load on the roads.
- Circulating area with adequate parking space, designated space for embarking and disembarking for vehicular-traffic (pick-drop zones) and feeder modes like Buses, IPT's and NMT.
- Availability of total carriageway and footpath widths required to cater to the proposed traffic volumes to be augmented through strengthening of road shoulder areas and relocation of vendors/hawkers, on-street parking and all encroachments from the service/access roads.

7.1.3.2. INTERCHANGE STATIONS

The metro corridors will serve as a major mass transit system in Pune. It will have major interchanges with metro system/bus/rail terminals which will serve as complementary/ feeder for the passengers from their respective origins to destinations and vice versa. To integrate the interchange stations many factors such as nature of interchange station, its catchment, availability of access/dispersal modes, and interchange with other public transport modes, distance from station, trip length and destinations etc. are considered. Some of the passenger facilities as expected in the interchange stations are described below:

- **Pedestrian Facilities:** Interchange stations will be expected to experience heavy pedestrian movements during peak hour. Therefore, pedestrian infrastructure facilities i.e. pedestrian pathways, skywalks, subways and foot over bridges are planned accordingly.

- **Traffic Dispersal Facilities:** Adequate traffic dispersal facilities in terms of continuous footpaths, city bus stops, IPT stands, pick-drop areas, traffic signage's and parking within the proximity of the entries/exits, pedestrian crossing facilities, traffic calming measures along with signage, road markings, signals, speed table and NMT crossings has been planned near the interchange station influence area to facilitate the safe and smooth movement for both pedestrians & vehicles.
- **Embarking/Disembarking Zones/Parking Areas:** At interchange stations, long and short duration parking spaces, pick and drop facilities for different public & private modes are planned as per peak hour passenger station boarding/alighting. The parking areas will directly be connected to the proposed interchange stations through pedestrian pathways/ FOB/ subways.

Table 7-2 presents the interchange stations on the proposed corridors with other modes of transport.

7.1.3.3. INTEGRATION OF METRO STATIONS & OTHER MODES OF TRANSPORT

While deciding the station locations, efforts have been made to make integration of Metro system with other modes of public transport such as BRTS, Railways, Airports etc. to the extent possible.

Table 7-2 summarizes the required physical integration of Metro system with other modes of transport for better inter-modal transfers.

TABLE 7-2: INTEGRATION OF METRO STATION WITH OTHER MODES OF TRANSPORT

Sr. No	Integration Opportunities	Modes of Transport
a	Integration with Public Transport – City Bus service	PMPML Bus Stops near proposed Metro Stations
b	Integration with Feeder Services	• All Metro Station are proposed to have feeder service operational within 2 to 2.5km radius of Metro station.
c	Integration with IPT services	• All proposed Metro Stations are proposed to have pick and drop facility for IPT
d	Integration with private transport and parking systems (park & ride facilities)	• Pick up and Drop off bays are proposed at all Metro Stations
e	Integration with BRT stops	• Tata Guard Room • Kharadi Bypass • Aaple Ghar
f	Integration with existing regional transport systems	• Kharadi Bypass • Chandani Chowk
g	Integration with MRTS Systems	• Viman Nagar Metro Station (Proposed HCMTR) • Kharadi Bypass (Proposed Hadapsar-Kharadi Corridor of Pune Metro Phase 2)

Inter-modal integration facilities at the stations are proposed in catchment areas. The city civic agencies shall provide the passenger infrastructure beyond this catchment area in order to facilitate seamless connectivity to metro stations.

The following inter-modal integration and dispersal facilities have been planned at metro stations for efficient passenger movement and to meet the shortfall in capacity in terms of road capacity, traffic movement/ circulation, pedestrian facilities, bus stops, IPT stands/ Pick-Drop areas and parking.

- **Augmentation of Road Geometry & Footpaths:**
  - It is proposed to utilize the complete Right of Way to cater to the future traffic volume. The existing road shoulder areas and service lanes have been augmented/ strengthened in the design wherever possible.
  - Features of the road are shown in the multi-modal integration plan to essentially identify the degree of improvement proposed as part of the proposal.
- **Seamless Connectivity/Effective Passenger Interchange with Feeder Modes:**
  - The circulating area adjoining the station building is proposed to be properly designed to ensure rapid/efficient dispersal of passengers, avoiding conflict between pedestrians and vehicular traffic. Demarcated pick-up and drop-off zones and bays for feeder modes like buses, IPT are proposed near the station.
  - The station entry/exit is planned considering the major growth centres/activity areas. The entry/exit has been designed to integrate the station with existing/ proposed bus stops/bus bays, pick-drop zones and IPT services within walking distance.
  - Off street parking is proposed wherein adequate land is available for encouraging park and ride. The existing on-street parking can be moved to these parking lots for increasing the availability of total carriageway for vehicular movement.
- **Uninterrupted Traffic Flow/Smooth Traffic Conditions:**
  - It is proposed to relocate the vendors/hawkers and parking for unobstructed movement of pedestrians and vehicles.
- **Pedestrian Friendly and Universally Accessible Design:**
  - To promote walking a minimum of 1.8 m wide footpath has been proposed on the local roads whereas a continuous footpath of appropriate width is proposed on the major roads to provide accessibility to people on wheel chairs. Wherever entry/exit is proposed on the footpath area, it has been ensured that minimum 3 m width is left for walking. Tactile have been proposed for the visually impaired commuters.
  - Junctions and intersections are proposed with proper pedestrian crossings. In the design, table top crossings have been proposed wherever possible, otherwise ramps with gentle slope ranging from 1:5 - 1:7 have been designed for pedestrians and wheelchair users.
  - Proper road markings, Traffic Signage's, Zebra crossings and pedestrian signals are proposed to provide safe and uninterrupted pedestrian movement

- Design considerations like ramps for wheelchair movement, lifts have been proposed in the station design for ease in movement of physically challenged.
- Dedicated drop off bay have been proposed for the Specially-Abled Commuters near the Elevator.

7.2. FEEDER SERVICES

The planning of seamless transport integration facilities at the influence zones of various metro stations is of utmost importance. Feeder services to the proposed metro network will be essential to provide convenient and quick transfer of passengers from one mode of transport to another. As all commuters will not be living within walking distance of the proposed network, proper planning for feeder services will be necessary based on analysis of passenger demand on the system.

Various modes of transportation like feeder buses, auto rickshaw/taxi and bicycles can provide first mile as well as last mile connectivity other than walking to the metro station. For catchment area of about 0.5-1 km from the proposed network, commuter can easily access it by walk. People residing in the next 1 km can reach the station by cycles, 2-Wheeler and auto-rickshaws. Areas beyond the 2 km catchment will require regular feeder bus services to reach the Metro station.

The feeder service facilities will be provided at the metro stations to connect the trip generation/ attraction areas in the influencing zone/ catchment area of Metro corridors.

7.2.1 EXISTING PT SCENARIO IN PUNE

Pune Mahanagar Parivahan Mahamandal Limited (PMPML) is responsible for operating the bus services in the city and its surroundings. The fleet size of PMPML is about 1,500. The average life of fleet is about 8 years. Average number of buses on road per day is 1,382 operating on 371 routes.

On an average, 17,000 trips are made and PMPML carries around 10.65 lakh trip passengers per day (Jan 2017). The average number of passengers per bus per day is about 770. PMPML operates various services like Regular Service, Rainbow Buses, Night Buses, Pune Darshan, Ladies Special and Airport Buses.

7.2.2 IMPORTANCE AND NEED OF FEEDER SYSTEM

Feeder Systems maximize the coverage of the Mass Transit Corridors providing last mile connectivity to enhance the overall travel experience of the public transit users. In general, there are four distinct types of feeder modes in Indian cities; non- motorized modes (such as walking, cycling), intermediate public transport (such as auto rickshaws, taxis), shared-ride services (such as shared taxis, shared auto rickshaws) and buses. The proposed feeder system is designed to cater the first and last mile connectivity needs of the

proposed metro system and bus-based systems in the city. The general characteristics of the feeder systems in an urban setting is as follows;

(a) The Feeder Services ideally serve short distances, serves typically below 6 km.
(b) The efficiency of the mass transit system can be best maintained when the feeder system frequencies are synchronized with the mass transit system.
(c) The mass transit system has a limitation in terms of its network, as the systems are designed for the trunk corridors. Feeder system has the flexibility to connect commercial, residential nodes and major activity destinations to the mass transit stations or CBD's. This system typically works as a Hub and Spoke Model, encouraging diversification of the routes and larger coverage.
(d) The feeder services extend the trunk corridor's area of influence, connecting the major residential, commercial, and other activity centres to the trunk corridor. Also, connecting areas where demand exists but no direct connectivity is available.
(e) The vehicle type generally varies from the trunk mode. As in case of India there are multiple modes available such as shuttle buses, mini vans, battery operated electric vehicles etc.
(f) The feeder system operates amongst mixed traffic without priority infrastructure or space.

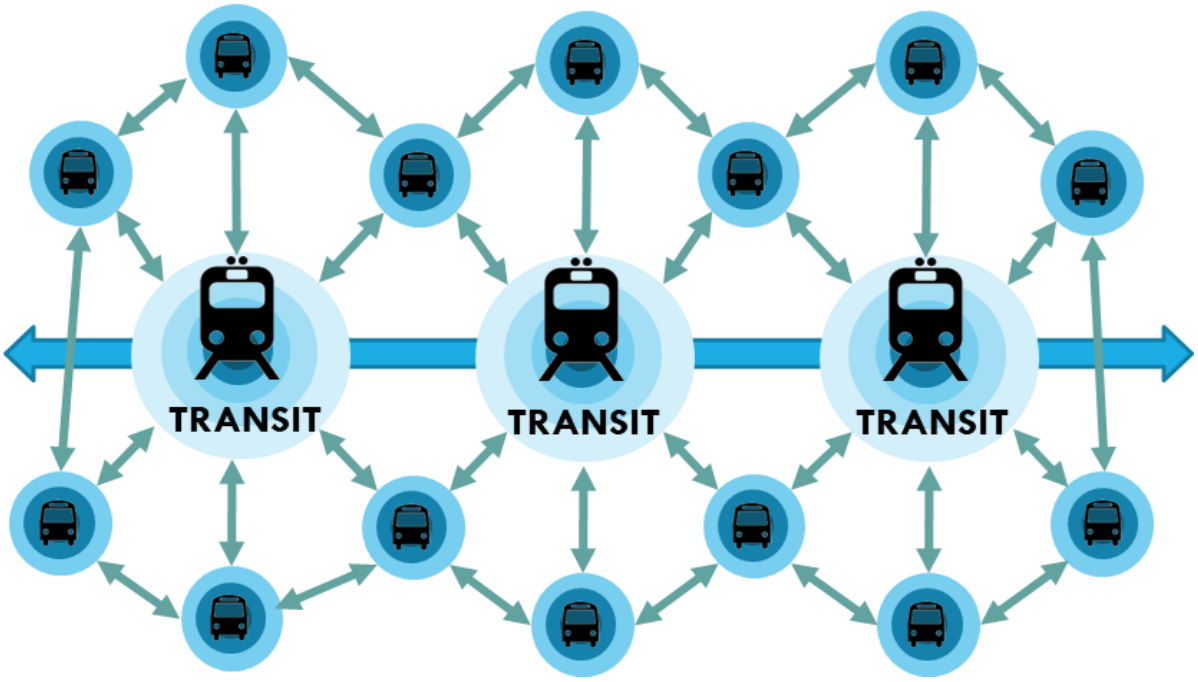


FIGURE 7-4: HUB AND SPOKE MODEL OF FEEDER SERVICES

Various Indian cities have adopted a various modes of feeder services to enhance the last mile connectivity of the mass transit users. Delhi Metro operates Standard (Airport Liner), Mini buses and E-rickshaws as metro feeders. Bangalore and Hyderabad have introduced feeder vehicles of 25 capacity plying on designated routes connecting the metro corridors.

In addition, these cities have also integrated with the Bike Hire agencies to strengthen the last mile connectivity in the city. Chennai has introduced three types of fleet in their feeder system which includes Mini Buses, Cabs and share auto-rickshaws.

The introduction of feeder systems has resulted in the steady increase in the metro ridership with commuters increasingly preferring the usage of these metro systems. The choice of the feeder mode depends on the demand, frequency and right of way availability along the identified routes.

FIGURE 7-5: METRO FEEDER SERVICES

Pune Metro has also started the Feeder Services for the operational Metro Station with help of PMPML. Circular routes have been planned for the Metro feeder services.

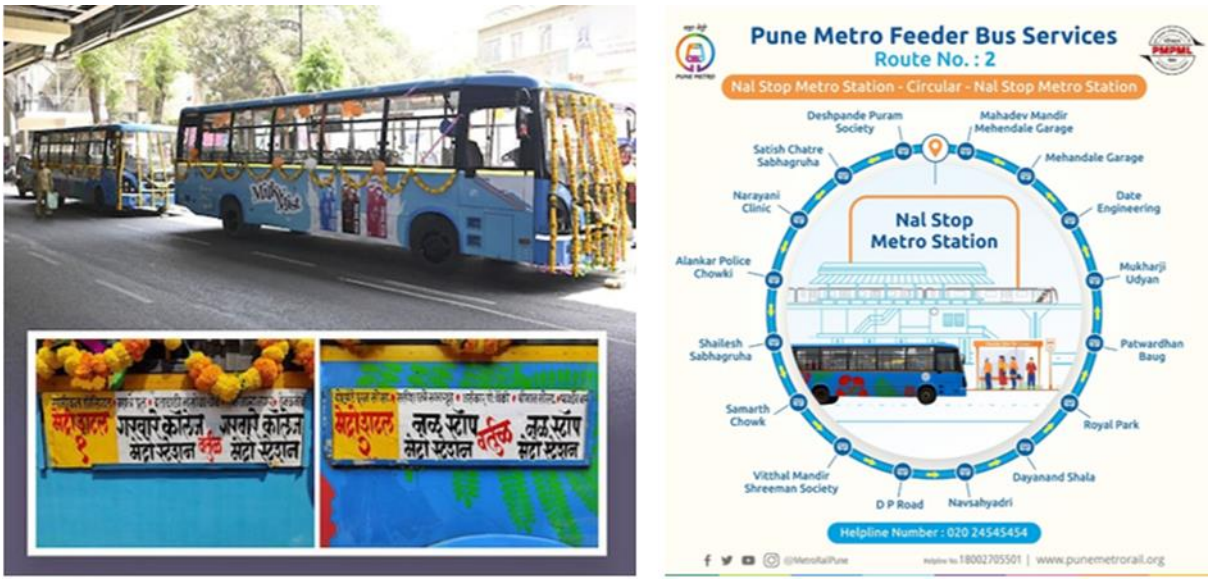


FIGURE 7-6: PUNE METRO FEEDER SERVICE

7.2.3 FEEDER ROUTES

Feeder network of about 58.5 Kms with about 11 routes are identified for the proposed extension Line 2A and Line 2B. The list of routes is as presented in the Table 7-3. The proposed routes are about 7-8 km connecting the major activity nodes and residential areas to the nearest metro corridors. The feeder routes for Line 2A and 2B are as depicted below.

TABLE 7-3: FEEDER ROUTES

S.No.	Feeder Routes	Type	Length (Km)
FR_1	Chandani Chowk Metro Station Chandani Chow–Maratha Mandir-Bavdhan Gaon-Bavdhan Road-Baltuka Corner- Dagadevasti-Chandani Chowk Highway-Chandani Chowk Metro Station	Circular	4.8
FR_2	Kothrud Depot-Pooja Park-Ekalavya Politechnic-Mahatrma Tekdi- Warje Kothrud Pass- Rosary School-RMD Sinhagad College-Wander Fanky-Raviraj Residency- Chandani Chowk- Chandani Chowk Metro Station-Kothrud Bus Depot	Circular	8.43
FR_3	Ramwadi Metro Station-Viman Nagar Metro Station- Clover Park-Datta Mandir Chowk-Gangapuram Mhada-MHADA Colony -Symbiosis Law School-Pune Airport-Airport Corner-Sanjay Park-Sakore Nagar-Ramwadi Metro Station	Circular	8
FR_4	Viman Nagar Metro Station- Somnath Nagar Metro Station- Sunita Nagar-Hanuman Nagar-	Circular	5.5

S.No.	Feeder Routes	Type	Length (Km)
	Mahavir Nagar-Wadgaon Sheri Bhaji Mandai-Dutta Mandir-Sainik Wadi-Viman Nagar Metro Station		
FR_5	Somnath Nagar Metro Station- Kharadi Bypass-Rakshaknagar Phase 1-Ambedkar Chowk-Bidi Kamgar Nagar-Tukaram Nagar-Kharadi Chowk-Sainath Nagar Chowk-Vishnu Udyog-Chandan Nagar Police Station-Somnath Nagar Metro Station	Circular	7.5
FR_6	Tulaja Bhavani Metro Station-Wagheshwar Parking-Sakore Nagar Corner-Gera Society-Eon IT Park Road-Eon Chowk- Fountain Road-Janak Baba Dargha-Tulaja Bhavani Metro Station	Circular	4.7
FR_7	Upper Kharadi Metro Station to Dhole Patil College Of Engineering Pune	Point to Point	3.4
FR_8	Wagheshwar Temple to Lohagaon	Point to Point	6.2
FR_9	Wagholi Vegetable Market to Awalwadi	Point to Point	3.0
FR_10	Wagholi to Kesnand	Point to Point	4.0
FR_11	Bakori Phata to Ramachandra College	Point to Point	3.0
Total			**58.5**

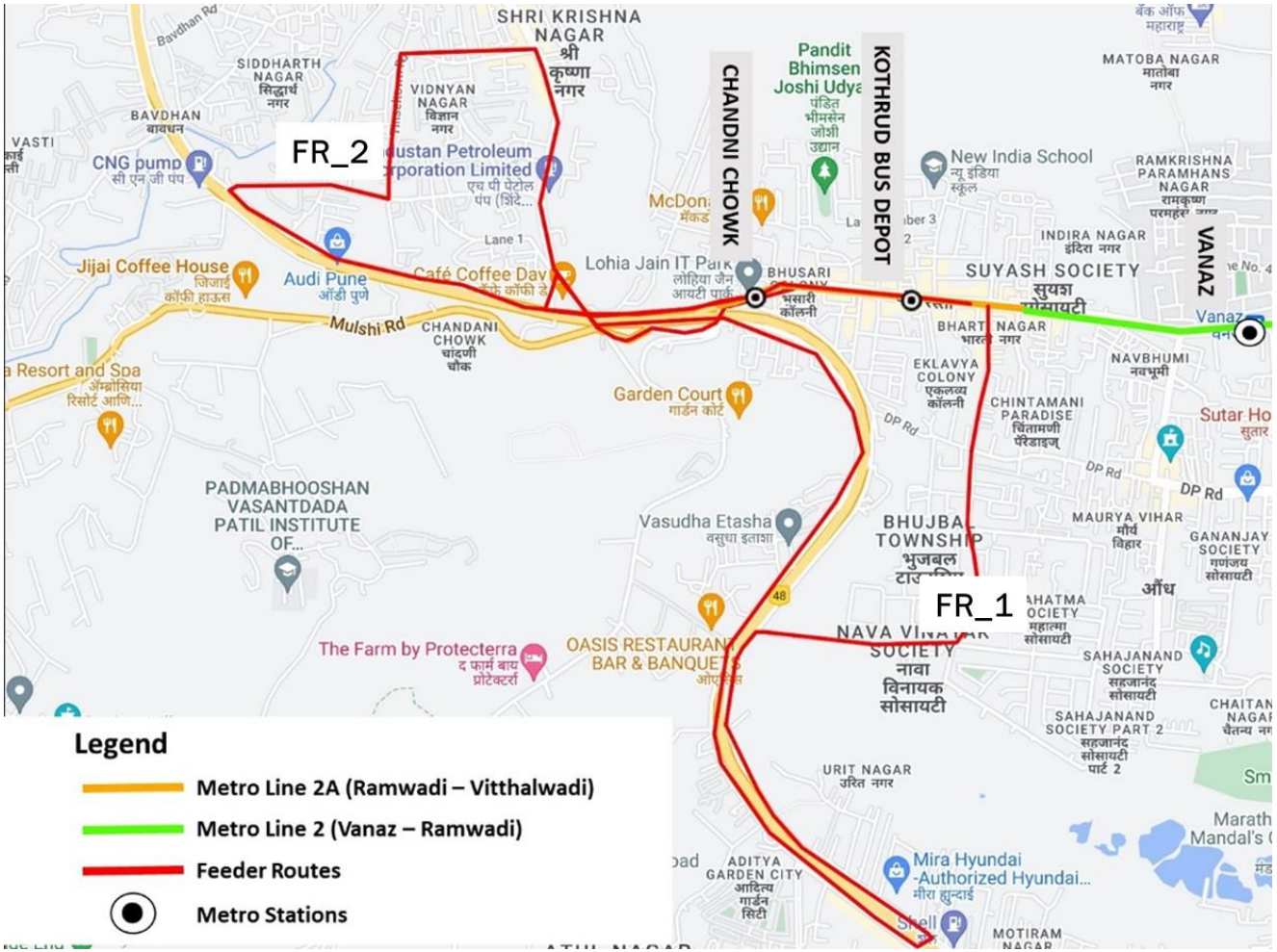


FIGURE 7-7: FEEDER ROUTES METRO LINE 2A

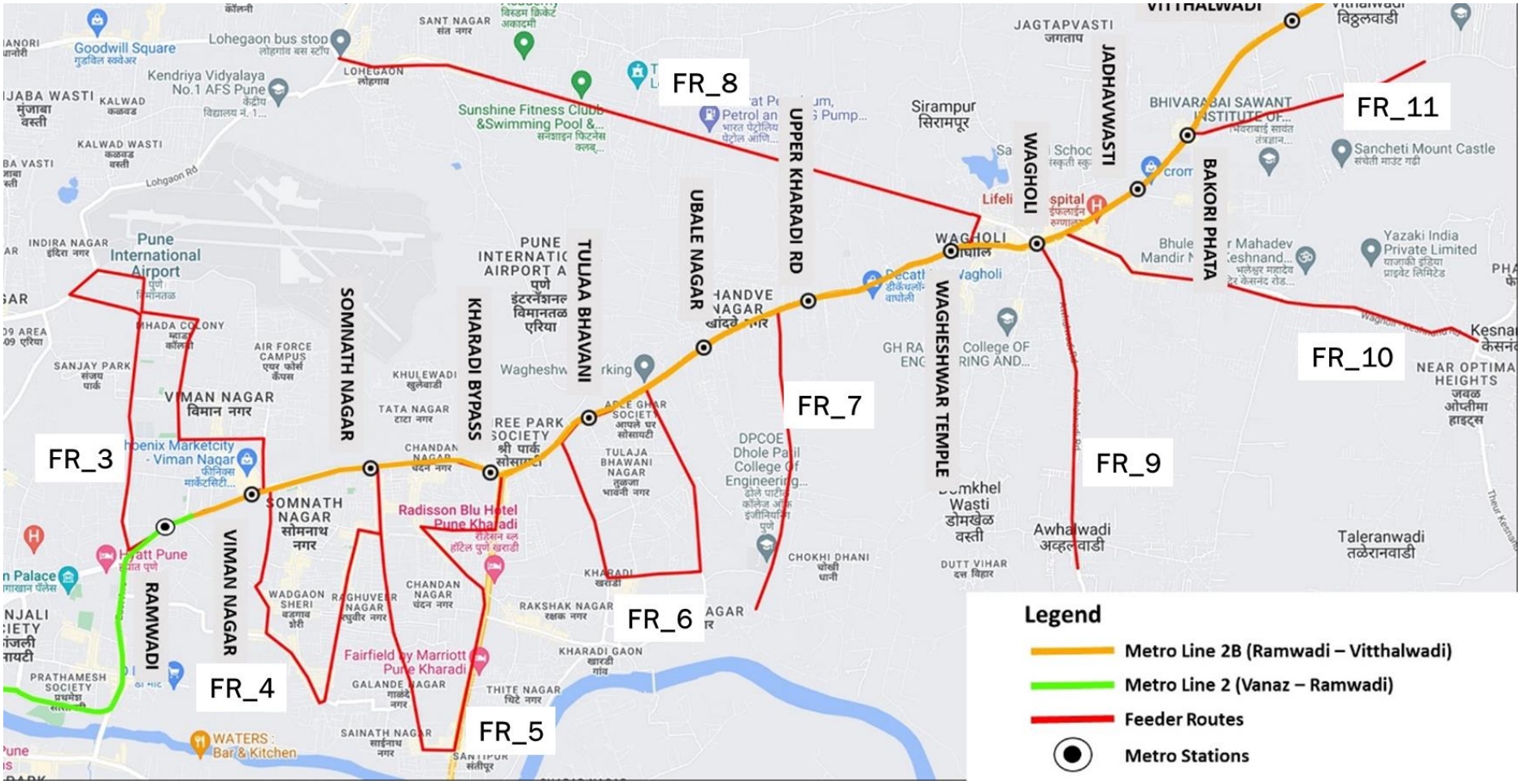


FIGURE 7-8: FEEDER ROUTES METRO LINE 2B

The characteristics of the proposed Feeder Services are as follows;

1. **Network:** The hub and spoke system of network has been proposed for the Feeder Services for Metro, such as each metro station acts as a hub and the neighbouring activity nodes are connected through feeders acts as spokes, this enables the system to cover larger areas as well as diversification of the routes.
2. **Connectivity:** The Feeder services are connected to all the major economic activity hubs, commercial zones, residential nodes and public transportation services such as bus stops, auto service stops to the nearest metro stations. The feeder routes are largely linear in nature connecting both metro corridors and the individual zones forming a chain leading to the nearest metro stations. The proposed feeder routes are perpendicular to the metro lines, providing direct access and reduced travel time.
3. **Route Length (km):** The distances covered by the feeder routes have been kept optimal. The routes have been designed for up to 8 kms of route length. A total of 10 routes were identified with a total network length of 50 km.
4. **Operational Hours:** The feeder services would be planned for 16 hours of operation between 6 am to 10 pm. The feeder services will be synchronized with the metro timings.
5. **Service Frequency (mins):** The service frequency of feeder to be in synchronization with Metro frequency. It is expected that the feeder service shall maintain 6 mins frequency as of the metro at the peak hours.
6. **Feeder Stops:** Feeder stops are recommended at a distance of 250 m apart to reduce the access and egress time.
7. **Vehicles:** To achieve the vision of Maha-Metro of reducing carbon emissions through sustainable public transport, environment friendly vehicles such as electric/CNG vans or mini buses are recommended.

The feeder buses shall be of high quality, ultra-modern and customer oriented that can deliver fast, comfortable and cost-effective urban mobility. Easy-to-board (low floor), attractive Mini and Midi buses with air conditioning are proposed for feeder system.

The required fleet and type of feeder buses have been estimated for peak hour in horizon year considering the required headway and presented in Table 7-4. It is however recommended to take up a detailed study for Planning and Operation of Feeder Buses including the Route Rationalization Study for existing PT routes, at the time of implementation.

TABLE 7-4: FEEDER BUSES REQUIRED

Sl. No.	Route No.	Length (KM)	Available ROW	Recommended Vehicle Type	Fleet Required			
					2027	2037	2047	2057
1	FR_1	4.8	18m-24m	Mini Electric/CNG Bus (21+1)	6	8	10	12

Sl. No.	Route No.	Length (KM)	Available ROW	Recommended Vehicle Type	Fleet Required			
					2027	2037	2047	2057
2	FR_2	8.43	18m-24m	Mini Electric/CNG Bus (21+1)	10	12	18	22
3	FR_3	8	24m to 30m	Mini Electric/CNG Bus (21+1)	10	12	16	20
4	FR_4	5.5	15m to 24m	Mini Electric/CNG Bus (21+1)	6	8	12	14
5	FR_5	7.5	15m to 24m	Mini Electric/CNG Bus (21+1)	8	12	16	18
6	FR_6	4.7	30m-36m	Mini Electric/CNG Bus (21+1)	6	8	10	12
7	FR_7	3.4	15m	Mini Electric/CNG Bus (21+1)	4	6	8	10
8	FR_8	6.2	18m	Mini Electric/CNG Bus (21+1)	8	10	12	16
9	FR_9	3.0	15m	Mini Electric/CNG Bus (21+1)	4	6	6	8
10	FR_10	4.0	15m	Mini Electric/CNG Bus (21+1)	6	6	8	10
11	FR_11	3.0	15m		4	6	6	8
Total					72	94	122	150

PMPML has started the operations of feeder buses for the operating stations of Phase - 1 Metro stations. It is proposed that Feeder Services for the Phase - 2 metro will also be taken up by the PMPML considering the availability of infrastructure and staff.

7.3. INFRASTRUCTURE FOR INTEGRATION

Integration refers to the provision of jointly used transport facilities and equipment to provide seamless mobility. Integration of physical space, network planning and physical infrastructure have to be planned to facilitate easy transfer of commuters.

7.3.1 PHYSICAL INTEGRATION

The concept of physical integration at the station precinct is shown below. The hierarchy to be considered while preparing station accessibility plans for each station of Pune Metro has been shown in Figure 7-9.

The integration of various modes of transport should address prioritizing needs of a user. Facilities like continues and dedicated infrastructure for pedestrians and cyclist, a defined space allocated for the cycle docks/ parking and drop-off bays for specially-abled to be provided near the entry-exit of Metro Station as the first priority.

Similarly dedicated bus bays and bus shelters for buses can be provided so as to ease the traffic flow and to reduce congestion problems on the main movement corridor. A Feeder Bus system with an organized route and stops for every Metro station can be introduced specially for the user to access Metro with ease. Also provision of separate pick-up/ drop-off bays for auto-rickshaws, taxies and other private vehicles is a part of comprehensive planning.

Top priority in planning is given to the pedestrians and differently-abled citizens. After pedestrians, Bicycles and other Public Transport Modes have been given priority. Parking for private vehicles gets the least priority after providing the adequate space for IPT and Other Vehicular Traffic.

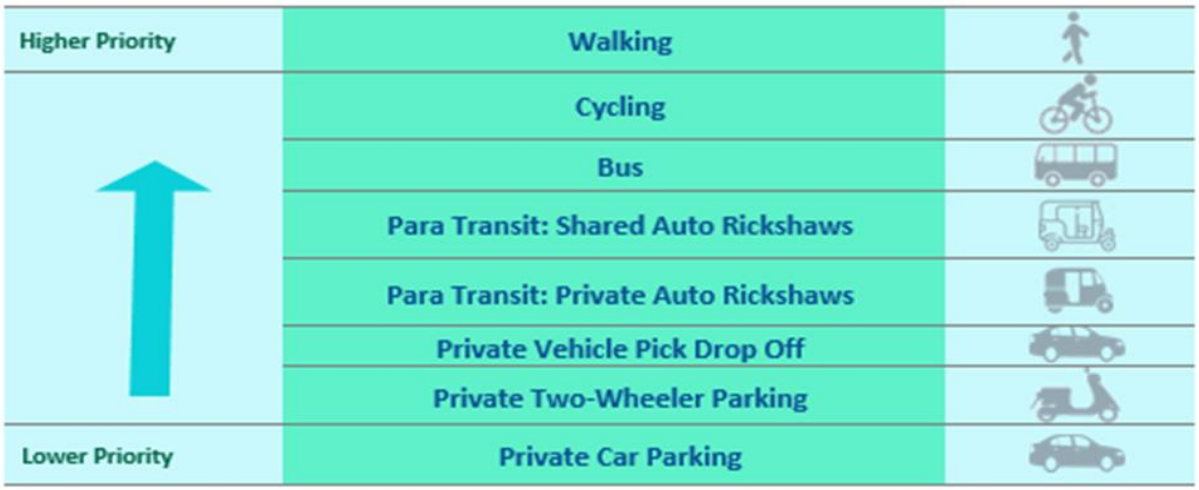


FIGURE 7-9: HIERARCHY OF MULTI-MODAL INTEGRATION PLANNING

To encourage the Public Transport and organize the activities in the station premises, in the multi-modal integration, primarily priority is given to NMT modes like pedestrians and bicycles which can be used to access the landmarks from Metro Station. The cycle parking and Public Bicycle Sharing (PBS) docks are located within a distance of 50 meters from Station entrances.

The next priority is given to pick up and drop off facilities such as feeders stops which should be located less than 100 meters from the Metro Station entrance, followed by public transport stops, IPT, private vehicles pick up/ drop off and parking. The drop-off for specially-abled person is provided near the lift blocks to minimize the travel distance and to make it convenient to access the lift. Figure 7-10 show the priority level for various modes to access/ egress the Metro Station.

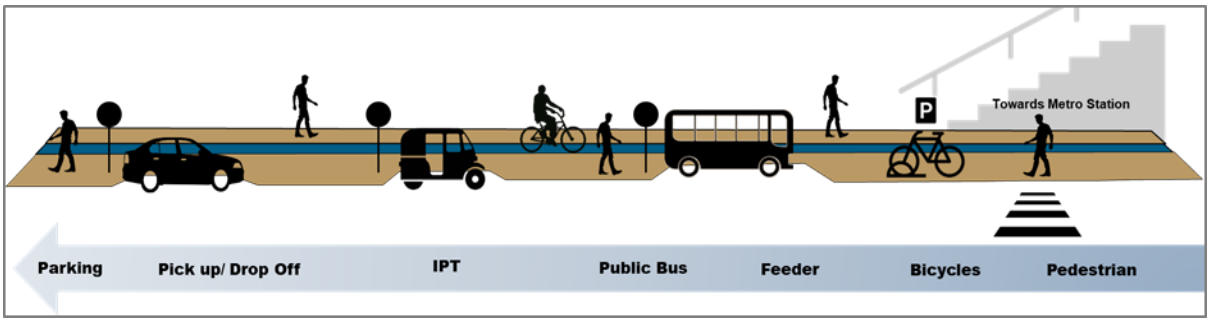


FIGURE 7-10: LEVELS OF PRIORITY

The proposed planning and design of multi-modal integration shall be based on the guidelines and codes organizations like Indian Road Congress (IRC), MoRTH guidelines, URDPFI guidelines. In addition, guidelines prepared by other Indian and international organizations like Institute of Urban Transport (IUT), Unified Traffic and Transportation Infrastructure Center (UTTIPEC), Institute for Transportation and Development Policy (ITDP), toolkit of Ministry of Housing & Urban Affairs (MoHUA) etc. shall be referred for developing Multi-Modal Integration proposals for Pune Metro.

Maha-Metro has planned and implemented the Multi Modal Integration for the Phase - 1 Stations of Pune Metro. All the stations in Phase - 1 have been planned to have seamless transfer of commuters and integration with PT, IPT and Private vehicles. Wider footpaths, dedicated cycle tracks and dedicated drop off bays have been planned.

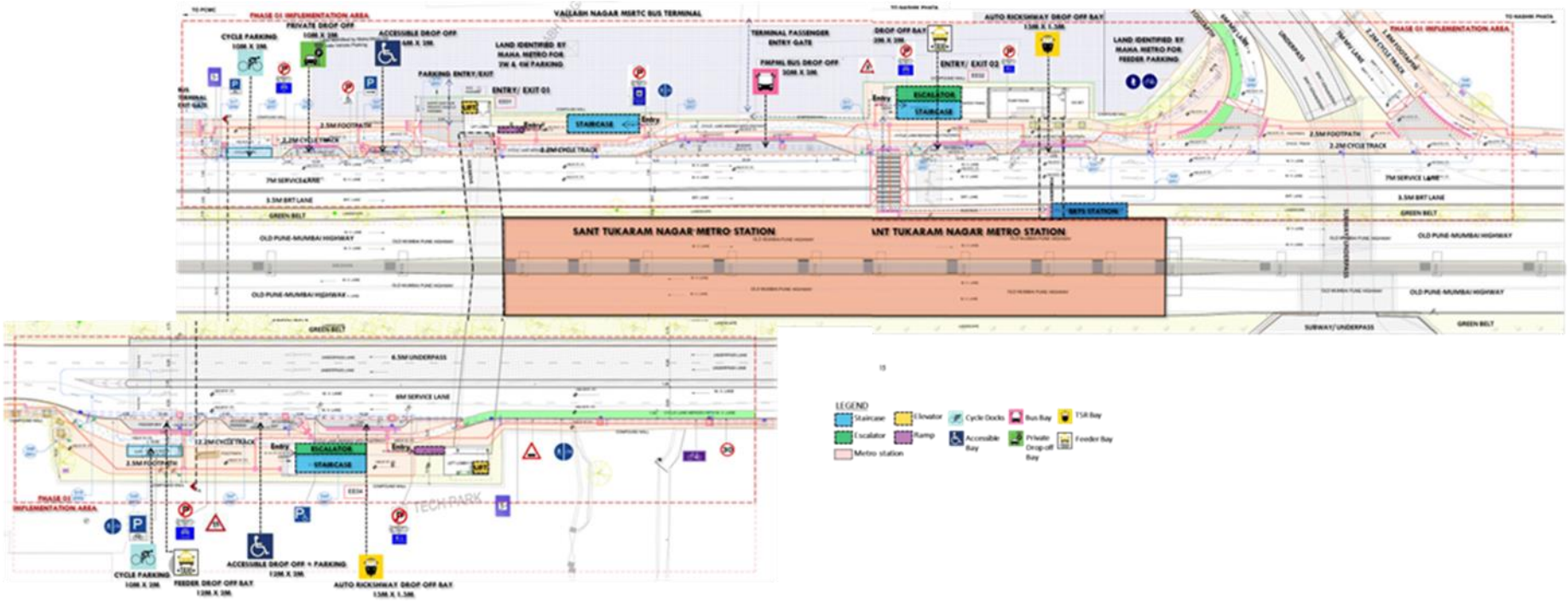


FIGURE 7-11: MMI PLANNING AT SANT TUKARAM METRO STATION (PUNE MRTS PHASE – 1)

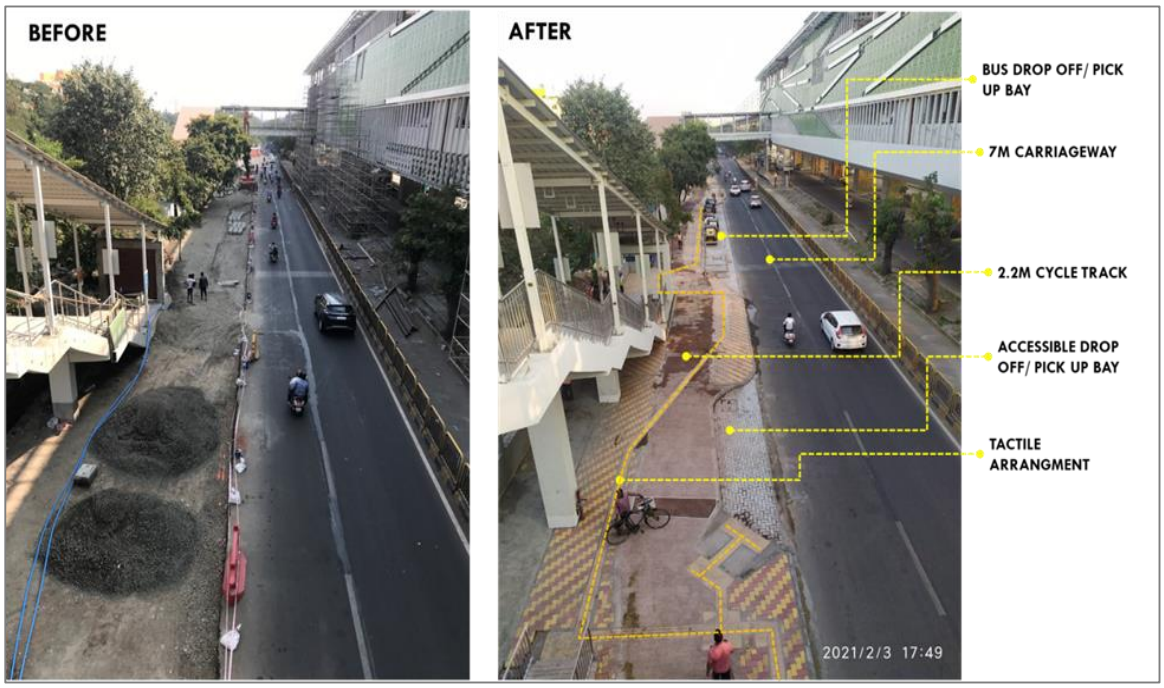


FIGURE 7-12: EXAMPLE 1: MMI IMPLEMENTATION FOR PUNE MRTS PHASE – 1

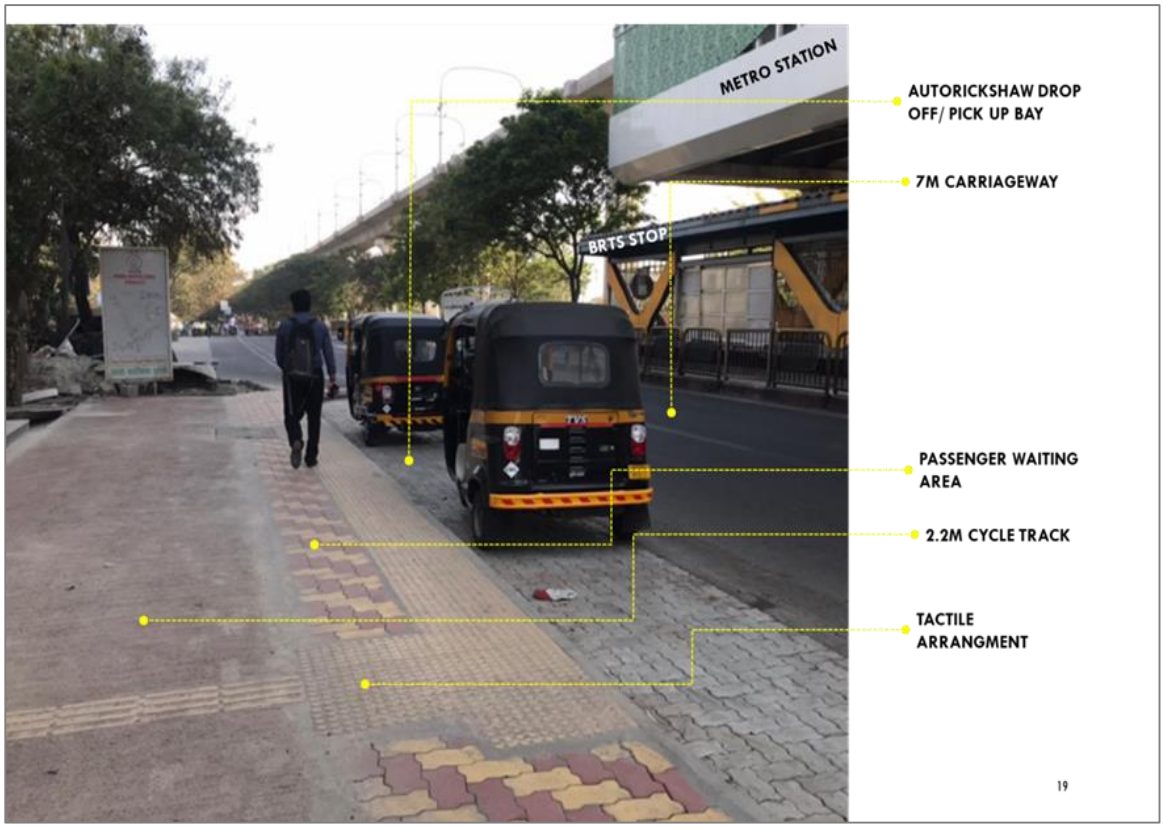


FIGURE 7-13: EXAMPLE 2: MMI IMPLEMENTATION FOR PUNE MRTS PHASE - 1

FIGURE 7-14: EXAMPLE 3: MMI IMPLEMENTATION FOR PUNE MRTS PHASE - 1

FIGURE 7-15: EXAMPLE 4: MMI IMPLEMENTATION FOR PUNE MRTS PHASE - 1

7.3.1.1. PROVISION OF PEDESTRIAN INFRASTRUCTURE

Pedestrians require a convenient and safe access to the proposed metro station. For smooth movement of pedestrian, all the footpaths in the metro station influence zone/ primary catchment area will be considered to be upgraded to desired level of comfort and also proposed new within the stations vicinity areas if not available. The clear footpath width should not be less than 1.8 m as per IRC. In immediate vicinity of entry/exit structures of metro stations, footpath width depends on peak period passenger flow/

footfalls. The required footpath widths near the metro station entrances shall be determined from boarding/alighting figures derived in DPR and shall be considered/ proposed in the station accessibility plans for stations of Pune Metro.

High quality pedestrian access will be accomplished through design factors such as directness and connectivity, ease of movement, safety and security. The vendors if any on the footpaths shall be removed and desired accessibility to metro stations will be provided. The facilities (footpaths/ walkways) will be directly integrated with the system.

7.3.1.2. BICYCLE INFRASTRUCTURE

Bicycles can be an important mode of access to the Metro Systems for the passengers for 1 km to 2 km of the metro stations influence area. It is hence essential to provide robust bicycle network for a city. Pune Municipal Corporation is implementing the dedicated cycle tracks on various roads in the city, whereas Maha-Metro has implemented the cycle tracks under the Multi Modal Integration Planning for Phase - 1 Stations of Pune Metro. 2.2 m wide dedicated Cycle tracks are to be proposed for Arterial roads whereas 1.5 m wide painted cycle lane to be provided for roads with narrow ROWs.

FIGURE 7-16: PUBLIC BICYCLE SHARING SYSTEM AT PUNE METRO STATION

A Public bicycle sharing system (PBS) is a subscription based service in which bicycles are made available for free and allowed for shared use to metro passengers on a short

term basis. The main purpose is to allow passengers to depart or arrive at metro stations. Maha-Metro has also started the PBS services for the Phase - 1 Metro Stations.

With advancement of technology and encouragement from Government, use of EVs and E-bikes have been on rise in recent year. Spaces can be provided at Metro Stations to accommodate such vehicles. The success of system is however dependant on the network coverage. It is thus essential to implement such a scheme on city level.

Figure 7-17: E-Bike Sharing Schemes

The success of PBS systems is however highly dependent on the coverage of system; hence it is essential to have a citywide network for PBS.

7.3.1.3. PUBLIC TRANSPORT AND FEEDER BUS SYSTEMS

Pune Mahanagar Parivahan Mahamandal Limited (PMPML) is responsible for operating the bus services in the city and its surroundings. The fleet size of PMPML is about 1,500. Average number of buses on road per day is 1,382 operating on 371 routes. Additionally, 10 feeder routes have been planned for the corridors. Drop off bays have been proposed for the buses at the metro station and bus stops are proposed at about 250m interval along the feeder routes.

7.3.1.4. INTERMEDIATE PUBLIC TRANSPORT

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 App based taxi aggregators like Ola and Uber. There are no specific route restrictions for auto rickshaws.

Auto rickshaws provide connectivity to the city core areas 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 7,759 other passenger vehicular permits are issued in Pune and Pimpri-Chinchwad.

The integration with IPT modes is done at the Metro Station by proposing the dedicated drop off bays for the Auto Rickshaws and Taxis.

7.3.1.5. PICK-UP/DROP-OFF BAYS

Separate Pick up/ drop off bays for all types of vehicles shall be provided in the station influence area at every metro station for better dispersal. Drop off bays for city/state transport buses, feeder vehicles, intermediate public transport vehicles like autos, taxies, etc. and private vehicles shall be provided. Drop off bays for public transport vehicles shall be located as near to Entry/exit structure as possible, then the priority shall be given to intermediate transport vehicles and lastly to private vehicles.

7.3.1.6. SIGNAGE'S AND WAY-FINDINGS

Informative, regulatory and warning shall be proposed inside Metro station as well as outside station. An effective signage system provides better accessibility to Public transport systems. A good signage should have combination of easily recognisable symbols using contrasting colours, Audible Signals or Auditory Signals along with a Braille marking and International symbol of Accessibility.

Way finding signage shall be proposed on every road in the station influence area guiding commuter/passenger towards nearest Metro station. These also give information about the neighbouring locations of the station and exit and entry directions.

Following images shows the signage/way findings installed by Maha metro for the Phase - 1 of Pune Metro.

FIGURE 7-18: SIGNAGES AND WAY-FINDINGS

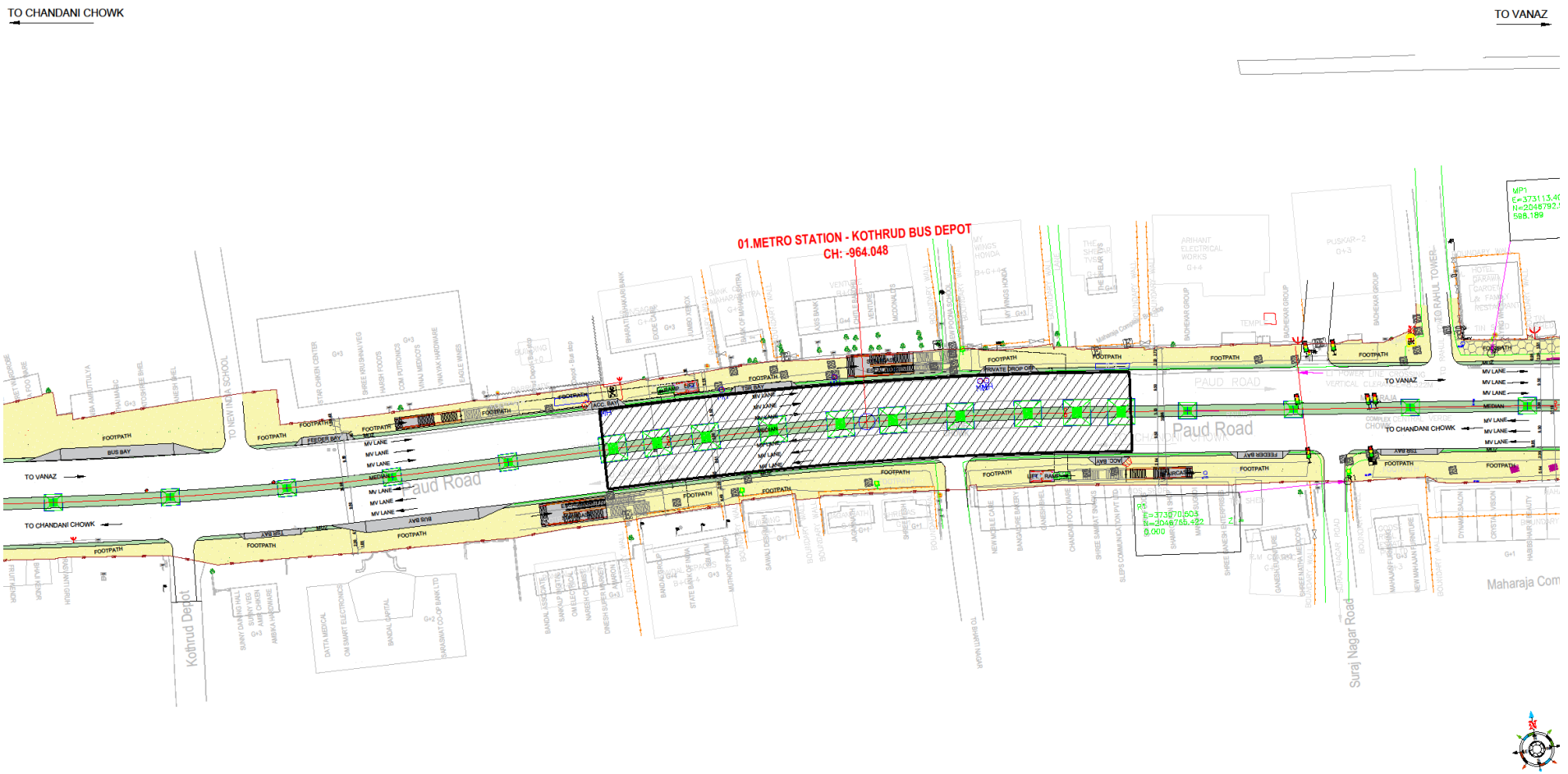


FIGURE 7-19; INTEGRATION – KOTHRUD BUS DEPOT STATION

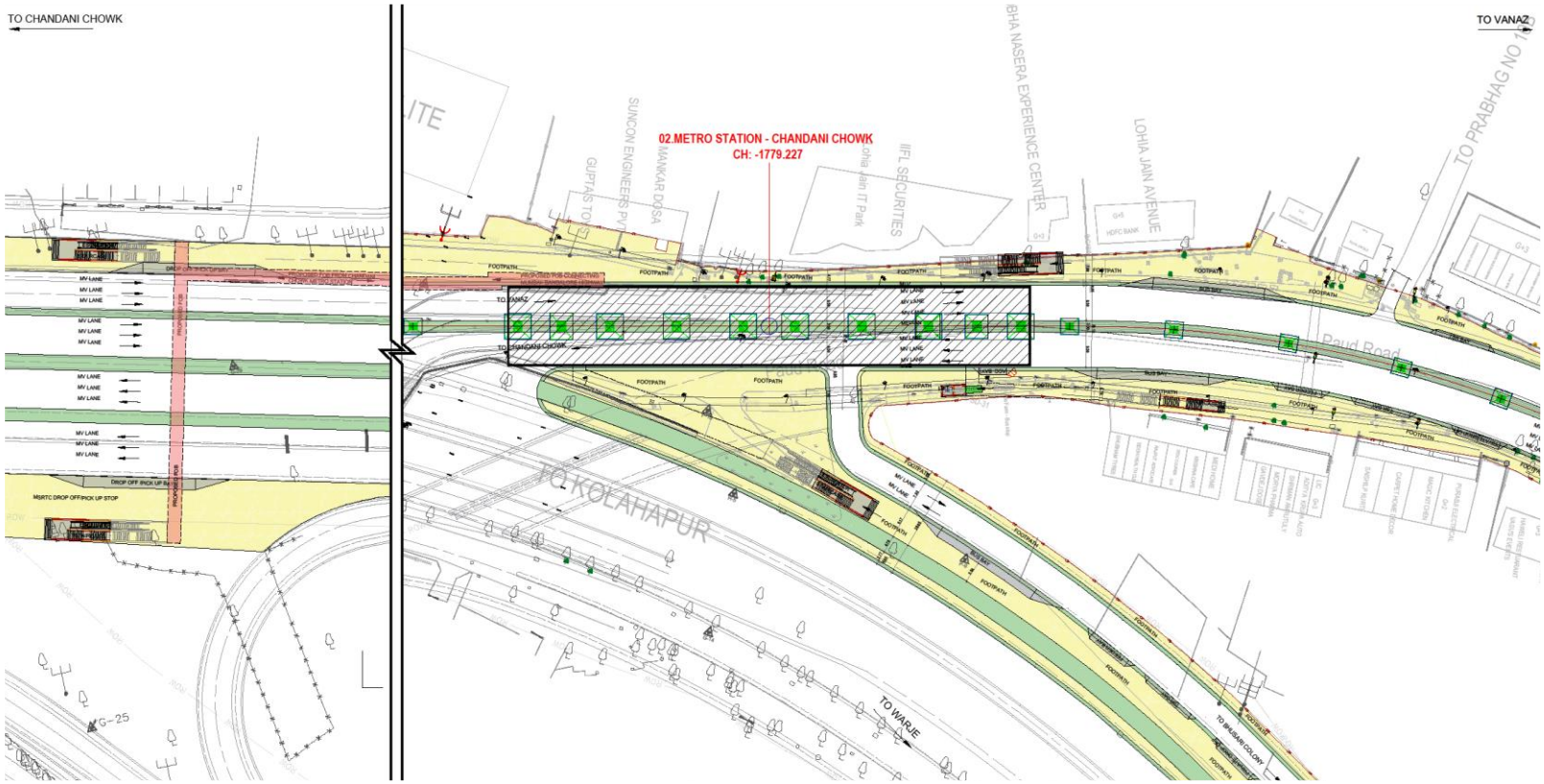


FIGURE 7-20: INTEGRATION - CHANDANI CHOWK STATION

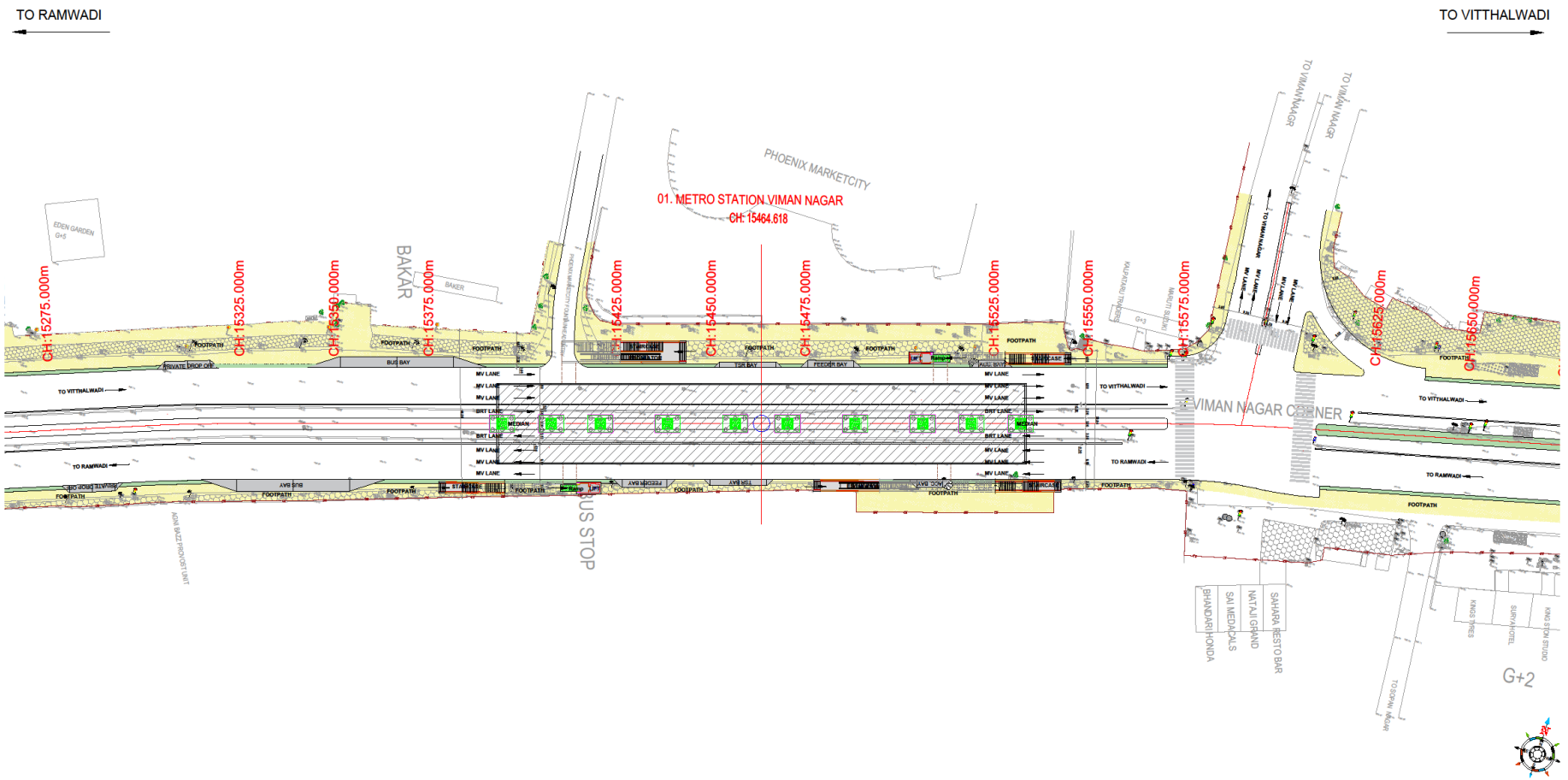


FIGURE 7-21: INTEGRATION: VIMAN NAGAR STATION

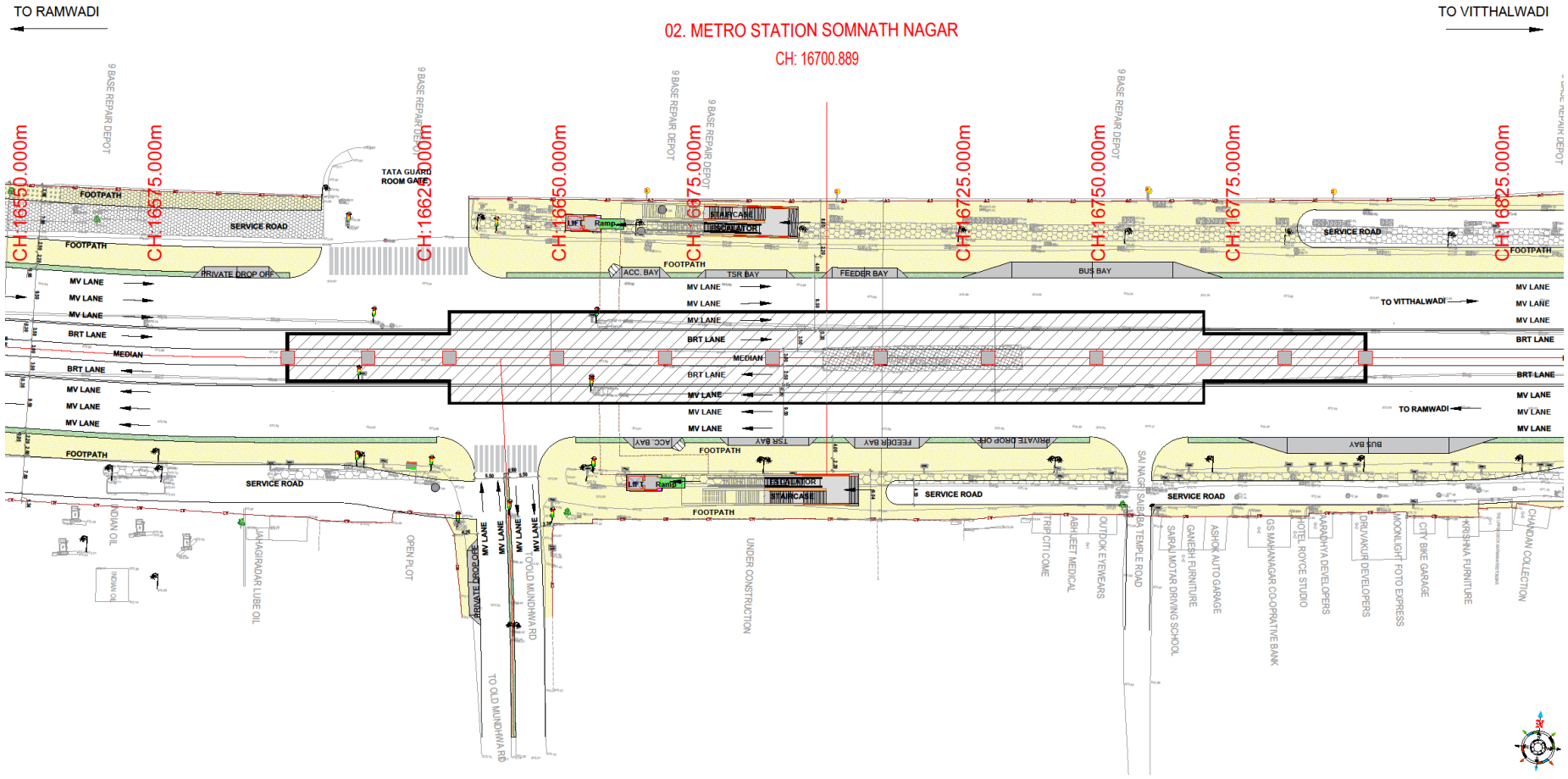


FIGURE 7-22: INTEGRATION: SOMNATH NAGAR STATION

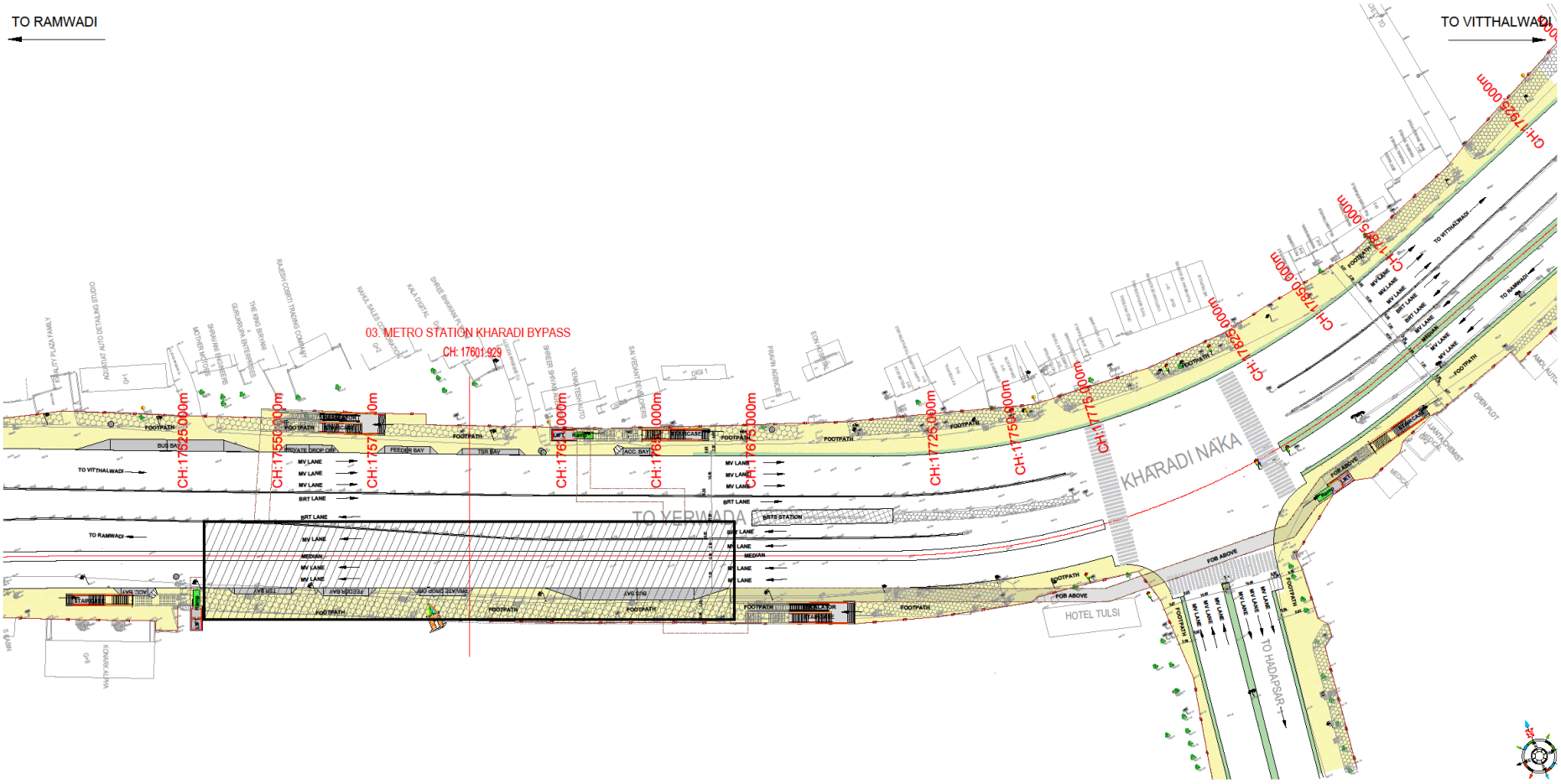


FIGURE 7-23: INTEGRATION – KHARADI BYPASS STATION

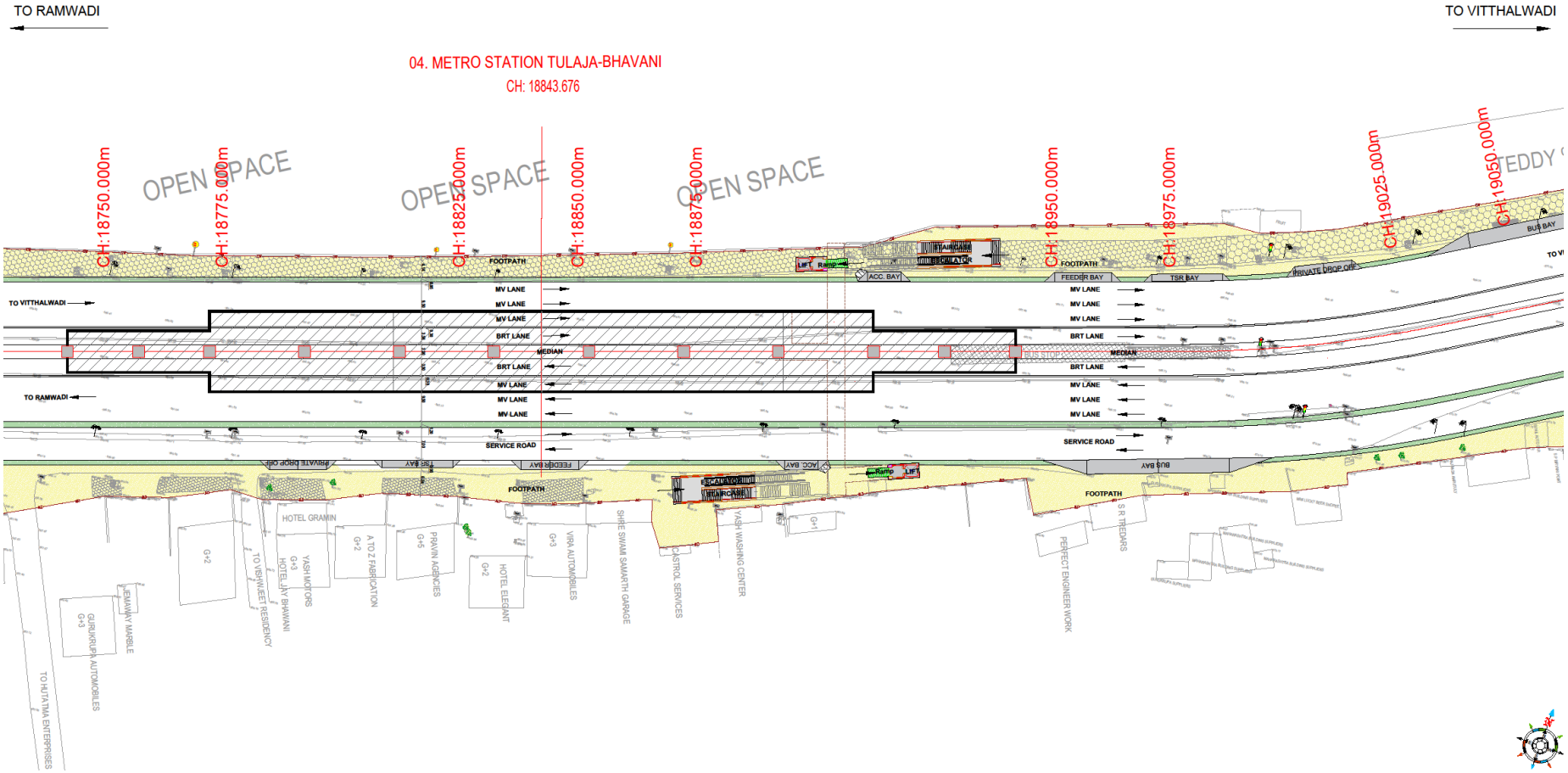


FIGURE 7-24: INTEGRATION - TULAJA BHAVANI STATION

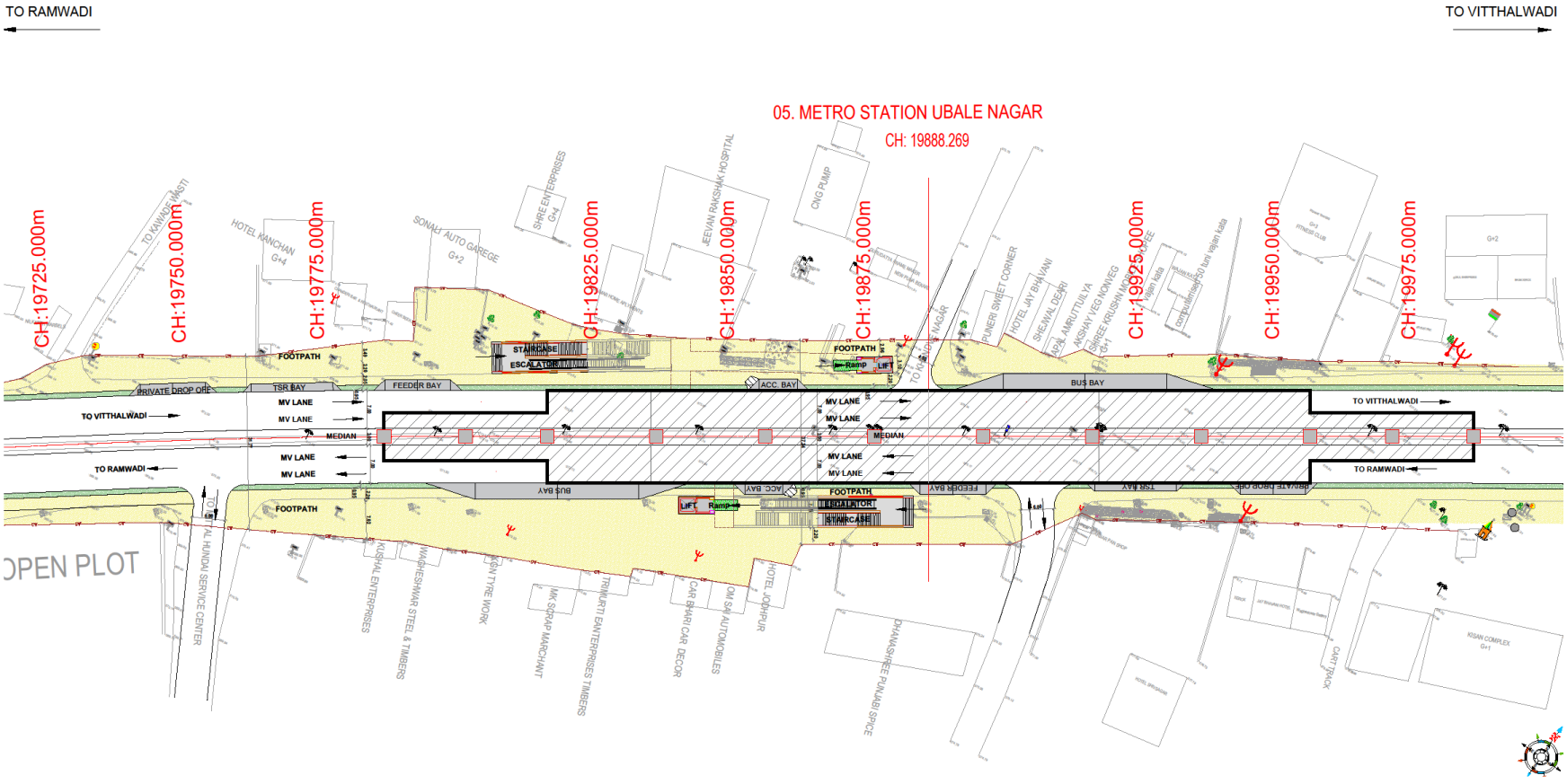


FIGURE 7-25: INTEGRATION - UBALE NAGAR STATION

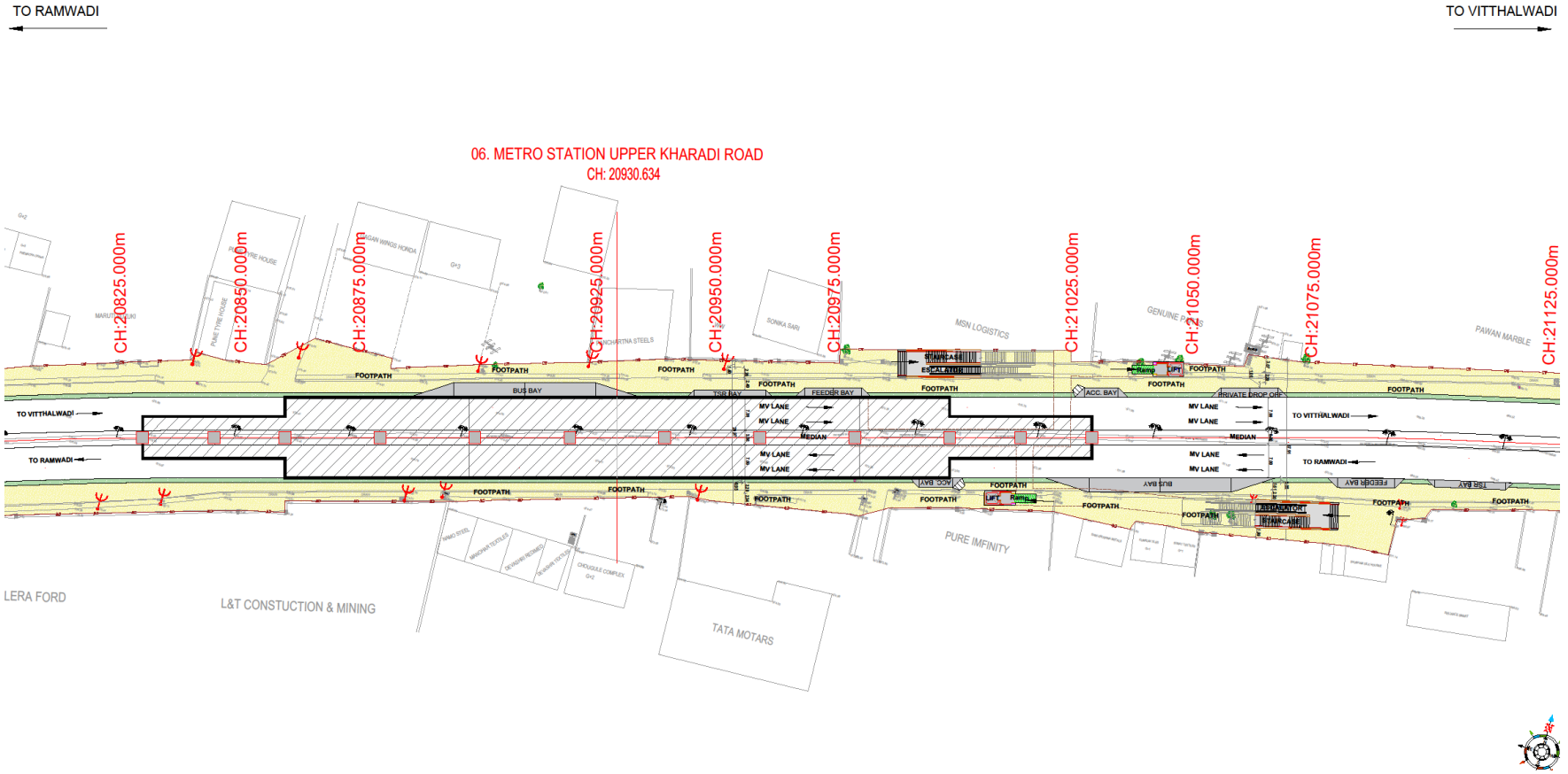


FIGURE 7-26: INTEGRATION - UPPER KHARADI ROAD STATION

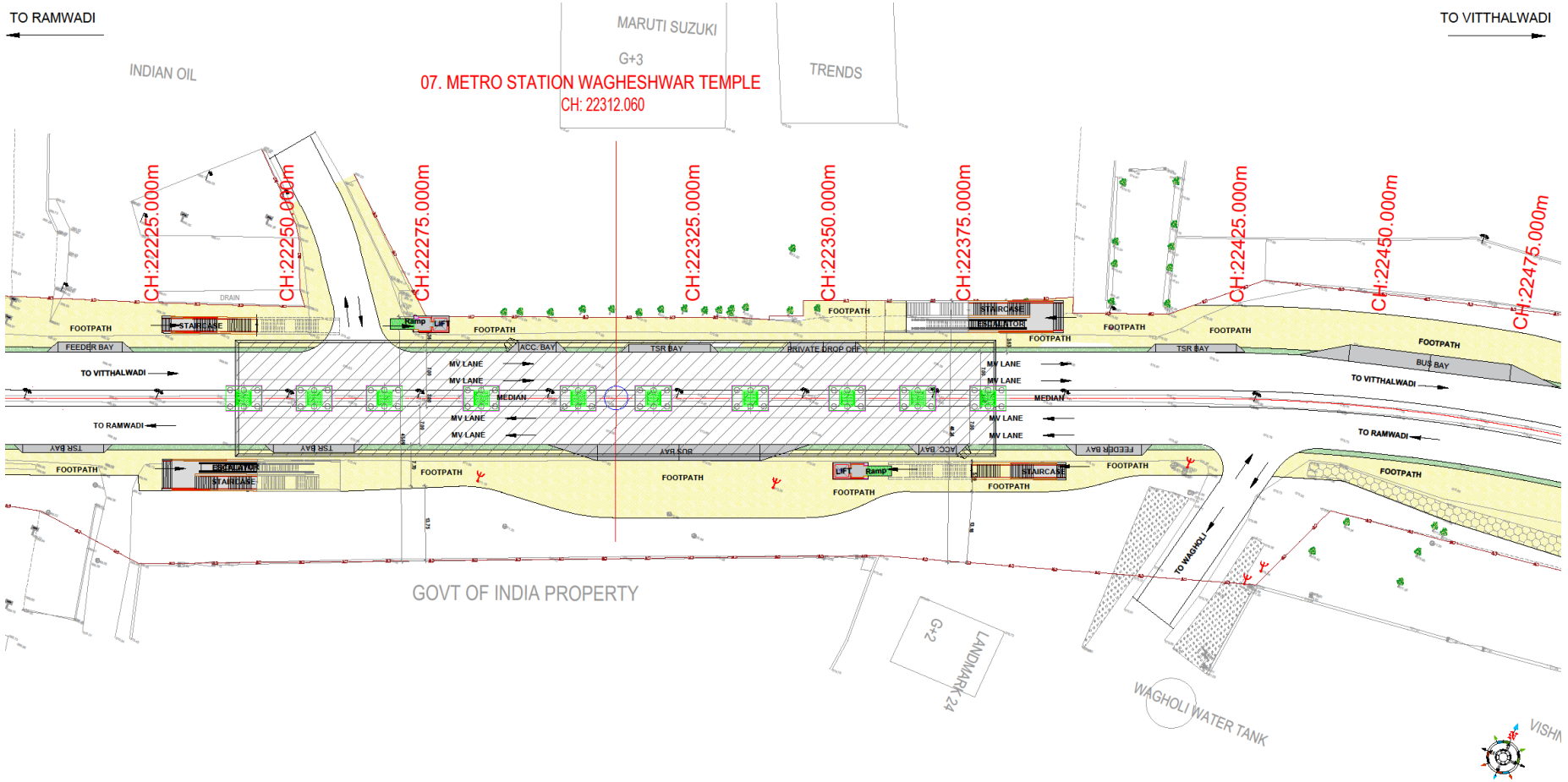


FIGURE 7-27: INTEGRATION - WAGHESHWAR TEMPLE STATION

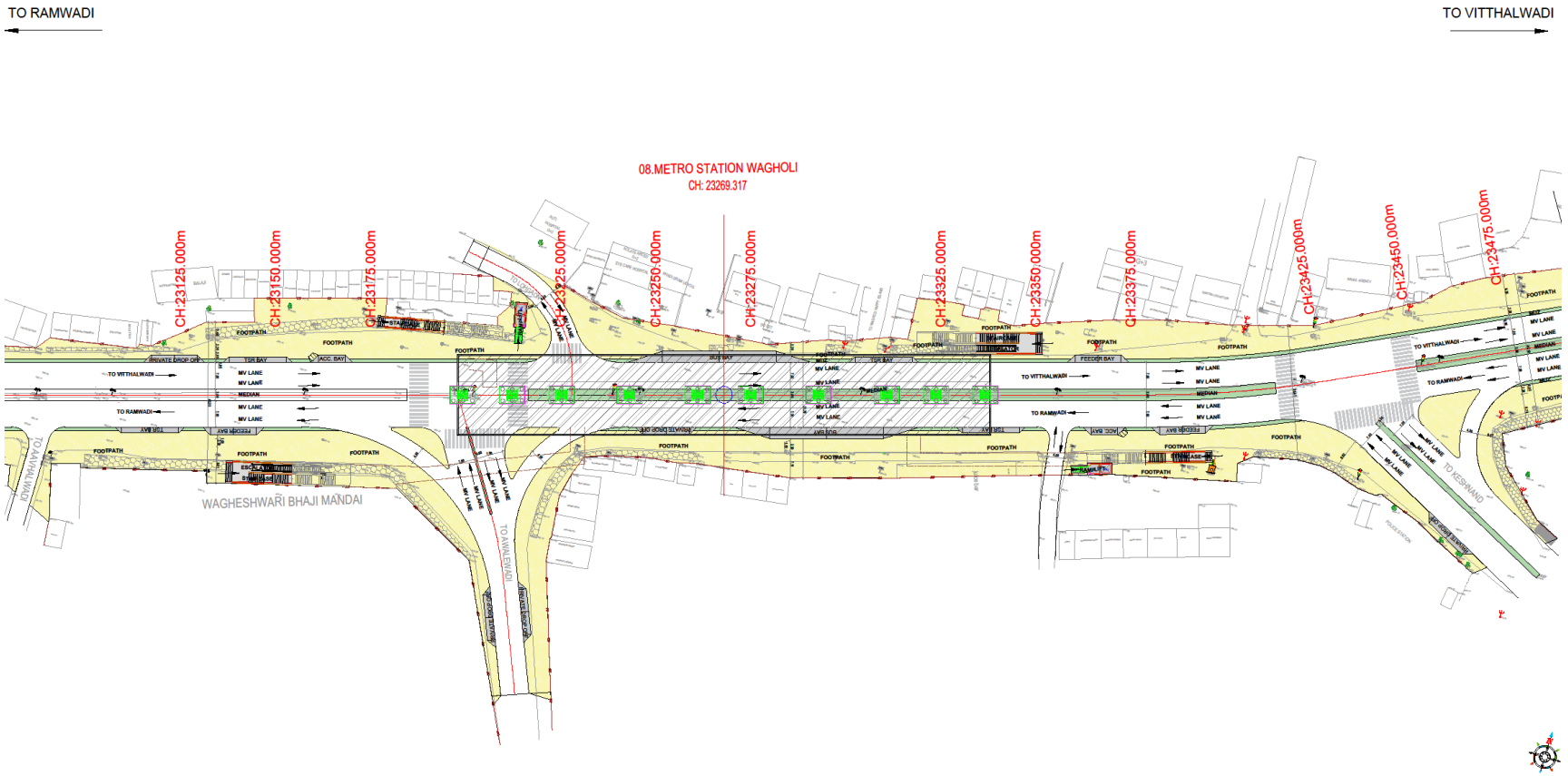


FIGURE 7-28: INTEGRATION - WAGHOLI STATION

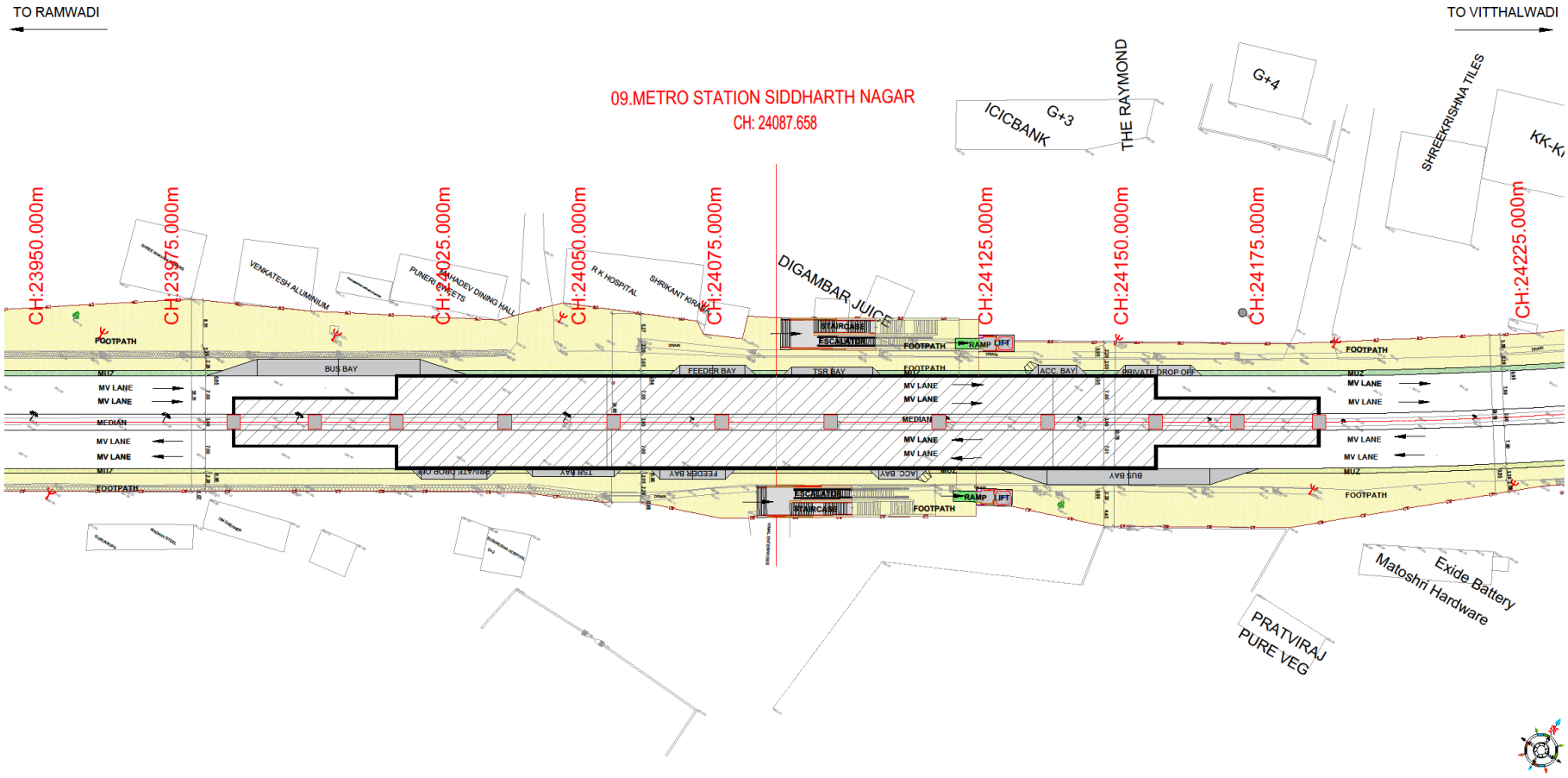


FIGURE 7-29: SIDDHARTH NAGAR STATION

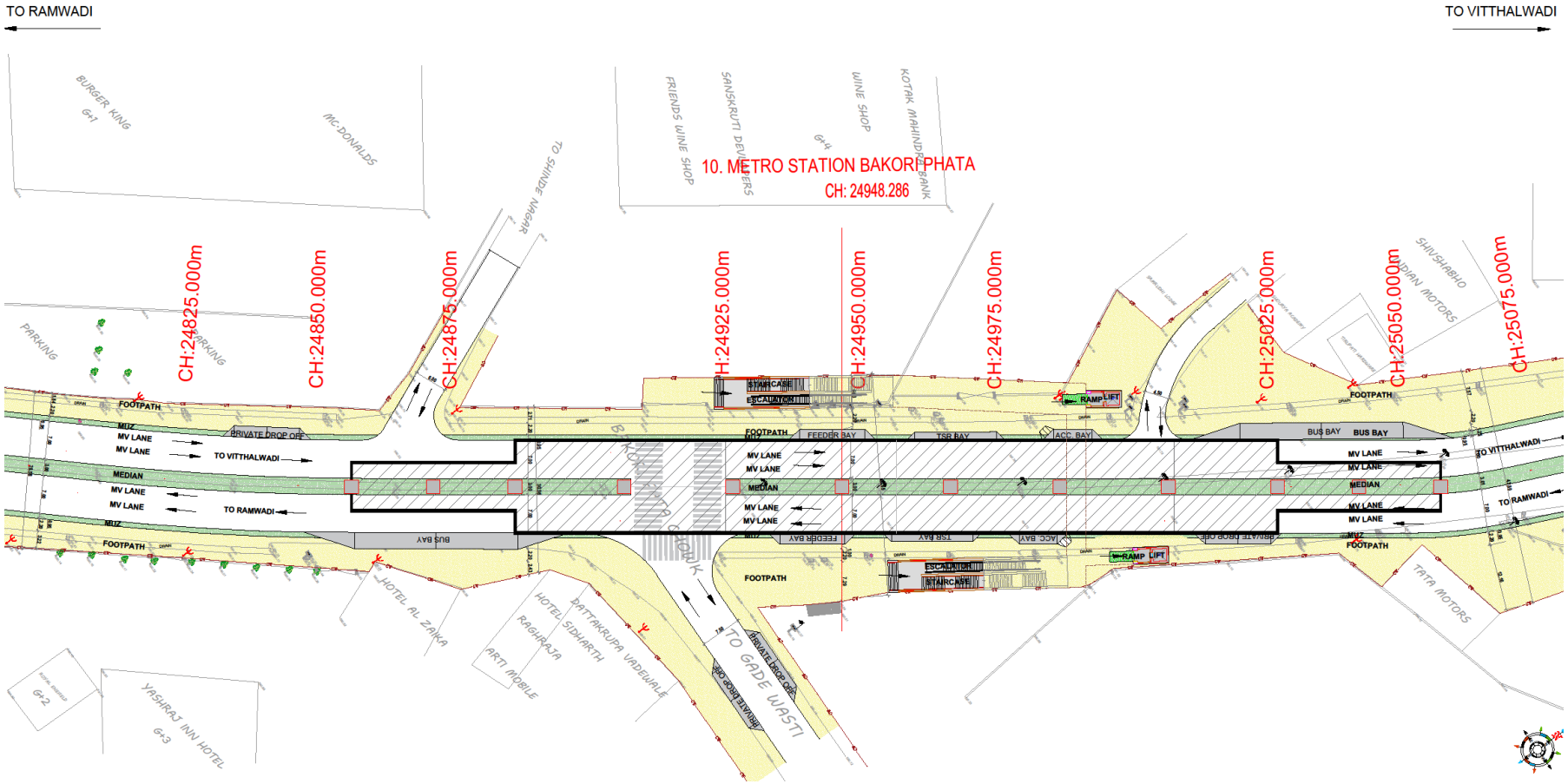


FIGURE 7-30: INTEGRATION - BAKORI PHATA STATION

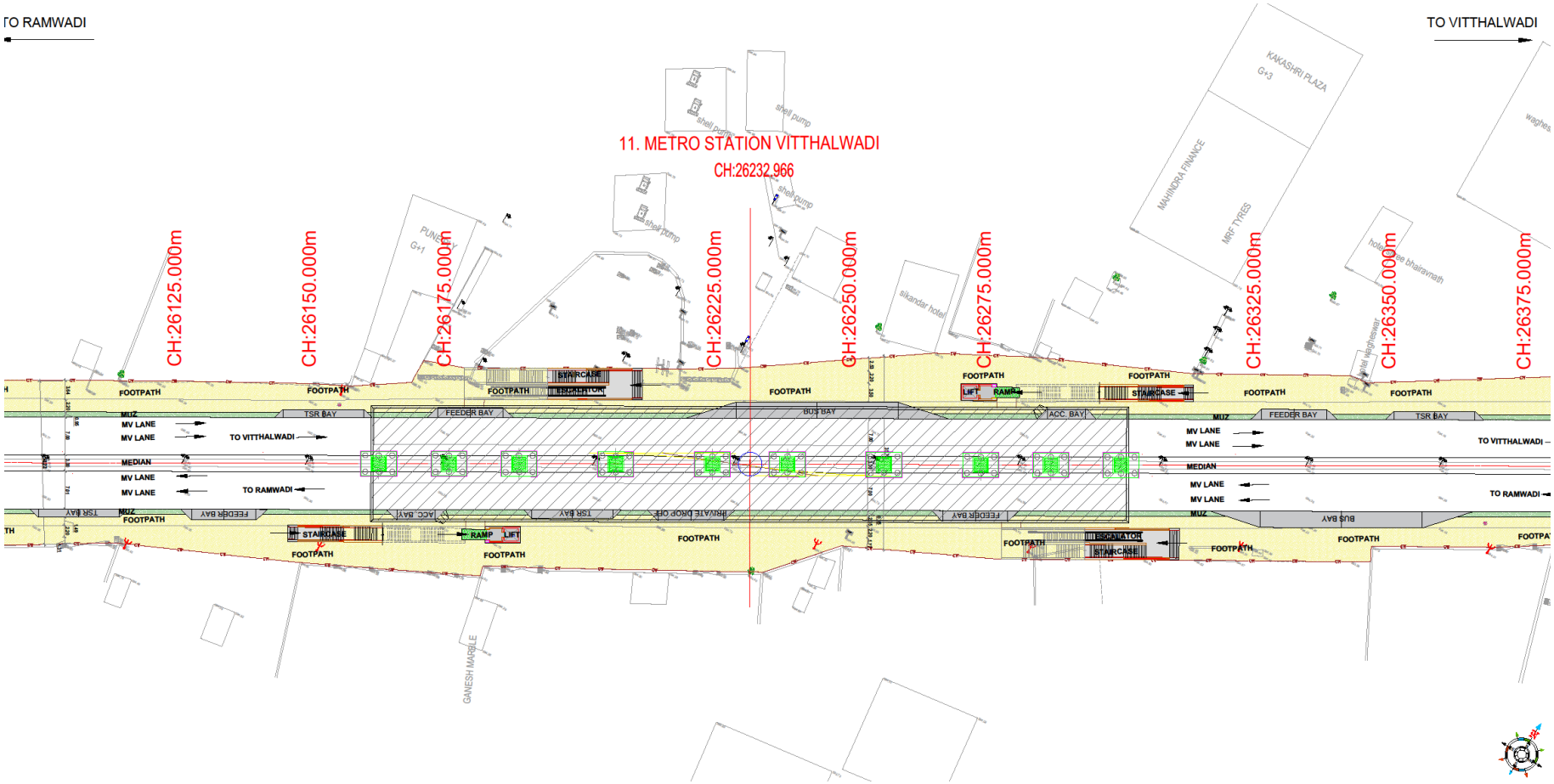


FIGURE 7-31: INTEGRATION - VITTHALWADI STATION

7.4. RECOMMENDATIONS FOR MULTI-MODAL INTEGRATION

7.4.1 PHYSICAL INTEGRATION

The facilities such as adequate footpaths, drop offs, cycle tracks, feeder network etc., provided at the station comes under the Physical integration. It is essential to plan for the physical integration for providing the seamless mobility, reduced travel time, and ease of access. Redesigning of the carriageway to provide adequate space for the facilities have been proposed.

7.4.2 OPERATIONAL INTEGRATION

This involves application of management techniques to optimize the allocation of transit resources and coordinate services. The techniques/principles of network integration include:

- **Coordinated Routing and Scheduling** – in which high-capacity, long-haul modes, such as rail transit is considered as the trunk system and buses act as feeder to the rail system. Accordingly, the integrated route network is planned by generating feeder bus routes for each rail station.
- **Rationalization of Redundant Services** – The wasteful duplication of transit service by competing systems is eliminated and resources are redeployed to reduce headways on existing routes and extend services into new areas.
- **Network coordination and access** – in which access facilities need to be provided for non-motorized transport (pedestrians and cyclists) and private transport to support and enhance the public transport operations, to achieve overall network integration.

The service integration takes into account all modes of services. That means all modes providing services should be complementary to each other.

7.4.3 FARE INTEGRATION

The basic principle behind fare integration is that one ticket provides access to all modes of transport even when managed by different companies. The financials of public transport provide important indicators to assess the sustainability of public transport. Choice of fare structure is a very important part of public transport planning. It directly influences operators' revenue.

At its simplest, integration of fares allows a person to make a journey that involves transfers (within or between different transport modes) with a single ticket that is valid for the complete journey, modes being buses, trains, subways, taxies, parking, etc.

The major benefits of fare integration are as follows:

- It encourages people to use public transport by simplifying the transfer between transport modes and by increasing the efficiency of the services
- Provides a common ticket across the modes
- Improves the experience of seamless mobility

Integrated payment solutions like smart card system can be introduced which can be used across various modes integrating the public transport system. It allows seamless access and payment across different modes. The same card can be used across other utility services on the lines of 'one city – one card' concept.

Smart Card - Smart Cards are small plastic cards which hold certain value of money and can be used as a fare paying system at Metro stations. Since bus & feeder passengers are likely to interchange with Metro, it is quite essential to integrate the payment methods of feeder and Metro system. The advantages of using a smart card are:

- One time issue multiple usages
- Same card for paying of feeder and Metro
- Remote recharge options

Maha-Metro has launched Common Mobility Card for the Nagpur Metro and Plans to implement similar system for Pune.

FIGURE 7-32: SMART CARD SYSTEM

7.4.4 INFORMATION INTEGRATION

Information integration is all about creating the possibility to get information about the entire journey and not having to enquire at different sources. To take an informed decision during travel, real-time access to information is of strategic importance.

Information integration deals with the Information on routes, schedules, fares, and transfer points for all transit modes and services throughout the urban area, which is provided by

a centralized source. Information services include route maps, timetables, fare schedules, promotion materials, uniform street signs and vehicle identification, display at stops, transfer points and major stations and telephone inquiry answering service. Providing integrated information during journey before and in between is important, to make them attractive.

7.4.5 INSTITUTIONAL INTEGRATION

City growth strategies are usually guided by documents like land use plans, development plans and master plans etc. and the urban transport models are determined by parameters like existing road network, public transport and its related infrastructure, personal vehicles, licensing mechanism and authorities, land ownership, fare structure of public transport, Intelligent Transport System (ITS) mechanism, traffic enforcement agencies and traffic law enforcing mechanisms, goods and freight movement and their operators, road safety and accident management system etc.

All these agencies which prepare these policy documents and are in charge of governing these functions generally work independently and usually it is observed that there is no synergy between them. There exists no umbrella agency that monitors and integrates these multiple bodies in order to ensure smoother functioning of all aspects related to urban transport in any city. Considering this, a Unified Authority is established for transport related matters, commonly known as Unified Metropolitan Transport Authority. Pune Unified Metropolitan Transport Authority (PUMTA) with Divisional Commissioner as Chairperson has been formed for Pune Metropolitan Region and includes PMC, PMRDA, PCMC, Maha-Metro, Traffic Department and other stakeholders are part of PUMTA.

CHAPTER 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 and 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;
- Introduction of short loops to cater to increased passenger load during peak hours with minimum number of trains.

8.2. EXISTING OPERATION PLAN FOR PHASE - 1

8.2.1. SYSTEM PLAN

The track plan for Line 2 Vanaz to Ramwadi of Phase - 1 is shown in Figure 8-1.

It may be seen that crossovers are provided at following locations;

- Vanaz (terminal) station on both sides
- Ramwadi (terminal) station on both sides
- Deccan Station at Ramwadi end (for priority section operation)
- Civil Court Station on both sides
- Pocket track between Civil Court and Pune Railway Station
- Ruby Clinic Station (Vanaz end)

The crossovers at Civil Court and Ruby Clinic facilitate start of train operation when parked train at Pocket Track is operated. Also, the Depot is provided at Vanaz end.

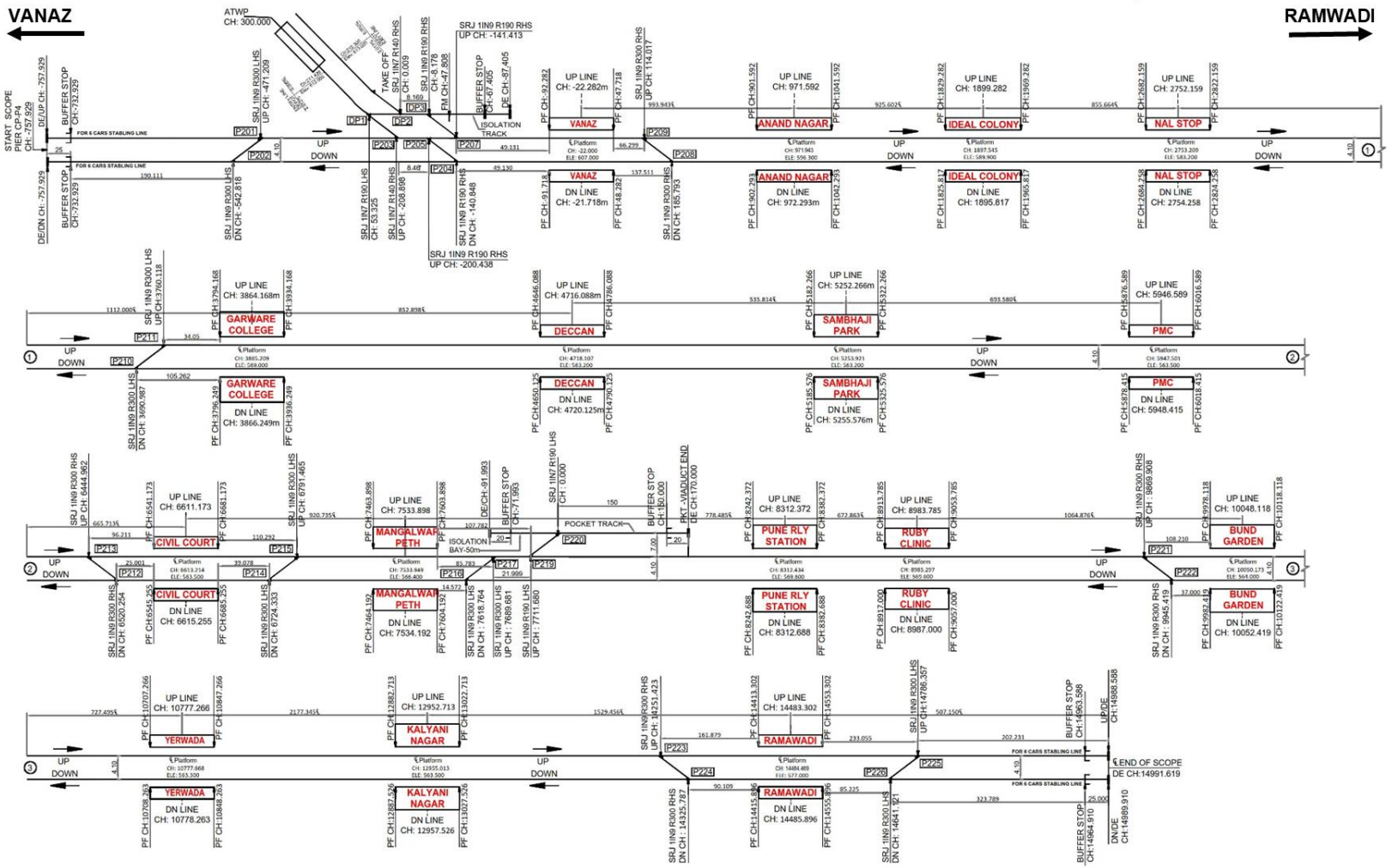


FIGURE 8-1: TRACK PLAN OF LINE 2 – VANAZ TO RAMWADI (PHASE-1)

The track plan for Line 2A and Line 2B Corridors is shown in the figure below:

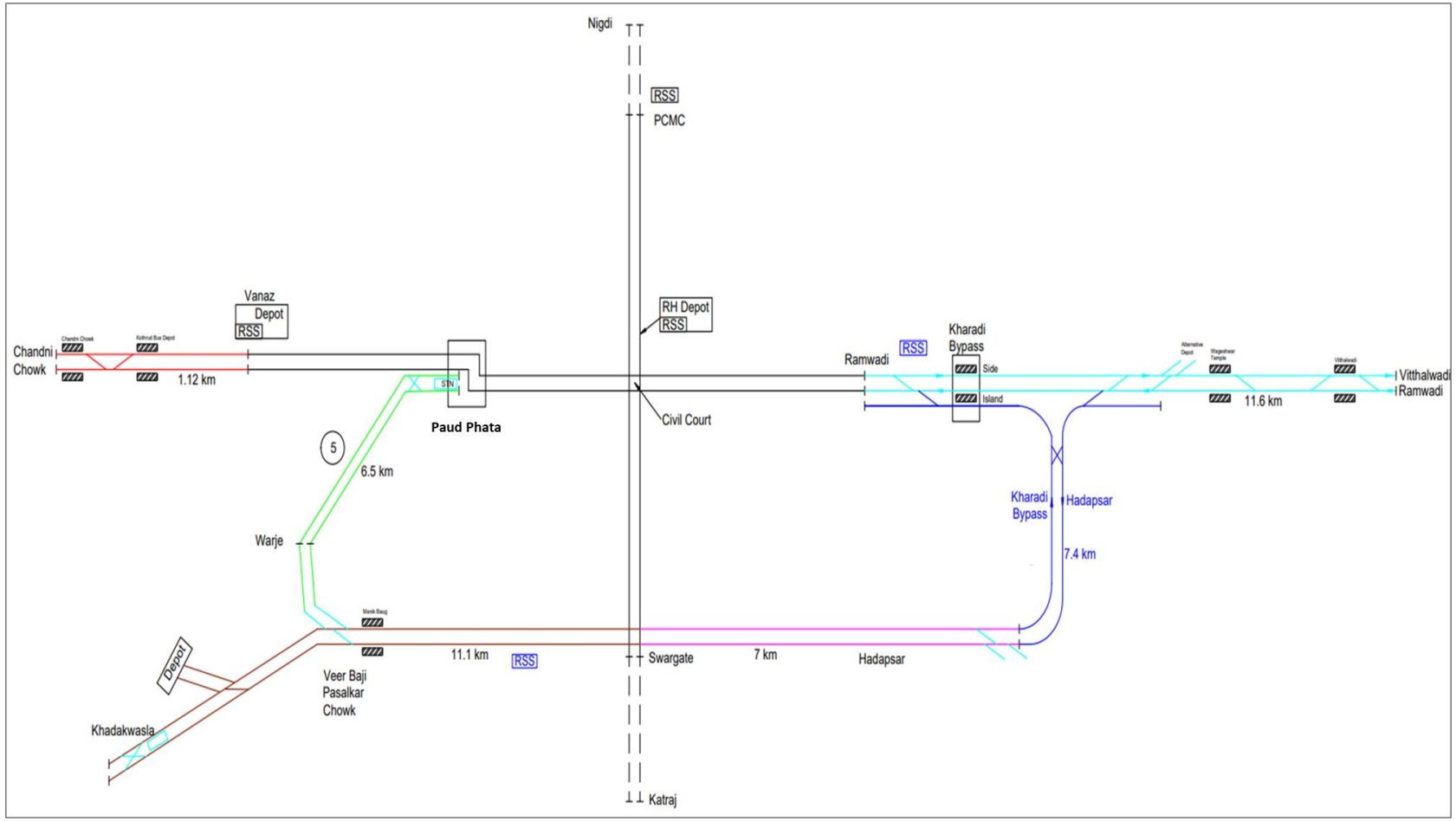


FIGURE 8-2: SCHEMATIC TRACK PLAN OF PUNE METRO PHASE-2

8.2.2. ROLLING STOCK

Since the Line 2 of Phase - 1 (i.e. Vanaz to Ramwadi) is partly operational, and its extensions on both sides are planned, therefore, it is necessary that operation plan of Phase - 1 is examined and then integrated operation plan with extensions is deliberated.

Pune MRTS Phase - 1 DPR was prepared by DMRC in August 2013 and the implementation of the project is based on that DPR with certain modifications as considered necessary during detailed design and planning stage. The key details of Pune MRTS Phase - 1 are provided in Table 8-1.

TABLE 8-1: LINE 2 DETAILS (PHASE - 1)

SN	Description	Year 2018	Year 2021	Year 2031	Remarks
1	Train formation as per DPR	4-car	4-car	4-car	
2	Trains actually procured and operated	3-car	3-car	3-car	
3	Peak Headway with 4-car train (as per DPR)	12 minutes	8 minutes	6.5 minutes	
4	Adjusted headway with 3-car train	9 minutes	6 minutes	4.875 minutes	
5	No. of cars as per DPR	28 (7 rakes)	40 (10 rakes)	48 (12 rakes)	
6	No. of cars actually procured	27 (9 rakes)	39 (13 rakes*)	48 (16 rakes*)	*Assumed
7	4-car train capacity with 6 passengers/m2 standing area	1034			As per DPR
8	4-car train capacity with 8 passengers/m2 standing area	1316			As per DPR

As per DPR, end-to-end train operation is considered despite availability of intermediate crossovers in the corridor.

8.2.3. STATION YARD PLANNING

Provision of front and/or rear crossovers at terminal stations, depending on feasibility, 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 as possible to the terminal station to achieve better headways when required.

The crossovers are provisioned as under:

- Two front crossovers (of opposite directions) at Chandani Chowk terminal station

- Two crossovers – one front and one rear - at Vitthalwadi terminal station
- Crossovers are provided at Kharadi junction station and one crossover provided at Wagheshwar Temple station

Provision of train stabling facility is recommended on mainline:

- For future stabling requirements, to minimize empty running of train and
- To stable trains, which might get faulty during service.

Recommended locations from operations perspective are minimum at terminal stations of extended corridor i.e., at Chandani Chowk Station and Wagholi/Vitthalwadi Station.

8.3. TRAIN OPERATION PLAN FOR LINE 2A & LINE 2B

Following sections provides a detailed train operation plan for Line 2A - Vanaz to Chandani Chowk & Line 2B - Ramwadi to Wagholi/Vitthalwadi of Pune MRTS Phase - 2.

8.3.1. SALIENT FEATURES

The salient features of the train operation plan are as given below;

- Running of services for 19 hours of the day (05:00 to 24:00 Hrs) with a maximum station dwell time of 30 seconds, which may be further optimized as per ridership trend when section opened for operations;
- Make up time – 5 to 10% with 8 to 12% coasting;
- Average operational speed – 32 km/hr for end-to-end running on extended corridor.

8.3.2. TRAFFIC DEMAND

Peak hour peak direction traffic (PHPDT) for horizon years are provided in Table 8-2.

TABLE 8-2: SUMMARY OF RIDERSHIP AND PHPDT

	Ridership	2027	2037	2047	2057
Chandani Chowk to Wagholi/Vitthalwadi	Peak hour ridership	35908	57688	81925	99338
	Daily ridership	359080	576880	819250	993380
	PHPDT	11200	17001	24255	29554
	Average trip length (km)	7.76	7.64	7.65	7.67
Vanaz to Ramwadi (Phase – 1)	Peak hour ridership	26308	37577	53226	64446
	Daily ridership	263080	375770	532260	644460
	PHPDT	8737	12184	17360	21131
	Average trip length (km)	5.08	5.11	5.12	5.12

The details of station boarding/alighting and maximum sectional traffic demand for horizon years is provided in Table 8-3 and Table 8-4.

TABLE 8-3: DETAILS OF STATION BOARDING AND ALIGHTING

S. N.	Station Name	Daily Boarding							
		2027		2037		2047		2057	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
1	Chandani Chowk	14,020	11,050	19,600	19,400	27,820	27,610	33,740	33,620
2	Kothrud Bus Depot	5,640	6,000	9,870	10,200	14,100	14,410	17,170	17,370
3	Vanaz	12,180	10,670	20,950	17,490	29,730	24,280	36,010	28,950
4	Anand Nagar	7,610	11,510	11,930	18,200	16,880	25,600	20,490	30,790
5	Ideal Colony	7,420	6,270	11,930	10,400	16,820	14,710	20,340	17,720
6	Nal Stop	14,760	13,580	38,010	36,370	53,850	51,420	65,160	62,230
7	Garware College	16,270	20,460	15,690	21,350	22,200	30,290	26,800	36,720
8	Deccan Gymkhana	5,110	6,670	6,000	8,740	8,470	12,400	10,230	15,050
9	Chatrapati Sambhaji Udyan	7,360	6,660	12,780	11,040	17,900	15,800	21,480	19,260
10	PMC	32,910	37,730	44,230	58,390	62,370	83,400	75,120	1,01,670
11	Civil Court	57,090	72,660	86,660	1,06,200	1,22,660	1,51,540	1,48,210	1,84,650
12	Mangalwar Peth	11,490	4,460	18,640	7,450	26,210	10,440	31,470	12,560
13	Pune Railway Station	26,990	21,840	30,010	27,570	42,440	39,110	51,260	47,410
14	Ruby Hall Clinic	2,700	6,030	4,130	9,060	5,860	12,850	7,120	15,600
15	Bund Garden	7,310	23,530	10,910	28,500	15,530	40,130	18,890	48,420
16	Yerwada	32,010	17,340	44,670	20,130	63,330	28,000	76,680	33,450
17	Kalyani Nagar	13,090	11,220	23,750	20,190	33,940	28,860	41,570	35,110
18	Ramwadi	7,600	6,100	11,350	8,600	16,140	12,060	19,560	14,480
19	Viman Nagar	10,170	8,290	30,380	25,000	43,430	35,720	52,810	43,470
20	Somnath Nagar	6,480	4,820	8,160	5,870	11,650	8,320	14,210	10,050
21	Kharadi By Pass	19,360	10,820	41,470	32,540	59,270	46,390	72,140	56,420
22	Tulaja Bhavani	3,170	2,860	5,720	5,360	8,190	7,750	10,000	9,470
23	Ubale Nagar	3,020	4,130	5,500	5,930	7,880	8,550	9,610	10,440
24	Upper Kharadi Road	800	1,580	1,490	3,040	2,150	4,220	2,660	5,040

S. N.	Station Name	Daily Boarding							
		2027		2037		2047		2057	
		Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
25	Wagheshwar Temple	12,530	14,860	23,680	25,300	34,280	36,140	42,300	43,900
26	Wagholi	11,400	14,030	20,280	27,030	29,270	39,170	35,890	47,860
27	Siddharth Nagar	3,950	510	6,530	900	9,220	1,220	11,150	1,420
28	Bakori Phata	850	760	1,610	1,420	2,250	1,880	2,690	2,160
29	Vitthalwadi	5,790	2,640	10,950	5,210	15,410	6,980	18,620	8,090
Total of Line 2 - Including the Extensions (Vanaz to Chandani Chowk and Ramwadi to Wagholi/Vitthalwadi)		3,59,080	3,59,080	5,76,880	5,76,880	8,19,250	8,19,250	9,93,380	9,93,380

TABLE 8-4: SECTIONAL TRAFFIC DEMAND FOR HORIZON YEARS

S. N.	From Station Name	To Station Name	Max Sectional Loadings - Peak Hour Peak Direction Trips (PHPDT)							
			2027		2037		2047		2057	
			Forward[1]	Reverse[2]	Forward	Reverse	Forward	Reverse	Forward	Reverse
1	Chandani Chowk	Kothrud Bus Depot	1402	1105	1960	1940	2782	2761	3374	3362
2	Kothrud Bus Depot	Vanaz	1913	1652	2865	2878	4074	4084	4947	4955
3	Vanaz	Anand Nagar	3029	2617	4810	4477	6835	6300	8291	7593
4	Anand Nagar	Ideal Colony	3707	3685	5881	6175	8350	8687	10130	10462
5	Ideal Colony	Nal Stop	4340	4203	6672	6813	9464	9590	11478	11548
6	Nal Stop	Garware College	5450	5195	9467	9444	13429	13312	16279	16056
7	Garware College	Deccan Gymkhana	5959	6123	9534	10077	13526	14218	16395	17164
8	Deccan Gymkhana	Chatrapati Sambhaji Udyan	6315	6635	9885	10702	14022	15107	16992	18243
9	Chatrapati Sambhaji Udyan	PMC	6524	6774	10178	10821	14428	15303	17477	18506
10	PMC	Civil Court	7264	7996	10821	12880	15316	18294	18522	22206
11	Civil Court	Mangalwar Peth	8911	11200	12988	17001	18389	24255	22226	29554
12	Mangalwar Peth	Pune RS	9280	10866	13503	16397	19116	23405	23096	28533
13	Pune RS	Ruby Hall Clinic	9657	10728	13482	16132	19088	23044	23060	28112
14	Ruby Hall Clinic	Bund Garden	9219	10623	12776	15919	18088	22743	21847	27747
15	Bund Garden	Yerwada	7439	10465	10604	15506	15037	22152	18174	27027
16	Yerwada	Kalyani Nagar	6470	8029	9600	12048	13672	17254	16566	21096

1 Forward Direction refers to the movement from Chandani Chowk to Vanaz to Ramwadi to Vitthalwadi
2 Reverse Direction refers to the movement from Vitthalwadi to Ramwadi to Vanaz to Chandani Chowk.

S. N.	From Station Name	To Station Name	Max Sectional Loadings - Peak Hour Peak Direction Trips (PHPDT)							
			2027		2037		2047		2057	
			Forward[1]	Reverse[2]	Forward	Reverse	Forward	Reverse	Forward	Reverse
17	Kalyani Nagar	Ramwadi	5669	7041	8491	10583	12088	15162	14644	18528
18	Ramwadi	Viman Nagar	5475	6697	8254	10071	11766	14432	14264	17640
19	Viman Nagar	Somnath Nagar	4978	6012	8368	9647	11937	13832	14472	16914
20	Somnath Nagar	Kharadi By Pass	4581	5449	8004	9054	11422	12984	13851	15877
21	Kharadi By Pass	Tulaja Bhavani	3874	3888	7183	7340	10256	10530	12432	12886
22	Tulaja Bhavani	Ubale Nagar	3606	3589	6677	6798	9524	9754	11537	11938
23	Ubale Nagar	Upper Kharadi Road	3347	3441	6181	6345	8808	9105	10662	11146
24	Upper Kharadi Road	Wagheshwar Temple	3220	3392	5891	6210	8405	8909	10182	10904
25	Wagheshwar Temple	Wagholi	1774	2179	3427	3908	4886	5576	5907	6789
26	Wagholi	Siddharth Nagar	387	1055	749	1905	1003	2683	1162	3241
27	Siddharth Nagar	Bakori Phata	338	662	661	1254	883	1763	1022	2128
28	Bakori Phata	Vitthalwadi	264	579	521	1095	698	1541	809	1862
Max Sectional Loading of Line 2 - Including the Extensions (Vanaz to Chandani Chowk and Ramwadi to Wagholi/Vitthalwadi)			**9657**	**11200**	**13503**	**17001**	**19116**	**24255**	**23096**	**29554**

8.3.3. TRAIN FORMATION

To meet the projected traffic demand, the possibility of running trains with different headways has been examined.

Accordingly, for Line 2A and Line 2B, 3 Car trains are proposed initially and as the traffic demand increase beyond 20000-25000 PHPDT, 6 Car trains can be deployed.

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

CAPACITY

TABLE 8-5: CAPACITY OF 3 CAR TRAIN AND 6 CAR TRAIN

Train Composition	Standee/sqm	Capacity
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 FOR LINE 2A & LINE 2B

Looking at the sectional PHPDT, it is seen that traffic significantly reduces on both ends extended sections. For example, on the Chandani Chowk end, the ratio of sectional peak PHPDT to this end PHPDT is of the order of 20%. Similarly, on the Wagholi/Vitthalwadi end extension, this ratio is of the order of 60% for all horizon years.

Since turn back facility (crossovers) is already provided at the terminal stations of the existing corridor, the following proposition is recommended:

- Chandani Chowk Extension: 50% of trains of existing Line 2 Corridor to be operated on this extension.
- Wagholi/Vitthalwadi Extension: 67% (two-third) trains of existing Line 2 Corridor to be operated on this extension

Hence, a total of 3 routes are proposed:

- Route 1 (Chandani Chowk to Vitthalwadi): This constitutes Line 2, Line 2A and Line 2B. 50% of trains services are proposed to be operated on this route.
- Route 2 (Vanaz to Vitthalwadi): This constitutes Line 2 and Line 2A. 17% of trains services are proposed to be operated on this route.
- Route 3 (Vanaz to Ramwadi): This comprises Line 2 of Phase-1. 33% of train services are proposed to be operated on this route.

The above proposition will achieve 100% train services in Vanaz to Ramwadi section, 67% train services in Ramwadi to Vitthalwadi section and 50% train services in Chandani Chowk to Vanaz section.

This approach will optimize rolling stock requirement as well as operation cost savings, and yet meeting the traffic demand well.

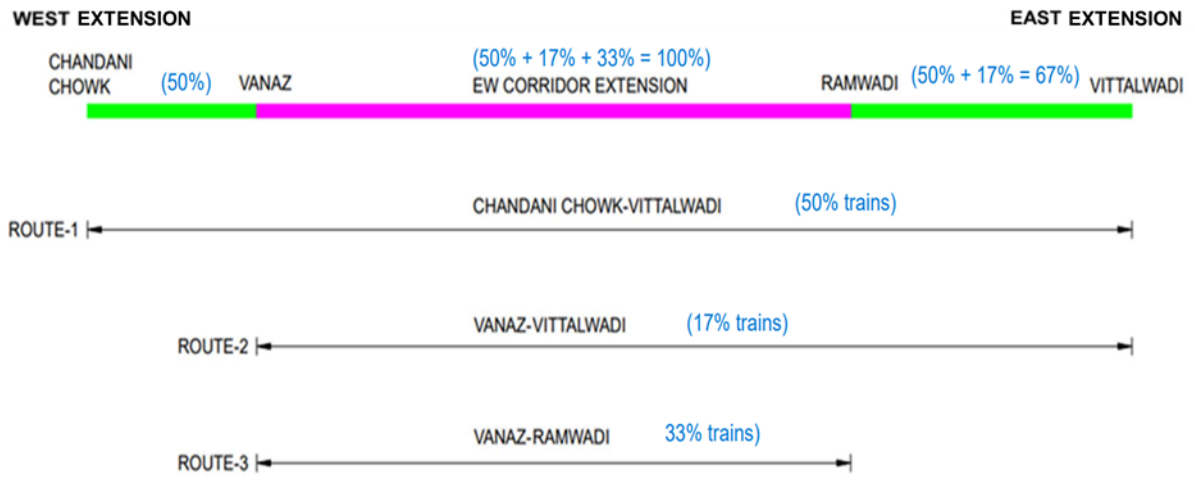


FIGURE 8-3: CONCEPTUAL OPERATION PLAN

Further, the Kharadi Bypass Station is planned as a junction station with an MRTS line from Hadapsar may get integrated with Line 2B at Kharadi Bypass Station. The tentative arrangement of the same is provided as under:

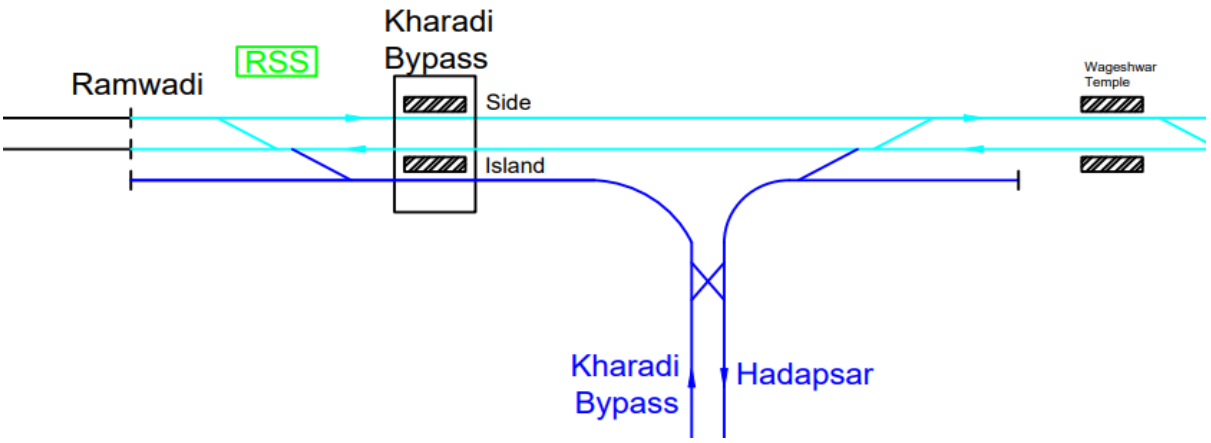


FIGURE 8-4: KHARADI BYPASS STATION – ARRANGEMENT

However, at present for the purpose of operation plan of Line 2A and Line 2B, integrated operation with Hadapsar - Kharadi Bypass is not considered. This will be deliberated in DPR of Hadapsar Corridor.

Train operation for Line 2A and Line 2B 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 2027, 2037, 2047 and 2057.

Year 2027: The peak traffic with PHPDT of 11200 in section Mangalwar Peth Station to Civil Court Station. To cater the traffic, train operation with headway of 270 seconds (4.5 minutes) is planned for Vanaz-Ramwadi Section with Peak Hour Peak Direction Capacity of 10187 @6 persons per square meter of standee area (Capacity of 13000 @8 persons per square meter of standee area under crush loading conditions).

Based on the PHPDT in extended sections (i.e., PHPDT of 1913 in West Extension and 6697 in East extension), the peak headway calculated for West Extension is 9 minutes and for East Extension is 6.75 minutes. Accordingly, to minimize the rolling stock and train operation requirements, few trains are planned to be short looped during peak hours.

The planned capacity of 10187 (13000 under crush loading) is less than the PHPDT demand in five sections out of 28 sections. With this planned 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 exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock.

The details of traffic demand and train capacity is tabulated in Table 8-6 and Table 8-7.

TABLE 8-6: SUMMARY – PROPOSED CORRIDORS (2027)

Demand (PHPDT) and Capacity Chart - Extended EW Corridor	
Year	2027
Headway (seconds)	270 / 405 / 540
No. of cars per train	3
Passenger capacity @6 persons/sqm of train	764
Passenger capacity @8 persons/sqm of train	975

TABLE 8-7: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2027)

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
1	Chandani Chowk	Kothrud Bus Depot	1402	1105	5093	6500
2	Kothrud Bus Depot	Vanaz	1913	1652	5093	6500
3	Vanaz	Anand Nagar	3029	2617	10187	13000
4	Anand Nagar	Ideal Colony	3707	3685	10187	13000
5	Ideal Colony	Nal Stop	4340	4203	10187	13000
6	Nal Stop	Garware College	5450	5195	10187	13000
7	Garware College	Deccan Gymkhana	5959	6123	10187	13000
8	Deccan Gymkhana	Chatrapati Sambhaji Udyan	6315	6635	10187	13000
9	Chatrapati Sambhaji Udyan	PMC	6524	6774	10187	13000
10	PMC	Civil Court	7264	7996	10187	13000
11	Civil Court	Mangalwar Peth	8911	11200	10187	13000
12	Mangalwar Peth	Pune RS	9280	10866	10187	13000
13	Pune RS	Ruby Hall Clinic	9657	10728	10187	13000
14	Ruby Hall Clinic	Bund Garden	9219	10623	10187	13000
15	Bund Garden	Yerwada	7439	10465	10187	13000
16	Yerwada	Kalyani Nagar	6470	8029	10187	13000
17	Kalyani Nagar	Ramwadi	5669	7041	10187	13000
18	Ramwadi	Viman Nagar	5475	6697	6791	8667
19	Viman Nagar	Somnath Nagar	4978	6012	6791	8667
20	Somnath Nagar	Kharadi Bypass	4581	5449	6791	8667
21	Kharadi Bypass	Tulaja Bhavani	3874	3888	6791	8667
22	Tulaja Bhavani	Ubale Nagar	3606	3589	6791	8667
23	Ubale Nagar	Upper Kharadi Road	3347	3441	6791	8667
24	Upper Kharadi Road	Wagheshwar Temple	3220	3392	6791	8667

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
25	Wagheshwar Temple	Wagholi	1774	2179	6791	8667
26	Wagholi	Siddharth Nagar	387	1055	6791	8667
27	Siddharth Nagar	Bakori Phata	338	662	6791	8667
28	Bakori Phata	Vitthalwadi	264	579	6791	8667

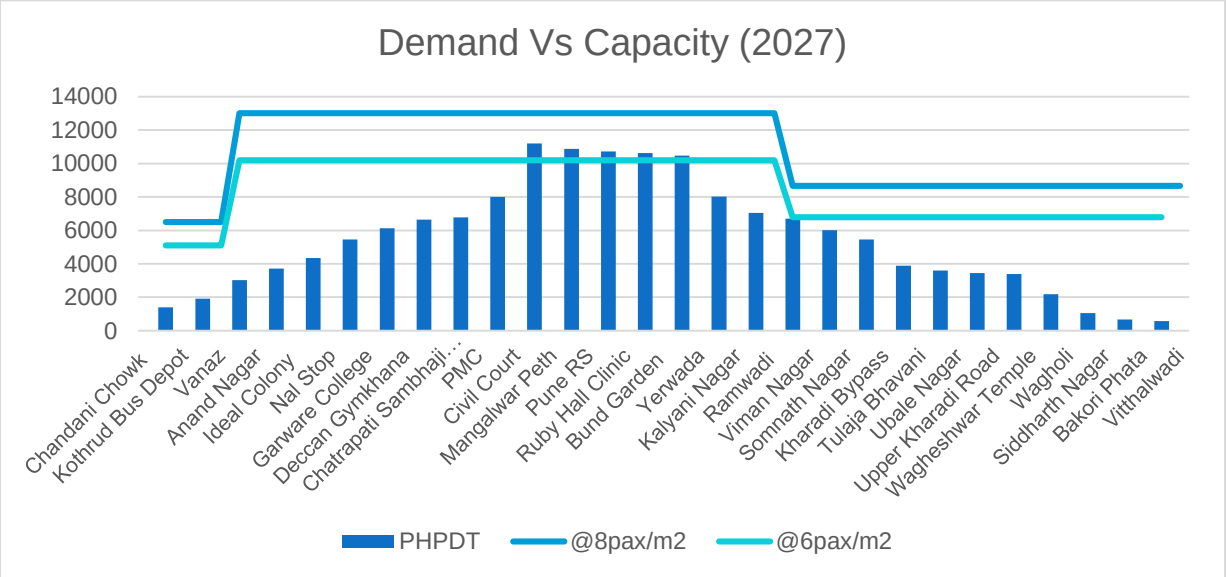


FIGURE 8-5: DEMAND AND CAPACITY (2027)

Year 2037: The peak traffic with PHPDT of 17001 in section Mangalwar Peth Station to Civil Court Station. To cater the traffic, train operation with 3-car trains headway of 200 seconds (3.33 minutes) is planned for Vanaz-Ramwadi Section with Peak Hour Peak Direction Capacity of 13752 @6 persons per square meter of standee area (Capacity of 17550 @8 persons per square meter of standee area under crush loading conditions).

Based on the PHPDT in extended sections (i.e., PHPDT of 2878 in West Extension and 10071 in East extension), the peak headway calculated for West Extension is 6.66 minutes and for East Extension is 5 minutes. Accordingly, to minimize the rolling stock and train operation requirements, few trains are planned to be short looped during peak hours.

The planned capacity of 13752 (17550 under crush loading) is less than the PHPDT demand in seven sections out of 28 sections. With this planned 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 exceeds the

planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock.

The details of traffic demand and train capacity is tabulated in Table 8-8 and Table 8-9.

TABLE 8-8: SUMMARY – PROPOSED CORRIDORS (2037)

Demand (PHPDT) and Capacity Chart - Extended EW Corridor	
Year	2037
Headway (seconds)	200 / 300 / 400
No. of cars per train	3
Passenger capacity @6 persons/sqm of train	764
Passenger capacity @8 persons/sqm of train	975

TABLE 8-9: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2037)

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
1	Chandani Chowk	Kothrud Bus Depot	1960	1940	6876	8775
2	Kothrud Bus Depot	Vanaz	2865	2878	6876	8775
3	Vanaz	Anand Nagar	4810	4477	13752	17550
4	Anand Nagar	Ideal Colony	5881	6175	13752	17550
5	Ideal Colony	Nal Stop	6672	6813	13752	17550
6	Nal Stop	Garware College	9467	9444	13752	17550
7	Garware College	Deccan Gymkhana	9534	10077	13752	17550
8	Deccan Gymkhana	Chatrapati Sambhaji Udyan	9885	10702	13752	17550
9	Chatrapati Sambhaji Udyan	PMC	10178	10821	13752	17550
10	PMC	Civil Court	10821	12880	13752	17550
11	Civil Court	Mangalwar Peth	12988	17001	13752	17550
12	Mangalwar Peth	Pune RS	13503	16397	13752	17550
13	Pune RS	Ruby Hall Clinic	13482	16132	13752	17550
14	Ruby Hall Clinic	Bund Garden	12776	15919	13752	17550
15	Bund Garden	Yerwada	10604	15506	13752	17550
16	Yerwada	Kalyani Nagar	9600	12048	13752	17550
17	Kalyani Nagar	Ramwadi	8491	10583	13752	17550
18	Ramwadi	Viman Nagar	8254	10071	9168	11700
19	Viman Nagar	Somnath Nagar	8368	9647	9168	11700
20	Somnath Nagar	Kharadi Bypass	8004	9054	9168	11700
21	Kharadi Bypass	Tulaja Bhavani	7183	7340	9168	11700

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
22	Tulaja Bhavani	Ubale Nagar	6677	6798	9168	11700
23	Ubale Nagar	Upper Kharadi Road	6181	6345	9168	11700
24	Upper Kharadi Road	Wagheshwar Temple	5891	6210	9168	11700
25	Wagheshwar Temple	Wagholi	3427	3908	9168	11700
26	Wagholi	Siddharth Nagar	749	1905	9168	11700
27	Siddharth Nagar	Bakori Phata	661	1254	9168	11700
28	Bakori Phata	Vitthalwadi	521	1095	9168	11700

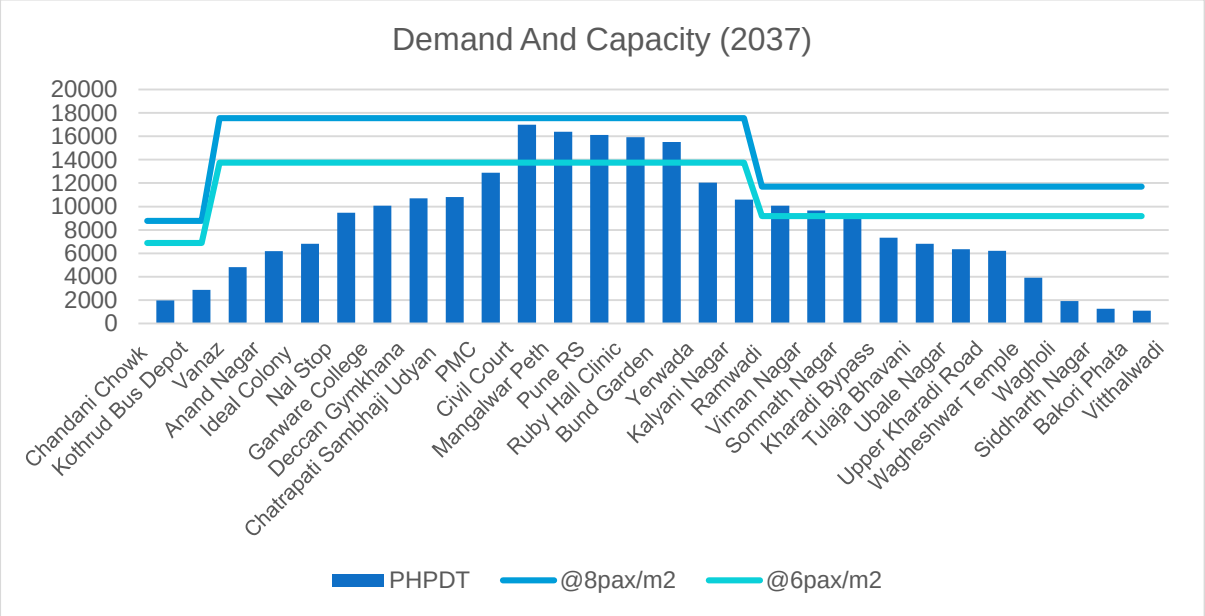


FIGURE 8-6: DEMAND AND CAPACITY (2037)

Year 2047: The peak traffic with PHPDT of 24255in section Mangalwar Peth Station to Civil Court Station. To cater the traffic, train operation with 3-car trains headway of 135 seconds (2.25 minutes) is planned for Vanaz-Ramwadi Section with Peak Hour Peak Direction Capacity of 20373 @6 persons per square meter of standee area (Capacity of 26000 @8 persons per square meter of standee area under crush loading conditions).

Based on the PHPDT in extended sections (i.e., PHPDT of 4084 in West Extension and 14432 in East extension), the peak headway calculated for West Extension is 4.5 minutes and for East Extension is 3.375 minutes. Accordingly, to minimize the rolling stock and train operation requirements, few trains are planned to be short looped during peak hours.

The planned capacity of 20373 (26000 under crush loading) is less than the PHPDT demand in seven sections out of 28 sections. With this planned 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 exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. The details of traffic demand and train capacity is tabulated in Table 8-10 and Table 8-11.

TABLE 8-10: SUMMARY – PROPOSED CORRIDORS (2047)

Demand (PHPDT) and Capacity Chart - Extended EW Corridor	
Year	2047
Headway (seconds)	135 / 202.5 / 270
No. of cars per train	3
Passenger capacity @6 persons/sqm of train	764
Passenger capacity @8 persons/sqm of train	975

TABLE 8-11: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2047)

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
1	Chandani Chowk	Kothrud Bus Depot	2782	2761	10187	13000
2	Kothrud Bus Depot	Vanaz	4074	4084	10187	13000
3	Vanaz	Anand Nagar	6835	6300	20373	26000
4	Anand Nagar	Ideal Colony	8350	8687	20373	26000
5	Ideal Colony	Nal Stop	9464	9590	20373	26000
6	Nal Stop	Garware College	13429	13312	20373	26000
7	Garware College	Deccan Gymkhana	13526	14218	20373	26000
8	Deccan Gymkhana	Chatrapati Sambhaji Udyan	14022	15107	20373	26000
9	Chatrapati Sambhaji Udyan	PMC	14428	15303	20373	26000
10	PMC	Civil Court	15316	18294	20373	26000
11	Civil Court	Mangalwar Peth	18389	24255	20373	26000
12	Mangalwar Peth	Pune RS	19116	23405	20373	26000
13	Pune RS	Ruby Hall Clinic	19088	23044	20373	26000
14	Ruby Hall Clinic	Bund Garden	18088	22743	20373	26000
15	Bund Garden	Yerwada	15037	22152	20373	26000
16	Yerwada	Kalyani Nagar	13672	17254	20373	26000
17	Kalyani Nagar	Ramwadi	12088	15162	20373	26000

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
18	Ramwadi	Viman Nagar	11766	14432	13582	17333
19	Viman Nagar	Somnath Nagar	11937	13832	13582	17333
20	Somnath Nagar	Kharadi Bypass	11422	12984	13582	17333
21	Kharadi Bypass	Tulaja Bhavani	10256	10530	13582	17333
22	Tulaja Bhavani	Ubale Nagar	9524	9754	13582	17333
23	Ubale Nagar	Upper Kharadi Road	8808	9105	13582	17333
24	Upper Kharadi Road	Wagheshwar Temple	8405	8909	13582	17333
25	Wagheshwar Temple	Wagholi	4886	5576	13582	17333
26	Wagholi	Siddharth Nagar	1003	2683	13582	17333
27	Siddharth Nagar	Bakori Phata	883	1763	13582	17333
28	Bakori Phata	Vitthalwadi	698	1541	13582	17333

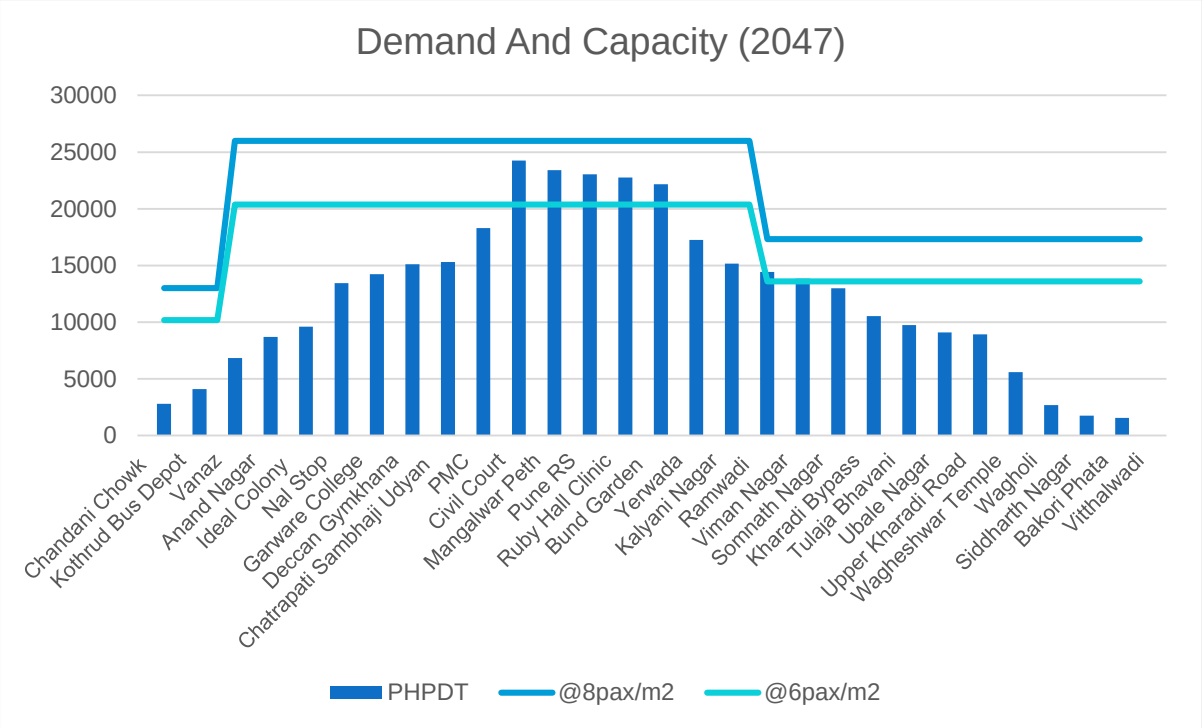


FIGURE 8-7: DEMAND AND CAPACITY (2047)

Year 2057: The peak traffic with PHPDT of 29554 in section Mangalwar Peth Station to Civil Court Station. To cater the traffic, train operation with 3-car trains headway of 135

seconds (1.95 minutes) is planned for Vanaz-Ramwadi Section with Peak Hour Peak Direction Capacity of 23508 @6 persons per square meter of standee area (Capacity of 30000 @8 persons per square meter of standee area under crush loading conditions).

Based on the PHPDT in extended sections (i.e., PHPDT of 4955 in West Extension and 17640 in East extension), the peak headway calculated for West Extension is 3.9 minutes and for East Extension is 2.925 minutes. Accordingly, to minimize the rolling stock and train operation requirements, few trains are planned to be short looped during peak hours.

The planned capacity of 23508 (30000 under crush loading) is less than the PHPDT demand in seven sections out of 28 sections. With this planned 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 exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. The details of traffic demand and train capacity is tabulated in Table 8-12 and Table 8-13.

TABLE 8-12: SUMMARY – PROPOSED CORRIDORS (2057)

Demand (PHPDT) and Capacity Chart - Extended EW Corridor	
Year	2057
Headway (seconds)	117 / 175.5 / 234
No. of cars per train	3
Passenger capacity @6 persons/sqm of train	764
Passenger capacity @8 persons/sqm of train	975

TABLE 8-13: DEMAND (PHPDT) AND CAPACITY CHART – PROPOSED CORRIDORS (2057)

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
1	Chandani Chowk	Kothrud Bus Depot	3374	3362	11754	15000
2	Kothrud Bus Depot	Vanaz	4947	4955	11754	15000
3	Vanaz	Anand Nagar	8291	7593	23508	30000
4	Anand Nagar	Ideal Colony	10130	10462	23508	30000
5	Ideal Colony	Nal Stop	11478	11548	23508	30000
6	Nal Stop	Garware College	16279	16056	23508	30000
7	Garware College	Deccan Gymkhana	16395	17164	23508	30000
8	Deccan Gymkhana	Chatrapati Sambhaji Udyan	16992	18243	23508	30000
9	Chatrapati Sambhaji Udyan	PMC	17477	18506	23508	30000
10	PMC	Civil Court	18522	22206	23508	30000

SN	Section		PHPDT		Train Capacity	
	From	To	Forward	Reverse	@6pax/m2	@8pax/m2
11	Civil Court	Mangalwar Peth	22226	29554	23508	30000
12	Mangalwar Peth	Pune RS	23096	28533	23508	30000
13	Pune RS	Ruby Hall Clinic	23060	28112	23508	30000
14	Ruby Hall Clinic	Bund Garden	21847	27747	23508	30000
15	Bund Garden	Yerwada	18174	27027	23508	30000
16	Yerwada	Kalyani Nagar	16566	21096	23508	30000
17	Kalyani Nagar	Ramwadi	14644	18528	23508	30000
18	Ramwadi	Viman Nagar	14264	17640	15672	20000
19	Viman Nagar	Somnath Nagar	14472	16914	15672	20000
20	Somnath Nagar	Kharadi Bypass	13851	15877	15672	20000
21	Kharadi Bypass	Tulaja Bhavani	12432	12886	15672	20000
22	Tulaja Bhavani	Ubale Nagar	11537	11938	15672	20000
23	Ubale Nagar	Upper Kharadi Road	10662	11146	15672	20000
24	Upper Kharadi Road	Wagheshwar Temple	10182	10904	15672	20000
25	Wagheshwar Temple	Wagholi	5907	6789	15672	20000
26	Wagholi	Siddharth Nagar	1162	3241	15672	20000
27	Siddharth Nagar	Bakori Phata	1022	2128	15672	20000
28	Bakori Phata	Vitthalwadi	809	1862	15672	20000

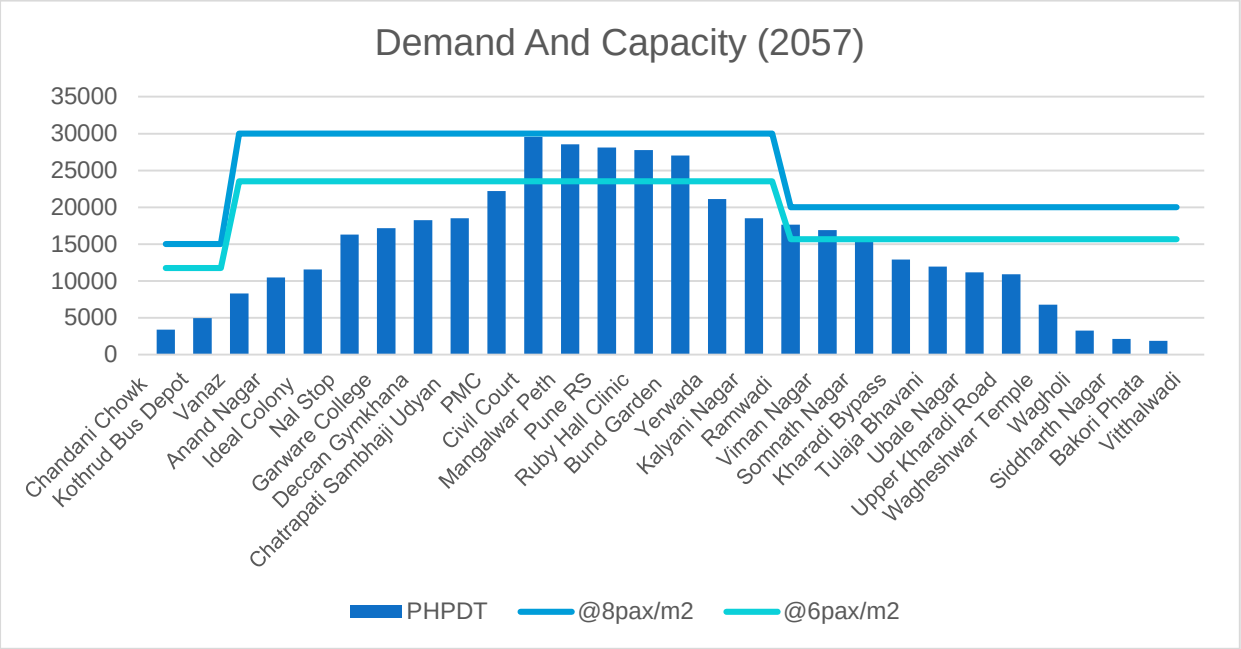


FIGURE 8-8: DEMAND AND CAPACITY (2057)

The capacity of the trains can be moderated suitably based on the actual traffic 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).

8.3.5. TRAIN FREQUENCY

The proposed headway is given in Table 8-14.

TABLE 8-14: SECTION WISE PROPOSED HEADWAY

SN	Year	Section	Headway (minutes)	
			Peak	Off peak
1	2027	Chandani Chowk – Vanaz	9.00	13-22
2		Vanaz – Ramwadi	4.50	6.5-11
3		Ramwadi – Vitthalwadi	6.75	9.8-16.5
4	2037	Chandani Chowk – Vanaz	6.67	10-16
5		Vanaz – Ramwadi	3.33	5-8.1
6		Ramwadi – Vitthalwadi	5.00	7.5-12.1
7	2047	Chandani Chowk – Vanaz	4.50	6-11
8		Vanaz – Ramwadi	2.25	3.1-5.4
9		Ramwadi – Vitthalwadi	3.375	4.6-8.25
10	2057	Chandani Chowk – Vanaz	3.90	5-9
11		Vanaz – Ramwadi	1.95	2.6-4.6
12		Ramwadi – Vitthalwadi	2.925	3.8-6.8

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 the proposed corridor for horizon years are provided in Table 8-15, Table 8-16, Table 8-17 and Table 8-18.

TABLE 8-15: HOURLY TRAIN OPERATION PLAN – 2027

Time	Headway (Minutes)			No. of trains (daily UP+DN)			Effective headway (minutes)		
	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vanaz	Vanaz - Ramwadi	Ramwadi - Vitthalwadi
0500-0600	22.00	67.00	33.00	5.5	1.8	3.6	22.00	11.03	16.56
0600-0700	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
0700-0800	13.00	40.00	20.00	9.2	3.0	6.0	13.00	6.58	9.81
0800-0900	**9.00**	**27.00**	**13.50**	**13.3**	**4.4**	**8.9**	**9.00**	**4.50**	**6.75**
0900-1000	**9.00**	**27.00**	**13.50**	**13.3**	**4.4**	**8.9**	**9.00**	**4.50**	**6.75**
1000-1100	**9.00**	**27.00**	**13.50**	**13.3**	**4.4**	**8.9**	**9.00**	**4.50**	**6.75**
1100-1200	13.00	40.00	20.00	9.2	3.0	6.0	13.00	6.58	9.81
1200-1300	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
1300-1400	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
1400-1500	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
1500-1600	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
1600-1700	13.00	40.00	20.00	9.2	3.0	6.0	13.00	6.58	9.81
1700-1800	**9.00**	**27.00**	**13.50**	**13.3**	**4.4**	**8.9**	**9.00**	**4.50**	**6.75**
1800-1900	**9.00**	**27.00**	**13.50**	**13.3**	**4.4**	**8.9**	**9.00**	**4.50**	**6.75**
1900-2000	**9.00**	**27.00**	**13.50**	**13.3**	**4.4**	**8.9**	**9.00**	**4.50**	**6.75**
2000-2100	13.00	40.00	20.00	9.2	3.0	6.0	13.00	6.58	9.81
2100-2200	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
2200-2300	19.00	60.00	30.00	6.3	2.0	4.0	19.00	9.74	14.43
2300-2400	22.00	67.00	33.00	5.5	1.8	3.6	22.00	11.03	16.56
Total				**173**	**57**	**113**			

TABLE 8-16: HOURLY TRAIN OPERATION PLAN – 2037

Time	Headway (Minutes)			No. of trains (daily UP+DN)			Effective headway (minutes)		
	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vanaz	Vanaz - Ramwadi	Ramwadi - Vitthalwadi
0500-0600	16.00	50.00	25.00	7.5	2.4	4.8	16.00	8.16	12.12
0600-0700	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
0700-0800	10.00	30.00	15.00	12.0	4.0	8.0	10.00	5.00	7.50
0800-0900	**6.67**	**20.00**	**10.00**	**18.0**	**6.0**	**12.0**	**6.67**	**3.33**	**5.00**
0900-1000	**6.67**	**20.00**	**10.00**	**18.0**	**6.0**	**12.0**	**6.67**	**3.33**	**5.00**
1000-1100	**6.67**	**20.00**	**10.00**	**18.0**	**6.0**	**12.0**	**6.67**	**3.33**	**5.00**
1100-1200	10.00	30.00	15.00	12.0	4.0	8.0	10.00	5.00	7.50
1200-1300	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
1300-1400	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
1400-1500	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
1500-1600	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
1600-1700	10.00	30.00	15.00	12.0	4.0	8.0	10.00	5.00	7.50
1700-1800	**6.67**	**20.00**	**10.00**	**18.0**	**6.0**	**12.0**	**6.67**	**3.33**	**5.00**
1800-1900	**6.67**	**20.00**	**10.00**	**18.0**	**6.0**	**12.0**	**6.67**	**3.33**	**5.00**
1900-2000	**6.67**	**20.00**	**10.00**	**18.0**	**6.0**	**12.0**	**6.67**	**3.33**	**5.00**
2000-2100	10.00	30.00	15.00	12.0	4.0	8.0	10.00	5.00	7.50
2100-2200	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
2200-2300	15.00	45.00	22.00	8.0	2.7	5.5	15.00	7.44	11.25
2300-2400	16.00	50.00	25.00	7.5	2.4	4.8	16.00	8.16	12.12
Total				**227**	**76**	**152**			

TABLE 8-17: HOURLY TRAIN OPERATION PLAN – 2047

Time	Headway (Minutes)			No. of trains (daily UP+DN)			Effective headway (minutes)		
	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vanaz	Vanaz - Ramwadi	Ramwadi - Vitthalwadi
0500-0600	11.00	33.00	16.00	10.9	3.6	7.5	11.00	5.44	8.25
0600-0700	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
0700-0800	6.00	20.00	10.00	20.0	6.0	12.0	6.00	3.16	4.62
0800-0900	**4.50**	**13.50**	**6.75**	**26.7**	**8.9**	**17.8**	**4.50**	**2.25**	**3.38**
0900-1000	**4.50**	**13.50**	**6.75**	**26.7**	**8.9**	**17.8**	**4.50**	**2.25**	**3.38**
1000-1100	**4.50**	**13.50**	**6.75**	**26.7**	**8.9**	**17.8**	**4.50**	**2.25**	**3.38**
1100-1200	6.00	20.00	10.00	20.0	6.0	12.0	6.00	3.16	4.62
1200-1300	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
1300-1400	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
1400-1500	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
1500-1600	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
1600-1700	6.00	20.00	10.00	20.0	6.0	12.0	6.00	3.16	4.62
1700-1800	**4.50**	**13.50**	**6.75**	**26.7**	**8.9**	**17.8**	**4.50**	**2.25**	**3.38**
1800-1900	**4.50**	**13.50**	**6.75**	**26.7**	**8.9**	**17.8**	**4.50**	**2.25**	**3.38**
1900-2000	**4.50**	**13.50**	**6.75**	**26.7**	**8.9**	**17.8**	**4.50**	**2.25**	**3.38**
2000-2100	6.00	20.00	10.00	20.0	6.0	12.0	6.00	3.16	4.62
2100-2200	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
2200-2300	9.00	30.00	15.00	13.3	4.0	8.0	9.00	4.74	6.92
2300-2400	11.00	33.00	16.00	10.9	3.6	7.5	11.00	5.44	8.25
Total				**356**	**113**	**226**			

TABLE 8-18: HOURLY TRAIN OPERATION PLAN - 2057

Time	Headway (Minutes)			No. of trains (daily UP+DN)			Effective headway (minutes)		
	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vitthalwadi	Vanaz - Vitthalwadi	Vanaz - Ramwadi	Chandani Chowk - Vanaz	Vanaz - Ramwadi	Ramwadi - Vitthalwadi
0500-0600	9.00	29.00	14.00	13.3	4.1	8.6	9.00	4.61	6.87
0600-0700	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
0700-0800	5.00	17.00	8.00	24.0	7.1	15.0	5.00	2.61	3.86
0800-0900	**3.90**	**11.70**	**5.85**	**30.8**	**10.3**	**20.5**	**3.90**	**1.95**	**2.93**
0900-1000	**3.90**	**11.70**	**5.85**	**30.8**	**10.3**	**20.5**	**3.90**	**1.95**	**2.93**
1000-1100	**3.90**	**11.70**	**5.85**	**30.8**	**10.3**	**20.5**	**3.90**	**1.95**	**2.93**
1100-1200	5.00	17.00	8.00	24.0	7.1	15.0	5.00	2.61	3.86
1200-1300	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
1300-1400	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
1400-1500	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
1500-1600	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
1600-1700	5.00	17.00	8.00	24.0	7.1	15.0	5.00	2.61	3.86
1700-1800	**3.90**	**11.70**	**5.85**	**30.8**	**10.3**	**20.5**	**3.90**	**1.95**	**2.93**
1800-1900	**3.90**	**11.70**	**5.85**	**30.8**	**10.3**	**20.5**	**3.90**	**1.95**	**2.93**
1900-2000	**3.90**	**11.70**	**5.85**	**30.8**	**10.3**	**20.5**	**3.90**	**1.95**	**2.93**
2000-2100	5.00	17.00	8.00	24.0	7.1	15.0	5.00	2.61	3.86
2100-2200	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
2200-2300	7.00	25.00	12.00	17.1	4.8	10.0	7.00	3.76	5.47
2300-2400	9.00	29.00	14.00	13.3	4.1	8.6	9.00	4.61	6.87
Total				**428**	**132**	**271**			

8.3.7. VEHICLE KILOMETRE

The vehicle kilometres for the proposed corridors is provided in Table 8-19.

TABLE 8-19: VEHICLE KILOMETRE FOR THE PROPOSED CORRIDORS

SN	Description	2027	2037	2047	2057
1	**No. of trains**				
1.1	Chandani Chowk - Vitthalwadi	173	227	356	428
1.2	Vanaz - Vitthalwadi	57	76	113	132
1.3	Vanaz - Ramwadi	113	152	226	271
2	**Route Length**				
2.1	Chandani Chowk - Vitthalwadi	28.01	28.01	28.01	28.01
2.2	Vanaz - Vitthalwadi	26.25	26.25	26.25	26.25
2.3	Vanaz - Ramwadi	14.51	14.51	14.51	14.51
3	**Train-km earned**				
3.1	Chandani Chowk - Vitthalwadi	4846	6358	9972	11988
3.2	Vanaz - Vitthalwadi	1496	1995	2966	3465
3.3	Vanaz - Ramwadi	1640	2206	3279	3932
4	**Car-km earned**				
4.1	Chandani Chowk - Vitthalwadi	14538	19074	29916	35964
4.2	Vanaz - Vitthalwadi	4488	5985	8898	10395
4.3	Vanaz - Ramwadi	4920	6618	9837	11796
	Total car-km	**23946**	**31677**	**48651**	**58155**
5	**Cars**				
5.1	Chandani Chowk - Vitthalwadi	42	56	83	96
5.2	Vanaz - Vitthalwadi	14	18	27	31
5.3	Vanaz - Ramwadi	16	21	31	36
	Total cars	**72**	**96**	**141**	**165**
6	**km/car/day**				
6.1	Chandani Chowk - Vitthalwadi	346	341	360	375
6.2	Vanaz - Vitthalwadi	321	333	330	335
6.3	Vanaz - Ramwadi	308	315	317	328
	Overall average km/car/day	333	330	345	352
7	**Annual train-km (10^5)**				
7.1	Chandani Chowk - Vitthalwadi	17.7	23.2	36.4	43.8
7.2	Vanaz - Vitthalwadi	5.5	7.3	10.8	12.6
7.3	Vanaz - Ramwadi	6	8.1	12	14.4
	Overall annual train-km (10^5)	29.2	38.6	59.2	70.8
8	**Annual car-km (10^5)**				
8.1	Chandani Chowk - Vitthalwadi	53.1	69.6	109.2	131.3
8.2	Vanaz - Vitthalwadi	16.4	21.8	32.5	37.9
8.3	Vanaz - Ramwadi	18	24.2	35.9	43.1
8.4	***Overall annual car-km (10^5)***	87.5	115.6	177.6	212.3

8.3.8. YEAR-WISE RAKE REQUIREMENT

The rake requirement is calculated based on the train formation and headway and the details are provided in Table 8-20.

TABLE 8-20: CONSIDERATIONS FOR CALCULATING RAKE REQUIREMENT

Route Description	Length (km)	No of stations	Avg speed (kmph)	Round trip length (km) [2 x section length]	Reversal Time (both ends) (minutes)	Train turnaround time (minutes)
Chandani Chowk – Vitthalwadi	28.0	29	32	56.0	8	113.0
Vanaz – Vitthalwadi	26.3	27	32	52.5	8	106.5
Vanaz – Ramwadi	14.5	16	32	29.0	8	62.4

Note: Reversal time of 4 minutes at end considered in view of availability of front crossover at terminal/intermediate reversal stations. The requirement of coaches is calculated based on the following assumptions:

- Coach requirement has been calculated based on headway during peak hours;
- 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;

TABLE 8-21: COACH REQUIREMENT

Train Operation / Route	Time horizon Year	Headway (minutes)	Section / route length (km)	Train turnaround time (minutes)	Rake required (3-car)	Total Coaches Req.	With Traffic + Maint. Spare @10% and rounded up
Chandani Chowk - Vitthalwadi Route	2027	9.00	28.0	113.0	12.6	37.7	42
	2037	6.67	28.0	113.0	17.0	50.9	56
	2047	4.50	28.0	113.0	25.1	75.4	83
	2057	3.90	28.0	113.0	29.0	87.0	96
Vanaz - Vitthalwadi Route	2027	27.00	26.3	106.5	3.9	11.8	14
	2037	20.00	26.3	106.5	5.3	16.0	18
	2047	13.50	26.3	106.5	7.9	23.7	27
	2057	11.70	26.3	106.5	9.1	27.3	31
Vanaz - Ramwadi Route	2027	13.50	14.5	62.4	4.6	13.9	16
	2037	10.00	14.5	62.4	6.2	18.7	21
	2047	6.75	14.5	62.4	9.2	27.7	31
	2057	5.85	14.5	62.4	10.7	32.0	36

Detailed step-by-step explanation of above computation

The below details show the step-by-step calculation of the first entry of the above table:

PHPDT capacity in Chandani Chowk - Vitthalwadi Route	5093 (refer Table 8-7 above)
Capacity of one 3-car train/rake	764 passengers
Trains / hour	(5093 / 764) = 6.67
Hence, headway	(60 / 6.67) = 9.0 minutes
Turnaround time	$\left[\frac{Length\ of\ corridor * 2}{Average\ speed}\right] + Reversal\ time$
	$= \left[\frac{28.0 * 2}{32}\right] * 60 + 8\ minutes = 113.0\ minutes$
Hence, no. of trains	$\frac{Turn\ around\ time\ (TO)}{Headway} = \frac{113.0}{9.0} = 12.6$
No. of coaches	= 12.6*3 = 37.7
No. of coaches with 10% spare (traffic + maintenance)	= 37.7 * 1.1 = 41.45 Rounded up to 42 nos.

The above method is applied to all rows. The number of coaches in above table for various routes and in different horizon years are first to be added and then rounded up to make it multiple of 3 (to form a 3-car train)

TABLE 8-22: RAKE REQUIREMENT

SN	Horizon Year	Total coaches (as per above table)	Total coaches req. (multiple of 3 to form 3-car train)	Coaches as per original EW Corr DPR	Coaches for Line 2A, 2B	Additional coaches for Line 2A, 2B in later years
1	2027	72	72	27*	45	
2	2037	95	96	48#	48	3
3	2047	141	141	48#	93	45
4	2057	163	165	48#	117	24

**This number is taken from DPR of Phase 1 and it also reflects the current procurement status for Phase 1 – Line 2 Corridor*

#There is no provision of rolling stock requirements in years beyond 2031 in DPR of Phase 1, therefore, the latest number of coaches are kept in later horizon years.

8.3.9. STABLING REQUIREMENT

Maintenance facilities in horizon year 2027 for the proposed corridors can be accommodated in already planned depot Vanaz station for Phase-1, therefore, another new depot is immediately not required. Stabling capacity for additional 12 number of 3-car trains is already provisioned in Phase-1 of existing Vanaz Depot with suitable augmentation.

However, in future an additional satellite depot will be required on east extension side at a suitable location. Planning of this depot need to be done at early stage itself though its development can be done in a phased manner.

CHAPTER 9. SIGNALLING AND TELECOMMUNICATION

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. As mentioned in Chapter 8: Train Operation Plan, the proposed metro will operate at a headway of 3.90 minutes on Vanaz to Chandani Chowk, 1.95 minutes on Vanaz to Ramwadi Route and 2.925 minutes on Ramwadi to Wagholi/Vitthalwadi Route during peak hour in the horizon year 2057. At the same time, heavy investment in infrastructure and rolling stock necessitates optimization of it capacity to provide the best service to the public.

These requirements of the metro are planned to be achieved by adopting Continuous Automatic Train Control System (CATC) based on Communication Based Train Control System (CBTC) which includes Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) 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 also bi-directional working, when necessitated;
- Eliminate accidents due to driver passing Signal at Danger (locations) by continuous speed monitoring and automatic application of brakes 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/her cab, enabling the driver 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 equipment by monitoring system status of trackside and train borne equipment and enabling preventive maintenance.

Signalling and 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 Sub-System/Components will conform to international standards like CENELEC, IEEE, IEC, BS, ITU-T etc.

Continuous Automatic Train Control (CATC)

The 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):** It is the primary function of the train control systems. This subsystem 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 safely 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 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 (CSR) with each Station Controller.

  The centralized system will be installed in the Operation Control Centre. The OCC will have a projection display panel with 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 and Workstation Interface;
  - Link to Passenger Information Display System for Online Information;
  - Computation of Train Schedule and Time Table.

Interlocking System

- **Computer Based Interlocking (CBI):** The entire route including turn back 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.

  The 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 station, 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 of 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 such as Multi Aspect Colour Light (LED) signals will be installed on the main line and depot entry/exit.
    - At stations with point and crossing for point protection catering for bi-directional working;
- **Point Machines:** Non-Trailable Electrical Point Machine capable of operating with 3-phase 380V AC will be used on main line. The depot point machine will preferably be trailable type.
- **Backbone Transmission Network and Data Communication System:** Optical Fibre cables with path redundancy will be laid along the tracks for provision of Backbone Transmission Network (BTN) and Data Communication System (DCS).

Train Depot - Signalling

For Line 2A and Line 2B, no new depot is proposed as the existing depot at Vanaz will be suitably augmented for additional trains.

All depot lines except the one which is used 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/Axle Counters will be used in the depot.

9.1.2. STANDARDS

The standards to be adopted for the signalling system are provided in Table 9-1.

TABLE 9-1: STANDARDS FOR SIGNALLING SYSTEM

SN	Components	Description
1	**Interlocking**	Computer Based Interlocking (CBI) adopted for station having switches and crossing. All related equipment as far as possible will be centralised in the equipment room at the station. The depot shall be interlocked except for lines mainly used for workshop/inspection shed areas.
2	**Operation of points**	With Direct current 110V DC point machines or 380 volts 3 phase, 50 Hz AC point machines
3	**Train detection**	Primary train detection system to use bi-directional 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 points & crossings**	Line Side signals to protect the points (switches). LED type signals for reliability and reduced maintenance cost.
5	**Uninterrupted Power Supplies (UPS) at stations and OCC**	For Signalling and Telecommunications, AFC, Emergency Lighting at stations
6	**Train protection system**	Automatic Train Protection system.

SN	Components	Description
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 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 station for signalling equipment shall be generally as follows;

- Space for UPS Room (common for signalling and telecom) – 55 sqm
- Space for Signalling Equipment Room – 50 sqm at interlocked station with points, if combined with Telecom
- Space for Signalling Equipment Room – 20 sqm at other stations, if combined with telecom

9.1.4. MAINTENANCE PHILOSOPHY FOR SIGNALLING SYSTEMS

The philosophy of continuous monitoring of system status and preventive and 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 multi-disciplinary skills. Each team shall be provided 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 to rectify the faults and undertake minor repairs. Cards/modules/equipment requiring major repairs as specified in supplier's document 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 run fully automatically without any operating staff on board.

Hence, increasing the level of GoA will allow implicitly to;

- Guarantee a high level of safety enforcement;
- Maximize the train capacity;
- More efficient energy system and train movement on the network;
- Also to optimize the operating costs.

For this project, the choice of automation is proposed to be same as that of the Phase - 1 (i.e., GoA2 for Line 1 and Line 2) and to be made fully compatible with the proposed system of signalling and train control.

9.2. TELECOMMUNICATION

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

For efficient Metro rail management and operation, it is essential to have a well-organized telecommunication network covering strategic locations like OCC, BCC, stations, 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 in terms of critical TETRA Radio communication;
- Exchange of managerial information;
- Crisis management during emergencies;
- Passenger information system

The proposed telecom system will cater to the following requirements:

- Assistance to Train Traffic Control;
- Maintenance Control;
- Emergency Voice Communication Control

9.2.2. STATION TO STATION DEDICATED COMMUNICATION

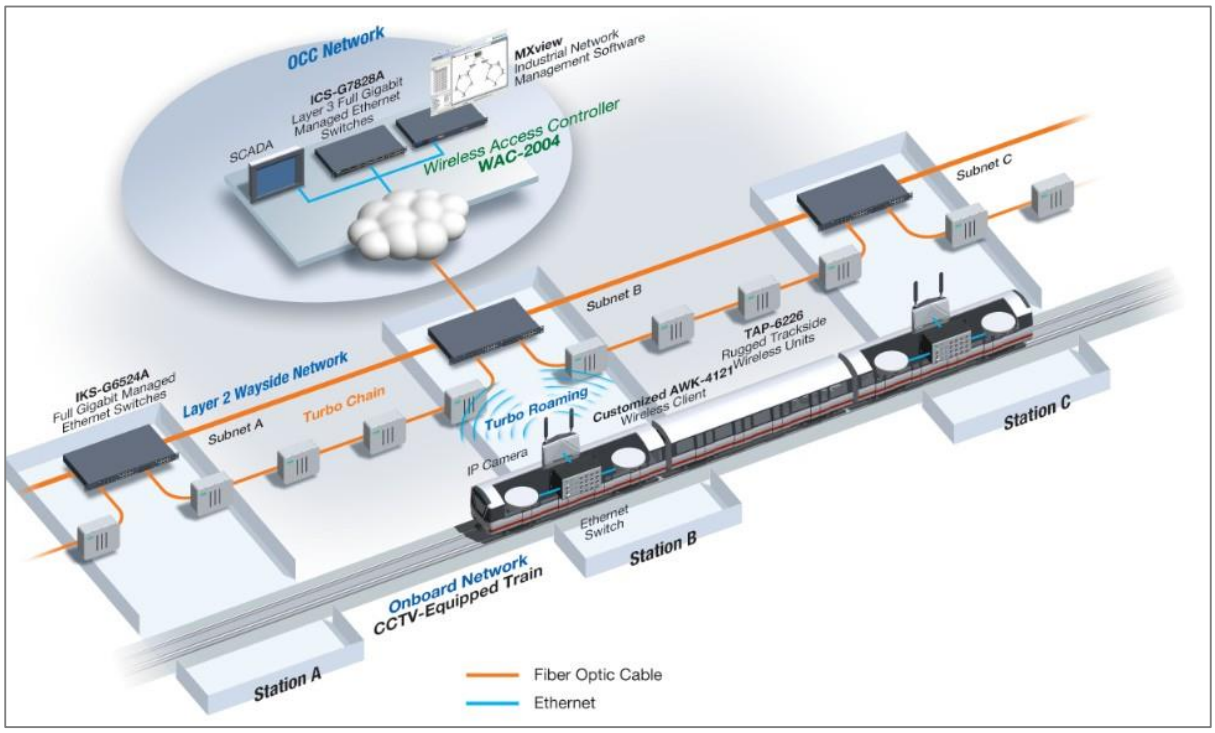
Following are the major communication requirements from station to station or station to OCC/BCC/Depot or vice versa:

- Telephone System;
- Public Address System and Passenger Information Display System within the station and from Central Control to each station;
- Centralized Master Clock System (MCS);
- TETRA Radio Communication between Central Control and Moving Cars and maintenance personnel;
- CCTV Surveillance Systems
- Access Control and Intrusion Detection System (ACIDS);
- Integrated SCADA for Telecom;
- Data Channels (FOTS) for Telecom subsystems, P-SCADA, Automatic Fare Collection etc.
- Forensic Debriefing Analysis and Cyber Security System
- Centralized Digital Recording System (CDRS)

9.2.3. TELECOMMUNICATION SYSTEM AND TRANSIMISSION MEDIA

1. Fibre Optics Transmission System (FOTS) - 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, two numbers of optical fibre cables of minimum 144 fibres are proposed to be laid on both UP-track and DOWN-track with path diversity.



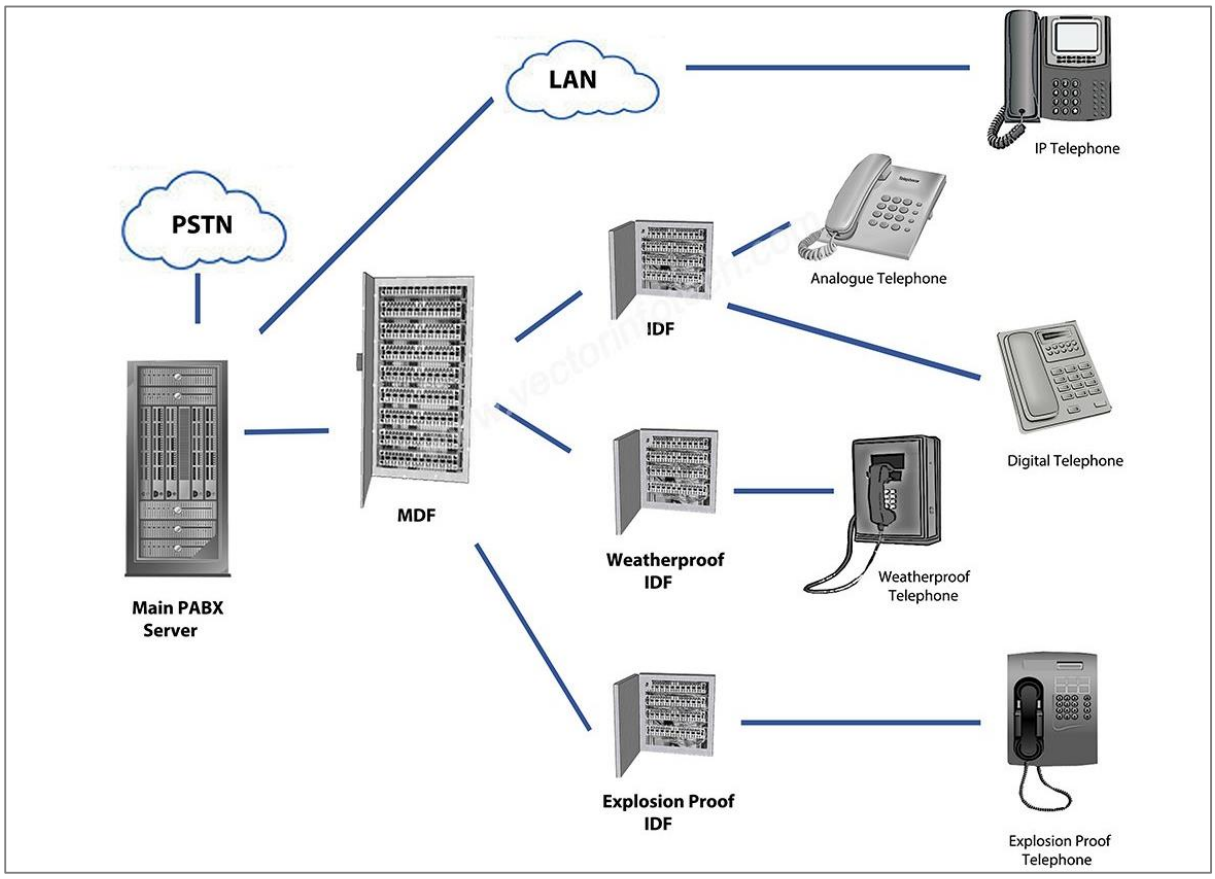
IP based min 10G Wide Area Network (FOTS Sub-system) shall provide all necessary communication channels for carrying voice, data, and video signals for Metro railway management and operation from Station/Depot TER to OCC/BCC CER.

2. Telephone System

The telephone system is IP-based and shall 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. Same is replicated in BCC also for high availability purpose.

The IP PBXs switch/exchange shall be installed in TER of all stations, depot, OCC/BCC and HQ (Headquarter). 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.



3. Centralized Digital Recording System (CDRS)

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.

At each station Free Space recording (FSR) device shall be provisioned inside Station Control Room (SCR). A CDRS is to be provided in CER at the OCC & BCC for minimum 30 days.

4. TETRA Radio Communication

TETRA 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 staff 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 and statutory clearance by DOT/WPC.

The system shall provide Instant mobile radio communication between the Train Operator (TO) of the moving cars from any place and the Central Control. The TO 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 Train PA announcements from OCC & BCC to the passengers on the train. A Centralized Digital Voice Recording System shall record all communications from OCC controller to personnel having radio fixed or handheld devices.

5. Public Address System (PAS)

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

At OCC/BCC, 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.

6. Centralized Master Clock System (MCS)

This will ensure an accurate display of date and time through a synchronization system of slave clocks driven from a Master Clock at the operation control centre. 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 Control 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.

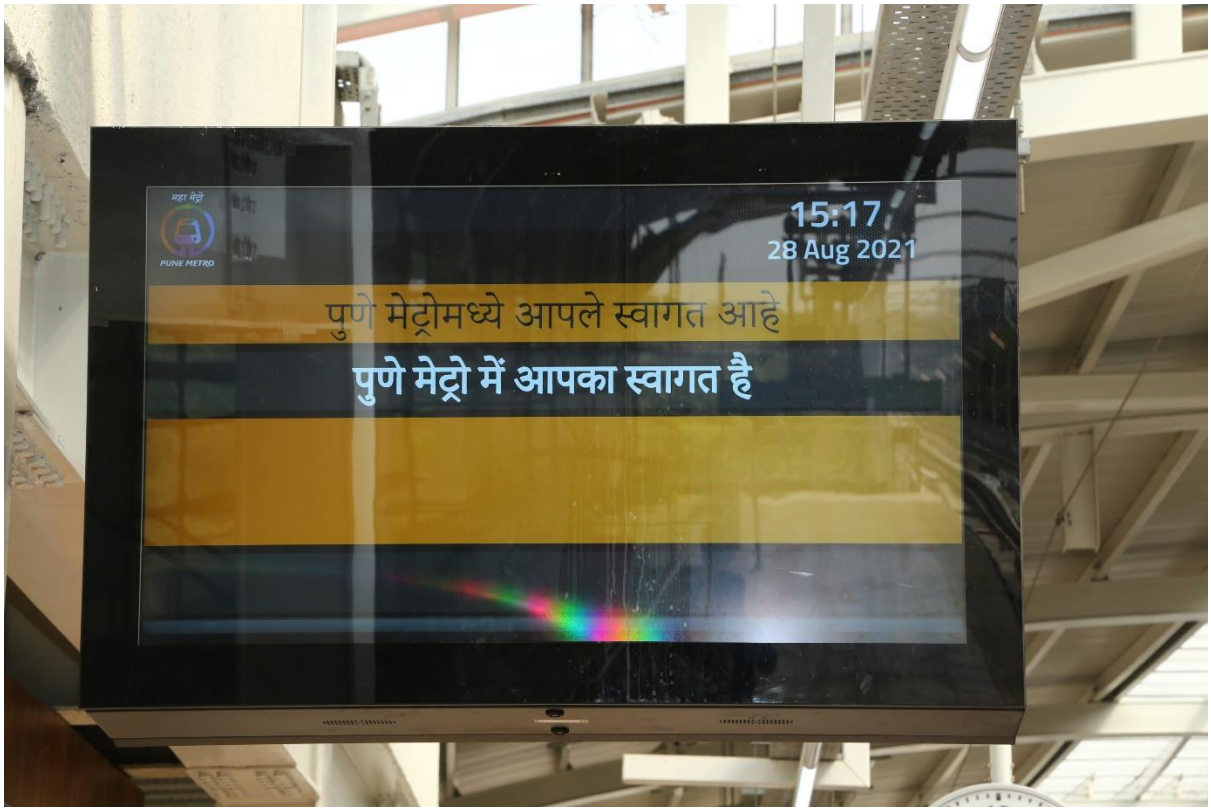
7. Passenger Information Display System

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/BCC, Central 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.



8. Wi-Fi

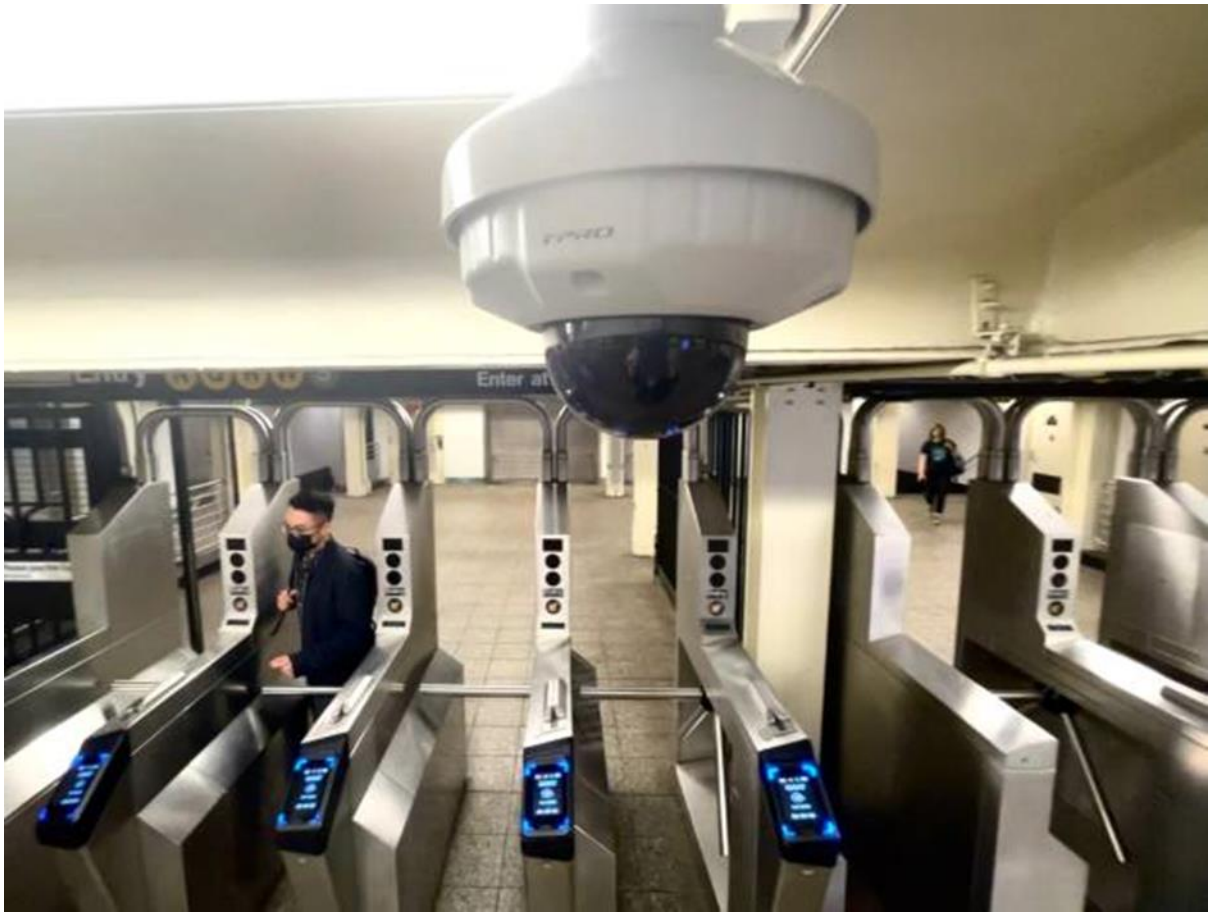
A Wireless communication system is proposed at stations separate from any signalling Wireless Communication System. The system shall be used to connect all staff devices and laptops to a central network. The Wireless communication system shall be standard commercial-off-the-shelf system and will conform 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.

9. CCTV Surveillance System

IP based 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 and other major strategic locations.



It shall be supervised from the station control room at each station, 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 local recording shall be provided at each station and its mirror recording at adjacent station.

A Centralized Digital Recording System is to be provided in CER at the OCC & BCC for minimum 30 days.

10. Access Control and Intrusion Detection System (ACIDS)

The Access Control and Intrusion Detection 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 equipment. The HMI of Access control shall be integrated with HMI of the CCTV system.

11. Network Monitoring and Management (NMS)

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.

12. 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
- Fibre Optic Transmission System
- Train Radio System
- Telephone System
- Passenger Information Display System
- Public Address System
- CCTV Surveillance System
- Centralized Master Clock System
- Centralized Digital Voice Recording System
- Access Control and Intrusion Detection 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 the proposed metro corridors to manage the cyber security needs and mitigate the project risks. The Cyber Security System shall be an integral part of the Telecom system.

The cybersecurity aspects are further elaborated in Chapter 22 of this DPR.

9.2.4. STANDARDS

The standards proposed to be adopted for telecommunication systems are shown in Table 9-2.

TABLE 9-2: 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 Train Operator (TO) 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 Master 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.
Public Address 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 and Intrusion Detection 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 equipment.

System	Standard
	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;
- Equipment room for UPS and power supply system for S&T system with emergency backup provisions
- 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 station, OCC/BCC, Depot UPS.

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 40-45 sqm each for Telecom Room and 50 sqm for UPS Room (common for signal, telecom and AFC). These areas shall also cater to local storage and space for maintenance personnel to work.

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.

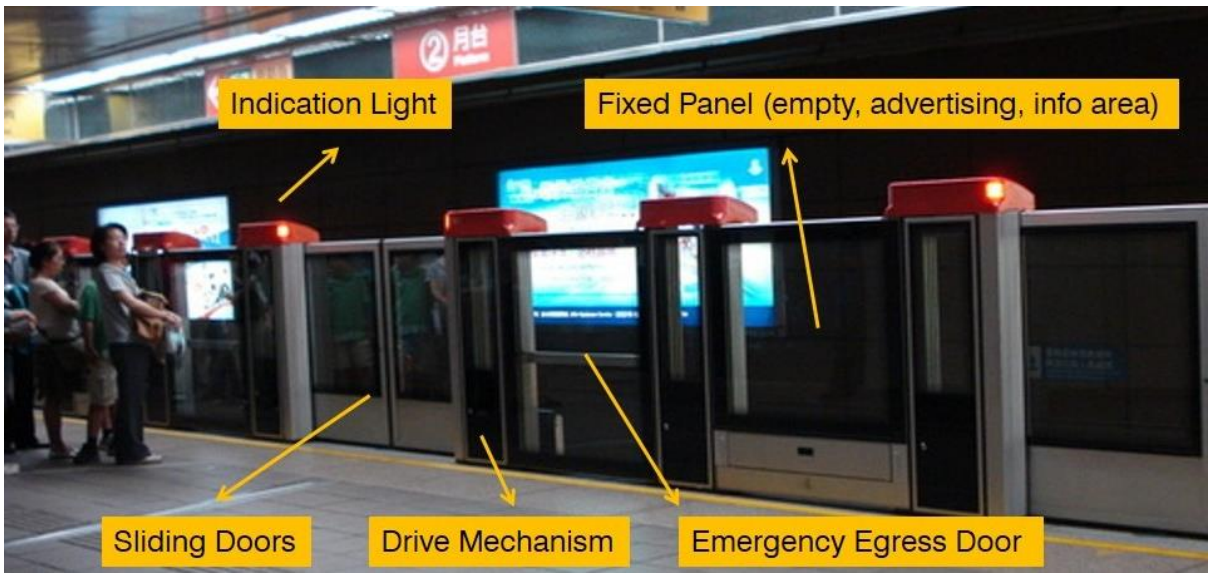
Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped special tools and instruments for effectively carrying out the maintenance from station to station.

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 (PSD) are mainly provided at metro stations to ensure safety and comfort of the passengers.

There are mainly two options for providing Platform Screen Doors i.e., Full Height PSD or Half Height PSD. To ensure the safety of the passengers, Half Height PSDs are proposed to be provided at all the metro stations of the proposed metro corridors.



9.4. ASSET MANAGEMENT SYSTEM

An integrated platform for integrating various SCADA/BMS systems used in Metro Railway is proposed. Multiple SCADA systems (viz. Traction SCADA, Facility SCADA, BMS, Fire Alarm System, Telecom SCADA, NMS, AFC SCADA etc.) are used in Metro Rail system and a super SCADA integrating all these SCADAs is considered very useful from operational point of view.

The integrated platform is further proposed to be evolved to have modules for Asset Management System, Operation & Maintenance Management System and use of Artificial Intelligence & Machine Learning module leading to condition monitoring and predictive maintenance. Some studies estimate cost savings on account of this approach to operation & maintenance to the tune of 10-15% of the O&M costs.

CHAPTER 10. AUTOMATIC FARE COLLECTION SYSTEM

The Automatic Fare Collection system forms a vital part of the operations of a transit system. The main objectives of an AFC system are:

- To 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 Phase - 1 of the project has an AFC system, a computer-based Automatic Fare Collection System is proposed for Line 2A and Line 2B Corridors. The objective is also to ensure easy integration and interoperability of the new system with the one already proposed/implemented.

The system shall be capable of open loop transactions as well to further integrate the mobility solution with the advancements in technology and allow for a 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) and RuPay
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 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 the proposed metro corridors shall be of contactless smart card and QR ticket type. For multiple journeys, stored value smart cards shall be available, and for single journeys, QR tickets shall be available, which can be tapped at the exit gates at the time of exit validation. Not only smart card, National Common Mobility Card, QR code on phone, and paper QR ticket, even the mobile-based Near Field Connectivity (NFC) wallet/card linked payments would have to be catered for Automatic Fare Collection at metro stations.

Automatic Fare Collection systems are proposed as they have certain advantages over the Semi-Automatic (Manual) systems:

Disadvantages of Manual Fare Collection System

- Larger staff 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
- The system is susceptible to fare revenue evasion and fraud through tampering or vandalism of the mechanical components of the equipment
- 100% ticket validation and authentication at entry/exit is not possible
- Greater transaction time, both for fare media purchase and authentication

Advantages of Automatic Fare Collection System

- Smaller staff required for fare media sales and validation/authentication
- The system offers greater flexibility both in terms of scalability and changes in the fare structure to be incorporated
- Increased fare revenue protection and minimized fare revenue evasion/fraud
- Data collection regarding system operation and ridership is simpler and easier
- The system allows the fare structure to be changed from the central processing server across the entire system quickly
- Efficient and easy to operate and allows degraded and disaster mode operations to deal with emergency situations
- The system has the capability to integrate multiple modes of transport via interoperability
- Smart cards can be used for other applications such as payments at third party vendors/outlets, etc.

As mentioned above, the AFC system shall be of the contactless card type. The equipment for the same shall be provided at each station at convenient locations and 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).

Note: Maha-Metro has designed an open loop chip based contactless smart card ('Ek Pune' Card) in compliance with the National Common Mobility Card (NCMC). The common mobility card can be used for Metro, Buses, Feeders, Parking, Utility and also other Retail Payments.[1]

1 Source: India Infrahub - March 2022

Automatic Gates

The automatic gates shall be of the retractable flap type. These offer high throughput and require less maintenance. Tripod turnstile type gates and flap type gates offer lesser throughput and require more maintenance.

Passenger Operated Machine (POM)

A minimum of two Passenger Operated Machines (Automatic Ticket Vending Machines) are proposed for all the stations. The POMs (i.e., Ticket Vending Machines (TVM)) provide a convenient way for passengers to buy fare media and avoid standing in queues at ticket offices, and provide services of an international standard.

10.1. STANDARDS

The standards adopted for the AFC system is given in Table 10-1.

TABLE 10-1: STANDARDS TO BE ADOPTED FOR AFC SYSTEM

Standards	Description
Fare media	QR ticket – For single/multiple journeys. QR tickets shall be tapped at entry as well as at exit gates. Contactless smart cards – For single/multiple journeys, weekly/monthly pass, retail transactions
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 people with disabilities
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 Center 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.
Automatic Ticket Vending Machine (TVM)	Ticket Vending Machines (TVMs) with the facility of issue of single journey QR tickets and recharge of travel cards using cash, debit/credit cards, etc. shall be installed in non-paid areas.

Standards	Description
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 readers shall be installed near EFO for passengers to check information stored in the token/cards.
Uninterrupted Power Supplies (UPS) at station and OCC	Common UPS of S&T system will be utilized.
Maintenance philosophy	Being fully contactless systems, manpower requirement for maintenance is much less, as compared to systems with magnetic tickets. However, adequate facilities are to be provided similar to that of S&T systems.

10.2. EQUIPMENT REQUIREMENT (AFC SYSTEM)

Assumptions:

- Each station has two accesses
- Minimum arrangement at each access is one (01) entry gate, one (01) exit gate, one (01) reversible gate, and one (01) EFO
- Throughput of gate is 30 PPM. For Ticket Office Machine (TOM) it is 10 PPM.
- 50% passengers are assumed to use smart cards and 50% on single journey QR tickets
- Each station has one (01) wide gate for specially-abled commuters. The exact equipment arrangement depends on the final station layout.

10.3. 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 providing for adequate space for specific rooms such as EFOs in the station architecture.

For central equipment at the OCC/BOCC, the existing equipment shall be utilized, provided that adequate provision for expansion was considered in Phase - 1 of the Pune Metro. No additional equipment shall be required to be installed at OCC/BOCC in case the central equipment was sized with the provision of expansion. In case additional equipment is required, the existing space provided at the OCC/BOCC locations shall be utilized, if there was provision for expansion.

AFC equipment requirements based on the available data and assumptions are given in Table 10-2.

TABLE 10-2: STATION EQUIPMENT REQUIREMENT

S.N.	Station	Boarding	Alighting	Gates			TOM	EFO	TVM	TR	RCTM
				Entry	Exit	Reversible					
Line 2A: Vanaz to Chandani Chowk											
1	Chandani Chowk	3374	3362	4	3	2	4	2	4	2	2
2	Kothrud Bus Depot	1717	1737	4	3	2	4	2	4	2	2
Line 2B: Ramwadi to Wagholi/Vitthalwadi											
1	Viman Nagar	5281	4347	5	4	3	4	2	4	2	2
2	Somnath Nagar	1421	1005	4	3	2	2	1	4	2	2
3	Kharadi Bypass	7214	5642	7	6	3	4	2	4	2	2
4	Tulaja Bhavani	1000	947	4	3	2	2	1	4	2	2
5	Ubale Nagar	961	1044	4	3	2	2	1	4	2	2
6	Upper Kharadi Road	266	504	4	3	2	2	1	4	2	2
7	Wagheshwar Temple	4230	4390	4	4	3	4	2	4	2	2
8	Wagholi	2476	4786	4	6	4	4	2	4	2	2
9	Siddharth Nagar	2228	142	4	3	2	2	1	4	2	2
10	Bakori Phata	269	216	4	3	2	2	1	4	2	2
11	Vitthalwadi	1862	809	4	3	2	4	2	4	2	2

Note:

*PHPDT Data as available has been used. Data for the year 2057 has been considered.
** The boarding and alighting data presented is for the peak hour.
***The number of gates is calculated considering the evacuation requirements and safety requirements.

CHAPTER 11. ROLLING STOCK

The required transport demand forecast is the governing factor for the choice of the rolling stock. Based on the calculated Peak Hour Peak Direction Traffic (PHPDT), a Mass Rapid Transit System is required for Pune city.

11.1. OPTIMIZATION OF COACH SIZE

The following optimum size of the coach has been chosen in line with the existing design, as mentioned in Table 11-1.

TABLE 11-1: 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 22.6 m (Depending upon the Kinematic Envelope).

11.2. PASSENGER CARRYING CAPACITY

In order to maximize the passenger carrying capacity, a longitudinal seating arrangement shall be adopted. The whole train shall be connected using vestibules to distribute the passengers evenly in all the coaches. The criteria for the calculation of standing passengers are three (03) persons per square meter of standing floor area in a normal state and six (06) persons in the crush state of the peak hour.

Therefore, for the Metro Rail Vehicles (MRV) with 2.9 m maximum width and longitudinal seat arrangement, conceptually, a crush capacity of 43 seated and 204 standing, thus a total of 247 passengers for a DMC, 50 seated and 220 standing, thus a total of 270 for a TC/MC is envisaged.

Train composition is recommended as 3-car DMC + TC + DMC & 6-car DMC + TC + MC + MC + TC + DMC. Table 11-2 shows the carrying capacity of medium rail vehicles.

TABLE 11-2: CARRYING CAPACITY OF MEDIUM RAIL VEHICLES

Particulars	Driving motor car			Trailer car / Motor Car			Train		
	Normal*	#Crush	$Dense Crush Load	Normal*	#Crush	$ Dense Crush Load	Normal*	#Crush	$ Dense Crush Load
3-Car Train									
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
6-Car Train									

Particulars	Driving motor car			Trailer car / Motor Car			Train		
	Normal*	#Crush	$Dense Crush Load	Normal*	#Crush	$ Dense Crush Load	Normal*	#Crush	$ Dense Crush 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
$ Dense Crush Load - 8 person/sqm of standee area

11.2.1. WEIGHT

The weight of the DMC and TC has been estimated as in Table 11-3, referring to the experiences in existing metros in India. The average passenger weight has been taken as 65 kg.

Composition

- DMC: Driving Motor Car
- MC: Motor Car
- TC: Trailer Car
- Car Train Composition DMC + TC + DMC
- 6 Car Train Composition DMC + TC + MC + MC + TC + DMC

TABLE 11-3: WEIGHT OF METRO RAIL VEHICLES (TONS) – 3 CAR TRAIN

	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	51.425	50.4	153.25
Crush load @6p/sqm	58.055	57.55	173.66
Engg. Load @8p/sqm	62.54	62.295	187.38
Crush axle load @6p/sqm	14.51	14.4	
Engg. Axle Load @8p/sqm	15.64	15.57	

TABLE 11-4: WEIGHT OF METRO RAIL VEHICLES (TONS) – 6 CAR TRAIN

	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	60.45
Crush load @6p/sqm	16.055	17.55	17.55	102.31
Engg. Load @8p/sqm	20.54	22.295	22.295	130.26

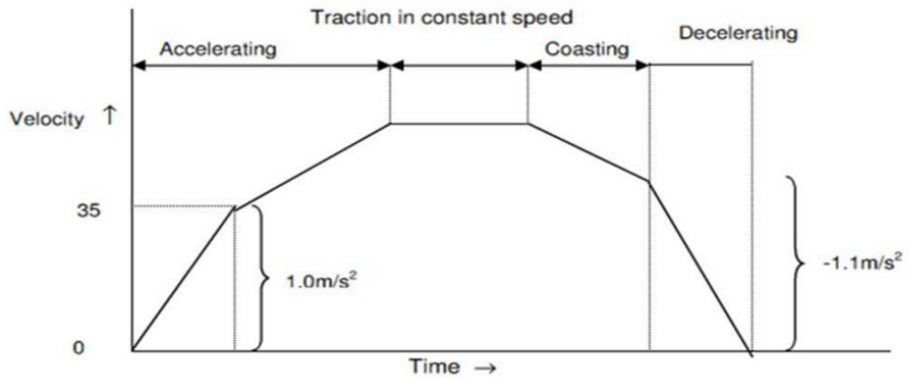
	DMC (Ton)	TC (Ton)	MC (Ton)	6-Car Train (Ton)
Gross load				
Normal load @3p/sqm	51.425	50.4	52.4	308.45
Crush load @6p/sqm	58.055	57.55	59.55	350.31
Engg. Load @8p/sqm	62.54	62.295	64.295	378.26
Crush axle load @6p/sqm	14.51	14.39	14.89	
Engg. Axle Load @8p/sqm	15.64	15.57	16.07	

The axle load @ 6 persons/sqm of standing area works out in the range of 14.40T to 14.52T. A heavy rush of passengers, with 8 standees per sqm 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. The coach and bogie should, therefore, be designed for 16T axle load.

11.2.2. PERFORMANCE PARAMETERS

The following values of acceleration and deceleration are assumed in consideration of riding comfort, adhesion and requirement of make-up time:

- Maximum Design Speed: 95 kmph
- Maximum Operating Speed: 85 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, eight (08) traction motors with about 220 KW installed on a 3-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.

11.2.3. COACH DESIGN AND BASIC PARAMETERS

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

- Proven equipment with high reliability
- Passenger safety feature
- Energy efficiency
- Lightweight 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/crassworthy

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

11.3. SELECTION OF TECHNOLOGY

11.3.1. LOW LIFE CYCLE COST

Low life cycle cost is achieved by way of reduced scheduled and unscheduled maintenance and high reliability of the sub-systems. It is possible to achieve these objectives by adopting suitable proven technologies. The following essential aspects will be considered for the achievement of a low life cycle cost:

- A life cycle cost plan with an aim to minimize the overall life cycle cost while 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.

11.3.2. CAR BODY

In the past, carbon high tensile steel was invariably used for car bodies. Infact, almost all the coaches built by the Indian Railways are of this type. These steel-bodied coaches need frequent painting and corrosion repairs, which may have to be carried out up to 4-5 times during the service life of these coaches. It is now a standard practice to adopt stainless steel or aluminium for the car body.

Pune Metro, for Line 1 and Line 2, procured aluminium body trains manufactured for the first time in India. Therefore, aluminium car bodies have also been considered for use, in addition to stainless steel body cars. Stainless steel sections are already available in India;

therefore, stainless steel car bodies have been specified. No corrosion repair is necessary for stainless steel cars during their service life.

Both aluminium and stainless steel car bodies lead to energy saving due to their light weight. They also result in cost saving due to easy maintenance and reduced repair costs because of their excellent anti-corrosive properties as well as on improvement of riding comfort and safety in case of a crash or fire.

11.3.3. 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 4,20,000 km.

The use of air spring at the 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 is 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 the provision of the above type of bogies.

11.3.4. 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 the 3-phase technology.

The regenerative braking should have air supplement control to bear the load of the trailer car. In addition, speed sensors mounted on each axle control the braking force of the axles with antiskid 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.

11.3.5. PROPULSION SYSTEM TECHNOLOGY

In the field of electric rolling stock, DC series traction motors have been used widely due to their ideal characteristics and good controllability for traction applications. But these require intensive maintenance because of commutators and electro-mechanical contractors, resistors, etc.

The brushless 3-phase AC induction motors have 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 the 3-phase AC drive and VVVF control is that regenerative braking can be introduced by lowering the frequency and the voltage to reverse the power flow and allow braking to very low speed.

For these corridors, 3-phase AC 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 an 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), 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 an optical fibre cable to connect the control unit to the gate interface. This optical fibre cable transmits the gate signals to drive the advanced IGBT via the gate interface. This optical fibre cable provides electrical isolation between the advanced IGBT and the control unit and is impervious to electrical interference. These are recommended for adoption in MRTS trains.

11.3.6. AUXILIARY POWER SYSTEM TECHNOLOGY

This shall consist of static converter-inverter(s) together with back-up batteries and battery charger. An 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 the 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 the entire 3-car train, except for HVAC load which may be restricted to one HVAC per car.

11.3.7. INTERIOR AND GANGWAYS

The passenger capacity of a car is maximized in a metro system by providing longitudinal seats and utilizing the remaining space for standing passengers. Therefore, all the equipment is 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.

The saloons shall be of differently-abled passenger-friendly design.

11.3.8. PASSENGER DOORS

For swift evacuation of the passengers in a short dwell period, four (04) doors of adequate width, on each side of the coach, have been considered. These doors shall be of such dimensions and at such locations that all the passengers inside the train would be able to evacuate within the least possible time without conflicting movement.

**The view shown below is one of the examples for the saloon interior.

FIGURE 11-1: EXAMPLE FOR INTERIOR VIEW OF THE CAR**

Automatic door closing mechanism is envisaged due to 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. The doors shall have anti-drag features.

The door shall be of bi-parting sliding type.

**Shown below is an example of a bi-parting door.

FIGURE 11-2: EXAMPLE FOR VIEW OF THE PASSENGER DOOR**

11.3.9. AIR-CONDITIONING

With heavy passenger loading of 6 persons/sqm in the standing area, doors being closed from consideration of safety, and windows being of the sealed type to avoid transmission of noise, the air-conditioning of coaches is considered essential.

Each coach shall be provided with two air-conditioning units capable of 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 failure of both ACs (in the same car), ventilation provision supplied from battery will be made. Provisions 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.

It is proposed that the HVAC system shall be with double speed condenser fan motors, which would help in complying with the noise criteria.

11.3.10. CAB LAYOUT AND EMERGENCY DETRAINMENT DOOR

The modem stylish driver panel shall be Fibre Reinforced Plastic (FRP) moulded which gives maximum comfort and easy accessibility of different monitoring equipment to the driver along with clear visibility. The driver's seat shall be in the cabin.

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

**Shown below is an example of the driver's cab.

FIGURE 11-3: EXAMPLE VIEW OF THE DRIVING CAB

11.3.11. 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 conversations between passengers and the drivers in case of any emergencies.

11.3.12. NOISE AND VIBRATION

The trains will pass through heavily populated urban areas. Thus, the noise and vibration for a MRT becomes an important criterion from the public acceptance viewpoint.

Sources of noise are (i) rail-wheel interaction (ii) noise generated by equipment like blower, compressor, air conditioner, door, inverter, etc., and (iii) traction motor in a running train.

For the elimination and reduction of noise, the following features 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 providing bolsterless type bogies with secondary air spring.

11.3.13. PASSENGER SAFETY FEATURES

1. Automatic Train Protection (ATP)

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

2. Fire

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

The trains shall have a fire detection system installed in the cars.

3. Emergency Door

The rolling stock is provided with an emergency door at front end of the Train Operator's cab to ensure well-directed evacuation of passengers in case of any emergency, including fire in the train.

4. Crashworthiness Features

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

5. Gangways

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

6. Condition and Health Monitoring System

It is proposed that extensive use of condition monitoring and artificial intelligence (AI) fro maintenance of infrastructure with a view to optimize O&M cost of rolling stocks.

The salient features of the proposed rolling stock are detailed in Table 11-5.

TABLE 11-5: SALIENT FEATURES OF ROLLING STOCK FOR MRT'S PARAMETER DETAIL

S.N.	Description	Particulars/Values
1	Gauge (nominal)	1435 mm
2	Traction system	
2.1	Voltage	25kV ac
2.2	Method of current collection	Overhead 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 or aluminium
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	1100 mm
6	Designed – passenger	
6.1	Design of propulsion system	8 passengers / m2
6.2	Design of mechanical system	10 passenger / m2
7	Carrying capacity - @6pax/m2	
7.1	Coach carrying capacity	
	DMC	247 (seating – 43; standing – 204)
	TC	270 (seating – 50; standing – 220)

S.N.	Description	Particulars/Values
	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):
8	Weight (tonnes)	
8.1	Tare weight (max)	
	DMC	42
	TC	40
	MC	42
8.2	Passenger weight in tons	@0.065 ton per passenger (65 kg)
	DMC	16.05
	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	52.40 (normal); 59.55 (crush)
9	Axle load (tonnes)	16
10	Maximum train length	
10.1	3-car train set	65m approx.
10.2	6-car train set	128m approx.
11	Train speed	
11.1	Maximum design speed	95 kmph
11.2	Maximum operating speed	85 kmph
12	Wheel profile	UIC 510-2
13	Noise limits (ISO 3381 and 3095 – 2005)	
13.1	Stationary (elevated and at-grade)	
13.1.1	Internal (cab and saloon)	LpAFmax 65 dB(A)
13.1.2	External (at 7.5m from track centre)	LpAFmax 68 dB(A)
13.2	Running at 85 kmph	Based upon applicable standard
13.2.1	Internal (cab and saloon)	LpAFmax 72 dB(A)
13.2.2	External (at 7.5m from track centre)	LpAFmax 85 dB(A)
13.3	Stationary (underground)	Based upon applicable standard
13.3.1	Internal (cab and saloon)	LpAFmax 72 dB(A)
14	Traction motors ventilation	3-phase induction motor
15	Acceleration on level	1.0 m/sec^2
16	Deceleration on level	1.1 m/sec2 (>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 Provision of smooth and continuous blending of EP Brake Electronic Control Unit (BECU)
20	Coupler	

S.N.	Description	Particulars/Values
20.1	Driving can end of DMC	Automatic coupler with mechanical and pneumatic
20.2	Between cars	Semi-automatic 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 70ºC
27.2	CI & SIV	10ºC temperature margin for junction temperature
27.3	Transformer	IEC specified limit minus 20ºC
		Cooling, heating & humidifier (as required)
		Automatic controlling of interior temperature
28	HVAC	Throughout the passenger area at 25ºC with 65% RH all the times under varying ambient 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 nos. on TC
	VCB	2 nos. on TC
	Transformer	1 no. on TC
	SIV	1 no. on TC
	Battery and Charger	1 no. on TC
	CI	Car bases in each DMC & MC
	Traction motor	Axle bases in each DMC & MC

CHAPTER 12. POWER SUPPLY AND TRACTION

12.1. INTRODUCTION

Traditionally, electric traction is used in Metro systems as a prerequisite 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. Presently, 750V dc traction system is in use in several metros in India (viz. Kochi, Kolkata, Ahmedabad, Kanpur, Agra, Bangalore etc.) and around world while 25kV ac catenary is in use in some metros in India (viz. Delhi, Chennai, Hyderabad and Jaipur Metro) as well as in Indian Railways. 1500 V dc system of Central and Western Railways in Mumbai suburban has since been converted to 25kV ac.

12.2. SELECTION OF TRACTION SYSTEM

Keeping in view the ultimate traffic requirements, standardization and other techno-economic considerations, and Phase-1 system of Pune metro, 25kV ac traction system is considered to be the optimum solution and hence, proposed for adoption.

As this is an extension of existing line (Line 2 of Phase-1), therefore system with existing design or compatibility shall be used.

This chapter broadly covers the Power supply system – power requirement for various horizon years, designed load, source of supply and broad description about the distribution network & major equipment etc. for the Pune metro.

12.3. TOTAL PROJECTED POWER DEMAND

Electricity is obtained from the utility supply systems (MSETCL for Pune), 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 2027, 2037, 2047 and 2057 – 400 kVA load is considered;

- Underground station load – not applicable;
- Depot auxiliary load – only some augmentation is needed.

Keeping in view the train operation plan, the demand of auxiliary and traction power requirements projected for the years 2027, 2037, 2047 and 2057 are summarized in the Table 12-1.

TABLE 12-1: POWER DEMAND (MVA) FOR LINE 2, LINE 2A AND LINE 2B

Corridor		Year Wise Demand			
		2027	2037	2047	2057
Line 2, Line 2A and Line 2B	Traction	9.3	12.5	18.5	21.4
	Auxiliary	14.0	14.0	15.1	15.1
Total		**23.2**	**26.4**	**33.6**	**36.5**

The apportioned demand for Line 2A and Line 2B is given in Table 12-2.

TABLE 12-2: POWER DEMAND (MVA) FOR LINE 2A AND LINE 2B

Corridor		Year Wise Demand			
		2027	2037	2047	2057
Line 2A	Traction	0.35	0.47	0.70	0.81
	Auxiliary	0.8	0.8	0.8	0.8
Total		**1.15**	**1.27**	**1.50**	**1.61**
Line 2B	Traction	3.12	4.22	6.25	7.21
	Auxiliary	4.4	4.4	4.4	4.4
Total		**7.52**	**8.62**	**10.65**	**11.61**

Detailed calculations of power demand estimation for Line 2, Line 2A and Line 2B is given in Table 12-3.

TABLE 12-3: DETAILED POWER ESTIMATION FOR LINE 2A, LINE 2A AND LINE 2B

SN	Description	Unit	2027	2037	2047	2057
	Traction power for whole corridor					
1	Car Tare weight	Ton	42	42	42	42
2	Car passenger carrying capacity (dense crush load)	Nos.	325	325	325	325
3	No. of cars	Nos.	3	3	3	3
4	Peak passenger weight per train (@65kg/pax)	Ton	63.4	63.4	63.4	63.4
5	Total train weight	Ton	189.4	189.4	189.4	189.4
6	Section length					
6.1	Chandani Chowk - Vitthalwadi	km	28.0	28.0	28.0	28.0
6.2	Vanaz - Vitthalwadi	km	26.3	26.3	26.3	26.3
6.3	Vanaz - Ramwadi	km	14.5	14.5	14.5	14.5
7	Headway					
7.1	Chandani Chowk - Vitthalwadi	Minutes	9.00	6.67	4.50	3.90

SN	Description	Unit	2027	2037	2047	2057
7.2	Vanaz - Vitthalwadi	Minutes	27	20.00	13.50	11.70
7.3	Vanaz - Ramwadi	Minutes	13.50	10.00	6.75	5.85
8	Specific Energy Consumption	Wh/GTKM	75	75	75	75
9	Number of trains per hour					
9.1	Chandani Chowk - Vitthalwadi	Nos.	13.3	18.0	26.7	30.8
9.2	Vanaz - Vitthalwadi	Nos.	4.4	6.0	8.9	10.3
9.3	Vanaz - Ramwadi	Nos.	8.9	12.0	17.8	20.5
10	Peak traction power requirement					
10.1	Chandani Chowk - Vitthalwadi	MW	5.3	7.2	10.6	12.2
10.2	Vanaz - Vitthalwadi	MW	1.7	2.2	3.3	3.8
10.3	Vanaz - Ramwadi	MW	1.8	2.5	3.7	4.2
11	Total Traction Power Peak Demand	MW	8.8	11.9	17.6	20.3
12	Traction power with pf of 0.95	MVA	9.3	12.5	18.5	21.4
	Traction power for Extensions					
6	Section length					
6.1	Line 2A	km	1.8	1.8	1.8	1.8
6.2	Line 2B	km	11.7	11.7	11.7	11.7
7	Headway					
7.1	Line 2A	Minutes	9.00	6.67	4.50	3.90
7.2	Line 2B	Minutes	6.75	5.00	3.38	2.93
9	Number of trains per hour					
9.1	Line 2A	Nos.	13.3	18.0	26.7	30.8
9.2	Line 2B	Nos.	17.8	24.0	35.6	41.0
10	Peak traction power requirement					
10.1	Line 2A	MW	0.3	0.4	0.7	0.8
10.2	Line 2B	MW	3.0	4.0	5.9	6.8
11	Total Traction Power Peak Demand	MW	3.3	4.5	6.6	7.6
12	Traction power with pf of 0.95	MVA	3.5	4.7	6.9	8.0
12.1	Line 2A	MVA	0.35	0.47	0.70	0.81
12.2	Line 2B	MVA	3.12	4.22	6.25	7.21
	Auxiliary Power					
1	Station aux. power requirement (per station)					
1.1	Elevated Station	MW	0.34	0.34	0.34	0.34

SN	Description	Unit	2027	2037	2047	2057
1.2	Underground Station	MW	2.5	2.5	2.5	2.5
1.3	Maintenance Depot	MW	2	2	3	3
2	No. of stations (Line 2A)					
2.1	Elevated Station	Nos.	2	2	2	2
2.2	Underground Station	Nos.	0	0	0	0
2.3	Maintenance Depot	Nos.	0	0	0	0
3	No. of stations (Line 2B)					
3.1	Elevated Station	Nos.	11	11	11	11
3.2	Underground Station	Nos.	0	0	0	0
3.3	Maintenance Depot	Nos.	0	0	0	0
4	Total – Line 2 + Line 2A + Line 2B					
4.1	Elevated Station	Nos.	29	29	29	29
4.2	Underground Station	Nos.	0	0	0	0
4.3	Maintenance Depot	Nos.	1	1	1	1
4	Total auxiliary power requirement					
4.1	Line 2A	MW	0.68	0.68	0.68	0.68
4.2	Line 2B	MW	3.74	3.74	3.74	3.74
4.3	Line 2 + Line 2A + Line 2B	MW	11.86	11.86	12.86	12.86
5	Aux. Power with pf of 0.85					
5.1	Line 2A	MVA	0.8	0.8	0.8	0.8
5.2	Line 2B	MVA	4.4	4.4	4.4	4.4
5.3	Line 2 + Line 2A + Line 2B	MVA	14.0	14.0	15.1	15.1

Note: The requirement of Property development is not considered in estimation of power calculation.

12.4. NEED FOR HIGH RELIABILITY OF POWER SUPPLY

The Pune metro system is being designed to cater to crush load of 25198 passengers per direction during peak hours when trains are expected to run at:

- 4.5 minutes' intervals in 2027,
- 3.33 minutes' interval in 2037,
- 2.25 minutes' (or 4.5 minutes with 6-car) interval in 2047 and
- 1.95 minutes' (or 3.9 minutes with 6-car) interval in 2057, respectively.

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.

12.5. 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 metro corridors. 220/132 kV substations are generally away from the alignment and therefore, it involves substantial cable and it's laying cost.

12.5.1. FOR EXTENSION OF LINE 2 OF PUNE MRTS PHASE - 1

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, one new RSS at a suitable location along Line 2A is proposed. Thus, there will be two RSSs for the proposed corridors viz. (1) Vanaz RSS at depot; and (2) along Line 2B. A Neutral Section will have to be provided at/near Ramwadi to segregate traction power supplies of the two TSSs. The sources of power supply near the Phase 2 corridors of Pune MRTS, which include the proposed corridor is given in Table 12-4.

TABLE 12-4: SOURCES OF POWER SUPPLY

Corridor	GSS Name	Corridor start from	Distance in meter – along the corridor	Distance in meter – from the alignment
Ramwadi – Wagholi	132kV Kharadi GSS	Ramwadi	2700	470
Swargate – Khadakwasla	220kV Nanded city GSS	Swargate	8650	760
	220kV Parvati GSS	Swargate	2900	200
Hadapsar – Kharadi	220kV Magarpatta GSS	Kharadi	4400	450
Swargate - Hadapsar	132kV Rasta Peth GSS	Swargate	1300	2100

*The exact length of cables from GSS to RSS can be assessed after the cable route survey.

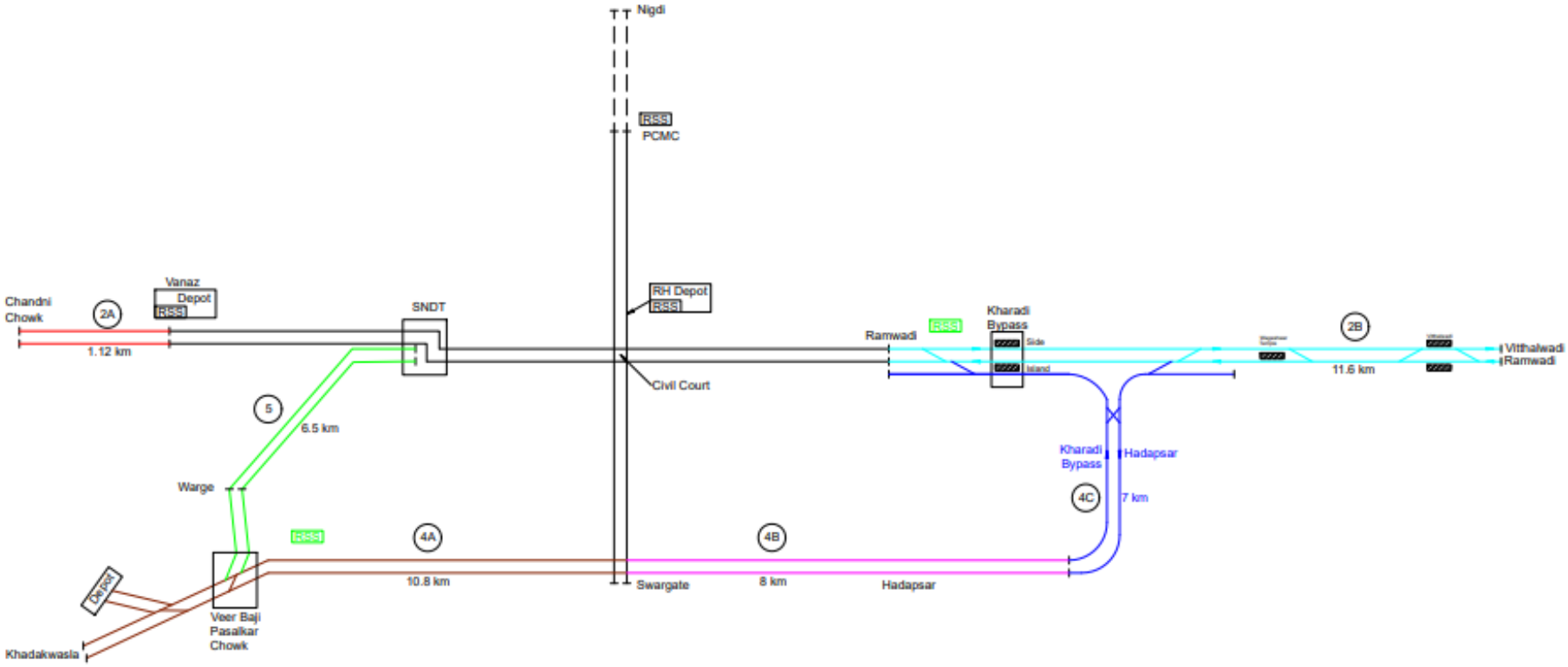


FIGURE 12-1: SCHEMATIC OF PUNE MRTS PHASE 2 CORRIDORS

- From the above GSSs, the following is the obvious choice for East Extension:
  - Kharadi GSS feeding RSS for Ramwadi – Wagholi/Vitthalwadi corridor (11.63 km)
  - Since The distance between Kharadi GSS and proposed RSS is approx. 150m the separate provision for cost of 132/220/400kv cabling from Grid to RSS is not required as per Report on “Benchmarking for Cost Estimation of Metro Rail Projects”, published by MoHUA
- SPs (Neutral Sections) will be required:
  - Between Kharadi RSS and Swargate RSS
- Normal feeding zone of the Kharadi TSSs would be Line 2A Extension as well as part of the Hadapsar-Kharadi line.
- The above sub-stations are being considered as a GIS sub-station, as GIS substation require lesser land space compared with conventional (AIS) substation, and land is costly in city area. Further, the maintenance cost for GIS substation is lower compared with AIS substation.
- 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 220 kV or 132kKV 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 12-2: 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 the proposed corridors, the primary RSSs shall be:

- One already existing at Vanaz depot; and
- A new RSS near Kharadi Bypass on Line 2B.

RSS shall be provided with 2 nos. (one as standby) 220/132/25 kV, 30/42 MVA single-phase traction transformers for feeding traction and 2 nos. (one as standby) 220/132/33 KV, 20 MVA three phase transformers for feeding auxiliary loads.

Further, a 3/5MW traction substation has been commissioned by Maha-Metro at Vanaz depot, which is a very handy facility and it can cater to Vanaz depot traction load as well as for train testing on mainline in the event of main RSSs are in outage.

12.6. AUXILIARY SUPPLY ARRANGEMENTS - STATIONS & 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 2057.

The station ASS's will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed to increase up to 500 kW in the year 2057. 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 transformers 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 12-3: TYPICAL INDOOR AUXILIARY SUB-STATION

12.7. ELECTROMAGNETIC INTERFACE & COMPATIBILITY

25kV ac traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Depending on the Electromagnetic Compatibility (EMC) Study outcome, requirement of appropriate mitigation measures viz. Booster Transformer and Return Conductor (BT/RC) System may be assessed. 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. EN 50121, EN 50123, IEC 61000 series etc. A detailed EMI/EMC plan will be required to be developed during project implementation stage.

12.8. 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 or 120 sq.mm Cd-copper catenary wire. Return conductor (RC) shall be All Aluminium Conductor (AAC) of 233 sq.mm cross section. From safety considerations, Hydraulic or spring type Auto-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.

12.9. RATING OF MAJOR EQUIPMENT

As mentioned above, 25kV ac Overhead Equipment (OHE) shall comprise 150 sq.mm HD-copper contact wire and 65 sq.mm or 120 sq.mm Cd-copper catenary wire. Return conductor (RC) shall be provided depending on EMC study.

Based on emergency demand expected at each RSS, two nos. 220 or 132/25kV traction transformers of 30/42 MVA capacity and 2 nos. 132/33 KV, 20MVA capacity Auxiliary transformers shall be provided at RSS along Ramwadi-Wagholi/Vitthalwadi extension. The 132kV incoming cable 3-phase single core XLPE insulated with 500 sq.mm copper conductor and 220kV, 3-phase single core XLPE insulated with 800 sq.mm copper conductor for 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 240/300 sq.mm FRLS Aluminium 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 sq.mm 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.

12.10. STANDARD 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 200 kVA capacity at the elevated stations to cater to the following essential services:

i. Essential lighting
ii. Signalling & telecommunications

iii. Firefighting 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.

12.11. SCADA SYSTEM

For the smooth functioning, high reliability and safety of the transit system, the Supervisory Control and Data Acquisition (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 proposed corridors.

Redundant Fibre 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 centre. In addition, the system shall be fully integrated with the SCADA system implemented for Phase-1.

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.

12.12. 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, Kochi 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 proposed corridors of the Pune Metro Phase-2 also.

12.12.1. 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., are proposed to be used for SPV installation at suitable orientation and inclination to optimize the solar energy potential. The roof of the sheds should be south facing to maximize the Solar power generation in depot. The solar power would be used locally to the extent of load in the building and the generation over and above the requirement of the building would be fed into the grid.

The average raw sunshine available which can be harnessed for the power generation depends on the geometrical coordinates of the place. The intensity of solar radiation varies with time of the day. The combined effect of these factors and the additional complication of the wobble of the seasons is that the average raw power of sunshine per square meter of south-facing roof in India is roughly 100 to 120W/m^2. Based on the solar radiation intensity in the city of 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).

12.13. 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 or aluminium 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/night, operation/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.

12.14. ELECTRIC POWER TARIFF

The cost of electricity is a significant part of Operation & Maintenance (O&M) cost of the Metro System, which constitutes about 20-35% of total annual working cost. Therefore, it is the key element for the financial viability of the project.

The annual energy consumption for Line 2A and Line 2B have been assessed as under:

- Line 2A: about 3.4 million units in initial years (2027), which will increase to about 5 Million Units by year 2057
- Line 2B: about 22.8 million units in initial years (2027), which will increase to about 37.03 Million Units by year 2057

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 the proposed metro corridors 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.

CHAPTER 13. VENTILATION & AIR CONDITIONING SYSTEM

13.1. INTRODUCTION

This chapter covers the ventilation and air-conditioning (VAC) system requirements for the stations and depot. It includes the following:

- Air-conditioning system for certain equipment rooms of the stations and depot
- Ventilation system for stations/depot equipment room

Since there are no underground section/stations in the proposed corridors, smoke management system and tunnel ventilation system are not relevant.

13.2. THE NEED FOR VENTILATION AND AIR-CONDITIONING

The stations in metro rail systems are built in confined spaces. A large number of passengers occupy the concourse halls and platforms, especially in peak hours. The elevated stations' platforms and concourse are designed to be naturally ventilated. However, certain equipment rooms in stations as well as depots require forced ventilation or air-conditioning for the following purposes:

- Supplying fresh air for the physiological needs of the staff
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing
- Preventing the concentration of moisture generated by sweat
- Removing vapour and fumes from the battery and heat emitted by light fittings, power equipment, etc. functioning in the stations
- Removing heat from the air-conditioning plant, substation and other equipment

The following equipment rooms/occupancies require air-conditioning:

- Station control room (SCR)
- Signalling and telecom equipment room
- Excess fare office (EFO)
- AFC equipment room
- PSD control room

The following are among the rooms that require mechanical ventilation:

- Auxiliary substations
- Receiving substations equipment room
- Battery room
- DG room

13.3. EXTERNAL ENVIRONMENT CONDITIONS & WEATHER DATA

The design weather data from the ASHRAE handbooks have been used to arrive at the design criteria. The climate pattern in Pune suggests that the summer season is generally between March and June. Between July and February, the weather is generally temperate.

Air pollution levels in Pune throughout the year add a new dimension to the matter. There is a critical need for maintaining the desired air quality (environmental control) in public places like metro rail stations. Due to the high levels of suspended particles, carbon monoxide, sulphur dioxide, etc., present in the air due to moving traffic, industries, etc., it is essential to consider appropriate measures for air pollution control in the metro stations while designing the VAC system.

13.4. DESIGN PARAMETERS FOR VAC SYSTEM

The following VAC system design parameters are proposed:

13.4.1. CLASSIFICATION OF EQUIPMENT ENVIRONMENT

The locations at which equipment may be installed have been divided into four (04) environmental classes. The classes increase in extremity from A to D.

TABLE 13-1: CLASSES OF ENVIRONMENT

Class	Location of Equipment
A	Air-conditioned offices, computer and equipment rooms
B	Ventilated equipment rooms in buildings
C	Train tunnels (not relevant for the metro corridors of this project)
D	Outdoors

The following are the minimum requirements for equipment to be installed in each class of environment. Where a class does not have a value for a parameter, the most extreme value quoted for the lesser class environments should be used.

TABLE 13-2: REQUIREMENTS FOR CLASS A

Minimum Temperature	5ºC
Ambient Temperature	24±2°C
Maximum Temperature	35ºC
Relative Humidity	Minimum 0%, Nominal 65%, Maximum 95% (Non-Condensing)
Electrical Noise	High frequency to 1MHz, 1kV damped to 50% after 6 cycles. Radio frequency field strength 10 V/m, UHF & VHF bands

TABLE 13-3: REQUIREMENTS FOR CLASS B

Ambient Temperature	30°C
Maximum Temperature	42.5ºC
Relative Humidity	Nominal 70%, Maximum 100% (Non condensing)
Air Quality	Polluted and dusty
SO_2	80-120mg/m^3
Suspended Particulate Matter	360-540mg/ m^3
Electrical Noise	Impulse 1kV, 1.2/50 µsec rise/decay, 500Ω source impedance, 0.5 J source energy High frequency to 1MHz, 1kV damped to 50% after 6 cycles. Radio frequency field strength 10 V/m, UHF & VHF bands

TABLE 13-4: REQUIREMENTS FOR CLASS C

Ambient Temperature	46°C
Maximum Temperature	60ºC
Relative Humidity	Nominal 70%, Maximum 100% (Non condensing)
Electrical Noise	Impulse 5kV Others as in Class B

TABLE 13-5: REQUIREMENTS FOR CLASS D

Maximum Ambient Temperature	42.5ºC
Minimum Ambient Temperature	2.5ºC
Solar Radiation	5.44 kWH/m2
Relative Humidity	82% saturation during rainy season
Rainfall	Rain generally occurs from June to October. Average annual rainfall is approximately 722mm.
Atmosphere	Dusty during the hot season Hot and humid
Wind speed	39 m/sec
SO2 level in atmosphere	6.39 µg/m3
NOx level in atmosphere	7.8 µg/m3
Respiratory Suspended Particles Matter in atmosphere ((RSSPM)	$PM_{2.5}$
Total Suspended Particles Matter in atmosphere (TSPM)	PM_{10}
Altitude	560 m above mean sea level
Conditions in stations	Above-ground stations shall have air-conditioning in certain designated rooms.

The designing of mechanical ventilation or air-conditioning shall consider air changes in accordance with extant practices in the Metro Rail system and NBC 2016.

13.4.2. CODES AND STANDARDS

Concept VAC design is guided by the following codes and standards:

TABLE 13-6: APPLICABLE CODES AND STANDARDS FOR VAC SYSTEM DESIGN

IS: 655	Specification for Metal Air Ducts
IS: 277	Specification for Galvanized Steel Sheet
IS: 737	Specification for Wrought Aluminium and Aluminium Alloy sheet and Strips.
UL: 555	Fire Damper
UL: 181	Safety of Air Ducts
SMACNA	HVAC Duct Construction Standards Metal and Flexible.
AMCA Standard 210	Laboratory Methods of Testing Fans for Rating
BS 848	Fans for General Purposes
IS/IS/IEC 60034	design, performance and efficiency of motors
ISO 5801	Industrial Fans – Performance Testing using Standardized Airways
IS 3588, ISO 10816-1, IS 1940 Gr-63	Axial Fans

13.5. SYSTEM BRIEF DETAILS

Multi-split air-conditioning systems are proposed for Station Control Room (SCR), Signalling Equipment Room (SER), Telecom Equipment Room (TER), etc., in n+1 configuration as these occupancies require 24-hour air-conditioning. Industrial-type exhaust fans are proposed for ventilation in all the substations.

CHAPTER 14. DEPOTS

14.1. EXISTING DEPOT FOR EW CORRIDOR

Currently, a depot at Vanaz has been provided for the Phase-1 Corridor (i.e., Vanaz to Ramwadi). The layout of the same is shown in Figure 14-1. As per this plan, the following facilities are provided in this depot:

TABLE 14-1: VANAZ DEPOT FACILITIES

SN	Facilities	Master Plan	Initial Phase	Ultimate Phase
1	Integrated workshop building			
a.	RCC shop floors + Admin offices on side of WS/IBL	90.5 x 20m	90.5 x 20m	
b.	Workshop Repair Lines	2 bays x 6 car long	2 bays x 3 car long	Extension of line to 6-car length- *Not Feasible due to insufficient length*
c.	Inspection Lines	2 bays x 6 car long	2 bays x 3 car long	Extension of line to 6-car length - *Not Feasible due to insufficient length*
2	Stabling lines	10 lines x (3+3) car long	10 lines x (3+3) car long	One line of 56m to be extended in Phase-2
3	ETU Building & Shed	80m x 8m RCC G+1 building 80x7m pre-fab shed	80m x 8m RCC G+1 building 80x7m pre-fab shed	
4	Pit Wheel Lathe (PWL) – West side	28.85m x 15.4m (for 6-car train)	28.85m x 15.4m (for 3-car train)	28.85m x 15.4m (for 6-car train) .- *Not Feasible due to insufficient length*
5	Automatic Train Wash Plant (ATWP)	55m long Wash Plant with control room & recycling	55m long Wash Plant with control room & recycling	
6	Heavy Internal Cleaning Shed (HIC)	160m x 8m for 6-car with prefab shed	80x8m for 3-car with prefab shed	Extension of line to 6-car length – *To be*

SN	Facilities	Master Plan	Initial Phase	Ultimate Phase
				done in Phase 2.
7	Auxiliary Substation (ASS)	40x20m / 800m2	40x20m / 800m2	
8	SBL-11	322.476m long (FM to BS)	322.476m long (FM to BS)	
9	Loading Unloading Deck	70x20m (min) permanent loading-unloading deck	70x20m (min) permanent loading-unloading deck	
10	Other Misc. Facilities	Road Network, Security Time Office, Main Gates, Car Parking Sheds, UGWT ETP/STP	Road Network, Security Time Office, Main Gates, Car Parking Sheds, UGWT ETP/STP	
11	Shunting line	For 6-car length	For 3-car length	For 6-car length - *To be done in Phase 2.*
12	PWL line – East side	For 6-car length	For 3-car length	For 6-car length - *To be done in Phase 2.*

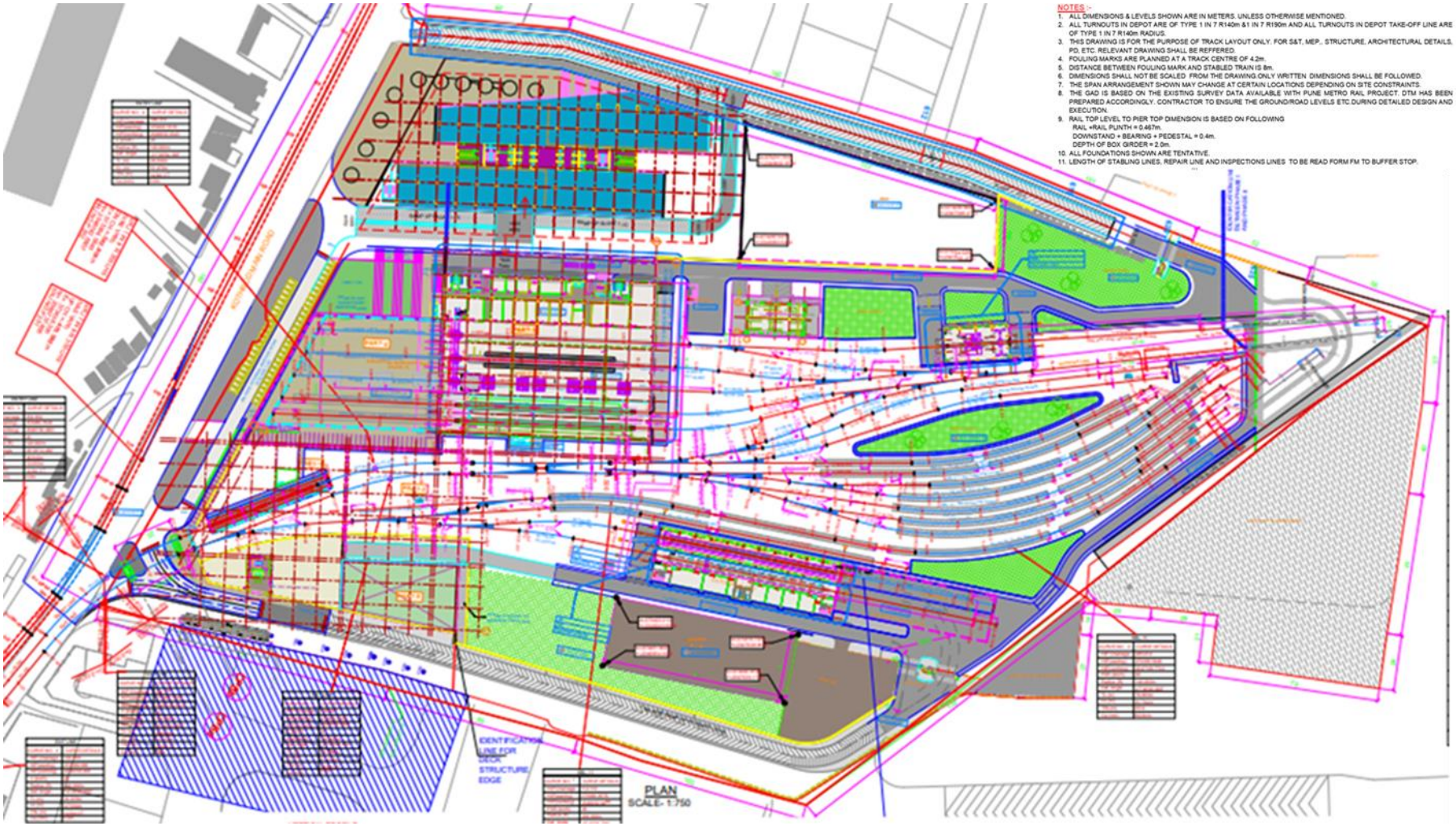


FIGURE 14-1: VANAZ DEPOT LAYOUT

The rake requirement details for the proposed corridors is given in Table 14-2.

TABLE 14-2: RAKE REQUIREMENT

SN	Horizon Year	Total coaches (as per above table)	Total coaches req. (multiple of 3 to form 3-car train)	Coaches as per original EW Corr DPR	Coaches for Line 2A, 2B	Additional coaches for Line 2A, 2B in later years
1	2027	72	72	27*	45	
2	2037	95	96	48#	48	3
3	2047	141	141	48#	93	45
4	2057	163	165	48#	117	24

**This number is taken from DPR of Phase 1 and it also reflects the current procurement status for Phase 1 – Line 2 Corridor*

#There is no provision of rolling stock requirements in years beyond 2031 in DPR of Phase 1, therefore, the latest number of coaches are kept in later horizon years.

The Vanaz Depot is planned with stabling of twenty-five (25) 3-car trains, two (02) inspection lines (currently for 3-car train and extendible for 6-car train) and two (02) heavy repair lines (currently for 3-car train and extendible for 6-car train).

Four (04) trains can be stabled at other available lines viz. inspection line, repair line or at stations.

Thus, a total holding of about 90 cars (30 trains of 3-car) can be catered to from the Vanaz depot with the development of 'Ultimate Phase' facilities. However, because of land constraints, few facilities cannot be augmented as mentioned in Table 14-1.

The total stabling capacity available in the Vanaz depot and wayside is as mentioned in Table 14-3.

TABLE 14-3: SUMMARY OF EXISTING VANAZ DEPOT

S.N.	Description	3-car Train Nos.
1	Stabling lines	25 nos.
2	Inspection lines	4 nos.
3	Internal cleaning line	1 no.
4	Pit wheel lathe line	2 nos.
5	Chandani Chowk Termination Station	4 nos.
6	Wagholi Wagholi/Vitthalwadi Terminal Station	4 nos.
7	Pocket track Mangalwar Peth	2 nos.
	Total	**42 nos.**

As the train holding increases towards the requirement for 2047, a satellite depot will be needed.

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14.1.1 AUGMENTATION OF FACILITIES IN THE VANAZ DEPOT

In addition to the 'Ultimate Phase' facilities mentioned in Table 14-1, some more facilities will need to be provisioned at the Vanaz depot for catering to the needs of the proposed corridor. These are:

1. Extension of both IBL lines and the workshop lines to capacity of 6 car length – *Not Feasible due to insufficient length*
2. Extension of pit wheel lathe on East side and one shunting line to 6 car length – *Feasible, and considered in the extension.*
3. Extension of HIC lines to 6 car length. – *Feasible, and considered in the extension.*
4. Extension of 5 nos. of stabling lines to accommodate 2 six car train on each stabling lines - *Not Feasible due to insufficient length.*
5. Additional Machine and plant required to cater EW Corridor Phase 2 requirement
    a. Bogie test stand
    b. Mobile jack for additional 3 car
    c. Shunter
    d. Wheel pressing machine
    e. Automatic wheel profile measuring machine
    f. Bearing puller
    g. Miscellaneous (viz. Jig & fixtures, forklift, scissor lifts, work/test benches, mobile compressor, trucks etc.)

The workshop & inspection line shed is built on concrete deck, with two floors below it planned to be utilised for property development. Extension of the WS and IBL for 6-car length will, therefore, require extension of structure in the already acquired land. Two floors below the Workshop/Inspection Bay (WS/IBL) in the extended area also can be utilised for property development.

Extension of PWL track for accommodating 6-car train length will require track extension by about 60m. Extension of some stabling lines for accommodating additional 3-car trains will require track extension by about 50-70m. Similarly, extension of shunting track will be needed.

Vanaz depot tentative plan duly indicating Work Shop Lines/Inspection Lines extension and Pit Wheel Lathe/Stabling Line track extensions is shown in the figure below:

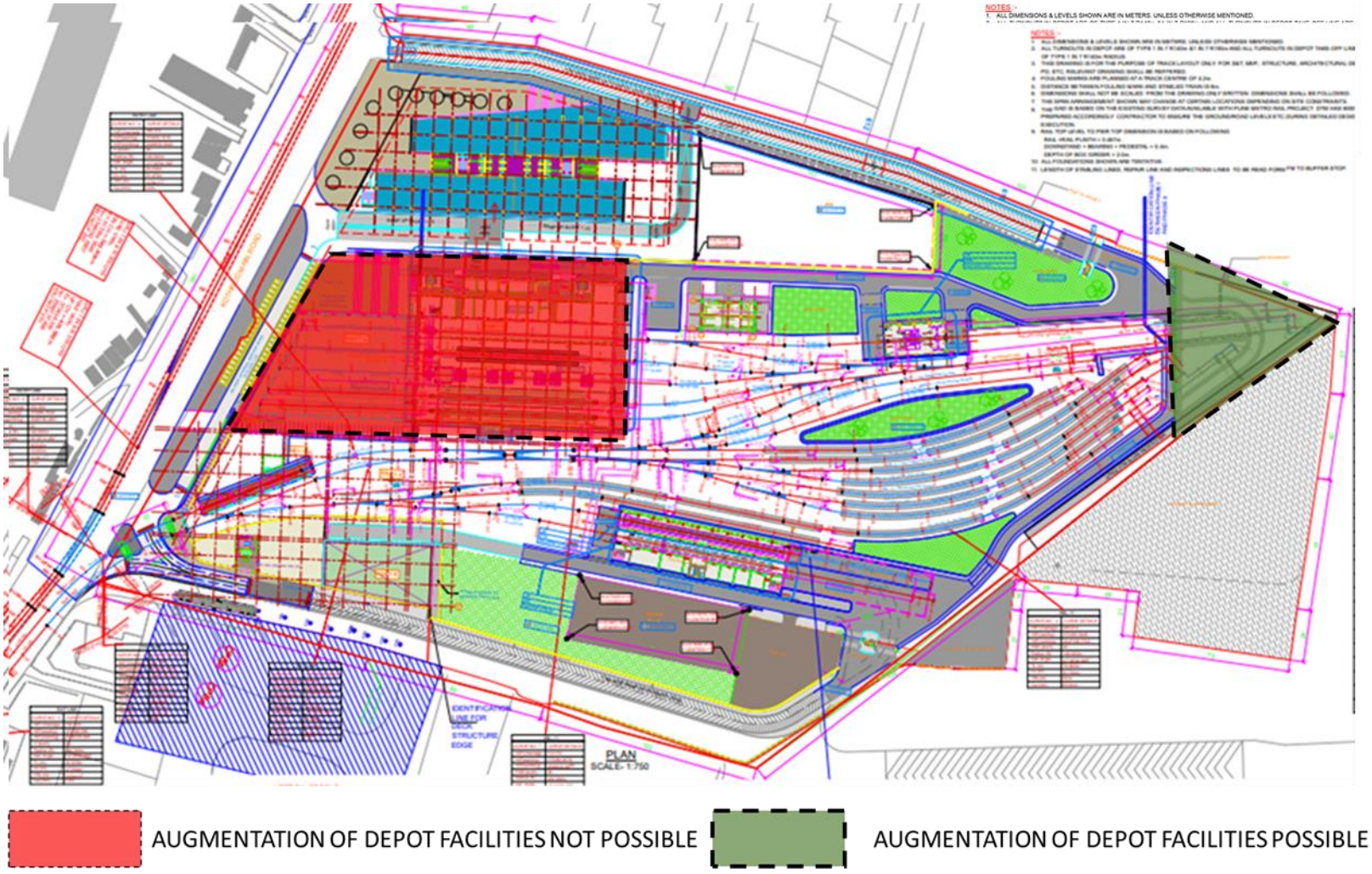


FIGURE 14-2: VANAZ DEPOT WITH AUGMENTATION

The augmentation work of Vanaz Depot consists of excavation in hard rock (cutting of hill at backside of existing depot), ballasted track work and E&M works.

Details of estimated cost at July 2022 price level is as given below,

Item No.	Components	Unit	Rate (Rs. per Unit)	Quantity	Amount (Rs. in Crores)	Remark
1	Excavation in Hard Rock	Cubic Mt.	864.75	48000.00	4.15	CPWD 2019, Item No 2.9, (Rs 729 including GST) escalated by 5% for July 2022 price level
2	Total Cost of the E & M				20.90	The cost of E & M for a typical full-fledged depot is Rs 77.13 Crore at July 2022 Prices. For the current depot 25% of the estimated Depot E & M Cost has been considered. As it is assumed that majority of the depot components have already been accounted for in the Phase 1 Depot and only minor components such as cabling, lighting etc. are required.
Total					**25.05**	

The estimated cost for the augmentation of depot has been considered under capex in chapter 17 and for FIRR.

14.1.2 SATELLITE DEPOT FOR EXTENDED LINE 2 DUE TO ADDITION OF LINE 2A AND LINE 2B

A satellite depot will need to be developed for extension of Line 2 due to addition of Line 2A and Line 2B at the west and east ends, for the projected train holding before 2047. First stage facilities at the satellite depot will be required to be developed around 2046 viz. few stabling lines, light inspection lines etc. Further facilities (such as Auto Wash Train Plant, ETU shed etc.) can be added in tandem with the build-up of traffic and consequent addition of trains.

This satellite depot needs to be planned for about 20 (3-car trains) or 10 (6-car trains).

This depot is recommended to be developed on the east extension side of the corridor.

The depot planning is based on the following assumptions:

- Enough space should be available for the establishment of the satellite depot;

- All inspection and stabling lines are designed to accommodate two trainsets of 3 cars each (or 1 train of 6-car)
- All stabling lines are planned in the proposed satellite depot assuming adequate space availability. In case of space constraints, 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 the following aspects and will work as a guide for detailed design later:

- Layout of stabling-shed, inspection-shed, minor repairs and cleaning of Rolling Stock;
- Operational and functional safety requirements;
- Ancillary buildings for other maintenance facilities;
- Electrical & mechanical services, power supply and distribution system;
- Water supplies, drainage & sewerage

The cost of satellite depot is considered in the O&M phase of the project under depot development in FY 2045-2046 and FY 2046-2047. The details of cost for the depot at July 2022 price level is given as below,

S. No	Component	Cost at July 2022 Price (Rs. In Cr)	Remark
1	**Land**	**88.62**	About 7 Ha open land at the Wagholi/Vitthalwadi end with ready reckoner rate of Rs. 12660 per sqm. for FY 2022-23
2	**Depot Development Cost**	**141.71**	
2a	Civil	87.53	70% of Benchmarking cost Considered for Satellite depot, escalated by 5% per annum to arrive at July 2022 price level
2b	E&M	54.18	
Total		**230.33**	

14.2. APPROACH AND 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 a 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.

14.3. ROLLING STOCK MAINTENANCE NEEDS

14.3.1. MAINTENANCE SCHEDULE

The following maintenance schedule has been envisaged for the conceptual design of depots:

TABLE 14-4: MAINTENANCE SCHEDULE

Type	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	5000 km (approx. 15 days)	Detailed inspection and testing of sub-systems, under frame, replacement / topping up of oils and lubricants.	Inspection bays
'B' service check	15000 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)	420000 km (3.5 years approx.)	Check and testing of all sub-assemblies (Electrical + Mechanical). Overhaul of pneumatic valves, compressor. Condition-based maintenance of subsystems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
Periodical overhaul (POH)	840000 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 and 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 the rolling stock finally procured.

14.3.2. WASHING NEEDS

Cleanliness of the trains is essential. The following schedules are recommended for the Indian environment:

TABLE 14-5: TRAIN CLEANING SCHEDULE

S.N.	Kind Inspection	Maintenance cycle	Time	Maintenance Place
1	Outside cleaning (wet washing on automatic washing plant)	3 days	10 min	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 and cleaning & washing shed

14.4. INSPECTION REQUIREMENT AT DEPOT

14.4.1. 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.

14.4.2. 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, these cannot be completed in the off-peak times.

Certain inspection lines will be nominated for "A" checks. For "B" checks, separate lines will be nominated where the rakes may be kept for a longer time.

One dedicated line in the shed will be used for minor repairs and for adjustment and testing. There shall be a spare line in the inspection bay for this purpose.

14.5. DESIGN OF DEPOT

This section is relevant for the Vanaz depot, including its augmentation, for information purpose only, as the depot is already operational with part facilities. For the satellite depot, heavy repair workshop is not envisaged.

The design of the workshop shall include the following key features:

- The unscheduled lifting and heavy repair line shall be fitted with a jack system capable lift-off lifting the 3-car unit simultaneously for quick change of bogie, thereby saving down time of the rolling stock.
- The arrangement of the jack system shall be such that lifting of any coach in the train formation for replacing bogie/equipment is also possible individually.
- One line shall be available for the stocking of bogies and wheels.
- These lines are to be provided with pits at regular intervals for the inspection of undercarriage with turn tables.
- Each workshop bay shall be equipped with two (02) trains 15T and 3T overhead cranes, each spanning the entire length of the workshop bay.
- Space shall be provided for repairs of HVAC, door, traction motor, etc. Distinct spaces shall be earmarked for dismantling, repairs, assembling and testing of each of these equipment's. Related machinery for overhauling/repairs and testing activities of all equipment are also to be housed in the earmarked space.
- 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 installed suitably 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 the movement of a train in an unloaded condition and shall also be capable of rotating with a fully-loaded bogie on it.
- The repair of heavy equipment such as air conditioners shall be so located so that it does not affect the movement inside the workshop.
- There shall be walkways on columns for roof inspections, along the workshop lines. These walkways shall not infringe on cars being lifted/lowered by means of mobile jacks. Suitable space between the nearest exterior of a car and the farthest edge of the walkway has to be ensured to avoid conflict in the lifting and lowering of cars.
- The small component, bogie painting and battery maintenance cells shall be located in the workshop in such an arrangement that fumes are extracted by suitable exhaust systems.
- The workshop will have a service building with an array of rooms along its length. The rooms can be made using a column and beam structure and architecture made of brickwork. These shall be used 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 and 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 mechanical components of bogies/axle.
- The repair shop shall be easily approachable from the workshop for the transportation of components.

The following equipment repair/overhaul facilities are planned in the workshop and wheel repairs shop at the workshop 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 aluminium coaches, if any)

14.6. EQUIPMENT AT DEPOT-CUM-WORKSHOP

The list of equipment at the depot-cum-workshop is given in Table 14-6.

TABLE 14-6: LIST OF EQUIPMENT AT DEPOT-CUM-WORKSHOP

S.N.	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)

S.N.	Equipment
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 and shop air supply
12	Travelling overhead crane workshop 15T/3T
13	Mobile jib crane
14	Mobile lifting table
15	Car-body stands
16	Bogie turntables
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 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	Fort lift tractor
32	Pallet trucks
33	RRV
34	Road vehicles (pickup van / truck)
35	Miscellaneous office equipment
36	Vertical boring machine for wheel discs
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 (Workshop & DCOS stores)
42	Test benches
43	Auto panto strip thickness meter
44	Vehicle mounted crane
45	Impulse tester for TMs
46	Bearing puller

For a satellite depot, heavy repair machines from the above tables (e.g., SN 2, 3, 6, 7, 12, 13-17, 23, 24, 36, 37, 38, 39, 44, 45, 46) will not be needed.

14.7. DESIGN OF DEPOT INFRASTRUCTURE FACILITIES

The design of other depot infrastructure facilities is described in the following section.

14.7.1. 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 road on trailers. To unload the coaches and bring them to the track, provision of space, along the side of the shunting neck, has to be made for the unloading of cars and other heavy materials. This area shall have an insulated track embedded in the floor, facilitating the movement of the road trawler that brings in the cars. The length of the track-embedded area shall be about 100-m long. There should be enough space available for the movement of heavy cranes for the lifting of coaches. The unloading area should be easily accessible for heavy duty hydraulic trailers.

14.7.2. AUTOMATIC COACH WASHING PLANT (AWP)

Provisions are to be made for the washing of rolling stock exterior surfaces using a fully automated Train Washing System, with a throughput capacity of approximately ten (10) trains per hour. The AWP shall be situated at a convenient point on the incoming route so that incoming trains can be washed before entry into the depot and undesirable movement/shunting over ingress and egress routes within the depot is avoided. Additional space for a plant room for the AWP system shall be earmarked alongside the washing apron.

14.7.3. TRAIN OPERATORS BOOKING OFFICE

A 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. These offices should have an attached cycle/scooter/car stand facility for the convenience of the train operating staff.

14.7.4. TEST TRACK

Test track is not envisaged in the satellite depot.

14.7.5. HEAVY CLEANING SHED

Heavy cleaning shed is not envisaged in the Satellite depot.

14.7.6. POWER SUPPLY

Auxiliary substations are planned for catering to the power supply requirement of the whole depot and workshop. Details of the connected load feeder shall be worked out. Taking a diversity factor of 0.5, the maximum demands shall be computed. Auxiliary substations are proposed as the demand due to machines in the workshop area would be very high. The standby power supply is proposed through DG set with AMF panel. The capacity of the DG set will be adequate to supply all essential loads without overloading.

14.7.7. COMPRESSED AIR SUPPLY

Silent-type compressor units shall be suitably installed inside the depots at convenient locations for the supply of compressed air to the workshop and inspection sheds. Thus, the pneumatic pipeline shall run within the workshop and inspection bays so as to have a compressed air supply line at all convenient points.

14.7.8. WATER SUPPLY, SEWERAGE AND DRAINAGE WORKS

In-house facilities shall be developed for water supply to each depot. Sewerage and storm water drainage shall be given due attention while designing the depots for efficient system functioning. Past records of the Municipal Corporation shall be used to design the drainage system. Rainwater harvesting would be given due emphasis to charge the underground reserves.

14.7.9. ANCILIARY WORKSHOP

This workshop will have a line at the floor level with the provision of pits. Arrangement for the repair of shunters, rail road vehicles, and other ancillary vehicles will be provided. These vehicles will also be housed here itself. The ancillary workshop will be used for storing OHE parts and their maintenance/repair for restoration of 25 kV feed system.

14.7.10. WATCH TOWERS

An adequate number of watchtowers will be provided for the vigilance of the depot boundary.

14.7.11. 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 close to the main entrance will also be provided. It shall be equipped with suitable access control system for the staff working in the complex:

- Ample parking space shall be provided for 2-wheelers and 4-wheelers at the following points:
    - Close to the depot entry
    - Close to the stabling lines
    - Close to the IBL
- Space for parking of road and re-railing equipment.
  There will be enough space for parking 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.

14.7.12. 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.

14.7.13. PLANT AND MACHINERY

A separate building is planned for housing the pit wheel lathe (PWL), approachable from the inspection bay and stabling lines through rail and road for the placement of cars for reprofiling of wheels within the depot along with space for storing scrap.

The following safety features should be incorporated in the design:

- 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'.
- Pillars in the inspection bay should have provision for power sockets.
- Placement of rakes from inspection lines on to washing lines for 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 openable doors to facilitate staff to go up to the roof for cleaning. Suitable safety interlock should be provided to ensure the maintenance staff is able to climb on to the roof inspection platform only after the OHE is isolated.
- Control centre, PPIO, and store depot should be close to light repair lines.
- The width of the doors of the sections wherein equipment repair is done should be at least 2 meters wide to allow free passage of equipment through them
- Provision of water hydrants should be done in inspection lines and stabling yards also

- Compressed air points, along with water taps, should be available in the interior of buildings for cleaning.
- Ventilation arrangement inside the inspection shed should be ensured. Arrangement for natural cross ventilation from one side to the other of the inspection bays is to be incorporated along with the optimum availability of natural light at the floor level.

14.8. OPERATIONAL FEATURES

The rake induction and withdrawal to the main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to the main line from inspection shed/workshop area.

Movement from the depot to the main line is so planned that the headway of the main line is not affected. Simultaneous receipt and dispatch of trains from the depot to the 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, the induction of trains from the stabling would be safe and without any loss of time. The proposition for a transfer track on the incoming line and outgoing line to facilitate the movement of rakes in the depot by the Operation Control Centre (OCC), even though the further path inside the depot is not clear, shall be explored at 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 the main line in the event of an emergency if necessary.

CHAPTER 15: ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

15.1 OBJECTIVE OF ENVIRONMENTAL IMPACT ASSESSMENT

The objective of Environmental Impact Assessment (EIA) is to ascertain the baseline environmental conditions and then assess the impacts as a result of the proposed project during various pre-construction, construction and operation phases of the project cycle.

The current EIA assessment is being undertaken for Line 2A-Vanaz to Chandani Chowk and Line 2B-Ramwadi to Wagholi/Vitthalwadi.

TABLE 15-1: DETAILS OF PROPOSED METRO CORRIDORS

S.No	Corridor	Length (km)	Stations	Remarks
1	Vanaz to Chandani Chowk	1.12	2	This corridor is an extension to the Metro Line 2 (Vanaz to Ramwadi) on the Vanaz side
2	Ramwadi to Wagholi/Vitthalwadi	11.63	11	This corridor is an extension to the Metro Line 2 (Vanaz to Ramwadi) on the Ramwadi side

15.2 APPLICABLE LEGAL FRAMEWORK AND POLICIES

The Acts, Rules and Norms which are generally relevant to Metro rail projects are listed below;

- The Air (Prevention and Control of Pollution) (Union Territories) Rules 1982, 1983 (Consent for emission form);
- The Water (Prevention and Control of Pollution) Rules 1975 (Consent to discharge form);
- National Ambient Air Quality Standards (NAAQS), 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;
- 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;
- World Bank, Operational policy OP 4.12, involuntary resettlement
- World Bank, Environmental Assessment OP 4.01
- ADB Safeguard Policy Statement, July 2009.

15.2.1 KEY APPLICABLE ENVIRONMENTAL LAWS & REGULATION

The project requires a number of statutory clearances under different Acts and Rules at different stages of the project. These are listed in Table 15-2.

TABLE 15-2: SUMMARY OF ENVIRONMENTAL 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
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	MPCB and Metro Authority
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	MPCB
Clearance for cutting trees and transporting	1964 / 71	Maharashtra Tree Felling Act. Tree removal will be guided as per state government rules.	Yes	Maharashtra 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 structures falling within right of way / Land Acquisition	2013	As per GOM act, Right to fair compensation and transparency	Yes	Competent Land Acquisition Authority

Act	Year	Objective	Applicability (Yes / No)	Responsible Institution
		in Land Acquisition, Rehabilitation and Resettlement Act, 2013		
Ancient Monuments and Archaeological Sites and Remains Act	1958 and 2010	Conservation of Cultural and historical remains found in India.	No	Archaeological Dept. (ASI) GoI
Hazardous and Other Wastes (Management and Transboundary Movement)	2016	To handle & dispose Hazardous Wastes	Yes	MPCB
Construction and Demolition Waste Management Rules	2016	To handle & dispose Construction and Demolition Waste	Yes	MPCB
e-waste (Management) Rules	2016	To handle & dispose E-waste	Yes	MPCB
Forest (Conservation) Act	1980	To protect and manage forests	No	MoEF&CC
Wildlife Protection Act	1972	To protect wild animals and birds through the creation of National Parks and Sanctuaries	No	MoEF&CC

MoEF&CC – Ministry of Environment, Forests & Climate Change; CPCB – Central Pollution Control Board; MPCB – Maharashtra Pollution Control Board; GoI – Government of India

15.3 BASELINE ENVIRONMENT SCENARIO

Data on land environment has been collected and compiled from various sources and during field surveys. Information about geology, hydrology, natural hazards like earthquakes etc. have been collected from literature reviews and authenticated information made available by government departments. Meteorological data was collected from Indian Meteorological Department (IMD). Water quality, soil quality, ambient air and noise environment in the surrounding areas were assessed primarily through monitoring and analysis of samples collected from field. The field studies were carried out in the months of April and May 2022.

The scoping matrix was formulated to identify the attributes likely to be affected due to the development of the proposed project and is presented in the Table 15-3.

TABLE 15-3: SCOPING MATRIX

Aspect	Likely Impact
LAND ENVIRONMENT	
Construction Phase	Increased soil erosion
	Pollution by construction spoils
	Solid waste from worker colonies and construction sites
WATER RESOURCES & WATER QUALITY	
Construction Phase	Water quality impacts due to disposal of wastewater from worker camps and construction sites, spoils.
	Depletion of groundwater resources
Operation Phase	Drainage, Water Requirement, and Disposal of waste water
AIR POLLUTION	
Construction Phase	Impacts due to emissions generated by construction machinery/vehicles
NOISE POLLUTION	
Construction Phase	Noise due to operation of various equipment
	Noise due to increased vehicular movement
Operation Phase	Noise from Metro operation
	Noise due to DG sets
ECOLOGY	
Construction Phase	Removal of vegetation cover/ loss of biomass
SOCIO-ECONOMIC	
Construction Phase	Loss of property, livelihood and community resources
	Improved employment, potential during project construction phase
	Development of allied sectors leading to greater employment
	Pressure on existing infrastructure facilities
Operation Phase	Loss of property, livelihood and community resources
	Increase in Employment opportunities in direct and indirect sectors
	Increased revenue from business development.

The baseline study begins with site visits and reconnaissance survey in the study area. Field monitoring was done for primary data collection of various environment components

such as air quality, water quality, soil quality and noise. Sampling locations are shown in Figure 15-1 and Figure 15-2.

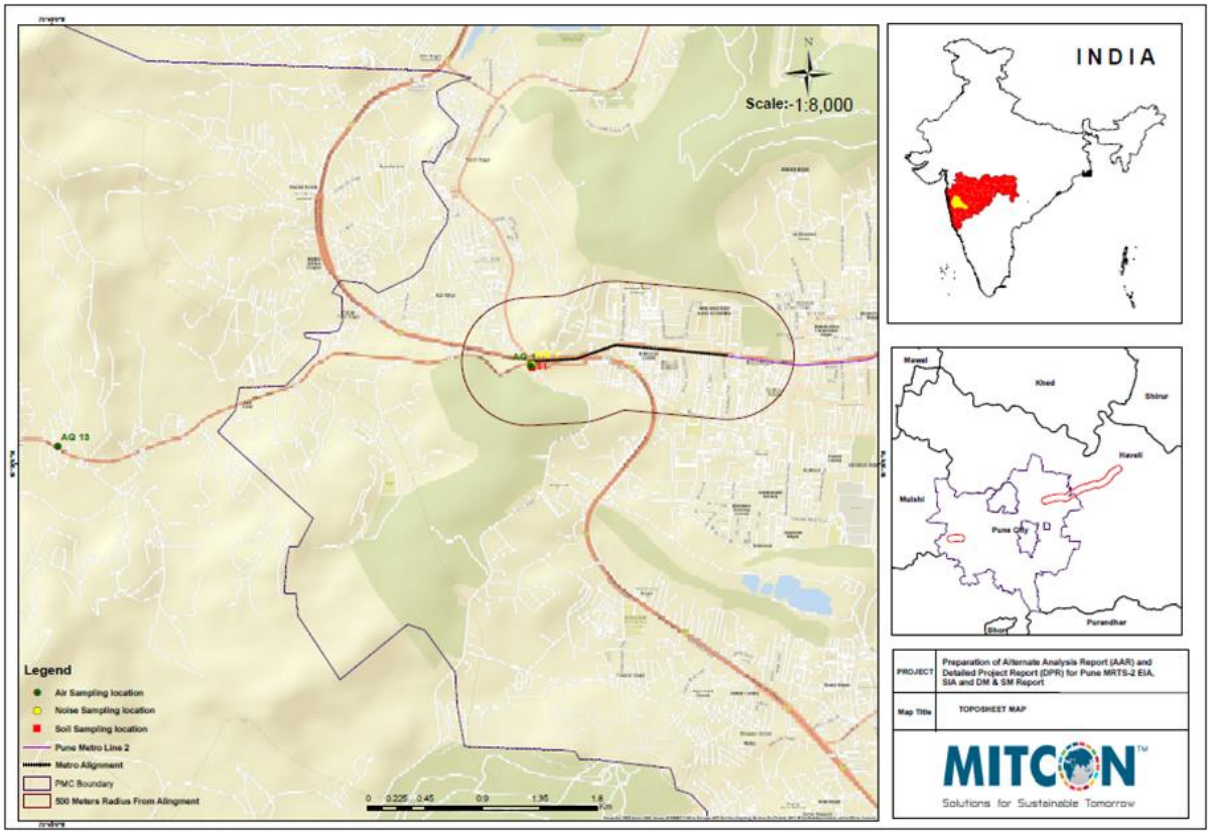


FIGURE 15-1: SAMPLING LOCATIONS – LINE 2A

Also, secondary data such as micrometeorology, flora and fauna, socio-economic, hydro-geological study, traffic study etc., collected from authenticated sources was used as a guideline and reference material. The entire data has been collected through actual physical surveys and observations, literature surveys, interaction with locals, government agencies and departments.

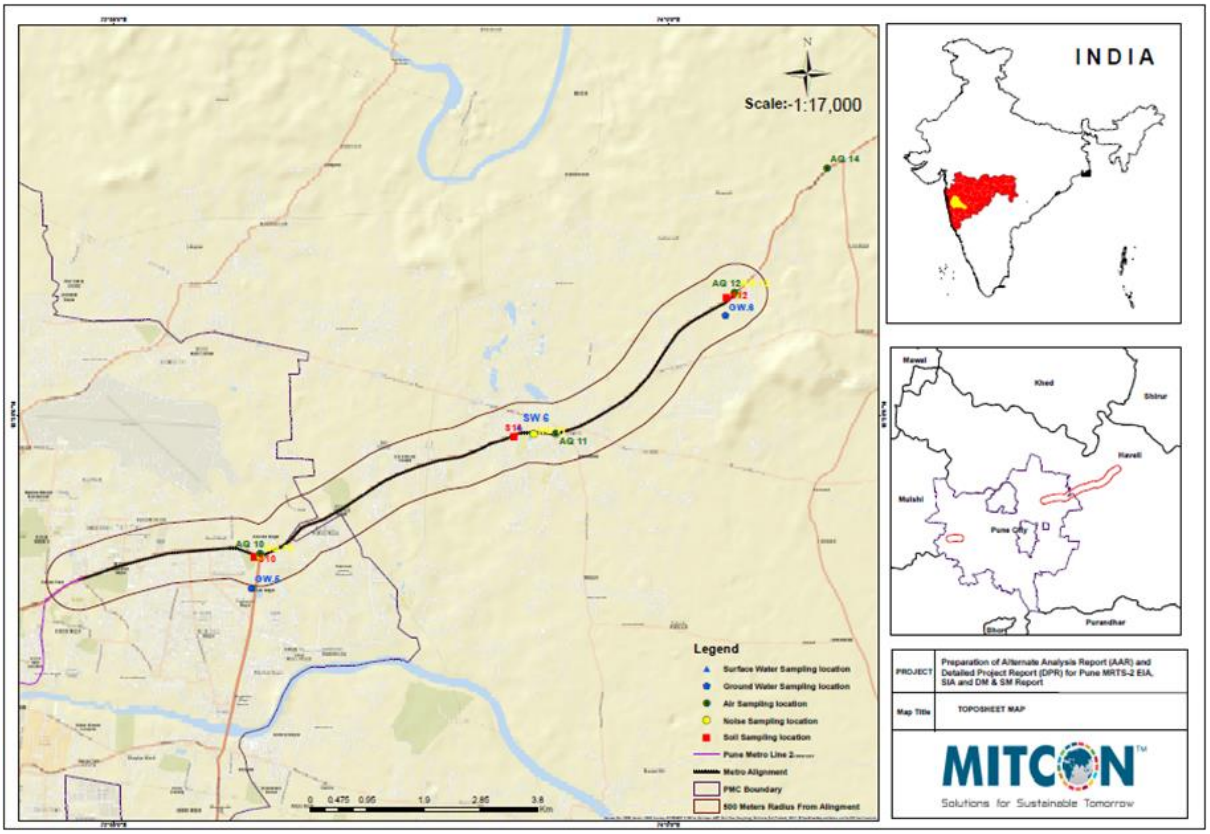


FIGURE 15-2: SAMPLING LOCATIONS – LINE 2B

15.3.1 LAND ENVIRONMENT

15.3.1.1.PHYSIOGRAPHY & TOPOGRAPHY

The district of Pune forms part of Western Ghats (Sahayadri range) which is a part of the Deccan Plateau. Physiographically the district shows three distinct physiographical patterns described as below.

i. The Hilly Area on the West: The district has 15 to 30 km strip of Sahayadri Mountains towards West known as “Ghatmatha”. The peak of the Sahayadri Mountain is at Bhimashankar, Tal. Khed (1,420m above MSL). The famous tourist places “Lonavala” and “Khandala” are located in this physiographic area. Altitude of this area ranges between 500 and 1500 m above MSL.
ii. The Hilly and Undulating Area: Towards East of “Ghatmatha”, 15-30 km belt is known as “Maval” which is hilly and undulating. A strip on the West of Taluka Junnar, Ambegaon, Khed, Bhor and Western & Central part of Taluka Maval, Mulshi and Velhe comes under this region. The altitude of this region ranges in between 100 and 500 m above MSL.
iii. The Eastern Plateau: On the East of `Maval’, remaining belt of plain is called “Desh”. This area covers basins of the river Bhima and its tributaries. Central and Western part of the Taluka Junnar & Khed, half Eastern part of the Taluka

Ambegaon, Eastern zone of Taluka Velhe, Mulshi, Bhor and Western part of the Taluka Haveli falls in this area. The area of Shirur, Daund, Baramati and Indapur Taluka is mostly plains.

Pune is a plateau city situated near the western margin of the Deccan plateau. It lies on the leeward side of the Sahayadri i.e. the Western Ghats and is hardly 50 km from the crest of the Ghat country. It is situated at a height of 560 m above the mean sea level, near the confluence of Mula and Mutha rivers.

Two more rivers Pavana and Indrayani traverse the north-western outskirts of the urban area. Mula-Mutha later empty into the Bhima River. In a sense, the city is located in the upper Bhima basin.

The city is surrounded by hills on the east and the south. The Sinhagad-Katraj-Dive Ghat range is the southern boundary of the urban area. The highest point within the city is the Vetal hill (800 m above msl), which lies approximately 2.60 km, aerially, from Pune Metro Phase 1 Extension Line 2A (Vanaz to Chandani Chowk).

DEM map of the project alignments is shown below in Figure 15-3.

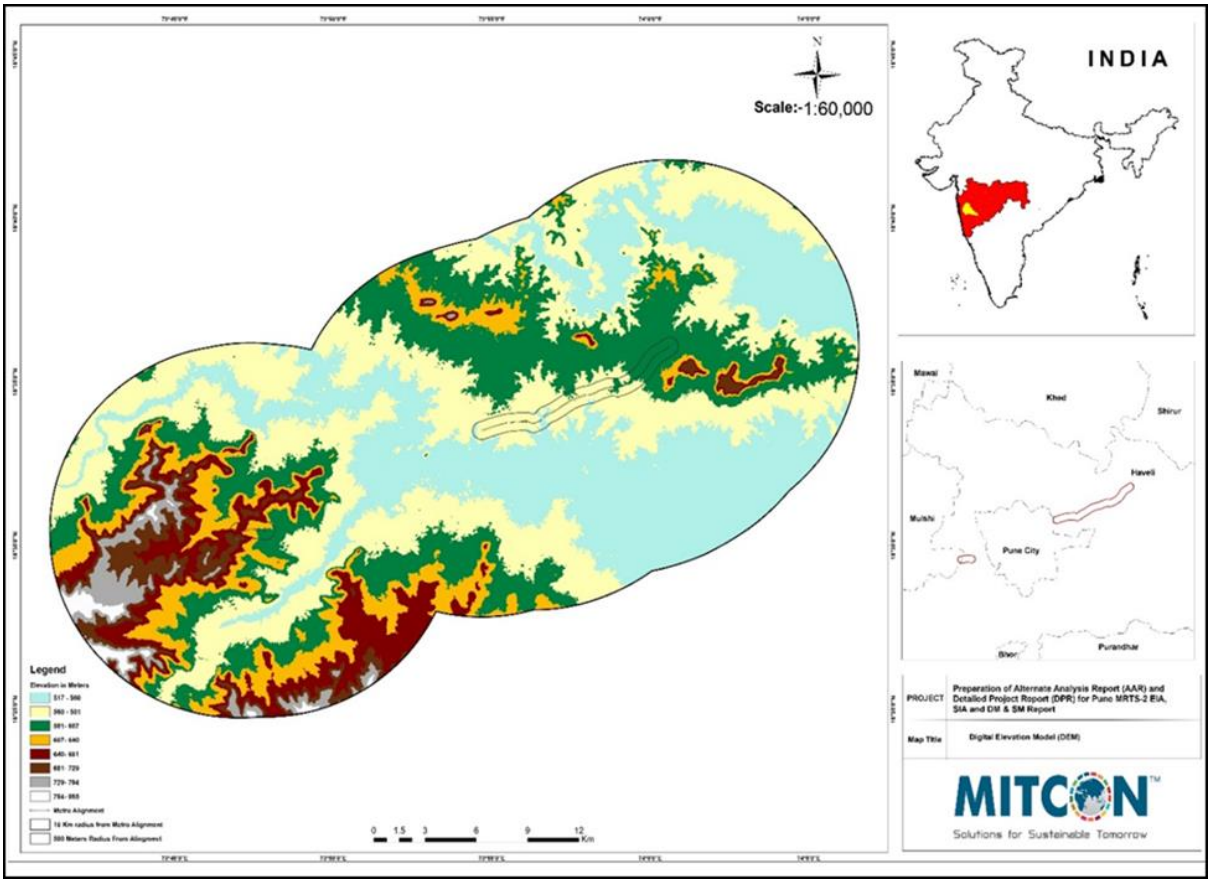


FIGURE 15-3: DEM MAP OF THE STUDY AREA

15.3.1.2.SOIL

Soil is the unconsolidated material on the earth surface that serves as a natural medium for plant growth. It is a product of a rock weathering and paedogenesis and on human timescale is a non- renewable natural resource.

On the basis of soil depth, drain, soil characteristics, slope etc. following soil types are identified in the district and shown in Table 15-4.

TABLE 15-4: SOIL TYPES FOUND IN PUNE DISTRICT[1]

Sr. No.	Soil Type	Locations in Pune district
1	Deep, Moderately Well-drained, strongly calcareous, fine soils on gently sloping plains and valleys with moderate erosion	Narrow stretches are spread in Talukas Ambegaon, Khed, Maval, Mulshi, Velhe, Haveli, Bhor, Purandar, Baramati and Indapur, along the river banks.
2	Slightly deep, well-drained, fine, calcareous soils on very gently sloping lands with *mesas* and *buttes* with moderate erosion	All Talukas in the district, Except Maval and Mulshi Talukas, have this soil coverage. These include major portions of Indapur, Baramati, Purandar, Pune-City, Haveli, Daund and Shirur Talukas. Narrow stretches are spread on the eastern side of Junnar, Khed, Ambegaon and Velhe Talukas.
3	Very deep, well drained, loamy soils on gently sloping narrow valleys with moderate erosion.	Patches are spread in Mulshi, Bhor and Velhe Talukas.
4	Shallow well drained, clayey soils on gently sloping lands with *mesas* and *buttes* with moderate erosion and slight stoniness.	Major portion of the district is covered by this type of soil, and includes major portions of Maval, Khed, Mulshi, Velhe, Bhor, Purandar, Haveli and Daund Talukas. Small stretches are spread in Pune-City, Indapur, Baramati, Ambegaon, Shirur and Junnar Talukas.
5	Shallow, well drained, clayey soils on gently sloping land with moderate erosion.	Stretches are spread in Ambegaon, Junnar, Maval, Shirur, Haveli, Purandar, Baramati, Daund, Khed and Indapur Talukas.

Soil samples were collected at four (04) locations within the study area as listed in the Table 15-5. Some photographs taken during soil sampling are shown in Figure 15-4. The results of all soil quality analyses are summarized in Table 15-6.

1 Source: NBSS&LP, Nagpur

TABLE 15-5: SOIL SAMPLING LOCATIONS

Sample Code	Alignment (Line) / Corridor	Sampling Location / Village	Geo-Coordinates	
			Latitude (DMS)	Longitude (DMS)
S.1	Line 2A (Vanaz – Chandani Chowk)	Chandani Chowk	18°30'24.66"N	73°47'2.27"E
S.10	Line 2B (Ramwadi to Wagholi/Vitthalwadi)	Chandan Nagar	18°33'43.02"N	73°56'16.26"E
S.11		Wagholi	18°34'48.26"N	73°58'36.40"E
S.12		Vitthalwadi	18°36'3.91"N	74° 0'31.51"E

FIGURE 15-4: SOME PHOTOGRAPHS OF SOIL SAMPLING IN THE STUDY AREA

TABLE 15-6: RESULTS OF SOIL SAMPLING IN STUDY AREA

Sl. No.	Parameters	Units	Location			
			S.1 – Chandani Chowk	S.10 – Chandan Nagar	S.11 – Wagholi	S.12 - Vitthalwadi
1	Texture	--	Clay loam	Clay loam	Silty clay	Silty clay loam
2	Percentage of Different Components					
	Sand	%	25	30	20	25
	Silt	%	35	40	30	40
	Clay	%	40	30	50	35
3	Soil Moisture	%	4.52	1.38	3.12	2.1
4	Bulk Density	gm/cm2	1.1	1.07	1.1	1.08
5	Water Holding Capacity	%	45.4	40.2	41.5	46.3
6	pH	--	7.02	7.38	7.27	7.36
7	Conductivity	µs/cm	567.2	504.3	311.4	402.6
8	Organic Carbon	%	0.34	0.24	0.2	0.36
9	Calcium (as Ca)	mg/kg	152.3	128.8	138.7	140.2
10	Magnesium (as Mg)	mg/kg	85.2	75.2	80.2	101.2
11	Available Nitrogen	kg/ha	101.4	114.3	90.2	50.5
12	Phosphorous (as P)	kg/ha	8.52	10.57	15.53	9.17
13	Potassium (as K)	kg/ha	145.2	171.5	203.7	194.8
14	Iron (as Fe)	mg/kg	1.23	0.72	0.93	0.75
15	Zinc (as Zn)	mg/kg	0.75	0.58	0.63	0.55
16	Copper (as Cu)	mg/kg	0.13	0.27	0.25	0.11
17	Sodium	mg/kg	23.2	25.2	21.2	20.2
18	Manganese (as Mn)	mg/kg	0.11	0.28	0.073	0.054
19	Total Chromium (as Cr)	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05
20	Nickel (as Ni)	mg/kg	< 0.02	< 0.02	< 0.02	< 0.02
21	Cadmium (as Cd)	mg/kg	< 0.05	< 0.05	< 0.05	< 0.05
22	Lead (as Pb)	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1
23	Sodium Absorption Ratio	--	0.78	0.9	0.74	0.66

INFERENCES OF SOIL SAMPLING

- All the samples having pH in range of 7.02 to 7.38
- Electrical Conductivity of the samples is in between 311.4 to 402.6 µs/cm.

- The water holding capacity of a soil is a very important agronomic characteristic.
- All the soil samples show 40-47% water holding capacity.
- Soil Organic Matter also acts the major sink and source of soil carbon.
- The concentration of the organic matter in the soil in all analysed samples is 0.2 to 0.36 %.
- All the soil samples show good NPK values. Nitrogen concentrations are in the range of 50.5 to 114.3 kg/Ha, Phosphorous concentrations are in the range of 8.52 to 15.53 kg/Ha, while Potassium concentrations are in the range of 145.2 to 203.7 kg/Ha.

15.3.1.3.LAND USE LAND COVER

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change, or maintain it. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment.

Land use of the study area varies and the Project study area largely demonstrates mixed type of land use. LU-LC map of 500 m area around each of the two alignments – Vanaz to Chandani Chowk and Ramwadi to Wagholi/Vitthalwadi – are shown respectively as Figure 15-5 and Figure 15-6. Figure 15-7 represents the Satellite Map of the Study Area.

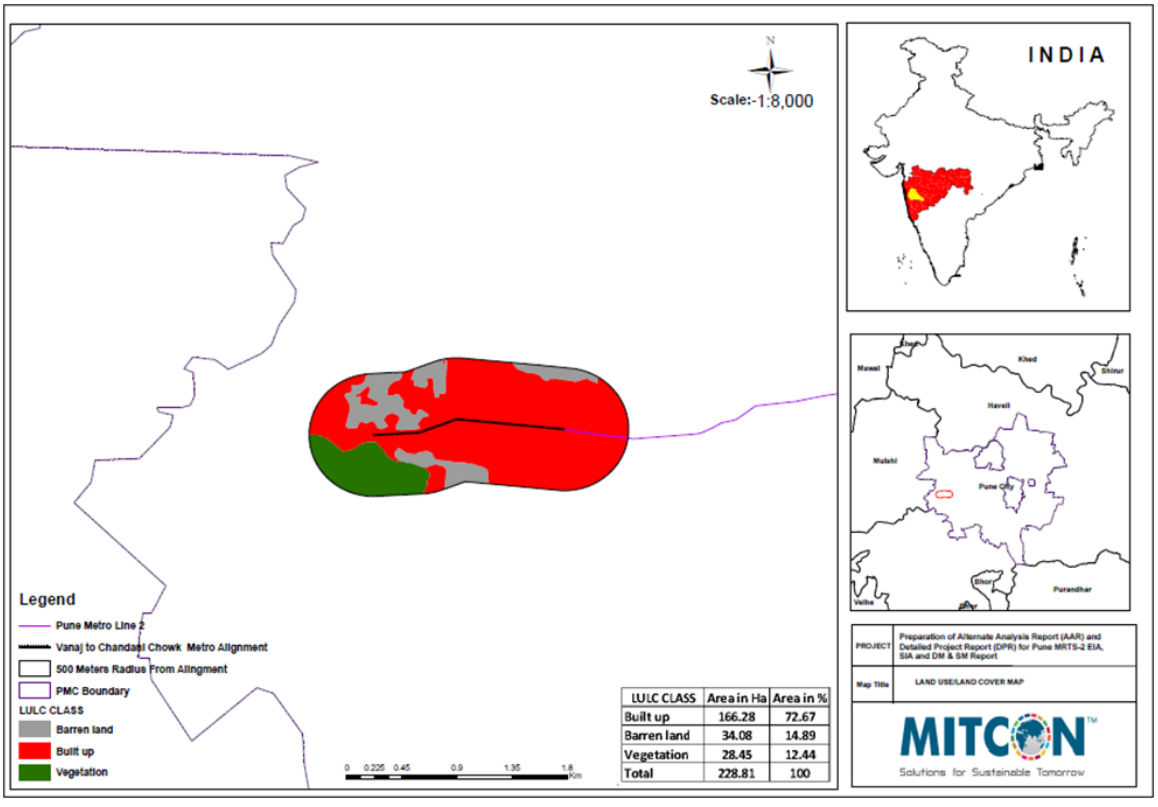


FIGURE 15-5: LAND USE/LAND COVER MAP OF 500M RADIUS AROUND LINE 2A

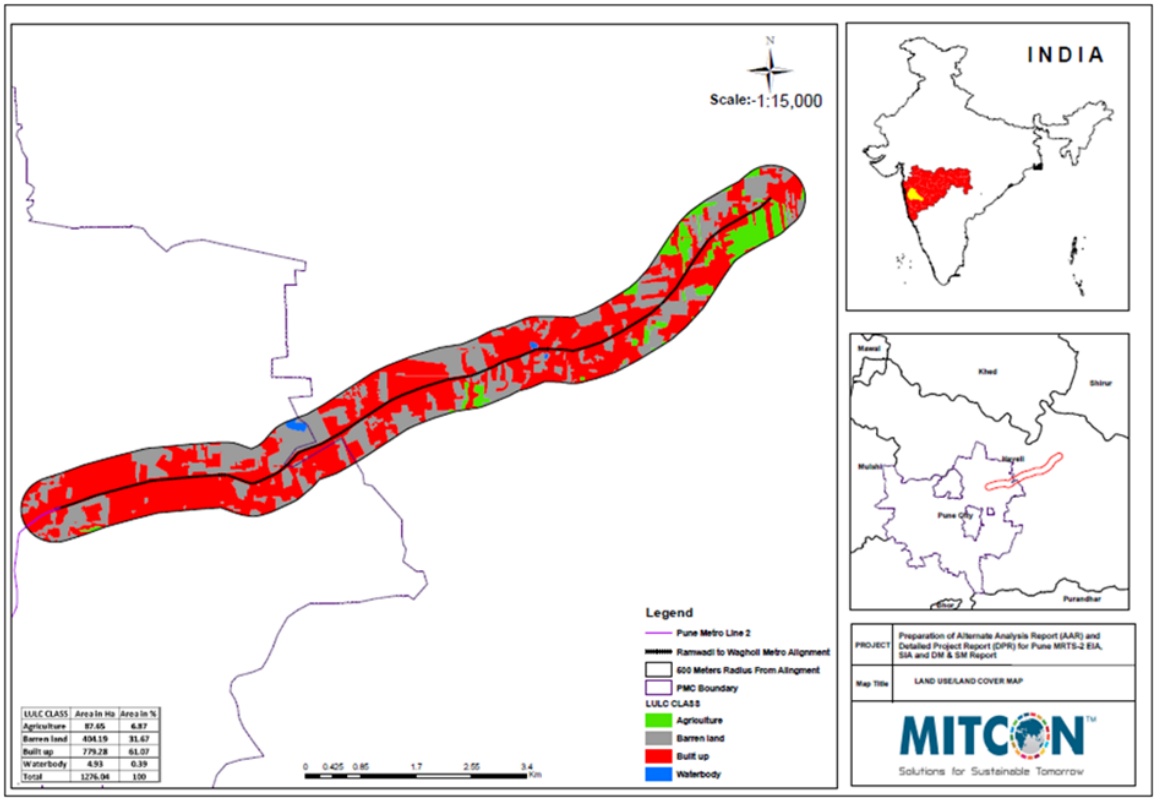


FIGURE 15-6: LAND USE/LAND COVER MAP OF 500M RADIUS AROUND LINE 2B

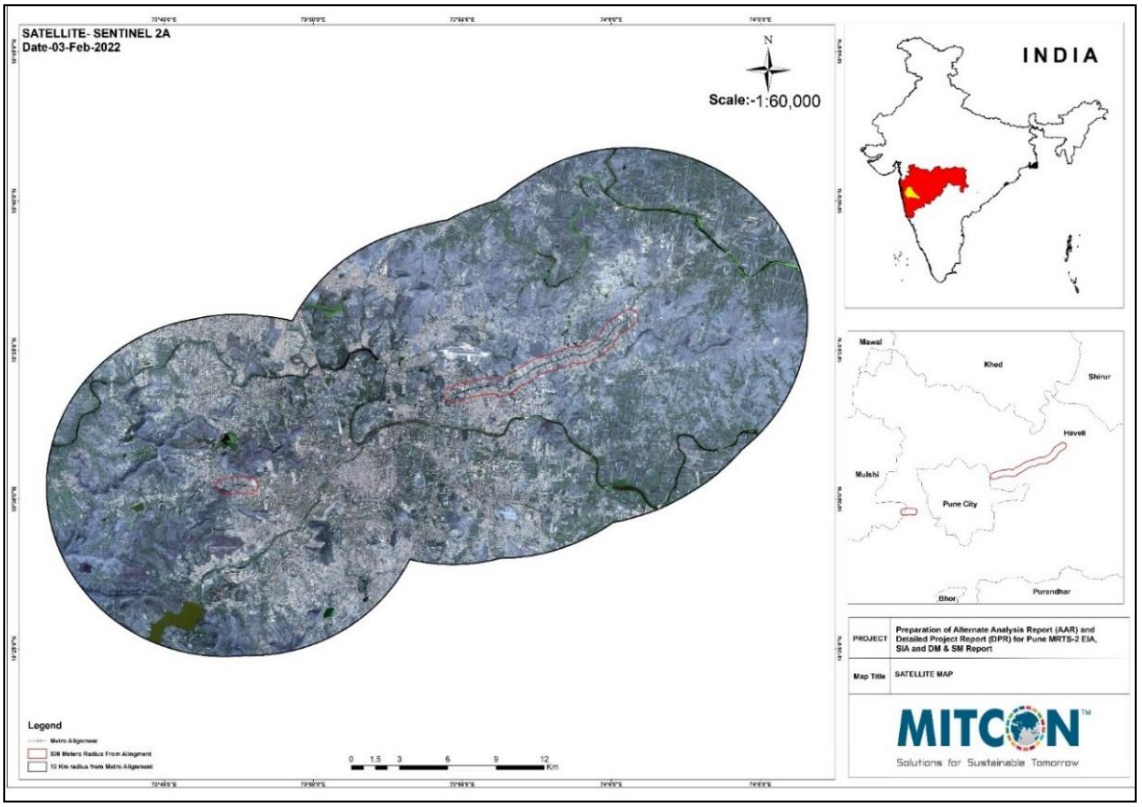


FIGURE 15-7: SATELLITE MAP OF THE STUDY AREA

Land cover is the observed (bio-) physical cover on the earth's surface. When considering land cover in a very pure and strict sense, it should be confined to the description of vegetation and man-made features.

Consequently, areas where the surface consists of bare rock or bare soil are land itself rather than land cover. Also, it is disputable whether water surfaces are real land cover. However, in practice, the scientific community usually includes these features within the term land cover.

Land Use/Land cover for 500m around each alignment and 10 km radius around the entire project site were delineated based on the Landsat ETM+ satellite data; the Land use/Land cover classes are categorized based on ground-truthing and site visit. Land is classified as vegetation, barren land, built-up area, water bodies, etc. classes.

15.3.1.4. SEISMICITY

As per the seismic map of India, the total area of the country is classified into four seismic zones. Zone V is seismically the most active region, while zone II is the least. Approximately, ~11% area of the country falls in zone V, ~18% in zone IV, ~30% in zone III and remaining in zone II.

According to the BMTPC Vulnerability Atlas of India, as well as the Seismic zonation map of India (BIS-2002), the State of Maharashtra lies majorly in Zone II (least active) & Zone III (Moderate damage), and only a small portion of the state lies in Zone IV (High damage).

The Project site & Study Area are located in Pune city i.e. Haveli taluka of Pune district, and lie in Zone III (Moderate Damage Risk Zone or MSK VI) as shown in Figure 15-8. 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 III by the India Meteorological Department (IM) and intensity upto 7 on Richer Scale. However, the probability of occurrence is 'Indeterminate'[2]

2 Source: Integrated Regional Disaster Management Plan for Pune Municipal Corporation (2014-2015) by the Regional Disaster Management Centre (PMC, Pune)

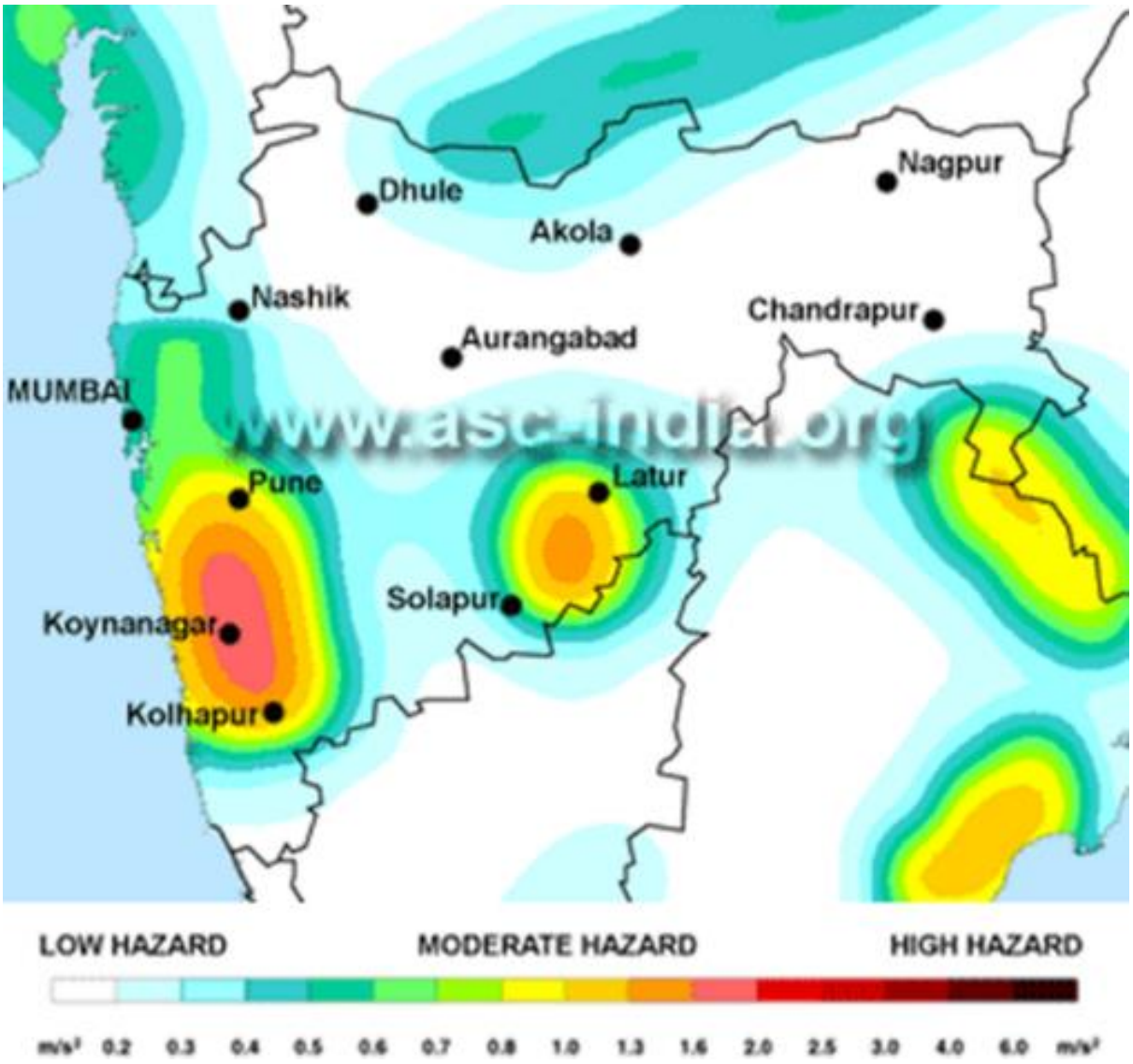


FIGURE 15-8: GSHAP SEISMIC HAZARD MAP OF MAHARASHTRA

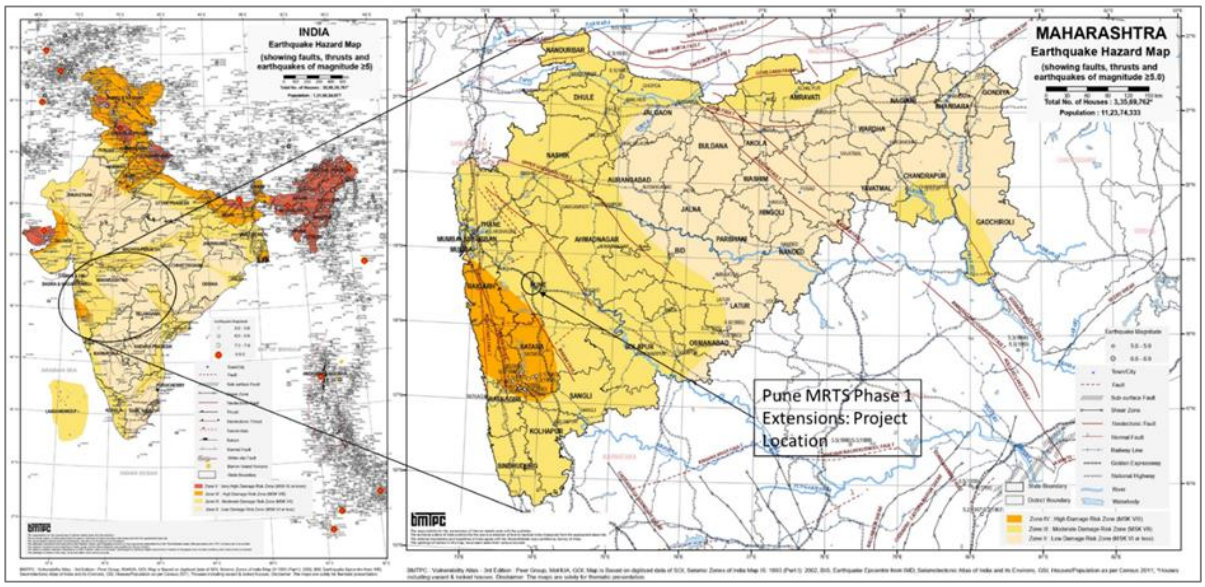


FIGURE 15-9: BMTPC EARTHQUAKE HAZARD MAP OF INDIA AND MAHARASHTRA WITH PROJECT SITE[3]

15.3.1.5. GEOLOGY & HYDROGEOLOGY

GEOLOGY

Almost the entire district is underlain by Deccan Volcanic Basalts belonging to Sahayadri Group of Upper Cretaceous to Eocene age, comprises of various lava flows, which can be classified in the field into two types as simple and compound flows. The compound flows occur at lower elevations whereas the simple flows are confined to the elevation above 680 m. The compound flows although vesicular and amygdaloidal in nature, hard and compact in their middle sections. They are fractured and jointed, and show moderate degree of weathering at places. Each individual lava flow consists of lower massive part becoming vesicular/amygdaloidal towards top, ranges in their individual thickness from a few centimetres to tens of meters. The flows have wide variation in colour and texture especially when they are amygdaloidal in nature with secondary mineral infillings such as Zeolites, calcite, and Agate and Chalcedony etc. The red /green/black bole beds constituting the marker horizons separating the two flows were discontinuous and generally inconsistent. The basalts are intruded by dykes and are found commonly in pahoehoe flows in the area. The generalised stratigraphy of Pune district is shown as Table 15-7, and map showing geological formations in Pune district is shown as Figure 15-10.

3 BMTPC Vulnerability Atlas & Maps of India - Earthquakes (3rd Edition - 2019)

TABLE 15-7: GENERALISED STRATIGRAPHY OF PUNE DISTRICT[4]

Age	Group	Sub-group	Formation	Thickness (m)	Lithology
Quaternary (Recent to Sub-recent) (> 1 mya)	Sahayadri Group (Deccan Trap Super Group)	--	Alluvium	(Various)	Poorly sorted arenaceous to rudaceous sediments (sand, silt & clay)
Upper Cretaceous to Eocene (30-60 mya)		Diveghat	Purandargad	300	Deccan Trap basalt with intertrappeans: Simple flows, aphyric to plagioclase micro-phyric
			Diveghat	350	Deccan Trap basalt with intertrappeans: Simple / Aa flows, aphyric
		Lonavala	Karla	250	Deccan Trap basalt with intertrappeans: Fine-grained, aphyric, 'Pahoehoe' flows.
			Indrayani	125	Deccan Trap basalt with Intertrappeans: a thick succession of 'Aa' flows - Aphyric to sparsely phyric
		Kalsubai	Upper and Lower Ratangad	250	Deccan Trap basalts: compound 'Pahoehoe' flows and Megacryst lava flows

4 Source: CGWB – Aquifer Maps and Ground Water Management Plan, Pune District, Maharashtra (2018)

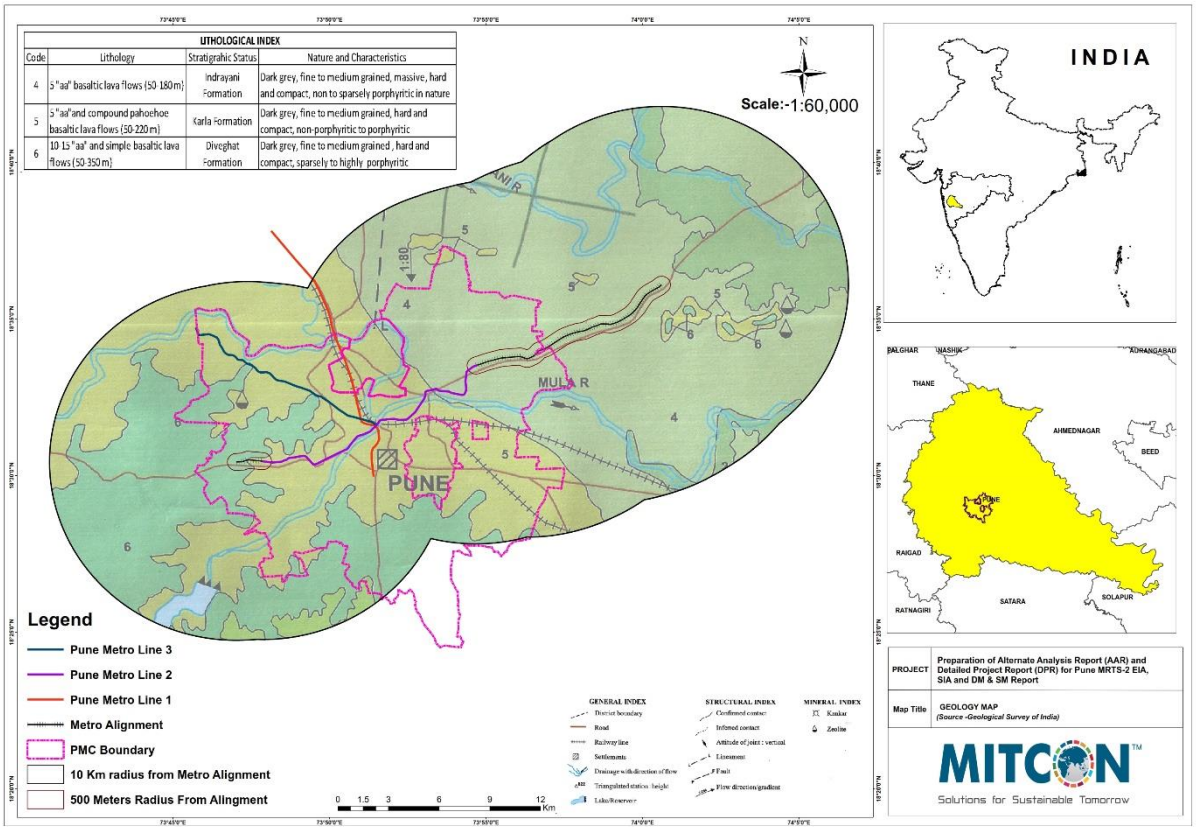


FIGURE 15-10: GEOLOGY OF PUNE CITY ALONG WITH PROJECT CORRIDORS AND STUDY AREA

HYDROGEOLOGY

Alluvium and Basalt aquifers are the main aquifers in the district. Two aquifer Systems in Basalt and one shallow aquifer in Alluvium (limed to river banks) are found to be prevailing in the district as shown in Figure 15-9. Deccan Trap Basalt of upper Cretaceous to lower Eocene age is the major rock formation in the district, whereas only a very narrow belt confined to the banks of rivers is underlain by Recent Alluvium. A map depicting hydrogeological features of Pune district is presented in Figure 15-11.

In Alluvial deposits, inter pore spaces constitutes the potential water bearing zones and prevalence of sand and gravels renders them a high degree of porosity and permeability and make them a potential ground water reservoir. However, alluvium occurrence is restricted to narrow belts along the banks of major river courses and has limited depth. The older Alluvium, which is more clayey with thin horizons of sand and silt, forms a comparatively lesser potential aquifer.

Ground water in Alluvium occurs mostly under water table and also under semi-confined to confined conditions in certain places. Shallow Aquifer occurs from 2 to 32 m BGL depth with shallow water levels. The yield varies from 50-300 m^3/day.

FIGURE 15-11: MAJOR AQUIFER SYSTEMS IN PUNE DISTRICT[5]

Deccan basalts are hydro-geologically in-homogeneous rocks. The weathered and jointed / fractured parts of the rock, as also permeable inter-flow beds constitute the zone of ground water storage and flow. The existence of multiple aquifers is characteristic of basalt and exhibits wide variation in the joint/fracture intensity. The yields of well is function of the permeability and transmissivity of aquifer and it depends upon the degree of weathering and topographic setting of the aquifer.

Due to wide variation in secondary openings, the potential areas for ground water are generally localized. In general, ground water occurs under phreatic/unconfined to semi-confined conditions in basalts. Two Aquifer systems have been delineated: Aquifer I from 9 to 30 m (Weathered /Jointed Basalt); and Aquifer II from 48 to 175 m (Jointed/fractured basalt). Shallow Aquifer generally tapped by the dug wells of 9 to 30 m depth, have water levels ranging from 2.1 to 25.0 m BGL and yield varies from 10 to 100 m^3/day.

The deeper Aquifer is being tapped by bore-wells with depth ranging from 50 to 180 m BGL and the water level from 6 to 45 m BGL.

5 Source: CGWB Report on Aquifer Mapping and Management of Ground Water Resources in Ambegaon, Baramati, Indapur, Junnar and Purandar Blocks of Pune District, Maharashtra

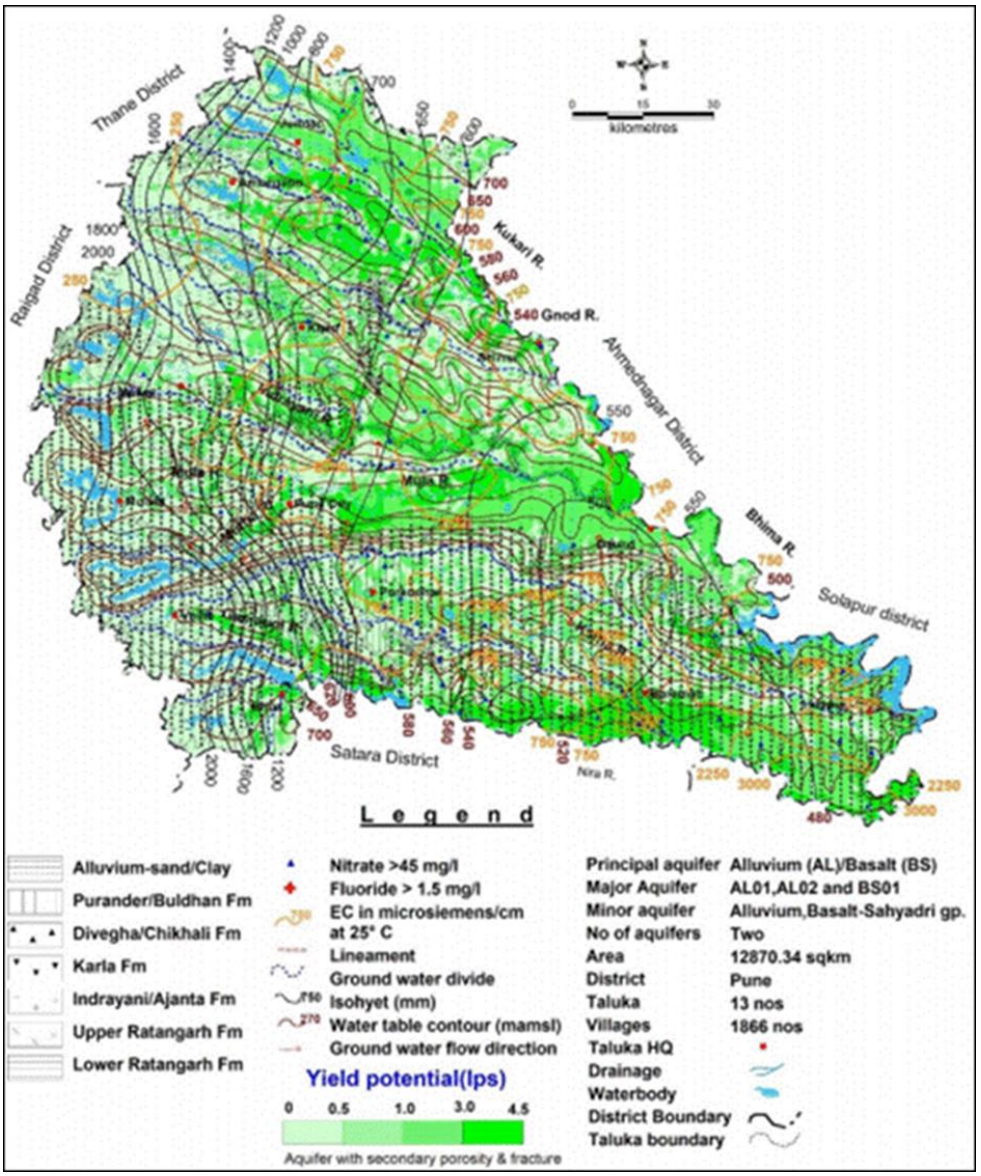


FIGURE 15-12: HYDROGEOLOGY OF PUNE DISTRICT[6]

Deccan Trap Basalts: Almost the entire district is underlain by Deccan Volcanic Basalts belonging to Sahayadri Group of Upper Cretaceous to Eocene age, comprises of various lava flows, which can be classified in the field into two types as simple and compound flows. The compound flows occur at lower elevations whereas the simple flows are confined to the elevation above 680 m. The compound flows although vesicular and amygdaloidal in nature, hard and compact in their middle sections. They are fractured and jointed, and show moderate degree of weathering at places. Each individual lava flow consists of lower massive part becoming vesicular /amygdaloidal towards top, ranges in their individual thickness from a few centimetres to tens of meters. The flows have wide variation in colour and texture especially when they are amygdaloidal in nature with

6 Source: CGWB Report on Aquifer Mapping and Management of Ground Water Resources in Anbegaon, Baramati, Indapur, Junnar and Purandar Blocks of Pune District, Maharashtra

secondary mineral infillings such as Zeolites, calcite, and Agate and Chalcedony etc. The red/green/black bole beds constituting the marker horizons separating the two flows were discontinuous and generally inconsistent. The basalts are intruded by dykes and are found commonly in pahoehoe flows in the area. The dykes vary in thickness from one or two meters to as much as 10 meters and extend for long distances. The dykes display the joints parallel to the walls, at right angle to the walls besides horizontal ones, with chilled margins. The dykes act as barrier or as water conduits / pathways for the movement of groundwater flow depending on intensity of fracturing in the dyke rock. The location and orientation of the dykes with respect to the groundwater flow are very important.

Alluvium: Alluvium, belonging to the Quaternary period forms a very productive aquifer in the district. The alluvial deposits are restricted as narrow belts along the banks of major river courses like Bhima and their tributaries. The alluvium occurs in patches in paleo-depressions. These shallow alluvium deposits comprise of loose or semi-consolidated medium to coarse grained sands, gravels, fine silt with admixture of clays resting directly on the massive, weathered or amygdaloidal zones of the basaltic lava flows.

Water Level Scenario: In Pune District, the water table varies from 480 m above MSL in south-eastern part of the area to about 700 m amsl in Northwest of study area, near river Bhima. The overall ground water movement in the area is from west to southeast and tends to flow towards surface drainages. It has been observed that the ground water flow direction follows the drainage and topography of the area. This indicates the topographic control for the ground water movement. The water level scenario in the district is shown below:

Pre-monsoon Depth to Water Level (May-2017)	: 0.90 to 30.35 m BGL
Post-monsoon Depth to Water Level (Nov.-2017)	: Ground level to 25.20 m BGL
Pre-monsoon Water Level Trend (2008-2017)	: Rise: 0.0001 to 0.750 m/year
	: Fall: 0.0116 to 0.42 m/year
Post-monsoon Water Level Trend (2008-2017)	: Rise: 0.0012 to 1.588 m/year
	: Fall: 0.0028 to 0.6992 m/year

Major Ground Water Problems and Issues: About 50 % area of Pune district falls under the 'Rain Shadow' zone. Long-term rainfall data analyses reveal that the eastern-, southern-, south-eastern, central- and north-central parts of the district around Indapur, Baramati, Jujuri, Daund, Talegaon Dhamdhare, Alandi, Shirur and Bhor talukas, covering about 50% geographical area, experiences drought conditions. Therefore, these areas are classified as 'Drought Prone Areas'. Decadal pre-monsoon water level trend (2008-17) reveals that by and large, during pre-monsoon periods, 65 % of the area and during post monsoon periods, about 68 % of the area shows fall in water levels. Falling trend of water level is observed in major parts of Pune City, Haveli, Khed, Junnar, Daund, Indapur, Baramati, Purandar, Bhor, Velhe, Mulshi and Maval Talukas of the district.

Groundwater Prospects & Block Categorisation: The prominent hill ranges, isolated hillocks, undulation etc. give rise to higher run off conditions in the district. The

predominance of hard rock formation in the form of basaltic lava flows facilitates the run off rather than natural recharge due to the poor ground water storage and transmission capabilities. As such ground water development in the region is low to moderate. Most of the dug wells become dry during peak summer. The bore wells range in depth from 45 to 90 m BGL and have been drilled in most of the villages in the district.

15.3.2 WATER ENVIRONMENT

15.3.2.1.HYDROLOGY/DRAINAGE

Surface Water quality within 10 Km radius of the study area has been studied for assessing the water environment and to evaluate the anticipated impact of the proposed project

All the river in Pune District originate in the Western part of Sahayadri Hill ranges in Junnar, Ambegaon, Khed, Maval, Mulshi, Velhe and Bhor Taluka and flows through the Eastern part of the district. The district is divided into two major river basins, Bhima and Nira. North-East, Eastern and Central part of the district comes under the Bhima river basin and the South-East and the Southern part of the district under the Nira river basin. River Bhima is the main river flowing through the district. River Bhima has its origin at `Bhimashankar' located in the Khed taluka and it flows through the central part of the district towards the South-East. The Ghod, Mula-Mutha and Nira are tributaries of river Bhima. River Ghod is a perennial river and flows across the Northern region of the district. River Kukdi and Mina are the two tributaries of river Ghod. Ghod River originates in the Ambegaon Taluka.

The confluence of the Bhima and Nira is at Nira-Narsingpur in Indapur Taluka. Eastern flowing Nira River flows along the Southern boundary of Pune district. The Karha River is a tributary of river Nira. Total length of the rivers in the district is about 1296 km. The present drainage pattern in Haveli taluka of Pune district, with approximate location of Project site is shown as Figure 15-13. Area wise distribution of the 'high', 'medium' and 'low' surface water flow is depicted in the Table 15-8. The three zones are:

1. '**High' flow areas**: These include the rivers / drainages with high flows with a buffer of 5 km to these drainages (Rivers Indrayani, Mula, Mutha, Nira, Bhima and Ghod.)
2. **'Medium' flow areas**: These include the rivers / drainages with medium flow and a buffer of 5 km to these drainages (Rivers Karha, Bhama etc.)
3. '**Low' flow areas:** This includes the seasonal streams and remaining watersheds.

TABLE 15-8: SURFACE WATER FLOW CHARACTERISTICS IN PUNE DISTRICT

Surface Water Flow Category	Area		Location
	Sq. km.	%	
High	7740.23	51.61	'High' flow exists in rivers Mula, Mutha, Nira, Ghod, Bhima throughout their stretch except in small

Surface Water Flow Category	Area		Location
	Sq. km.	%	
			stretches in between, and also in rivers Indrayani & Pavna to some extent.
Medium	**5128.36**	**34.19**	**'Medium' flow exists in Karha river of Baramati Taluka, Bhama river in Khed Taluka, Indrayani & Pavna rivers in Maval Taluka, and Mina river in Junnar Taluka.**
Low	2129.89	14.20	'Low' water flow areas are found along the Western boundary of the district covering seven talukas. Low water flow areas also found in some portion of Baramati, Indapur, Daund, Shirur, Haveli and Purandar Talukas.

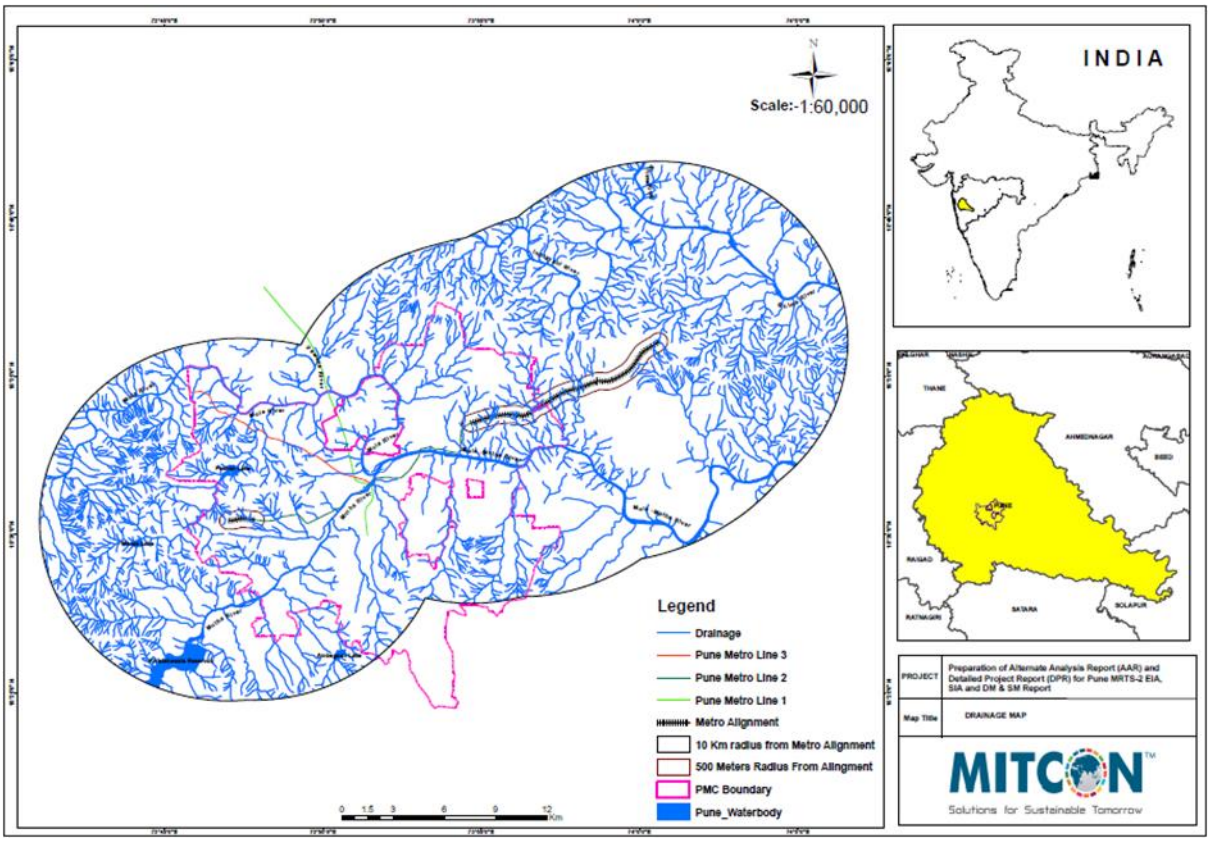


FIGURE 15-13: DRAINAGE MAP OF THE STUDY AREA

15.3.2.2.WATER QUALITY ANALYSIS

The development of any region is dependent on the availability of sufficient water resources, as developmental activities require water for construction, domestic and other purposes. The water resources in the study area broadly fall into following categories:

- Surface Water resources: Rivers / Ponds & Lakes / Canals / Dam Reservoirs.
- Ground Water resources: Dug Wells / Bore wells / Hand pumps.

The surface and ground water quality of the project area may get affected due to various factors like sedimentation & deposition of natural organic material, nutrients, bacteria & toxic substances, etc.

Water environment consists of water availability in the form of surface and ground water resources, its quality and use (both present and intended). Study of the water environment is essential in preparation of EIA for identification of critical issues including planning the mitigation measures with a view to have optimum use of the water resources.

Assessment of baseline data of the Water environment (both surface- and ground-water) in a study area includes:

- Identification of surface water sources
- Identification of ground water sources
- Collection of water samples
- Analysing water samples for physio-chemical and biological parameters

In this context, 2 groundwater samples and 1 surface water samples were collected from the study area for analysis of existing water quality in the area.

The criteria for selection of sites for water sampling was based on the following rationale:

- To characterize the groundwater in the study area in terms of location, behaviour, and quality.
- To identify potential effects of road construction and operation activities on groundwater regime of the area and any potential effects of groundwater quality on road construction and integrity.
- To identify measures to avoid, mitigate and manage any potential effects including any relevant design features of the road or techniques for construction.
- To identify residual effects of Project construction and operation activities on groundwater in the project area.

MONITORING STATIONS FOR WATER QUALITY ASSESSMENT

Water quality sampling was carried out in the month of May 2022. During the study period, very few surface water bodies were found within the project study area i.e. in 10 km radius of the project site. The details of sampling locations for Surface water and Groundwater samples are shown in Table 15-9 and Table 15-10 respectively.

TABLE 15-9: MONITORING STATIONS FOR SURFACE WATER QUALITY ASSESSMENT

Sample Code	Date of Sampling	Sampling Location / Village	Type	Geo-Coordinates	
				Latitude (DMS)	Longitude (DMS)
SW.6	10/05/2022	Wagheshwar Temple Pond	Lake	18°34'53.49"N	73°58'39.40"E

TABLE 15-10: MONITORING STATIONS FOR GROUND WATER QUALITY ASSESSMENT

Sample Code	Date of Sampling	Sampling Location / Village	Type	Geo-Coordinates	
				Latitude (DMS)	Longitude (DMS)
GW.5	09/05/2022	Chandan Nagar	Tube-well	18°33'26.43" N	73°56'14.43" E
GW.6	09/05/2022	Vitthalwadi	Dug-well	18°35'53.80" N	74° 0'30.74" E

Some photographs taken during water sampling in the study area are presented in Figure 15-14.

SW.6 – Wagheshwar Temple pond | GW.5 – Chandan Nagar | GW.6 – Vitthalwadi

FIGURE 15-14: SOME PHOTOGRAPHS SHOWING WATER QUALITY MONITORING

WATER QUALITY ANALYSES RESULTS

Results of the Surface Water quality & Groundwater quality assessments are given in Table 15-11.

TABLE 15-11: WATER QUALITY RESULTS FOR SURFACE WATER SAMPLES COLLECTED

Sr. No.	Parameter	Unit	IS: 10500:2012 Required Standards	Surface Water Sampling Location: SW.6 – Wagheshwar Temple pond
Chemical Potability				
1	pH at 25°C	-	6.50 to 8.50	7.83
2	Colour	Hz.	< 5	< 5
3	Odour	-	Agreeable	Not Agreeable
4	Temperature	°C	N.S.	28.6
5	Electrical Conductivity at 25°C	µS/cm	N.S.	430.5

Sr. No.	Parameter	Unit	IS: 10500:2012 Required Standards	Surface Water Sampling Location: SW.6 – Wagheshwar Temple pond
6	Turbidity	NTU	≤ 1	< 1
7	Total Dissolved Solids (TDS)	mg/l	≤ 500	268
8	Total Solids (TS)	mg/l	N.S.	272
9	Total Suspended Solids (TSS)			-
10	Acidity as $CaCO_3$	mg/l	N.S.	< 5
11	Total Alkalinity as $CaCO_3$	mg/l	≤ 200	95.47
12	Total Hardness as CaCO3	mg/l	≤ 200	131.4
13	Calcium as Ca	mg/l	≤ 75	28.33
14	Magnesium as Mg	mg/l	≤ 30	14.73
15	Chloride as Cl^-	mg/l	≤ 250	34.98
16	Sulphates as SO_4	mg/l	≤ 200	16.28
17	Nitrate as NO_3	mg/l	≤ 45	2.09
18	Ammonical Nitrogen as NH_4-N	mg/l	N.S.	< 0.1
19	Total Kjeldahl Nitrogen as NH_3-N	mg/l	N.S.	< 1
20	Salinity	ppt	N.S.	0.063
21	Fluoride as F	mg/l	≤ 1.0	< 0.1
22	Total Phosphorous	mg/l	N.S.	< 1
23	Silica as SiO_3	mg/l	N.S.	3.03
24	Sodium as Na	mg/l	N.S.	6
25	Potassium as K	mg/l	N.S.	2
26	Hexavalent Chromium (as Cr_6^+)	mg/l	N.S.	< 0.02
27	Iron (as Fe)	mg/l	≤ 0.3	< 0.05
28	Copper (as Cu)	mg/l	≤ 0.05	< 0.04
29	Nickel	mg/l	≤ 0.01	< 0.01
30	Zinc as Zn	mg/l	≤ 5	< 0.05
31	Manganese	mg/l	≤ 0.1	< 0.1
32	Chromium	mg/l	≤ 0.05	< 0.03
33	Lead	mg/l	≤ 0.01	< 0.01
34	Cadmium	mg/l	≤ 0.003	< 0.003
35	Phenol	mg/l	≤ 0.001	< 0.001
36	Biochemical Oxygen Demand (BOD)	mg/l	N.S.	7
37	Chemical Oxygen Demand (COD)	mg/l	N.S.	18
38	Dissolved Oxygen (DO)	mg/l	N.S.	4.3
39	Boron	mg/l	≤ 0.5	< 0.04
Bacteriological Potability				
1	Total Coliform	Per 100 ml	Absent	Present
2	*E. coli*	Per 100 ml	Absent	Present

TABLE 15-12: WATER QUALITY RESULTS FOR GROUNDWATER SAMPLES COLLECTED

Sr. No.	Parameter	Unit	IS: 10500:2012 Required Standards	Groundwater Sampling Locations	
				GW.5 – Chandan Nagar	GW.6 – Vitthalwadi
Chemical Potability					
1	pH at 25°C	-	6.50 to 8.50	7.36	7.89
2	Colour	Hz.	< 5	< 5	< 5
3	Odour	-	Agreeable	Agreeable	Agreeable
4	Temperature	°C	N.S.	28.5	28.7
5	Electrical Conductivity at 25°C	µS/cm	N.S.	880.9	887.8
6	Turbidity	NTU	≤ 1	< 1	<1
7	Total Dissolved Solids (TDS)	mg/l	≤ 500	568	574
8	Total Solids (TS)	mg/l	N.S.	572	578
9	Total Suspended Solids (TSS)			< 5	<5
10	Acidity as $CaCO_3$	mg/l	N.S.	< 5	<5
11	Total Alkalinity as $CaCO_3$	mg/l	≤ 200	271.35	261.3
12	Total Hardness as CaCO3	mg/l	≤ 200	293.13	313.35
13	Calcium as Ca	mg/l	≤ 75	72.86	60.72
14	Magnesium as Mg	mg/l	≤ 30	27	39.28
15	Chloride as Cl^-	mg/l	≤ 250	36.98	37.48
16	Sulphates as SO_4	mg/l	≤ 200	37.01	57.73
17	Nitrate as NO_3	mg/l	≤ 45	5.12	5.41
18	Ammonical Nitrogen as NH_4-N	mg/l	N.S.	< 0.1	<0.1
19	Total Kjeldahl Nitrogen as NH_3-N	mg/l	N.S.	< 1	<1
20	Salinity	ppt	N.S.	0.067	0.068
21	Fluoride as F	mg/l	≤ 1.0	< 0.1	<0.1
22	Total Phosphorous	mg/l	N.S.	< 1	<1
23	Silica as SiO_3	mg/l	N.S.	6.42	6.44
24	Sodium as Na	mg/l	N.S.	12	13
25	Potassium as K	mg/l	N.S.	3	4
26	Hexavalent Chromium (as Cr_6^+)	mg/l	N.S.	< 0.02	< 0.02
27	Iron (as Fe)	mg/l	≤ 0.3	< 0.05	< 0.05
28	Copper (as Cu)	mg/l	≤ 0.05	< 0.04	< 0.04
29	Nickel	mg/l	≤ 0.01	< 0.01	< 0.01

Sr. No.	Parameter	Unit	IS: 10500:2012 Required Standards	Groundwater Sampling Locations	
				GW.5 – Chandan Nagar	GW.6 – Vitthalwadi
30	Zinc as Zn	mg/l	≤ 5	< 0.05	< 0.05
31	Manganese	mg/l	≤ 0.1	< 0.1	< 0.1
32	Chromium	mg/l	≤ 0.05	< 0.03	< 0.03
33	Lead	mg/l	≤ 0.01	< 0.01	< 0.01
34	Cadmium	mg/l	≤ 0.003	< 0.003	< 0.003
35	Phenol	mg/l	≤ 0.001	< 0.001	< 0.001
36	Biochemical Oxygen Demand (BOD)	mg/l	N.S.	-	-
37	Chemical Oxygen Demand (COD)	mg/l	N.S.	-	-
38	Dissolved Oxygen (DO)	mg/l	N.S.	-	-
39	Boron	mg/l	≤ 0.5	-	-
Bacteriological Potability					
1	Total Coliform	Per 100 ml	Absent	Absent	Absent
2	*E. coli*	Per 100 ml	Absent	Absent	Absent

WATER QUALITY INFERENCE

- **Surface Water Quality:** All the parameters were compared with IS 10500:2012, and were found to be within the permissible limits or only slightly exceeding permissible limits. Microbiological parameters – Total coliform and E-coli are present in the sample in negligible amounts (< 2 per 100ml).
- **Ground Water Quality:** All the analysed physicochemical parameters are within permissible limits as per IS 10500:2012.

15.3.3 METEOROLOGICAL AND AIR EVIRONMENT

15.3.3.1. METEOROLOGY

Micro-meteorological data within the study area during the air quality survey period is an indispensable part of air pollution studies.

The meteorological data recorded during the monitoring period is a useful tool for the interpretation of the baseline condition as well as for the input to predictive models for air quality dispersion.

As per IMD's classification of meteorological seasons in India, the year can be classified into the following four seasons:

i. Winter season (January to February)
ii. Pre-monsoon season (March to May)

iii. Monsoon season (June to September)
iv. Post-monsoon season (October to December)

The monitoring period for the baseline environmental studies was during April-May 2022 (i.e. Pre-monsoon season).

METHODOLOGY

The methodology adopted for monitoring surface observations is as per the standard norms laid down by Bureau of Indian Standards, and the India Meteorological Department (IMD). On site monitoring was undertaken for various meteorological variables in order to generate the site-specific data. The data generated has been compared with meteorological data generated by the nearest IMD Observatory at Shivajinagar, Pune. Monitoring was done as per IS: 8829: Micro-meteorological Techniques in Air Pollution. The details of parameters monitored, equipment used and the frequency of monitoring are given in Table 15-13.

TABLE 15-13: METEOROLOGICAL PARAMETERS MONITORED AT PROJECT SITE

Sr. No.	Parameters	Instruments	Frequency
1.	Wind speed	Counter Cup Anemometer	Hourly / Continuous
2.	Wind direction	Wind vane	Hourly / Continuous
3.	Temperature	Thermo sensor	Hourly / Continuous
4.	Relative humidity	Thermo–hydro sensor	Hourly / Continuous

AVERAGE METEOROLOGICAL CONDITION (SOURCE: IMD - PUNE)

The IMD has three stations in Pune district viz. at Shivajinagar, Lohagaon and Pashan which record temperature, humidity, rainfall and other key atmospheric parameters. Of these, the Lohagaon weather station is operated in collaboration with Pune International Airport, while the other two are directly monitored by the IMD.

The mean maximum temperature, highest maximum temperature, mean minimum temperature, lowest minimum temperature and total monthly rainfall for the period - 1981 to 2010 from the IMD observatory at Shivajinagar, Pune was collected and is presented in Table 15-14.

TABLE 15-14: AVERAGE OF METEOROLOGICAL DATA FROM IMD PUNE (CLIMATOLOGICAL TABLES)

Location: IMD Pune, (Latitude: 18°31'45.60"N, Longitude: 73°50'57.00"E)									
Approximate aerial distance from Project Site: 46.70 Km towards SW.									
Elevation: 15 m above MSL									
Month	**Temperature ° C**				**Humidity %**		**Rainfall**		**Mean Wind Speed m/s**	**Dominant Wind direction**
	Daily Mean Max	**Daily Mean Min**	**Monthly Highest**	**Monthly Lowest**	**Max**	**Min**	**Monthly Total (mm)**	**No. of Rainy Days**		
January	29.8	11.2	32.8	7	85	34	1.1	0.2	2.5	E, W - NW

Location: IMD Pune, (Latitude: 18°31'45.60"N, Longitude: 73°50'57.00"E)										
Approximate aerial distance from Project Site: 46.70 Km towards SW.										
Elevation: 15 m above MSL										
Month	Temperature ° C				Humidity %		Rainfall		Mean Wind Speed m/s	Dominant Wind direction
	Daily Mean Max	Daily Mean Min	Monthly Highest	Monthly Lowest	Max	Min	Monthly Total (mm)	No. of Rainy Days		
February	32.1	12.2	35.2	7.8	72	26	0.3	0.1	3.2	W - NW
March	35.6	15.7	38.7	11.1	55	21	2.2	0.2	4	E, W - NW
April	37.6	19.6	40.6	14.9	48	24	8.5	0.8	5.4	W - NW
May	36.9	22.6	40.9	18.4	59	37	26.8	1.9	8.5	W - NW
June	31.9	23.1	37.4	20.7	77	66	173.4	9.5	9.1	W
July	28.3	22.4	31.5	21	83	76	181.4	12.4	9.2	W
August	27.6	21.7	30.1	20.1	86	79	145.2	9.8	8.2	W
September	29.4	20.9	32.6	18.2	84	73	146.1	8	5.4	W
October	31.5	18.4	33.7	12.9	79	53	86.3	4.4	2.9	E, W - NW
November	30.4	14.5	32.5	9.7	76	43	25	1.2	2.7	E
December	29.2	11.5	31.5	7.6	82	39	7	0.3	2.5	E
Annual Total or Mean	**31.7**	**17.8**	**41.4**	**6.1**	**74**	**47**	**803**	**48.7**	**5.3**	**W-NW**

TEMPERATURE

The winter season starts from December and continues till the end of February. During this season, monthly mean maximum temperature is found to be 32.3°C occurring in the month of February whereas, monthly mean minimum temperature occurs in the month of December & January as 11.1°C. Both the day and night temperatures increase rapidly during the onset of Pre monsoon season from March to May.

Graphical representation of monthly temperature data of Pune is shown below as Figure 15-15, while that showing the diurnal temperature variation is shown as Figure 15-16.

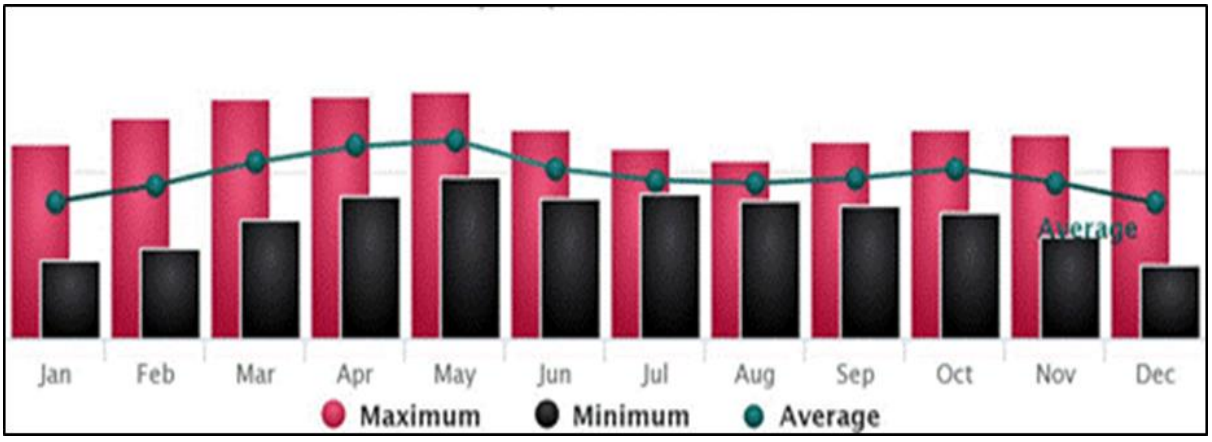


FIGURE 15-15: MONTHLY TEMPERATURE DATA OF PUNE

During Pre monsoon the monthly mean maximum temperature found to be 37.8°C in the month of April and monthly mean minimum temperature as 15.6°C in the month of March. An appreciable drop in mean maximum temperature is recorded with the onset of

monsoon. The monthly mean maximum temperature in monsoon season was observed to be 31.7°C in the month of June, while monthly mean minimum temperature was observed to be as 20.9°C in the month of September.

By end of September with the onset of post monsoon season (October & November), day temperature rises slightly with the monthly mean maximum temperature was observed to be as 31.5°C in October and the minimum temperature is observed as 14.5°C in November.

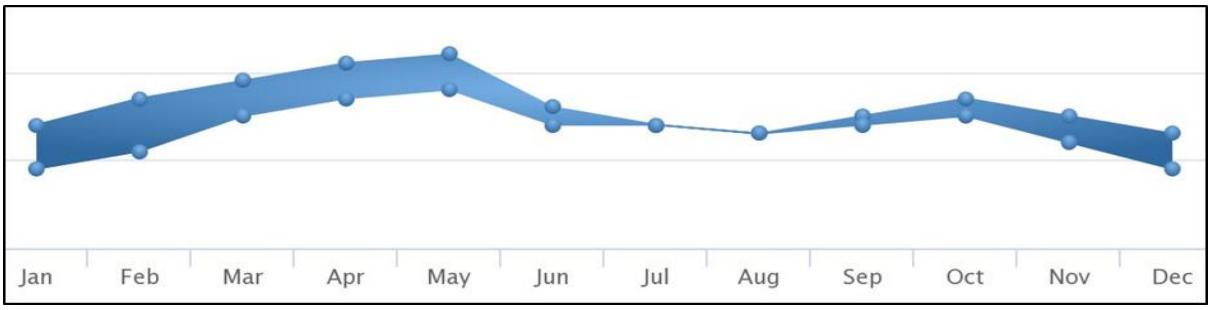


FIGURE 15-16: DIURNAL TEMPERATURE VARIATION IN PUNE

RELATIVE HUMIDITY

During Pre-monsoon period, the monthly mean relative humidity was observed to be in the range of 48%-61% at 0830 hrs. and at 1730 hrs. it is observed in the range of 21%-39%. During the monsoon season, relative humidity ranges between 77% - 86% at 0830 hrs. and 66% - 78% at 1730 hrs. In the post-monsoon season the range was observed to be between 78% - 81% at 0830 hrs. and at 1730 hrs. the range of relative humidity occurred between 46% - 56%.

Graphical representation of monthly ranges of Relative Humidity in the district is shown below as Figure 15-17 while that showing the diurnal variation is shown as Figure 15-18.

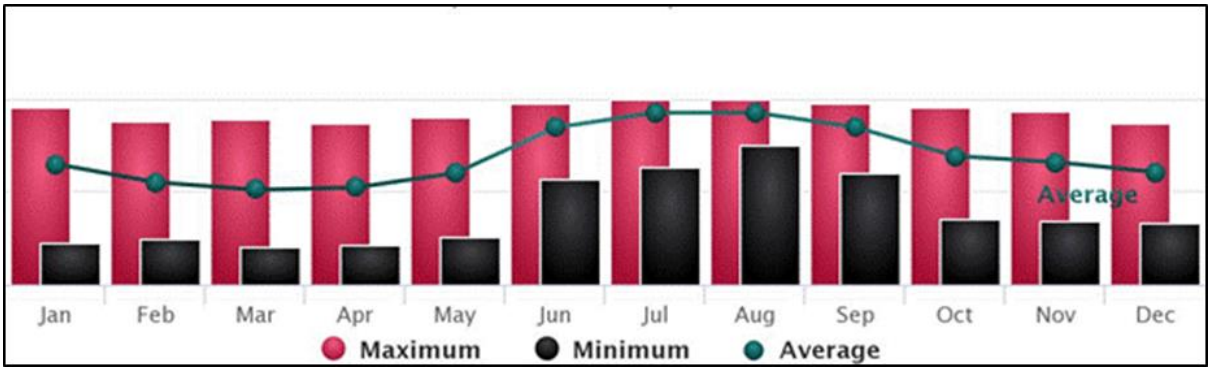


FIGURE 15-17: MONTHLY RELATIVE HUMIDITY DATA OF PUNE

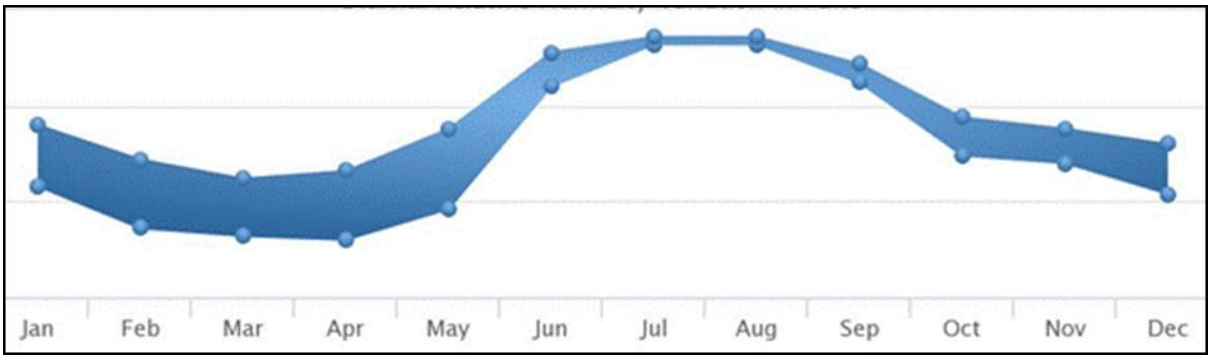


FIGURE 15-18: DIURNAL RELATIVE HUMIDITY VARIATION IN PUNE

During winter season the range of humidity was observed between 75% - 87% at 0830 hrs. and 27% - 39% at 1730 hrs. It is observed from the data that the air is dry in pre monsoon and winter seasons while it is humid during monsoon and post monsoon seasons due to heavy rains in the region.

PRECIPITATION

The climate of Pune district is characterized by hot tropical climate with moderate summer, mild winter season and general dryness throughout the year except during the south-west monsoon season, i.e., June to September. As per Agro-climatic Zones of the Agriculture Department, major part of Pune district falls under 'Assured Rainfall Zone'.

The average rainfall is about 1000 mm. The drought prone areas in the extreme east receive rainfall of 500 to 600 mm. Taluka falling in the highest rainfall intensity zone (rainfall >1000 mm) are Velhe, Mulshi and Maval, while those falling in moderate rainfall intensity zone (rainfall between 500 and 1000 mm) are Bhor, Ambegaon, Junnar, Khed, Haveli, Pune city and Purandar. Shirur, Daund, Indapur and Baramati Talukas fall within the lowest rainfall intensity zone, i.e. the dry and semi-arid zone (rainfall < 500 mm).

The decline in the amount of rainfall towards the East is due to the Sahayadri mountainous zone, which creates a rain-shadow region hardly 100 km east of the divide. The Average annual rainfall (1981-2010) of the district is 1468.8 mm spread over an average of 62.8 rainy days.

WIND SPEED AND WIND DIRECTION

Generally light to moderate winds prevails throughout the year with slightly stronger winds in the early monsoon period. Winds are light and variable in the post-monsoon and winter seasons particularly during the morning hours, while during the afternoon hours the winds are slightly stronger. The wind pattern for the period of 1990-2003 is presented as wind-roses below.

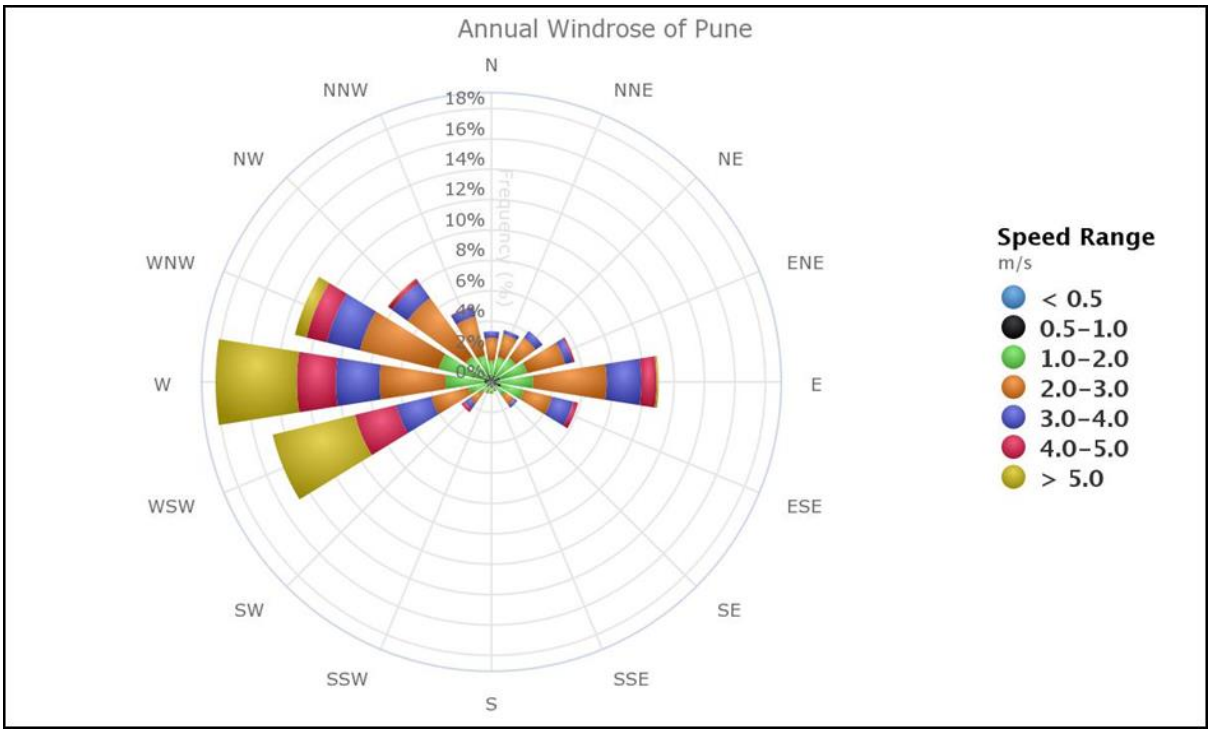


FIGURE 15-19: ANNUAL WIND ROSE DIAGRAM OF PUNE

It is observed from the data that the predominant wind direction in the region is east followed by west for most part of the year. The average wind speed in the region is observed to be in the range of 1.0-11.0 kmph. Annual wind rose for Pune city is shown as Figure 15-19.

The monthly wind rose diagrams, based on wind directions observed during the Study period, reveal that wind was blowing predominantly from East and east north-east directions in December and January, and from West-Northwest (WNW) – East-Northeast (ESE) in February.

15.3.3.2.AIR QUALITY

SAMPLING PERIOD, FREQUENCY AND PARAMETERS

Air quality is an important parameter of the baseline environment and its study is an indispensable tool for planning further development in the adjoining areas of the project. The extant air quality was studied to assess the current status of the same and to check the air quality status of the region vis-à-vis the air quality standards prescribed by the Central Pollution Control Board. The ambient air quality monitoring was conducted at 6 locations in total for the two Phase - 1 extension alignments (1 location for Vanaz to Chandani Chowk alignment, 3 locations for Ramwadi to Wagholi/Vitthalwadi alignment and 1 location each on up-wind and down-wind directions of the project, respectively), details of which are given in Table 15-15. Some photographs taken during air monitoring are shown as Figure 15-20. The monitoring locations have been selected primarily based

on the predominant wind direction, followed by topography, representative nature of the sample, accessibility, location of receptors and availability of power, etc.

AQ.1 – Chandani Chowk

AQ.10 – Chandan Nagar

AQ.11 – Wagholi

AQ.12 – Vitthalwadi

AQ.13 – Bhugaon

AQ.14 – Lonikand

FIGURE 15-20: SOME PHOTOGRAPHS SHOWING AMBIENT AIR QUALITY MONITORING

TABLE 15-15: AMBIENT AIR QUALITY MONITORING LOCATIONS FOR PHASE 1 EXTENSIONS

Sample Code	Sampling Location / Village	Geo-Coordinates		Wind Type*
		Latitude (DMS)	Longitude (DMS)	
AQ.1	Chandani Chowk	18°30'25.10"N	73°47'1.89"E	UW
AQ.10	Chandan Nagar	18°33'45.53"N	73°56'18.99"E	CW
AQ.11	Wagholi	18°34'50.08"N	73°58'58.96"E	DW
AQ.12	Vitthalwadi	18°36'6.18"N	74° 0'35.55"E	DW
AQ.13	Bhugaon	18°30'4.54"N	73°45'1.44"E	UW
AQ.14	Lonikand	18°37'13.58"N	74° 1'25.69"E	DW

TECHNIQUES FOR MEASUREMENT

The ambient air quality monitoring was carried out in the study area during pre-monsoon season of April 2022. The monitoring was carried out as per CPCB/MoEF&CC guidelines.

The concentrations of PM10, PM2.5, SO2, NOX and CO samples were collected as 8 hourly readings once during the study period at each location, on average by drawing air at the rate of 1.0 - 1.5 m3/min through glass fibre filter paper, and analysing the same by Gravimetric method. Pre-calibrated fine dust particulate samplers were used for monitoring of PM10 & PM2.5.

Concentrations of SO2 and NOX were analysed by absorption & colorimetric method, While CO was monitored using CO meter

TABLE 15-16: TECHNIQUES USED FOR THE ANALYSIS OF AMBIENT AIR QUALITY PARAMETERS

Sr. No	Parameter	Monitoring Equipment	Technique	Minimum Detectable Limit	Unit	Test Method
1	Particulate Matter >10µ (PM_{10})	Fine Dust Sampler	Gravimetric method	1.0 mg/m^3	µg/m^3	IS: 5182 (Part-IV) 2006, First Revision
2	Particulate Matter < 2.5µ ($PM_{2.5}$)			1.0 mg/m^3	µg/m^3	IS 5182 Part-II .2001 First Revision
3	Sulphur dioxides (SO_2)	Gaseous Sampler	Improved West and Geake method	4.0 mg/m^3	µg/m^3	IS 5182 (Part 23) :2006 Reaff 2012
4	Nitrogen Oxides (NO_X)		Modified Jacob & Hochheiser method	4.0 mg/m^3	µg/m^3	USEPA (40 CFR Ch. I (7–1–14 Edition) Appendix L to Part 50)
5	Carbon monoxide (CO)	CO meter	IS: 5182 (Part-X) & CPCB Guidelines	-	mg/m^3	Non-Dispersive Infra-Red (NDIR) spectroscopy

AMBIENT AIR QUALITY RESULTS AND INFERENCES

The result of air quality monitoring in the project Study Area as summarised in the Table 15- 17, were compared with National Ambient Air Quality Standards laid down by Ministry of Environment, Forest & Climate Change (MoEF&CC) on 16th November 2009 (Table 15-18). It was found that all the parameters are within permissible limits.

TABLE 15-17: RESULTS OF ANALYSIS OF AMBIENT AIR MONITORING

Corridor	Sample Code	Sampling Location / Village	Concentrations of Air Quality parameters				
			PM_{10}	$PM_{2.5}$	SO_X	NO_X	CO
Line 2A Vanaz to Chandani Chowk	AQ.1	Chandani Chowk	71.4	48.2	22.5	28.9	0.821
	AQ.13	Bhugaon	65.1	46.7	21.6	26.8	0.786
Line 2B Ramwadi to Wagholi/Vitthalwadi	AQ.10	Chandan Nagar	74.3	49.3	23.4	28.2	0.869
	AQ.11	Wagholi	74.3	46.5	21.2	26.6	0.741
	AQ.12	Vitthalwadi	68.6	45.9	21.7	24.8	0.651
	AQ.14	Lonikand	64.5	43.1	20.5	23.6	0.684

TABLE 15-18: NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

Pollutant, Unit	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural, and Other Areas	Ecologically Sensitive Area (notified by Central Government)
Particulate matter (< 10 µm) or PM_{10}, µg/m³	Annual	60	60
	24 hours	100	100
Particulate matter (< 2.5 µm) or $PM_{2.5}$, µg/m³	Annual	40	40
	24 hours	60	60
Sulphur dioxide (SO_2), µg/m³	Annual	50	20
	24 hours	80	80
Nitrogen dioxide (NO_2), µg/m³	Annual	40	30
	24 hours	80	80
Carbon Monoxide (CO); mg/m³	8 Hours	2	2
	1 Hour	4	4

15.3.4 NOISE QUALITY

The hourly noise monitoring was carried out in the month of May 2022 at 4 locations along the metro corridors (1 location along Vanaz to Chandani Chowk alignment and 3 locations along Ramwadi to Wagholi/Vitthalwadi alignment) as given in Table 15-19.

SAMPLING LOCATIONS AND PERIOD

Noise levels monitoring was carried out at various locations within the study area during Pre Monsoon period, i.e. May 2022, as per standard guidelines of MoEF&CC and CPCB.

TABLE 15-19: NOISE MONITORING LOCATIONS

Corridor	Sample Code	Sampling Location / Village	Geo-Coordinates	
			Latitude (DMS)	Longitude (DMS)
Vanaz to Chandani Chowk	NQ.1	Chandani Chowk	18°30'25.57"N	73°47'2.21"E
Ramwadi to Wagholi/Vitthalwadi	NQ.10	Chandan Nagar	18°33'43.26"N	73°56'19.52"E
	NQ.11	Wagholi	18°34'49.91"N	73°58'47.20"E
	NQ.12	Vitthalwadi	18°36'6.03"N	74° 0'37.35"E

METHODOLOGY OF NOISE LEVEL MONITORING

The noise monitoring has been carried-out by using digital noise meter having a noise level measuring range of 35 dB (A) to 100 dB (A). In this monitoring, at each location, the maximum and the minimum values of noise levels, and the equivalent noise levels were monitored. Test Method Used for Ambient Noise Level Monitoring is presented in Table 15-20 below.

TABLE 15-20: TEST METHOD USED FOR AMBIENT NOISE LEVEL MONITORING

Sr. No.	Parameter	Unit	Test Method
01	Noise level	dB	IS 4954 ,1968 Reaff. 2014

NOISE QUALITY SAMPLING RESULTS

Noise level monitoring was carried out in the Study Area once during the study period. Noise levels were measured by Noise meter, and results are presented in below Table 15-21.

TABLE 15-21: RESULTS OF ANALYSIS OF AMBIENT NOISE LEVEL DATA AT VARIOUS LOCATIONS

Corridor	Sample Code	Location	Category of Area / Zone	24 hourly Average Noise Level Values [in Leq DB (A)]	
				Day	Night
Line 2A: Vanaz to Chandani Chowk	NQ.1	Chandani Chowk	Commercial	63.4	53.6
Line 2B: Ramwadi to Wagholi/Vitthalwadi	NQ.10	Chandan Nagar	Commercial	64.2	54.8
	NQ.11	Wagholi	Commercial	63.6	54.2
	NQ.12	Vitthalwadi	Commercial	58.9	50.1

NOISE QUALITY INFERENCES

All sampling locations are urban areas and can be classed in Commercial category/zone. The Noise monitoring results at all sampling locations are within the prescribed standards for Noise quality as shown in Table 15-22. Some photographs taken during noise monitoring in the study area are shown as Figure 15-21.

FIGURE 15-21: SOME PHOTOGRAPHS OF NOISE MONITORING IN THE STUDY AREA

TABLE 15-22: NATIONAL AMBIENT AIR QUALITY STANDARDS IN RESPECT OF NOISE[7]

Area	Category	Limits in decibels, dB(A)	
		Day Time*	Night Time*
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone**	50	40

Note:

- *Day time shall mean 6.00 a.m. to 10.00 p.m.
- *Night time shall mean from 10.00 p.m. to 6.00.a.m.
- **Silence zone is defined as an area comprising not less than 100 meters around hospitals, educational institutions and courts. The silent zones are zones which are declared as such by the competent authority.
- Mixed categories of areas may be declared as one of the four above-mentioned categories by the competent authority.
- dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A.

15.3.5 ECOLOGY AND BIODIVERSITY

An ecological study is essential to understand the impact due to project development activities on flora and fauna of the area.

The proposed corridors do not pass through any reserve / protected forest in their entire stretches. Moreover, no protected areas/environmentally sensitive areas are found in the Indirect or Secondary Influence zone (10 km radial distance around both the alignments).

Tree survey was carried out along the proposed alignments. Most of the trees exist along the road on sides and median. The predominant tree species found along the corridors are *Terminalia mentally* (China Almond tree), *Azadirachta indica* (Neem tree), *Ficus benjamina* (Green Ficus tree), *Ficus racemosa* (*Umbar*/Cluster Fig tree), *Syzygium cumini* (Java Plum tree), *Delonix regia* (Gulmohar tree), *Acacia nilotica* (Babul), *Terminalia catappa* (Badam/Indian Almond tree) and *Ficus religiosa* (Pimpal/Sacred Fig tree), etc. The predominant shrub species observed in the study area are *Nerium oleander, Lantana camara, Calotropis gigantean*, etc.

Common birds observed in the project area are pigeons, parrots, bulbuls, and crows. The predominant mammals observed in the project area are bat, langur, monkey, rabbits and mice etc. No rare or endangered faunal species was observed during the surveys.

About 96 trees (27 along Line 2A and 69 along Line 2B) will be affected during site construction activities along both the corridors. Girth-wise inventory of all trees likely to be affected along Line 2A has been prepared and summarized in the Table 15-23, while the

7 Source: Ministry of Environment Forests & Climate Change (MoEF&CC), Government of India vide 'The Noise Pollution (Regulation and Control) Rules, 2000.

same for Line 2B is summarised in Table 15-24 and details are given in Annexure 15.4. Estimated cost of the total compensatory afforestation of 960 trees in lieu of total 96 affected trees in both the corridors, at the rate of 1:10, along with maintenance for a year, is included in the Environmental Management Plan (EMP) costing.

TABLE 15-23: GIRTH-WISE SUMMARY OF TREES LIKELY TO BE AFFECTED ALONG LINE 2A

Side of Alignment	Girth size (in cm)						Total
	0 – 30	31 – 60	61 – 90	91 – 120	121 – 150	> 150	
LHS	0	1	7	2	3	3	**16**
RHS	5	0	4	1	0	1	**11**
Total	**5**	**1**	**11**	**3**	**3**	**4**	**27**

TABLE 15-24: GIRTH-WISE SUMMARY OF TREES LIKELY TO BE AFFECTED ALONG LINE 2B

Side of Alignment	Girth size (in cm)						Total
	0 – 30	31 – 60	61 – 90	91 – 120	121 – 150	> 150	
LHS	7	8	8	3	1	1	**28**
RHS	14	12	5	5	2	3	**41**
Total	**11**	**20**	**13**	**8**	**3**	**4**	**69**

15.3.6 ARCHAEOLOGICAL SITES AND MONUMENTS

No archaeological sites/monuments are located on or along the proposed corridors.

15.3.7 DEPOTS

The existing depot at Vanaz is planned to be utilized for operations of Line 2A and Line 2B. There is no impact envisaged due to depot considering it to be already under implementation.

15.4 IDENTIFIED ENVIRONMENTAL IMPACTS

15.4.1 POSITIVE ENVIRONMENTAL IMPACTS

Based on project particulars and existing environmental conditions, positive potential impacts have been identified that are likely to result from the proposed metro project and where feasible within the scope of this report these are quantified. The positive environmental impacts are listed below:

- Employment Opportunities
- Benefits to Economy,
- Traffic Congestion Reduction, Quick Service and Safety,
- Traffic Noise Reduction,
- Reduction of Traffic on Road,
- Less Fuel consumption,
- Reduced air pollution.

Employment Opportunities:

It is assumed that the civil works of the project is likely to be completed in a period of 4 years. During this period manpower will be needed for various project activities. In the construction phase around 365 people in the form of skilled/unskilled and permanent/temporary basis will be employed additionally. In the post-construction phase, about 365 people will be employed for operation and maintenance of the system. In addition to these, more people would be indirectly employed for allied activities.

Benefits of Economy:

The project will streamline and facilitate movement of public between different parts of Pune city. These corridors will yield tangible and non-tangible saving due to equivalent reduction in road traffic and certain socio-economic benefits. Introduction of this metro will result in the reduction in number of buses, usage of private vehicles.

This in turn will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers and road accidents. With the extension of the corridor of Pune Metro, it is likely that more people will be involved in trade, commerce and allied services.

Direct Benefits to Passengers:

The project will result in direct benefits to users of Metro and other modes: reduction in vehicle operating costs, savings in travel time, improvement in quality of life, reduction in loss of productivity due to health disorders resulting from pollution and reduction in road accidents

Traffic Noise Reduction:

Reduction in traffic volume of 10% & 50% reduces noise at the tune of 0.5 dB & 3.0 dB respectively. An introduction of Metro Rail substantially reduces the vehicular traffic which ultimately reduces noise level.

Reduction of Traffic on Road:

On implementation of the project, the consumption of petrol, diesel CNG and LPG will get reduced. The estimated numbers of vehicles kilometres that will be reduced due to construction corridors of Pune Metro Phase 1 extensions are given in Table 15-25.

TABLE 15-25: REDUCTION IN DAILY VEHICLE KM (IN LAKHS)

Sr. No.	Mode	Daily Vehicle Km Reduced due to Pune Metro Phase 1 extensions in Horizon years			
		2027	2037	2047	2057
1.	TW	1.132	2.656	4.231	5.131
2.	Car	0.707	1.659	1.501	1.428
3.	Auto	0.578	1.356	2.377	2.584
4.	Bus	0.078	0.183	0.301	0.316
	Total	**2.495**	**5.853**	**8.411**	**9.459**

Less Fuel Consumption:

Based on reduction of vehicle kilometres, reduction in fuel (diesel, petrol & LPG) consumption is reported in Table 15-25. It is estimated that about 0.14 lakh litre will be saved daily in year 2027 and 0.50 lakh litre in 2057 as presented in Table 15-26.

TABLE 15-26: DAILY REDUCTION IN FUEL CONSUMPTION (DAILY LTS IN LAKHS)

Fuel	2027	2037	2047	2057
Petrol	0.071	0.167	0.233	0.264
Diesel	0.061	0.144	0.195	0.2
Gas (Kg)	0.009	0.022	0.034	0.036
Total	**0.141**	**0.333**	**0.462**	**0.5**

The saving of Diesel, Petrol and LPG will directly benefit the country in monetary terms. Net saving on fuel expenditure at current price level (June 2022) is summarised in Table 15-27.

TABLE 15-27: DAILY NET SAVINGS ON FUEL EXPENDITURE (IN RS. MILLION)

Fuel	2027	2037	2047	2057
Petrol	₹ 0.79	₹ 1.86	₹ 2.59	₹ 2.92
Diesel	₹ 0.68	₹ 1.59	₹ 2.16	₹ 2.22
Gas (Kg)	₹ 0.10	₹ 0.25	₹ 0.37	₹ 0.40
Total	**₹ 1.57**	**₹ 3.70**	**₹ 5.12**	**₹ 5.54**

Reduced Air Pollution:

Ambient emissions from operation of metro rail are limited to those from backup DG equipment. System-level generation of CO_2 from generation of grid electricity which powers Metro are not included in the ambient emissions. The major vehicular pollutants that define the ambient air quality are: Particulate matter, Nitrogen oxides, Carbon monoxide, Hydro Carbons, Carbon dioxide and Sulphur dioxide. In addition to the above pollution, un-burnt products like aldehydes, formaldehydes, acetaldehyde and smoke are by products of vehicular emissions.

TABLE 15-28: POLLUTION REDUCTION (IN TONS/YEAR)

Pollutants	2027	2037	2047	2057
CO	427.25	1002.56	1495.54	1667.41
HC	134.42	315.43	501.81	579.48
NOX	100.20	235.13	370.35	408.25
PM	13.56	31.83	50.41	56.76
CO2	23729.79	55680.38	75295.51	79582.25
Total	24405.23	57265.34	77713.62	82294.14
Annual Treatment Cost (Rs in Crores)	**2.90**	**6.80**	**10.20**	**11.35**

15.4.2 NEGATIVE ENVIRONMENTAL IMPACTS

Based on project particulars and existing environmental conditions potential negative impacts likely to result from the proposed development are quantified. Negative impacts are listed under the following headings:

- Impacts due to project location;
- Impacts due to project design and construction;
- Impacts due to project operation

Impacts Due to Project Location:

Impacts which are likely to take place due to the location of the project, have been assessed and summarised as follows:

- **Project Affected People (PAPs):** In a project of this magnitude, some people are bound to be displaced or lose their livelihood due to the acquisition of land however the proposed alignment is primarily in the median with and station entries being proposed in the RoW, there are people are bound to be displaced or lose their livelihood due to the acquisition of land.
- **Change of Land Use:** Land will be required permanently for stations and running sections. Both government and private land will be acquired for the project. The details are given in the following sections. Since most of the alignment will be constructed on medians of existing roads, and along its sides, no major change in land use is envisaged.
- **Loss of Trees:** The proposed corridors do not pass through any forests. However, there are approximately 96 trees in total along both the extension corridors (27 along Line 2A and 69 Along Line 2B), which are likely to be affected during construction of the project. Trees are major assets in purification of urban air, which by utilizing CO2 from atmosphere, release oxygen into the air. However, with removal of these trees, the process for CO2 sequestration will get effected, as follows:
    - Total number of Trees: 96
    - Decrease in Carbon-dioxide absorption due to loss of trees: 1920 kg/year
    - Decrease in Oxygen production due to tree loss: 10560 kg/year
- **Utility/Drainage Problems:** The proposed metro corridors are planned to run through the urban area above the ground i.e. elevated. The alignment will cross drains, large number of sub-surface, surface and utility services, viz. sewer, water mains, storm water drains, telephone cables, overhead electrical transmission lines, electric pipes, traffic signals etc. These utilities / services are essential and have to be maintained in working order during different stages of construction by creating temporary / permanent diversions or by supporting in position. Plans and cost of such diversions are covered in the Chapter on Civil Engineering.

- **Impact on Historical & Cultural Monuments:** No Archaeological Monuments or sites are located along the proposed extension of metro corridors.
- **Impact on Local Transport Facilities:** The metro system has been proposed to cater the additional demand of present and future traffic requirement. The drivers of local transport facilities like buses, taxis, autos and rickshaws may be utilized to cater the requirement of transport from metro stations to work place and vice-versa. Additional employment opportunities are also anticipated due to the proposed metro.

Impacts Due to Project Design:

Impacts due to project design are seen in following ways:

- **Right of way:** Visually less-intrusive viaducts and stations can be constructed subject to construction cost on account of specialized formwork and high strength materials. In case of elevated metro energy consumption is lower while noise, during operation phase, is higher in comparison to underground metro.
- **Alignment and architectural design**: An alignment with less number of curves and radius - which is desirable rather than minimum, optimal station spacing, track with elastic fittings result in decrease in energy consumption, wear & tear and noise & vibration. Elevated metro with sleek structural elements provides aesthetically appealing structures. The spatial design of station has significant impact on safely of passengers, time spent in ingress & egress from station and energy consumption in stations.
- **Inter-modal integration:** Physical and operational integration of metro with other modes especially walk, public transport and intermediate public transport (hired modes) is found to increase ridership and decrease congestion inside and outside the stations.
- **Uses of Energy and Water at stations:** Consumption of energy for climate control, lighting and other facilities at stations is significantly reduced by proper design of passenger flow inside stations, space & facilities inside stations.
- **Risk Due to Natural Hazards:** Engineering construction shall be done so as to meet codal provisions. No other natural hazards such as due to climate change are foreseen.

Impacts During Construction Phase

Although environmental hazards related to construction works are mostly temporary in nature, it does not mean that these should not be considered. Appropriate measures should be included in the work plan and budgeted for. The most likely negative impacts related to the construction works are:

- **Soil erosion and Land subsidence:** Run off from unprotected excavated areas can result in excessive soil erosion, especially when the erodibility of soil is high.

Land subsidence is anticipated at stations which will be constructed by cut and cover method. Suitable measures including maintaining adequate distance of the trench from existing structures adjacent the trench, measures to support the walls of the trench as well strengthen soil underneath adjacent structures will be required.

- **Traffic diversion:** During construction period, complete / partial traffic diversions on road will be required, as most of the construction activities are on the road.
- **Dust Generation & Air Pollution:** Air pollution occurs due to excavation, loading and unloading of construction materials, and emissions from vehicles, construction equipment and DG sets etc. It also occurs in sites of muck disposal, debris disposal and pre-casting yards. Air pollution from road based vehicles especially particulates are found to cause diseases of brain, heart, lungs and kidneys. Dust suppression measures have to be put in place during entire Construction phase.
- **Increased water demand:** Water consumption during construction is around 722 (m^3/day).
- **Impact due to labour camp:** Sewage and municipal solid waste generated from labour camp need to be treated before disposal. The labour camp of Pune MRTS Phase-I will be used for the extension corridors.
- **Welfare & Safety of Labour on construction site:** Facilities such as shelter at workplace, canteen, first aid and day crèche are statutory requirement and essential to productivity. Safety of labour during construction is a statutory requirement and also has impact on progress of work.
- **Impact due to supply of construction material:** Construction material such as aggregate and earth are sourced from approved quarries such that environmental impacts as well as wastage of natural resources are minimized and mitigated.
- **Impact due to construction/demolition waste (Muck) Disposal:** Debris disposal can result in air and water pollution, noise, diversion of green parks and temporary displacement.
- **Impact due to Hazardous Waste:** Hazardous waste would mainly arise from the maintenance of equipment which may include used engine oils, hydraulic fluids, waste fuel, spent mineral oil/cleaning fluids from mechanical machinery, scrap batteries or spent acid/alkali, spent solvents etc. Unsafe disposal can result in water and soil pollution, diversion of green parks and temporary displacement.
- **Impact due to Pre-casting yards and Material stockpiling**: Sites for casting of structural concrete elements and material stockpiling can result in air and water pollution, noise, diversion of open areas like green parks and temporary displacement.
- **Loss of Archaeological Monuments/sites:** No Archaeological Monuments/sites will be lost as a result of the corridors.
- **Impact on ground water and surface water quality:** Ground water contamination can take place if sewage from labour camp or chemical substances from construction site or dumped muck or construction/demolition waste or used water from the RMC plant get leached by precipitation of water and percolate to the

ground water table. During Construction phase no major impact on flow of water, surface water and ground water quality is anticipated due to this project. Contamination of surface water bodies may result due to spillage of construction material, however, the quantity of such spills will be negligible.

- **Noise pollution:** Noise is a contributing factor to degradation of human health. The major sources of noise pollution during construction are movement of vehicles for transportation of material and equipment. Permitted number of impacts (example piling) at various noise levels is prescribed under Model Rules of the Factories Act, 1948. Actual noise from construction equipment (Lmax) measured at 50 feet distance typically ranges from 76 dB(A) to 84 dB(A); vibratory pile driver at 101 dB(A).
  CPCB standards specified for limited construction equipment reflect that noise emission specifications for such equipment should not exceed 75 dB (A). With respect to occupational exposure, the permissible threshold is 90 dB (A) (continuous exposure over 8 hours). Considering typical noise from a range of construction equipment, sensitive receptors (i.e. labour colonies) should be located beyond 125 m from the noise generating source location during construction activities.
- **Vibration and risk to existing buildings:** If significant impacts due to vibration are expected, mitigation measures have to be implemented and building condition survey have to be conducted before, during and after construction. Damage to structures is a possibility in case of pile driving or trains passing within 7.5 m from normal buildings or unreinforced structures or between 15m to 30 m from historical buildings or buildings in poor condition; heavy truck traffic within 30 m, major construction within 60 m, freight trains within 90 m or pile diving within 180 m can cause disruption of operation of sensitive instrumentation.
  Threshold criteria are listed in Table 15-29. These criteria for monuments are more stringent than those prescribed in UK, Germany, Switzerland and Japan.

TABLE 15-29: GUIDELINE VIBRATION DAMAGE THRESHOLD CRITERIA[8]

Structure and Condition	Maximum PPV (in/sec)	
	Transient Sources	Continuous / Frequent Intermittent Sources
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5
Note: Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous / frequent intermittent sources include impact pile drivers, pogo-stick		

8 Source: Transportation and Construction Vibration Guidance Manual, Caltrans, September 2013

Structure and Condition	Maximum PPV (in/sec)	
	Transient Sources	Continuous / Frequent Intermittent Sources
compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.		

Vibration source levels for typical construction equipment are listed in Table 15-30. In case of construction of underground stations or tunnelling by NATM in hard rock which require controlled blasting, vibration in structures will be observed. As per Transportation and Construction Vibration Guidance Manual (Sept 2003) by Caltrans, using cast-in-place or auger cast piles eliminates impact driving and limits vibration generation to the small amount generated by drilling, which is negligible.

TABLE 15-30: VIBRATION SOURCE LEVELS FOR CONSTRUCTION EQUIPMENT[9]

Equipment		PPV at 25 ft. (in/sec)	Approximate L_v# at 25 ft.
Pile Driver (impact)	Upper Range	1.518	112
	Typical	0.644	104
Pile Driver (sonic)	Upper Range	0.734	105
	Typical	0.170	93
Calm shove drop (slurry wall)		0.202	94
Hydro-mill (slurry wall)	in soil	0.008	66
	in rock	0.017	75
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	85
Jackhammer		0.0345	79
Small bulldozer		0.003	58
# RMS velocity in decibels (VdB) re 1 µinch/sec			

As per RDSO Guidelines 2015 for vibration studies of metro projects, screening distances for vibration are prescribed in Table 15-31. Accordingly, vibration studies have to be conducted along the corridors to determine the extent of impacts. If significant impacts are expected mitigation measures have to be implemented and building condition survey have to be conducted before and during construction. Cost of such building condition survey can be estimated after vibration study is conducted and structures falling within likely corridor of impacts are identified.

TABLE 15-31: SCREENING DISTANCES (IN METERS) FOR VIBRATION ASSESSMENT[10]

Type of Project	Critical Distance for Land Use Categories Distance from Right-of-Way or Property Line		
	Category 1	Category 2	Category 3
Conventional Commuter Railroad	183	61	37
Rail Rapid Transit	**183**	**61**	**37**

9 Source: Transit Noise & Vibration Impact Assessment, FTA 2006

10 Source: Guidelines for Noise and Vibrations, MRTS, RDSO, Ministry of Railways, September 2015

Light Rail Transit	138	50	30
Intermediate Capacity Transit	61	30	15
Category 1: Buildings where vibration would interfere with interior operations including concert halls and TV studios *Category 2: Residences and buildings where people normally sleep including theatres and auditoriums* *Category 3: Institutional land uses with primarily day time use*			

Impacts During Operation Phase:

Although the project will have many positive environmental impacts, the following negative impacts are also envisaged during operation of the project due to the increase in the number of passengers and trains at the stations:

- **Noise Pollution:** Typical noise level due to rapid rail transit on viaduct at speed 50 mph and distance 50 feet from tracks is 85 dB (A); respective value for at grade is 80 dB (A); and rail transit at stations is 65dB (A). 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. Noise levels at particular distance from the source are predicted and presented in Table 15-32. It is assumed that train average speed is 32 km/hr, and no barrier is present. Due to reduction of vehicular traffic, the road traffic noise is expected to come down.
- **Vibration:** Passing of metro trains on elevated sections causes vibrations. The dominant component due to passing on elevated sections is horizontal.
- **Water supply and sanitation at Stations:** The water demand at stations arises from cleaning and air conditioning of stations and drinking and toilet demands for staff. Water Demand is calculated and presented in Table 15-33.
  Solid waste generation from stations is likely to be around 0.8-1.2 cum/day per station, while sewage generated is estimated to be around 250 m^3/day.
- **Pedestrians and traffic congestion issues:** Commencement of metro services results in passenger rush at stations which in turn results in congestion.
- **Vibration:** Passing of trains on elevated section causes vibrations. The dominant component of vibration due to passing on elevated section is horizontal while in tunnel vertical component is dominant. Impact is more in solid rock.

TABLE 15-32: NOISE LEVELS (LDN) IN DB(A) AT DIFFERENT DISTANCES

Distance (m)	Noise Level (dB)
10	84
20	78
30	74
40	71
50	70
60	68
70	67

Distance (m)	Noise Level (dB)
80	65
90	64
100	64

TABLE 15-33: WATER REQUIREMENT

Sr. No.	Particulars	Water Demand at each station (m^3/day)	Total Water Demand (m^3/day)
1.	At Stations for Drinking Purpose	6.00	78.00
2.	In Elevated stations for AC, cleaning, chiller and other purposes	16.60	215.8
Total			**293.8**

Impacts Due to Depots:

Since existing Vanaz Depot is planned to be used for both the extension corridors, no further impacts due to depots are envisaged for the project.

15.4.3 ENVIRONMENTAL IMPACTS MATRIX

The Impact matrix summarizing environmental parameters impact and nature of impact for the project is presented in Table 15-34.

TABLE 15-34: POTENTIAL ENVIRONMENTAL IMPACT OF PROJECT

Environmental Parameters Impact	Nature of potential impact 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 Resource	✓			✓			✓			✓
Water Quality	✓			✓			✓		✓	
Land Use	✓					✓	✓ (construction)	✓ (Operation)		✓
Ambient Air Quality	✓		✓				✓		✓	
Noise and Vibration	✓		✓				✓			✓
Flora	✓			✓			✓ (construction)	✓ (Operation)	✓	
Fauna	✓			✓			✓ (construction)	✓ (Operation)	✓	
Employment	✓			✓		✓		✓	✓	
Aesthetics	✓		✓ (construction)	✓ (Operation)				✓	✓	

15.4.4 ENVIRONMENTAL ASSESSMENT CHECKLIST

A checklist has been prepared based on the environmental screening to assess the Environmental and Social sensitivity of the project

TABLE 15-35: ENVIRONMENTAL ASSESSMENT CHECKLIST FOR ENVIRONMENTAL & SOCIAL SENSITIVITY OF PROJECT

Screening Question	Yes	No	Remarks
Project Siting **Is project Adjacent to or within any of the following environmentally Sensitive areas?**			
Cultural Heritage Site		✓	No Cultural heritage site within proximity of project
Protected Area		✓	No Forest is in the vicinity of the project. No wild life protected areas close to the alignment
Wetland		✓	No designated wetland
Mangrove		✓	None
Estuarine		✓	Not Applicable
Buffer Zone of Protected Area		✓	None
Special Area for protecting Biodiversity		✓	None
Potential Environmental Impact			
Encroachment on historical/cultural areas, disfiguration of landscape by road embankment, cuts, fills and quarries?		✓	• No encroachment of historical/cultural sites • 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 (eg. Sensitive of protected area)		✓	No protected 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		✓	Adequate sanitary facilities and drainage in the worker's camps will help to avoid

Screening Question	Yes	No	Remarks
off and sanitary wastes from worker-based camps and chemicals used in construction?			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 chemicals from asphalt processing?	✓		Localised air pollution level is likely to increase for a short duration during the construction period due to construction vehicle movement and 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.
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.	✓		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 Equipment's will be taken to minimize the adverse effects.
Dislocation or involuntary resettlement of people?		✓	As it is an elevated metro corridor following the median of existing RoW, the project-affected persons are expected to be very less At stations areas there will be need for small land acquisition, however relocation is avoided by avoiding permanent structures while planning for station entries.
Other social concerns relating to inconveniences in living conditions in the		✓	Appropriate mitigation measures to curb the air pollution within permissible levels will keep a check on this problem.

Screening Question	Yes	No	Remarks
project areas that may trigger cases of upper respiratory problems and stress?			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?		✓	Suitable traffic management plan will be designed and implemented by the contractor to minimize the construction interference.
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?		✓	Not such condition along the RoW of proposed corridors
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.
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 provide a comfortable travel and provide pollution free alternate mode for commuters
Increased risk of water pollution from oil, grease and fuel spills, and other	✓		This possibility is minimal but cannot be ruled out. Controlled construction activities and proper drainage system will reduce this possibility.

Screening Question	Yes	No	Remarks
materials from vehicles using the road?			
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 chemicals during construction and operation?		✓	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 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 15-36: ENVIRONMENTAL ASSESSMENT CHECKLIST FOR CLIMATE CHANGE & DISASTER RISK OF PROJECT

Screening Question	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.

Screening Question	Yes	No	Remarks
Could changes in temperature, precipitation, or extreme events patterns over the Project lifespan affect technical or financial sustainability (eg. increased erosion or landslides could increase maintenance costs, permafrost melting or increased soil moisture content could affect sub-grade).		✓	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 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.

15.5 ENVIRONMENTAL MANAGEMENT PLAN (EMP)

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 and 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 (pre-construction), 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.

15.5.1 EMP FOR DESIGN & PRE-CONSTRUCTION PHASE

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, and possible transplantation of affected 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 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.

15.5.2 EMP FOR CONSTRUCTION PHASE

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.

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.

15.5.3 EMP FOR OPERATION PHASE

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 carried out.

TABLE 15-37: SUMMARY OF ENVIRONMENTAL MANAGEMENT PLAN (EMP) INCLUDING MITIGATION MEASURES PROPOSED

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
Pre-Construction / Design Phase			
Energy conservation / natural ventilation (Provision for Green Buildings)	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
Energy Conservation measures (use of Renewable Energy) by installation of Solar Power Systems, etc.	Possibility of installing Solar Power System will be checked and same to be installed wherever feasible	Periodic checks on use of renewable energy sources	DPR / Design Consultant, Environmental Management Cell / Unit
Water Conservation including planning for Rain-water Harvesting	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 MPCB and Traffic Police
Environmental Enhancement in the form of Compensatory Afforestation	Development of Green belt as a part of Station building / landscaping: Since 96 trees will be affected due to construction activities, a compensatory plantation (@ 1:3) of 288 trees	Landscaping plan	DPR/ Design Consultant or Design unit of Metro Authority in consultation with Environmental

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
	is proposed. Location for the afforestation will be decided by Project Authority in consultation with the State Forest Department		Management Cell / Unit and State Forest Department
Fire Management	Providing Firefighting facilities as per National Building Code (2004) provisions, Periodic maintenance / checking of the fire & educate the occupants for fighting facilities.	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 aspects 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	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 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 / Civil Engg. 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 Cell / Unit
	Compaction of soil during various construction activities	Construction logs	Contractor / Civil Engg. Unit at the Project site

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
	Ambient Air Quality Monitoring within construction zone to be monitored	The Ambient Air Quality will conform to the standards for SPM, SO2, NOx, and CO	Contractor / Environmental Management Cell / Unit of Metro Authority
Noise Pollution	List of all noise generating machinery on site along with age to be prepared. Equipment to be maintained in good working order	Equipment logs, noise readings to be maintained	Contractor / Environmental Management Cell / Unit 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	Contractor / Environmental Management Cell / Unit of Metro Authority
	Implement good working practices (equipment selection and siting) to minimize noise and also reduce its impacts on human health (ear muffs, safe distances, enclosures, PPE, etc.)	Site working practices records, noise readings	DPR / Design Consultant / Civil Engg. unit of Metro Authority
	No machinery running when not required	Log books / physical supervision	Contractor / Civil Engg. unit at the Project site
	Acoustic mufflers / enclosures to be provided for 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

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
	All equipment to be operated within specified design parameters	Random checks of equipment logs / manuals	Contractor / Civil Engg. 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 a part of landscaping to compensate the loss of trees / vegetation, development of green belt, avoid providing concrete flooring outside the Station buildings to the extent possible	Physical inspection / supervision	Contractor / Civil Engg. unit at the Project site in consultation with Environmental Management Cell/ Unit of Metro Authority
Surface Runoff	Covering the overburden to prevent 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	Disposal of spoils / overburden / earthwork / construction waste generated during construction phase at the pre-designated site by the contractor, reuse of construction waste at the construction site itself. Providing sufficient no. of garbage bins, segregation of biodegradable and non-biodegradable wastes and dispose of them accordingly	Log books of disposal trucks, 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	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	Work Contract	Contractor / Civil Engg. Unit of Metro Authority at the Project site

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
	to be included in the civil / electrical work contract awards		
Environmental Management Cell / Unit	Setting up of Environmental Management Cell / Unit to ensure implementation and monitoring of environmental safeguards	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 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	Air pollution monitoring	Environmental Management Cell/ Unit of 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 75 dB(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

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
Solid Waste Management including Hazardous wastes	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. Classification of waste as Hazardous shall be in accordance with the Hazardous and Other Wastes (Management, Handling & Trans-boundary movement) Rules 2016. The contractor shall file Application for obtaining authorization.	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 ACs 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

Environmental Parameters / Issues	Mitigation measures proposed	Parameters for Monitoring	Responsibility / Implementation
Training and Capacity Building	Training for engineers and managers to be imparted by Project Authority on regular basis to implement the environmental protection clauses of the tender document and to implement the best environmental practices during the Operation Phase	DPR	Environmental Management Cell/ Unit of Metro Authority

15.6 ENVIRONMENTAL MONITORING PLAN (EMOP)

The main purpose of environmental monitoring is to evaluate the effectiveness of implementation of Environmental Management Plan (EMP) by periodically monitoring. The environmental monitoring will be required during construction and operational phases. A comprehensive monitoring programme is suggested here. Environmental attributes to be monitored during construction and operational phase are presented in below Table 15-38.

TABLE 15-38: SUGGESTED ENVIRONMENTAL MONITORING PROGRAM (EMOP)

Environ-mental Compo-nent	Project Stage	Parameters	Special Guidance	Monitoring		Frequency	Duration	Institutional Responsibility	
				Standards	Location			Implementation	Supervision
Air	Construction Stage	PM10, PM2.5, SO2, NOx, CO	High volume sampler to be located 40 m from the earthworks site in 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 2 Locations along Line 2A and 6 locations along Line 2B	Quarterly	Continuous 24 hours / Weekly twice for two non-consecutive day.	Contractor through approved monitoring agency	**Engineer, Metro Authority**

Environ-mental Compo-nent	Project Stage	Parameters	Special Guidance	Monitoring		Frequency	Duration	Institutional Responsibility	
				Standards	Location			Implementation	Supervision
	Operation Stage	PM10, PM2.5, SO2, NOx, CO	High Volume Sampler to be located at 15m from edge of the pavement	The Air (Prevention and Control of Pollution) Rules, CPCB, 1994	At 2 Locations along Line 2A and 4 locations along Line 2B as per requirement.	Quarterly	Continuous 24 hours / for 1 full working day.	Contractor through approved monitoring agency	**Engineer, Metro Authority**
Water Quality	Construction Stage	pH, BOD, COD, TDS, TSS, DO, total coliform, conductivity, Oil & Grease and Lead	Grab sample collected from source and analyzed as per Standard Methods for Examination of Water and Wastewater	Water quality standards by CPCB	At 3 locations each for groundwater and surface water as per requirement.	Quarterly	-	Contractor through approved monitoring agency	**Engineer, Metro Authority**
	Operation Stage	pH, TDS, TSS, DO, Temperature, Lead, Oil & Grease	Grab sample collected from source and analyzed as per Standard Methods for Examination of Water and Wastewater	Water quality standards by CPCB	At 3 locations as per requirement.	Yearly	-	Metro Authority	**Metro Authority**
Noise Levels	Construction Stage	Noise levels on dB (A) scale	Free field at 1 m from the noise-generating equipment whose noise levels are being determined.	Noise standards by CPCB	At Noise generating equipment, as per requirement	Quarterly	Continuous over 24 hours	Contractor through approved monitoring agency	**Engineer, Metro Authority**

Environ-mental Compo-nent	Project Stage	Parameters	Special Guidance	Monitoring		Frequency	Duration	Institutional Responsibility	
				Standards	Location			Implementation	Supervision
	Construction Stage	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 6 Locations	Quarterly	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 6 selected locations	Quarterly	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 4 locations	Quarterly	One time sample	Contractor through approved monitoring agency	**Engineer, Metro Authority**
	Operation Stage	Monitoring of heavy metals	Contamination standards given by EPA	As per IRC code of practice	At Selected **4** locations	**Yearly**	One time sample	Contractor through approved monitoring agency	**Engineer, Metro Authority**

15.7 EMP 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 15-39 for Line 2A and Table 15-40 for Line 2B.

TABLE 15-39: DETAILS OF TENTATIVE EMP COSTING FOR LINE 2A

Environmental Aspect	Frequency of Monitoring	No. of Samples (Locations)	Total Samples	Rates per sample (Rs.)	Total Cost (Rs.)
Construction Phase					
Air Pollution Monitoring	Quarterly	2	16	10,000	**1,60,000**
Noise Pollution Monitoring	Quarterly	2	8	5,000	**40,000**
Ground Water Quality Monitoring	Quarterly	1	4	10,000	**40,000**
Surface Water Quality Monitoring	Quarterly	1	4	10,000	**40,000**
Soil Monitoring	Quarterly	2	8	8,000	**64,000**
Waste Management	Lump sum	-	-	-	**5,00,000**
Water Conservation & Rain Water Harvesting	One time	-	10 (5 nos. of recharge pits at each of the 2 stations)	1,00,000	**10,00,000**
Training & Education to Workers for Environment Conservation & Awareness	One time	-	-	-	**5,00,000**
Dust Suppression & Air & Noise Pollution Control Measure	Daily during Construction	-	-	-	**10,00,000**
Compensatory Plantation of 270 trees in	One time	-	270	1000	**2,70,000**

Environmental Aspect	Frequency of Monitoring	No. of Samples (Locations)	Total Samples	Rates per sample (Rs.)	Total Cost (Rs.)
lieu of 27 affected trees					
Tentative Tree Cutting Cost for 27 no. of trees	One time	-	27	10,000	**2,70,000**
Tentative Tree Transplantation Cost for 27 no. of trees	One time	-	27	20,000	**5,40,000**
Sub Total (A)					**44,24,000**
Operation Phase					
Air Pollution Monitoring	Quarterly	2	8	10,000	**80,000**
Noise Pollution Monitoring	Quarterly	2	8	5,000	**40,000**
Ground Water Quality Monitoring	Yearly	1	1	10,000	**10,000**
Surface Water Quality Monitoring	Yearly	1	1	10,000	**10,000**
Soil Monitoring	Yearly	2	2	8,000	**16,000**
Maintenance Cost for Compensatory Plantation	Yearly	-	81	1,000	**81,000**
Training & Education to Workers for Environment Conservation & Awareness	One time	-	-	-	**5,00,000**
Maintenance cost for Environment Safeguards Implementation	One time	-	-	-	**5,00,000**
Setting up of Environmental Management Cell (EMC) / Unit	One time	-	-	-	**10,00,000**
Sub Total (B)					**22,37,000**
Total EMP Cost (A)+(B)					**66,61,000**

TABLE 15-40: DETAILS OF TENTATIVE EMP COSTING FOR LINE 2B

Environmental Aspect	Frequency of Monitoring	No. of Samples (Locations)	Total Samples	Rates per sample (Rs.)	Total Cost (Rs.)
Construction Phase					
Air Pollution Monitoring	Quarterly	4	32	10,000	**3,20,000**
Noise Pollution Monitoring	Quarterly	4	16	5,000	**80,000**
Ground Water Quality Monitoring	Quarterly	2	8	10,000	**80,000**
Surface Water Quality Monitoring	Quarterly	2	8	10,000	**80,000**
Soil Monitoring	Quarterly	2	8	8,000	**64,000**
Waste Management	Lump sum	-	-	-	**15,00,000**
Water Conservation & Rain Water Harvesting	One time	-	55 (5 nos. of recharge pits at each of the 11 stations)	1,00,000	**55,00,000**
Training & Education to Workers for Environment Conservation & Awareness	One time	-	-	-	**15,00,000**
Dust Suppression & Air & Noise Pollution Control Measure	Daily during Construction	-	-	-	**30,00,000**
Compensatory Plantation of 690 trees in lieu of 69 affected trees	One time	-	690	1000	**6,90,000**
Tentative Tree Cutting Cost for 69 no. of trees	One time	-	69	10,000	**6,90,000**
Tentative Tree Transplantation Cost for 69 no. of trees	One time	-	69	20,000	**13,80,000**
Sub Total (A)					**1,48,84,000**
Operation Phase					
Air Pollution Monitoring	Quarterly	4	16	10,000	**1,60,000**

Environmental Aspect	Frequency of Monitoring	No. of Samples (Locations)	Total Samples	Rates per sample (Rs.)	Total Cost (Rs.)
Noise Pollution Monitoring	Quarterly	4	16	5,000	**80,000**
Ground Water Quality Monitoring	Yearly	2	2	10,000	**20,000**
Surface Water Quality Monitoring	Yearly	2	2	10,000	**20,000**
Soil Monitoring	Yearly	2	2	8,000	**16,000**
Maintenance Cost for Compensatory Plantation	Yearly	-	207	1,000	**2,07,000**
Training & Education to Workers for Environment Conservation & Awareness	One time	-	-	-	**15,00,000**
Maintenance cost for Environment Safeguards Implementation	One time	-	-	-	**15,00,000**
Setting up of Environmental Management Cell (EMC) / Unit	One time	-	-	-	**30,00,000**
Sub Total (B)					**65,03,000**
Total EMP Cost (A)+(B)					**2,13,87,000**

Thus total cost of EMP in construction as well as operation Phases of the project works out to be:

For Line 2A = **Rs. 0.67 Cr.**
For Line 2B = **Rs. 2.14 Cr.**
Total EMP budget for both Line 2A and Line 2B= Rs. 2.81 Cr.

15.8 SOCIAL IMPACT ASSESSMENT (SIA)

Development of the proposed two metro rail extension corridors involves acquisition of land for stations, running sections, TSS, Depot and for other facilities. Acquisition of this private land may cause social disruption and economic loss for the families/people who are likely to be affected.

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 minimise any negative impacts. The details of land

acquisition, number of affected structures and expected families likely to be affected and preliminary Resettlement Action Plan (RAP) is presented in this section.

15.8.1 OBJECTIVES OF SIA AND RAP

The objective of Social Impact Assessment is to:

- Identify Project Affected Families (PAFs) by type and extent of loss
- Identify the possible adverse impacts of the project on the people and the area
- Suggest culturally and economically appropriate measures for mitigation of adverse impacts of the project
- Recommend institutional mechanism for implementation of RAP
- Recommend grievance redress mechanism
- Identify time frame for implementation of RAP
- Estimate budget for RAP and
- Recommend mechanism for Monitoring & Evaluation (M&E) of implementation of RAP.

15.8.2 APPROACH AND METHODOLOGY

The SIA which includes RAP shall be prepared in accordance with the State and national policy and guidelines. The input tasks are desk research, site visits and information dissemination, enumeration of affected structures and families, sample socio-economic survey and local public consultation.

Potential Social Impacts:

The proposed metro rail will have number of positive impacts like (i) Employment opportunities (ii) timely and safe travel (iii) reduced traffic congestion on road, and (iv) savings in fossil fuel (reduction in air pollution). The anticipated negative impacts are (i) loss of land (ii) loss of homes, commercial and community structures and (iii) loss of livelihood.

15.8.3 LAND REQUIREMENT FOR ACQUISITION

The project shall require the acquisition / transfer of 106.26 sqm of land in Line 2A and 5711.34 Sqm for Line 2B (including stations, running section, RSS+TSS). About, 25115.98 sqm. of land is to be acquired on temporary basis for construction activities of Line 2A and 26081.27 Sqm for Line 2B. No land is required in the running section. The details of land requirement and acquisition are presented in below tables.

TABLE 15-41: DETAILS OF PERMANENT ACQUISITION SQ MTS FOR LINE 2A

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	Private	Total	PMC	GoM (Govt)	Private	Total
1	Running Section								
2	Stations			106.26	106.26	0.00	0.00	2.18	2.18
3	Depot								
4	RSS/TSS								
Total		**0.00**	**0.00**	**106.26**	**106.26**	**0.00**	**0.00**	**2.18**	**2.18**

TABLE 15-42: DETAILS OF PERMANENT ACQUISITION SQ MTS FOR LINE 2B

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Running Section				0.00				0.00
2	Stations	190.35	0.00	520.99	711.34	0.19	0.00	8.54	8.73
3	Depot				0.00				0.00
4	RSS/TSS		5000.00		5000.00		5.27		5.27
Total		**190.35**	**5000.00**	**520.99**	**5711.34**	**0.19**	**5.27**	**8.54**	**14.00**

TABLE 15-43: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2A

S. No	Description	Area (Sqm)				Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	Private	Total	PMC	GoM (Govt)	Private	Total
1	Stations	0.00	0.00	115.98	115.980	0.000	0.000	0.10	0.10
2	Casting Yard		25000.00		25000.00		2.64		2.64
Total		**0.00**	**25000.00**	**115.98**	**25115.98**	**0.00**	**2.64**	**0.10**	**2.74**

TABLE 15-44: SUMMARY OF TEMPORARY LAND REQUIREMENT FOR CONSTRUCTION ACTIVITIES FOR LINE 2B

S. No	Description	Land Requirement (Sqm)				LA Cost (Rs. in Cr.)			
		PMC	GoM (Govt)	PVT	Total	PMC	GoM (Govt)	PVT	Total
1	Stations	132.43	0.00	948.84	1081.27	0.02	0.00	0.57	0.59
2	Casting Yard		25000.00		25000.00		2.64		2.64
		132.43	**25000.00**	**948.84**	**26081.27**	**0.02**	**2.64**	**0.57**	**3.23**

15.8.4 INVENTORY OF AFFECTED STRUCTURES

The alignment is planned along the median of existing road whereas station entries are planned within the ROW, thus very less number of structures are affected. The affected structure includes the compound walls (partially affected) and BRTS of 4.5km (fully affected) The number of affected structures as identified from the alignment drawings are summarised below in Table 15-45. The details of the same are enclosed in the Annexure 15.1.

TABLE 15-45: AFFECTED STRUCTURES

Corridor	No. of Structures affected	
	Boundary Wall (m)	BRTS (m)
Vanaz to Chandani Chowk	37	-
Ramadi to Vitthalwadi	337	4500
Total	**374**	**4500**

15.8.5 RELIGIOUS STRUCTURES AFFECTED

There are no religious structures affected due to both the alignment.

15.8.6 PUBLIC CONSULTATIONS

Preliminary public consultations and discussions have been undertaken during April-May 2022, through community meetings with the Project Affected Persons (PAPs) as well as general public discussions at identified station locations in Pune. The consultation process involved various sections of affected persons such as traders, residential kiosks, students, auto-drivers and other inhabitants. The objectives of organizing public consultation are as follows:

- Disseminate information to the people about the project in terms of its activities and scope of work; and understand the views and perceptions of the people affected and local communities with reference to acquisition of land or loss of property and its due compensation.
- Understand views of affected people on land acquisition and resettlement options and generate idea regarding the expected demand of the affected people;
- Identify and assess major economic and social information and characteristics of the project area to enable effective social and resettlement planning and its implementation.
- Resolve issues related to impacts on community property and their relocation. Establish an understanding for identification of overall developmental goals and benefits of the project.

During the Public Consultations, participants were briefed about the objectives of the meeting regarding various social issues related to the project i.e., land acquisition, compensation, loss of livelihood, cost of travelling, employment and development of the city, etc. Participants were invited to give their valuable suggestions on these issues and their suggestions shall be incorporated, within the technical limitations and scope of the project. Some photographs taken during public consultations and socioeconomic surveys conducted in the Project study area during April - May 2022 are shown as Figure 15-22.

Photographs of Public Consultations and Socio-economic Surveys carried out in the Project Study Area

FIGURE 15-22: PHOTOGRAPHS OF PUBLIC CONSULTATIONS IN PROJECT STUDY AREA

15.8.7 SOCIO-ECONOMIC PROFILE OF PROJECT INFLUENCE AREA

Pune is one of the largest cities in Maharashtra. Pune district is located in the western part of the state of Maharashtra, bounded by district Thane to the northwest, Raigad to the west, Satara district to the south, Solapur district to the southeast and Ahmednagar district to the north and northeast. The district is situated in the Western Ghats or Sahayadri mountain range and it extends on to the Deccan Plateau on the west.

Baseline data regarding the socio-economic profile with reference to demographic structure, infrastructure resource base, health status and economic resource base is collected using secondary sources Census data for the year 2011 within 10 km radius around project site.

Socio-Demographic profile of Pune district is summarised in Table 15-46.

TABLE 15-46: SOCIO-DEMOGRAPHICS OF PUNE DISTRICT

Indicators	Pune
Area Sq. Km	15,643
Actual Population	9,429,408
Male	4,924,105
Female	4,505,303
Total Child Population (0-6 Age)	1,104,959
Population Growth (%)	30.37
Density/km^2	603
Sex Ratio (Per 1000)	915
Child Sex Ratio (0-6 Age)	883
Average Literacy	86.15
Male Literacy	90.34
Female Literacy	81.05
Child proportion (0-6 Age) (%)	11.72

15.8.6.1. APPLICABLE LAWS/GUIDELINES FOR LAND ACQUISITION, R&R

15.8.7.1 APPLICABLE LAWS/GUIDELINES FOR LAND ACQUISITION, R&R

As per the observation received from Maha Metro, following guidelines and circulars of Government of Maharashtra are applicable for land acquisition, rehabilitation and resettlement compensation.

- The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (No. 30 of 2013)
- Government Circular No. Misc.-03/2015/C.N34/A-2 dated 12th May 2015, 30th September, 2015 and LQN-01/2017/CN 12/A-2 dated 25th January, 2017, Revenue Forest Department, Government of Maharashtra, in the context of acquiring land of private sector by method of direct purchase through private negotiation for irrigation and other projects. Direct purchase method ensures that the property owners are negotiated directly for purchase of land by giving them an amount amicably accepted by the affected person which is 250% of the market value. In the process the concerned person is getting better price for the involved land and structure. This has been adopted for this DPR.
- Order of CBDT, Ministry of Finance, Govt. Of India dated 25/10/2016
- Asian Development Bank's Safeguard Policy Statement (SPS), 2009

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 sqm. 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 are 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.

Order of CBDT, Ministry of Finance, Govt. Of India dated 25/10/2016

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.

15.8.8 INSTITUTIONAL ARRANGEMENT

15.8.7.1. EXECUTING AGENCY (EA)

Maharashtra Metro Rail Corporation Limited (Maha Metro) was incorporated by Government of India- Ministry of Corporate affairs on 18th February 2015 as a Special Purpose Vehicle (SPV) for smooth implementation and operations of the Pune Metro Rail Project. It has now been converted into a Joint Venture of Government of India (GoI) and Government of Maharashtra (GoM) with equal equity holding.

The GoM and GoI will be the executing agency of the proposed corridors of metro project. The GoM will be responsible for overall execution of the RAP. An independent Monitoring and Evaluation (M&E) Agency/Specialist will be hired by GoM to monitor the implementation of the various provisions and activities planned in the RAP. The independent M&E Agency/Specialist will review the plan implementation in lights of targets, budget and duration that has been laid down in the plan.

15.8.7.2. IMPLEMENTING AGENCY (IA)

Maha Metro shall be responsible for implementation of the proposed corridors of metro rail project. The Managing Director (MD) will be the in charge of the overall project activities and will facilitate land acquisition, capacity building and implementation of RAP. Maha Metro will be responsible for coordinating with other concerned government departments, NGO, and R&R Supervision Consultant for land acquisition, planning and implementation of RAP which will include the disbursement of compensation, assistance, shifting and relocation of affected people. Maha Metro will be entrusted to the GoM (i.e. the EA) for the implementation of the RAP.

15.8.7.3. PROJECT IMPLEMENTATION UNIT (PIU)

The PIU headed by the Project Director (PD) is responsible for the overall execution of the project and planning and implementation of resettlement and rehabilitation component during preparation, implementation and post implementation phase of the project. The PIU will coordinate with all implementing agencies and monitoring the progress of the project.

15.8.7.4. SOCIAL MANAGEMENT UNIT (SMU)

Maha Metro shall set up a Social Management Unit (SMU) which shall look after land acquisition, resettlement and rehabilitation activities. A Sr. Social Development Officer (SSDO) will be appointed on full time by Maha Metro. The SMU shall ensure that all land acquisition issues are handled according to the Land Acquisition and Rehabilitation &

Resettlement Act. It will also monitor that all the procedural and legal issues involved in land acquisition are fulfilled. The SMU will assist in getting all the necessary clearances and implementation of the resettlement activities prior to start of any civil work.

A Resettlement and Rehabilitation Officer (RRO) may be appointed in this SMU to supervise and monitor overall activities of RAP and he/she will report day to day progress to SSDO. RRO will also work closely with the District Collector to expedite the payment of compensation for land acquisition and assistance to APs. The RRO will form Local Resettlement Committees (LRC) in each project affected areas consisting of local representatives and other stakeholders. Specific functions of the SMU in regards to resettlement management will include the following:

- Overall responsibility of planning, implementation and monitoring of land acquisition, resettlement and rehabilitation activities in the project;
- Ensure availability of budget for R&R activities;
- Liaison lined agencies support for land acquisition and implementation of land acquisition and resettlement;
- Coordinating with line departments

15.8.7.5. ROLE OF NON-GOVERNMENT ORGANIZATION (NGO)

An NGO will be appointed by Maha Metro to extend implementation support to Maha Metro in the form of assisting affected families/persons during relocation and preparation of Income Restoration Plan (IRP). The NGO will help educating PAPs on proper utilization of compensation and rehabilitation grant and help them in getting financial assistance. The NGO will be supervised by SSDO, SMU.

15.8.7.6. IMPLEMENTATION SUPPORT CONSULTANT(R&R)

During implementation phase of RAP, Maha Metro will appoint a consultant (R&R) through General Engineering Consultancy (GEC) to assist Maha Metro in implementation of resettlement plan. The consultant will carry out due diligence in the implementation of resettlement and rehabilitation programmes through periodic monitoring. The consultant will be responsible for (i) preparation of database of affected structures, families, persons, (ii) verification of database through field survey, (iii) improve monitoring system, (iv) capacity building of implementation staffs, (v) regular follow up implementation activities and other relevant activities.

15.8.7.7. GRIEVANCE REDRESSAL COMMITTEE (GRC)

Efficient grievance redressal mechanism will be developed to assist the PAPs resolve their queries and complaints. Grievances of PAPs will be first brought to the attention of field level staff of Maha Metro. Grievances not redressed by the staffs (field level) will be brought to the Grievance Redressal Committee (GRC). The proposed GRC will have representatives from PAPs, women, NGO and local body; Project Director (PIU), SSDO, SMU of Maha Metro and Land Acquisition Officer (LAO). The main responsibilities of the GRC are to: (i) provide support to PAPs on problems arising from land/property

acquisition; (ii) record PAPs grievances, categorize, and prioritize grievances and resolve them; (iii) immediately inform the SMU of serious cases; and (iv) report to PAPs on developments regarding their grievances and decisions of the GRC. Other than disputes relating to ownership rights under the court of law, GRC will review grievances involving all resettlement benefits, compensation, relocation, replacement cost and other assistance.

15.8.7.8. TRAINING AND CAPACITY BUILDING

Establishing sufficient implementation capacity to launch and carry out those components of project resettlement that must be completed before civil works. Exposure visits and training through specialists in the field will be arranged for SMU staff.

15.8.7.9. IMPLEMENTATION SCHEDULE OF RESETTLEMENT ACTION PLAN

The implementation of RAP will consist of four major stages:

1. Identification of Cut-off Date (CoD) and notification for land acquisition as per Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (thereafter land will be purchased). For non-titleholders the cut-off date for each corridor shall be from the start of Census Survey.
2. Verification of properties of PAFs/PAPs and estimation of their type and level of losses.
3. Preparation of list of PAFs/PAPs for relocation/rehabilitation.
4. Relocation and rehabilitation of the PAPs.

Timing of Resettlement:

The resettlement process must be completed before the start of civil works on the particular corridor. Requisite procedure will be developed by the Maha Metro to carry out resettlement of PAPs located within Corridor of Impact (CoI), before the civil work starts on any section of the project. All activities related to the land acquisition and resettlement shall be planned to ensure that 100% compensation is paid prior to displacement and the affected people will be given at least four months of notice to vacate their property before civil work begins. Stretches which are free of encroachment and other encumbrances will be handed over first to the contractor.

15.8.7.10. IMPLEMENTATION SCHEDULE

The period for implementation of RAP has been taken as two and half years. However, monitoring and evaluation will continue beyond the period of implementation. The R&R activities of proposed project are in three phases: project preparation, RAP implementation and Monitoring and Evaluation (M&E).

- **Project Preparatory Stage (Pre-Implementation Stage):** Setting up relevant institutions for the resettlement activities will be the major task during the preparatory stage which is pre implementation phase. The major activities to be performed in this

period include establishment of SMU and additionally, the GRC needs to be appointed at this stage.

- **RAP Implementation Stage:** The RAP, at this stage, needs to be approved and will be disclosed to the PAPs. Upon the approval of RAP, all the arrangements for fixing the compensation and the disbursement needs to be done which includes payment of all eligible assistance; relocation of PAPs; initiation of economic rehabilitation measures; site preparation for delivering the site to contractors for construction and finally commencement of the civil work. Internal monitoring will be the responsibility of Maha Metro which will start in early stage of the project when implementation of RAP starts and will continue till the completion of the implementation of RAP. Maha Metro will be responsible for carrying out the monitoring on half yearly basis.
- **RAP Implementation Schedule:** RAP implementation schedule for R&R activities in the proposed project including various sub tasks and time line matching with civil work schedule will be finalised after finalisation of station locations and subsequent socio-economic survey of project affected areas.

15.8.7.11. R&R COST ESTIMATE

The compensation cost for land is calculated @ 250% of the circle rate. This will include cost of land, value of assets attached to the land, one-time resettlement and rehabilitation cost i.e. transportation, compensation for livelihood, subsistence allowance, etc. Allowances and benefits applicable under RFCTLARR Act 2013 have been used to estimate R&R cost. Land acquisition proposed for the alignment is predominantly for station entry structures. The land requirement and cost associated with Land Acquisition is presented in statement which forms part of civil engineering chapter in DPR.

The alignment and station entries are planned such that minimum land acquisition is required and no civil structures/buildings are hampered. The BRTS alignment on Nagar road however will be affected. About 4.5km of BRTS corridor will have to be dismantled and restored. Additionally, 374m of compound walls will be affected at the station entry structures. The list of affected structures is presented in para 15.8.4 above and details are enclosed in the Annexure 15.1. The Cost of the dismantling and restoration has been considered in the R&R cost.

TABLE 15-47: LAND AND R&R COST

S. No	Particulars	Cost (Rs. in Cr.)	Remark
1	Cost of Land	22.15	Section 15. 8.3
2	Cost for Dismantling and Restoration of BRTS	57.26	Annexure 15.1
3	Cost of Dismantling and Restoration of Compound Wall	0.38	

ANNEXURE 15

ANNEXURE 15.1- R&R Details

S. No	Chandani Chowk to Vanaz								
	Chaninage	**Location**	**Type**	**Unit**	**Quantity**	**Unit Rate**	PMC (in Cr)	GoM (In Cr)	**Total Cost (Cr)**
1	-1705-1740	Lohia IT park	Compund Wall	m	37.03	10000		0.037	0.037
Total for Chandani Chowk to Vanaz								0.037	0.037
S. No	**Ramwadi to Wagholi/Vitthalwadi**								
	Chaninage	**Location**	**Type**	**Unit**	**Quantity**	**Unit Rate**	PMC (in Cr)	GoM (In Cr)	**Total Cost (Cr)**
1	17674-17707	Kharadi Bypass Entry 3	Compund Wall	m	33	10000		0.033	0.033
2	18882-18900	Tulja Bavani Entry 1	Compund Wall	m	8	10000		0.008	0.008
3	19832-19844	Ubale Nagar Entry 2	Compund Wall	m	12	10000		0.012	0.012
4	20982-21035	Uppar Kaharadi Entry 1	Compund Wall	m	53	10000		0.053	0.053
5	22332-22370	Waghwshwar temple Entry 1	Compund Wall	m	38	10000		0.038	0.038
5	23132-23162	Wagholi Entry 4	Compund Wall	m	40	10000		0.040	0.040
6	22082-22104	Siddharth Nagar Entry 1	Compund Wall	m	22	10000		0.022	0.022
7	24932-25005	Bakori Phata Entry 1	Compund Wall	m	73	10000		0.073	0.073
8	24996-25007	Bakori Phata Entry 2	Compund Wall	m	11	10000		0.011	0.011
9	26032-26064	Vitthalwadi Entry 1	Compund Wall	m	34	10000		0.034	0.034
10	26157-26170	Vitthalwadi Entry 2	Compund Wall	m	13	10000		0.013	0.013
11	14864-19364	Nagar Road	BRTS	Km	4.5	127236200	57.256		57.256
Total for Ramwadi Wagholi							57.256	0.337	57.593
Total of DPR 1							**57.256**	**0.374**	**57.630**

Sl. No.	Work Type	Aundh Stretch	OPMH	Sangamwadi	Total	
1	Civil Work	469,306,096	780,894,953	97,002,794	1,347,203,843	86.3%
2	Electrical Work	34,284,134	22,300,730	7,586,243	64,171,107	4.1%
3	Bus Shelter 1	51,842,862	51,842,862	11,520,636	115,206,360	7.4%
	Bus Shelter 2	12,381,620	12,381,620		24,763,240	1.6%
4	Toilet	2,878,628	2,878,628	1,439,314	7,196,570	0.5%
5	Kiosk	795,294	795,294	397,647	1,988,235	0.1%
A	**Total**	**571,488,634**	**871,094,087**	**117,946,634**	**1,560,529,355**	100.0%
B	Length	6.50	5.70	1.25	13.67	
C	Cost Per Km Cost	87921328	152823524	94357307	114183354	
	Cost Per Km (in Crores)	8.79	15.28	9.44	11.42	
		2016 prices	2022 prices			
	Average Cost per km - Civil for BRTS	11.17	14.97	4.5	67.36034137	
			15% to be reused			
	Cost Per Km (in Crores) for Dismantling and Restoration		12.724			

ANNEXURE 15.3- Block Cost for Compound Wall

NAME OF WORK: BLOCK COST ESTIMATE FOR WALL COMPOUND LENGTH-100 M						
Prepared by-						
SR. NO.	**Reffernce**	**ITEM DESCRIPTION**	**UNIT**	**QTY**	**RATE**	**AMOUNT**
1	CPWD DSR 2.6 Page No.92	Earth work in excavation by mechanical means (Hydraulic excavator)/manual means over areas (exceeding 30 cm in depth, 1.5 m in width as well as 10 sqm on plan) including getting out and disposal of excavated earth lead upto 50 m and lift upto 1.5 m, as directed by Engineer-in-charge. 2.6.1 All kinds of soil	CUM	84.38	205.45	17334.84
2	CPWD DSR 2.25 Page No.95	Filling available excavated earth (excluding rock) in trenches, plinth, sides of foundations etc. in layers not exceeding 20cm in depth, consolidating each deposited layer by ramming and watering, lead up to 50 m and lift upto 1.5 m.	CUM	33.75	253.95	8570.81
3	CPWD Page No.82	By Mechanical transport including loading, unloading and stacking upto 5 km distance	CUM	50.63	271.45	13742.16

SR. NO.	Reffere nce	ITEM DESCRIPTION	UNIT	QTY	RATE	AMOUNT
4	CPWD DSR 4.20.2 Page No.113	Providing and laying in position ready mixed plain cement concrete, using fly ash and cement content as per approved design mix and manufactured in fully automatic batching plant and transported to site of work in transit mixer for all leads, having continuous agitated mixer, manufactured as per mix design of specified grade for plain cement concrete work, including pumping of R.M.C. from transit mixer to site of laying and curing, excluding the cost of centering, shuttering and finishing,	CUM	5.63	7102.95	39954.09
5	CPWD DSR 5.1.2 Page No.121	Providing and laying in position specified grade of reinforced cement concrete, excluding the cost of centering, shuttering, finishing and reinforcement - All work up to plinth level : 5.1.2 1:1.5:3 (1 cement : 1.5 coarse sand (zone-III): 3 graded stone aggregate 20 mm nominal size)	CUM	29.93	8364.20	250298.685
6	CPWD DSR 5.9.1 Page No.123	Centering and shuttering including strutting, propping etc. and removal of form for 5.9.1 Foundations, footings, bases of columns, etc. for mass concrete	SQM	171.00	307.95	52659.45
7	CPWD DSR 5.22.6 Page No.127	Steel reinforcement for R.C.C. work including straightening, cutting, bending, placing in position and binding all complete upto plinth level. 5.22.6 Thermo-Mechanically Treated bars of grade Fe-500D or more	Kg	1879.29	89.65	168478.35

SR. NO.	Reffere nce	ITEM DESCRIPTION	UNIT	QTY	RATE	AMOUNT
8	CPWD DSR-2021 6.47	Providing and laying autoclaved aerated cement blocks masonry with 150mm/230mm/300 mm thick AAC blocks in super structure above plinth level up to floor V level with RCC band at sill level and lintel level with approved block laying polymer modified adhesive mortar all complete as per direction of Engineer-in-Charge. (The payment of RCC band and reinforcement shall be made for seperately).	CUM	36.80	6994.15	257384.72
9	CPWD DSR-2021 13.13	12 mm cement plaster 1:2 (1 cement : 2 stone dust).	SQM	325.80	442.75	144247.95
					Sub Total	**952671.06**
					Contingencies 3%	28580.13
					Grand Total	**981251.19**
					Cost per Meter	**9812.511915**

NAME OF WORK: BLOCK COST ESTIMATE FOR WALL COMPOUND

Prepared by-							
SR.NO.	DESCRIPTION	UNIT	NOS	L	B	H	QUANTITY
1	Earth work in excavation by mechanical means (Hydraulic excavator)/manual means over areas (exceeding 30 cm in depth, 1.5 m in width as well as 10 sqm on plan) including getting out and disposal of excavated earth lead upto 50 m and lift upto 1.5 m, as						
	For Footing	CUM	25.00	1.50	1.50	1.50	84.38
	Sub Total						**84.38**
2	Filling available excavated earth (excluding rock) in trenches, plinth, sides of foundations etc. in layers not exceeding 20cm in depth, consolidating each deposited layer by ramming and watering, lead up to 50 m and lift upto 1.5 m.	CUM					
	Total Quantity of excavation	CUM					**84.38**
	Consider 40% for site backfilling	CUM					**33.75**
3	By Mechanical transport including loading, unloading and stacking upto 5 km distance	CUM					**50.63**
4	Providing and laying in position ready mixed plain cement concrete, using fly ash and cement content as per approved design mix and manufactured in fully automatic batching plant and transported to site of work in transit mixer for all leads, having continuous agitated mixer, manufactured as per mix design of specified grade for plain cement concrete work, including pumping of R.M.C. from transit mixer to site of laying and curing, excluding the cost of centering, shuttering and finishing, including cost of curing, admixtures in recommended proportions as per IS : 9103 to accelerate/ retard setting of concrete, improve workability without impairing strength and durability as per direction of the Engineer-in-charge. Note : (1) Excess/less cement used than specified in this item is payable/ recoverable separately. (2) Fly ash conforming to grade I of IS 3812 (Part-1) only be used as part replacement of OPC as per IS : 456. Uniform blending with cement is to be ensured in accordance with clauses 5.2 and 5.2.1 of IS: 456 -2000 in the items of BMC and RMC. Concrete of M10 grade with minimum cement content of 220 kg /cum.						
	For Footing	CUM	25.00	1.50	1.50	0.10	5.63
	Sub Total						**5.63**
5	Providing and laying in position specified grade of reinforced cement concrete, excluding the cost of centering, shuttering, finishing and reinforcement - All work up to plinth level : 5.1.2 1:1.5:3 (1 cement : 1.5 coarse sand (zone-III): 3 graded stone aggregate 20 mm nominal size)						
	Footing	CUM	25.00	1.20	1.20	0.50	18.00
	Column - C1	CUM	25.00	0.30	0.30	2.10	4.73
	Beam	CUM	1.00	80.00	0.30	0.30	7.20
						Sub Total	**29.93**

6	Centering and shuttering including strutting, propping etc. and removal of form for 5.9.1 Foundations, footings, bases of columns, etc. for mass concrete						
	For footing	SQM	100.00	1.20	0.50		60.00
	For Column - C1	SQM	100.00	0.30	2.10		63.00
	Beam	SQM	2.00	80.00	0.30		48.00
	Sub Total						**171.0**
7	Steel reinforcement for R.C.C. work including straightening, cutting, bending, placing in position and binding all complete upto plinth level. 5.22.6 Thermo-Mechanically Treated bars of grade Fe-500D or more						
	Footing & Column	Kg					1879.29
						Sub Total	**1879.29**
8	Providing and laying autoclaved aerated cement blocks masonry with 150mm/230mm/300 mm thick AAC blocks in super structure above plinth level up to floor V level with RCC band at sill level and lintel level with approved block laying polymer modified adhesive mortar all complete as per direction of Engineer-in-Charge. (The payment of RCC band and reinforcement shall be made for seperately).	CUM		80.00	0.23	2.00	**36.80**
9	18 mm cement plaster in two coats under layer 12 mm thick cement plaster 1:5 (1 cement : 5 coarse sand) finished with a top layer 6 mm thick cement plaster 1:6 (1 cement : 6 fine sand).						
	Wall area	SQM	2.00	100.00		2.10	420.00
						Sub Total	**420.00**

Sr.No.	Botanical Name	Family	Common Name	GBH (cm)	Height (m)	Canopy (m)	Age in years (approx)	GPS Location
1	*Mangifera indica* L.	Anacardiaceae	Mango	63	7	4	9	18°30'27.58"N 73°47'50.14"E
2	*Terminalia catappa* L.	Combretaceae	Indian Almond	64	9	6	9	18°30'27.6"N 73°47'50.1"E
3	*Ficus religiosa* L.	Moraceae	Sacred fig tree	150	11	6	27	18°30'27.6"N 73°47'49.9"E
4	*Syzygium cumini (L.)* Skeels	Myrtaceae	Jamun	107	7	4	16	18°30'27.6"N 73°47'49.7"E
5	*Terminalia catappa* L.	Combretaceae	Indian Almond	69	7	4	8	18°30'27.7"N 73°47'49.2"E
6	*Ficus benghalensis* L.	Moraceae	Banyan tree	152	10	7	39	18°30'27.8"N 73°47'48.8"E
7	*Ficus benghalensis* L.	Moraceae	Banyan tree	214	8	8	65	18°30'27.8"N 73°47'48.4"E
8	*Ficus racemosa* L.	Moraceae	Cluster fig	74	6	3	11	18°30'28.0"N 73°47'44.9"E
9	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	149	13	7	16	18°30'28.0"N 73°47'44.8"E
10	*Sterculia foetida* L.	Malvaceae	Wild Indian Almond	62	10	5	9	18°30'28.1"N 73°47'44.8"E
11	*Millingtonia hortensis* L.f.	Bignoniaceae	Indian Cork Tree	40	6	3	7	18°30'28.2"N 73°47'44.7"E
12	*Millingtonia hortensis* L.f.	Bignoniaceae	Indian Cork Tree	69	7	4	10	18°30'28.2"N 73°47'44.5"E
13	*Khaya senegalensis* (Desv.) A.Juss.	Meliaceae	African Mahogany	170	12	9	31	18°30'28.0"N 73°47'44.2"E
14	*Eucalyptus globulus* Labill.	Myrtaceae	Nilgiri	113	9	6	27	18°30'28.2"N 73°47'43.8"E
15	*Terminalia catappa* L.	Combretaceae	Indian Almond	73	8	5	11	18°30'28.8"N 73°47'47.6"E
16	Ficus racemosa L.	Moraceae	Cluster fig	70	7	5	10	18°30'28.8"N 73°47'47.8"E
17	*Cocos nucifera* L.	Arecaceae	Coconut	87	5	2	13	18°30'29.0"N 73°47'47.8"E
18	*Polyalthia longifolia* (Sonn.) Thw. var angustifoli	Annonaceae	Ashok	23	4	0	5	18°30'28.9"N 73°47'47.7"E

19	*Polyalthia longifolia* (Sonn.) Thw. var angustifoli	Annonaceae	Ashok	22	3	0	5	18°30'28.9"N 73°47'47.3"E
20	*Polyalthia longifolia* (Sonn.) Thw. var angustifoli	Annonaceae	Ashok	30	6	1	5	18°30'28.9"N 73°47'47.2"E
21	*Polyalthia longifolia* (Sonn.) Thw. var angustifoli	Annonaceae	Ashok	29	6	1	5	18°30'29.0"N 73°47'47.1"E
22	*Polyalthia longifolia* (Sonn.) Thw. var angustifoli	Annonaceae	Ashok	28	6	1	5	18°30'28.9"N 73°47'46.9"E
23	*Cocos nucifera* L.	Arecaceae	Coconut	109	6	3	14	18°30'29.0"N 73°47'46.6"E
24	*Ficus racemosa* L.	Moraceae	Cluster fig	81	7	5	24	18°30'29.4"N 73°47'23.5"E
25	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	76	8	5	12	18°30'28.0"N 73°47'14.7"E
26	*Ficus religiosa* L.	Moraceae	Sacred fig tree	147	12	7	39	18°30'29.1"N 73°47'22.7"E
27	*Ficus religiosa* L.	Moraceae	Sacred fig tree	213	11	7	41	18°30'29.0"N 73°47'19.5"E
28	*Ficus benghalensis* L.	Moraceae	Banyan tree	389	12	9	52	18°33'38.1"N 73°55'03.5"E
29	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	Sweet tamarind	118	9	6	23	18°33'38.1"N 73°55'03.2"E
30	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	Sweet tamarind	113	8	5	18	18°33'38.0"N 73°55'03.3"E
31	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	Sweet tamarind	85	7	5	14	18°33'38.1"N 73°55'03.5"E
32	*Eucalyptus globulus* Labill.	Myrtaceae	Blue gum tree	149	9	6	29	18°33'47.3"N 73°56'11.0"E
33	*Albizia saman* (Jacq.) Merr.	Leguminosae	Rain tree	169	8	7	37	18°33'47.4"N 73°56'11.3"E
34	*Mangifera indica* L.	Anacardiaceae	Mango	76	6	4	14	18°33'47.2"N 73°56'11.8"E
35	*Ficus racemosa* L.	Moraceae	Cluster fig	77	5	4	16	18°33'47.0"N 73°56'11.7"E
36	*Khaya senegalensis* (Desv.) A.Juss.	Meliaceae	African Mahogany	60	5	4	8	18°33'46.9"N 73°56'12.1"E
37	*Ficus racemosa* L.	Moraceae	Cluster fig	96	4	5	19	18°33'45.9"N 73°56'14.9"E
38	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	Vilayati Chinch	81	5	2	13	18°33'43.3"N 73°56'20.2"E

39	*Delonix regia* (Hook.) Raf.	Leguminosae	Gulmohar	168	10	9	26	18°33'43.1"N 73°56'19.9"E
40	*Pongamia pinnata* (L.) Pierre	Fabaceae	Pongam Tree	11	3	2	4	18°33'43.7"N 73°56'15.7"E
41	*Ficus benghalensis* L.	Moraceae	Banyan tree	13	3	2	5	18°33'43.7"N 73°56'15.5"E
42	*Acacia farnesiana* (L.) Willd.	Leguminosae	Dev babhul	23	3	2	5	18°33'43.8"N 73°56'15.2"E
43	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	38	5	3	6	18°33'44.33"N 73°56'13.90"E
44	*Ziziphus jujuba* Mill.	Rhamnaceae	Indian Jujube	41	5	4	6	18°33'44.38"N 73°56'13.68"E
45	*Ficus religiosa* L.	Moraceae	Sacred fig tree	132	10	8	29	18°33'44.8"N 73°56'12.7"E
46	*Ficus racemosa* L.	Moraceae	Cluster fig	97	7	6	15	18°33'44.9"N 73°56'12.3"E
47	*Ficus religiosa* L.	Moraceae	Sacred fig tree	56	7	4	11	18°33'45.0"N 73°56'12.1"E
48	*Ficus religiosa* L.	Moraceae	Sacred fig tree	50	6	4	10	18°33'45.2"N 73°56'11.6"E
49	*Ficus religiosa* L.	Moraceae	Sacred fig tree	51	6	4	10	18°33'45.5"N 73°56'10.8"E
50	*Ficus benghalensis* L.	Moraceae	Banyan tree	195	10	8	44	18°33'45.8"N 73°56'10.1"E
51	*Syzygium cumini (L.)* Skeels	Myrtaceae	Jamun	47	4	3	8	18°33'43.7"N 73°56'19.7"E
52	*Azadirachta indica* A.Juss.	Meliaceae	Neem	71	5	4	8	18°34'18.8"N 73°57'16.7"E
53	*Plumeria alba L.*	Apocynaceae	White Frangipani	18	3	2	4	18°34'18.9"N 73°57'18.5"E
54	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	103	7	6	12	18°34'34.97"N 73°57'52.05"E
55	*Jacaranda mimosifolia* D.Don	Bignoniaceae	Blue Jacarand	26	5	3	6	18°34'35.12"N 73°57'52.22"E
56	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	57	5	3	7	18°34'35.24"N 73°57'52.77"E
57	*Azadirachta indica* A.Juss.	Meliaceae	Neem	14	3	1	4	18°34'35.38"N 73°57'53.29"E
58	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	16	3	2	4	18°34'35.41"N 73°57'53.44"E

59	*Jacaranda mimosifolia* D.Don	Bignoniaceae	Blue Jacarand	76	7	5	10	18°34'35.65"N 73°57'53.62"E
60	*Azadirachta indica* A.Juss.	Meliaceae	Neem	135	5	4	28	18°34'34.69"N 73°57'54.65"E
61	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	65	7	5	8	18°34'49.69"N 73°58'36.74"E
62	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	38	6	4	6	18°34'49.60"N 73°58'36.58"E
63	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	13	4	1	4	18°34'49.52"N 73°58'36.35"E
64	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	Sweet tamarind	73	6	5	9	18°34'49.22"N 73°58'35.68"E
65	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	79	7	6	10	18°34'49.17"N 73°58'35.57"E
66	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	60	7	5	7	18°34'49.12"N 73°58'35.41"E
67	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	41	6	3	5	18°34'49.06"N 73°58'35.28"E
68	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	28	4	2	6	18°34'48.97"N 73°58'35.02"E
69	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	Scholars Tree	42	6	3	7	18°34'48.85"N 73°58'34.86"E
70	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	Scholars Tree	62	7	3	7	18°34'48.81"N 73°58'34.65"E
71	*Holoptelea integrifolia* Planch.	Ulmaceae	Indian Elm	59	5	4	8	18°34'48.76"N 73°58'34.55"E
72	*Albizia saman* (Jacq.) Merr.	Leguminosae	Rain tree	113	6	6	14	18°34'51.65"N 73°59'3.62"E
73	*Ficus religiosa* L.	Moraceae	Sacred fig tree	15	4	1	3	18°34'52.91"N 73°59'8.33"E
74	*Delonix regia* (Hook.) Raf.	Leguminosae	Gulmohar	23	3	2	5	18°34'50.13"N 73°59'3.20"E
75	*Delonix regia* (Hook.) Raf.	Leguminosae	Gulmohar	35	5	3	5	18°34'50.03"N 73°59'2.82"E
76	*Bauhinia variegata* L.	Leguminosae	Varigated Bauhinia	17	3	1	4	18°34'49.96"N 73°59'2.65"E
77	*Delonix regia* (Hook.) Raf.	Leguminosae	Gulmohar	39	5	4	6	18°34'49.94"N 73°59'2.57"E
78	*Delonix regia* (Hook.) Raf.	Leguminosae	Gulmohar	30	5	3	5	18°34'49.91"N 73°59'2.42"E

79	*Ficus religiosa* L.	Moraceae	Sacred fig tree	17	4	1	3	18°34'49.84"N 73°59'2.29"E
80	*Delonix regia* (Hook.) Raf.	Leguminosae	Gulmohar	23	4	3	4	18°34'49.76"N 73°59'2.00"E
81	*Azadirachta indica* A.Juss.	Meliaceae	Neem	15	3	2	3	18°35'24.70"N 73°59'51.38"E
82	*Tectona grandis* L.f.	Lamiaceae	Teak	79	8	5	16	18°35'25.42" 73°59'53.27"E
83	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	113	8	4	9	18°35'25.24"N 73°59'53.14"E
84	*Tectona grandi* s L.f.	Lamiaceae	Teak	23	4	3	5	18°35'25.09"N 73°59'53.07"E
85	*Azadirachta indica* A.Juss.	Meliaceae	Neem	71	7	5	10	18°35'24.89"N 73°59'53.05"E
86	*Tectona grandis* L.f.	Lamiaceae	Teak	75	7	4	10	18°35'24.78"N 73°59'53.12"E
87	*Tectona grandis* L.f.	Lamiaceae	Teak	43	5	3	7	18°35'24.92"N 73°59'53.18"E
88	*Roystonea regia* (Kunth) O.F.Cook	Arecaceae	Royal Bottle Palm	45	4	3	6	18°35'56.89"N 74° 0'21.85"E
89	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	23	4	2	4	18°35'56.87"N 74° 0'24.03"E
90	*Ficus benghalensis* L.	Moraceae	Banyan tree	47	4	3	8	18°35'56.64"N 74° 0'23.66"E
91	*Azadirachta indica* A.Juss.	Meliaceae	Neem	39	4	2	6	18°35'56.40"N 74° 0'23.42"E
92	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	23	4	2	5	18°35'53.61"N 74° 0'18.80"E
93	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	47	4	3	6	18°35'53.51"N 74° 0'18.56"E
94	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	17	3	2	2	18°35'53.40"N 74° 0'18.39"E
95	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Wild tamarind	19	4	2	2	18°35'53.27"N 74° 0'18.26"E
96	*Caryota urens* L.	Arecaceae	Fishtail Palm	93	6	4	9	18°35'53.24"N 74° 0'18.13"E

CHAPTER 16: DISASTER MANAGEMENT & SECURITY

16.1. INTRODUCTION

A 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 situations that cause acute distress to passengers, employees and outsiders and may even be caused by external factors. It may also destroy infrastructure, buildings, communication channels, essential services, etc.

As per the Disaster Management Act, 2005, a "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, the 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 the World Health Organisation (WHO), it is “any occurrence that causes damage, economic disruption, loss of human life and deterioration of health and services on a scale sufficient to warrant an extraordinary response from outside the affected community or area.”

16.2. THE NEED FOR DISASTER MANAGEMENT MEASURES

The effect of any disaster spread over in the operational area of the Pune Metro is likely to be substantial as the metro system will deal with thousands of passengers daily on 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 the 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 the Metro.

Therefore, there is an urgent need to provide for an efficient disaster management plan.

16.3. OBJECTIVES

The main objectives of the disaster management measures are as follows:

- To save life and alleviate suffering

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

16.4. LIST OF SERIOUS INCIDENTS

The list of serious incidents requiring the use of the provisions of the disaster management measures are given below. Metro-specific disasters can be classified into two broad categories: Natural and Man-Made.

Natural Disasters

- Earthquakes
- Floods
- Cyclone

Man-Made Disasters

- Terrorist attack
- Bomb threat/Bomb blast
- Hostage situation
- Release of chemical or biological gas in trains and/or stations
- Fire in train, metro buildings, elevated infrastructures, power stations, train depots etc.
- Train accident and train collision/derailment of a passenger carrying train
- Sabotage and stampede

16.5. AUTHORITIES TO BE CONTACTED IN CASE OF DISASTERS

The following are the provisions made under the Disaster Management Act.

The National Disaster Management Authority (NDMA)

Establishment of the National Disaster Management Authority:

1. With effect from such date as the Central Government may, by notification in the Official Gazette appoint on 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 NDMA 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 Disaster Management Authority shall consist of the following:
    a. The Prime Minister of India, who shall be the Chairperson, ex officio;
    b. Other members, not exceeding nine, to be nominated by the Chairperson.
3. The Chairperson of the NDMA may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice-Chairperson of the NDMA.
4. The term of office and conditions of service of members of the National Disaster Management Authority shall be such as may be prescribed.

State Disaster Management Authority (SDMA)

Establishment of the 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 SDMA 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 SDMA 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 SDMA may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice-Chairperson of the State Disaster Management Authority.
4. The Chairperson of the State Executive Committee shall be the Chief Executive Officer of the SDMA; 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 SDMA shall be such as may be prescribed.

Command & Control at the National, State and District Levels

The mechanism to deal with natural as well as manmade crises already exists and it has a four-tier structure as stated below:

1. National Crisis Management Committee (NCMC) under the chairmanship of the Cabinet Secretary.
2. Crisis Management Group (CMG) under the chairmanship of the Union Home Secretary.

3. State Level Committee under the chairmanship of the Chief Secretary.
4. District Level Committee under the Chairmanship of the District Magistrate.

All the agencies of the Government at the National, State and District Levels will function in accordance with the guidelines and directions given by these committees.

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:

1. Prepare a disaster management plan setting out the following, namely:
    a. Provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;
    b. Provisions for taking measures relating to capacity-building and preparedness as laid down in the District Plan;
    c. The response plans and procedures, in the event of, any threatening disaster situation or disaster;
2. 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;
3. Regularly review and update the plan
4. Submit a copy of its disaster management plan, and of any amendment thereto, to the District Authority.

16.6. PROVISIONS AT METRO STATIONS/OTHER INSTALLATIONS

To prevent emergency situations and to handle such emergency situations effectively, should it arise, there need to be the following provisions for a system that can detect the threats timely and help suppress/mitigate the same.

i. Fire detection and suppression system
ii. Smoke management
iii. Environmental control system (ECS)
iv. Track-way exhaust system (TES)
v. Station power supply system
vi. DG sets and UPS
vii. Lighting system
viii. Station area lights
ix. Seepage system
x. Water supply and drainage system
xi. Sewage system
xii. Cyber security system
xiii. 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.

16.6.1. MEASURES IN CASE OF FIRE

Fire has been recognized as one of the most dreaded accidents, primarily because of the 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 in case of metros.

For better management and safety from fire disaster in a metro system, various Signage's, 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
- A total ban on carrying inflammable/explosive substance within metro premises and in trains
- Non-accumulation of garbage in the metro station premises and inside trains
- All staff posted at stations must ensure instructions are enforced rigidly through regular checks
- Installation of fire alarms and detection systems

Fire and Smoke

In the event of fire and/or smoke either in trains, station premises, right of way 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 the fire by using portable fire extinguishers, blankets, water, sand, etc. available at site depending on the source of the fire. Standards steps to extinguish to be followed from NBC of India, 2016 & NFPA 130.
- Disconnect the electricity supply, if necessary
- Prevent the fire from spreading and seek the assistance of fire services

Fire in a Train/Metro

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 the passenger area
- The extent of occupation of the train (number of passengers) - If the number is manageable, he will ask passengers in the affected coach to move away to other coaches.
- Proximity of the next station: Passenger evacuation and handling of emergency is much easier at stations than in between stations. The Train Operator (TO) has to exercise his judgment about extreme cases where the train has to be stopped forthwith to save lives by prompt evacuation or taken to the next station expeditiously.

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 the OCC and Station Controller and take assistance from the station staff as required. The power supply to the fire-affected area also has to be cut off during such an emergency.

Fire Suppression System

A wet Fire Main System covers the station areas. 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 the past experience of other metro systems to handle fire incidents.

Fire in 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 and auxiliary electrical substations

In case of fire in areas where passengers enter/leave the station premises, the endeavour of station staff should be to cordon off the area so that it is not approachable for intending Metro users or by Metro passengers leaving the station area.

16.6.2. MEASURES IN CASE OF COLLISION OF TRAINS OR DERAILMENT

Collision of metro trains is a rare occurrence, as the signalling system provides protection from such incidents. Only in case the signalling system is disabled, a train collision is possible, also in case of wrong side failure or poor design/maintenance.

Appropriate O&M procedures should be in place taking into account the past experience of other metro systems to avert a collision scenario and to handle the event of a train collision, if it happens.

Medical Assistance

Provisions for medical assistance and procedures for O&M staff to handle the 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. OCC should maintain a list of hospital/medical centres in the vicinity of all metro stations, to garner medical help in such circumstances.

16.6.3. MEASURES IN CASE OF TERRORIST ACTIONS

The increase in terrorist actions against public transport worldwide indicates that public transport systems are becoming more vulnerable as potential targets for terrorist(s). It is clear that preventing terrorist activities is a primary responsibility of security agencies and the state police.

However, the concern for passenger well-being and security and the adverse effects of such mishaps on the public image of transport systems requires the best possible level of preparedness for guarding against such threats within the metro premises. The key components of such preparatory and preventive action include:

- Encouraging and guiding passengers to be cautious
- An awareness program for appealing to users to be alert and report any suspect package
- Well thought out crisis communication to prevent misinformation, confusion, panic and shock
- Clear procedures and systems of communication need to be established for emergencies and regularly tested to ensure working communication during a crisis situation
- Frequent mock drills to test the 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 attacks may take place anywhere in the metro rail's jurisdiction, however, when they take place on the right of way, particularly at metro stations and in a running train, it may have serious impacts in terms of human distress and the restoration of normal operation. On the receipt of information of any terrorist act in metro trains, stations or on the right of way, the OCC will take prompt action to get the entire metro network cleared of all passengers.

Bomb Blast on Track

There may be derailment of the train causing large-scale damage to the train and fixed structures as well as injury to passengers in the train. In case of derailment, the train should immediately be brought to stop.

Appropriate O&M procedures shall be in place to handle bomb threats or suspicion, and for bomb detection and rescue operation and providing medical assistance, in case a bomb explosion takes place. A coordinated effort with the bomb squad may be required to neutralize further threats and restore normal operation.

Release of Chemical, Poisonous or Biological Gases in Tunnels, Trains or at Stations

While the terrorist activities described above produce a loud noise, explosion, fire and smoke, the release of lethal or harmful gases works silently and can only be inferred generally from:

- An unusual smell
- Passengers or employees complaining of breathing problems, including choking/ fainting, severe eye/skin irritation, vomiting, etc.

16.6.4. 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 neutralize the effects of such attacks. Passenger awareness measures shall be taken to help them in case they are caught in such a scenario, and cooperate with the O&M staff.

Measures in Case of Natural Calamities

The traction power supply shall be switched off in a manner that it does not shut down station supplies unless it is unsafe for occupants/passengers.

In the event of a significant earthquake, trains should be stopped until the earthquake is confirmed to have subsided. Passenger evacuation shall be done following appropriate operating procedures for such a scenario.

16.6.5. PROVISION OF INTEGRATED SCADA

An integrated SCADA that integrates various SCADAs, BMSs, and other control and monitoring systems shall be provided. This will help greatly with decision-making during incidents as a single workstation will provide information of all systems running in the metro.

16.7. PREPAREDNESS OF 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 concerned staff is essential to train them to become fully conversant with the action required to be taken while handling emergencies.

They also need to be trained in appropriate communication skills while addressing passengers during incident management to assure them about their wellbeing and seek 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 the use of rescue and relief train.

16.8. SECURITY MEASURES IN METRO

16.8.1. INTRODUCTION

The Metro Rail system has emerged as the most reliable mode of urban transportation in India. However, the inherent characteristics of the 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, the high cost of infrastructure, its economic impacts on society, and their being the lifeline of a city with high news value, pose a 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, or to create general scare among the public. These threats range from daily operational security problems such as disorder, vandalism and terror threats.

The public transportation system is becoming increasingly important for urban areas to prosper in the face of challenges such as congestion and pollution. Therefore, a security system for public transportation like the metro rail plays an important role in helping the system become the preferred mode choice for commuters. Therefore, the provision of an excellent and reliable security system is a prerequisite for metro systems and for increasing their market share. Metro railway administration must ensure that their security models keeps pace with their rapid expansion and changing security scenarios.

16.8.2. THE THREE PILLARS OF SECURITY

Security means the 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. The three important pillars of security are:

- The human factor
- Procedures
- Technology

Staff interaction with passengers creates a sense of reassurance, which cannot be achieved fully by technology. For the human factor to be more effective, staff must be qualified, trained, well-equipped and motivated. Staff members should be skilful, trained, drilled, and experienced. 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 a number of technologies which can be used to enhance security, e.g., surveillance systems. The objectives of security systems are detection of the plan before an attack, deny the access for carrying out an attack, and mitigation measures after an attack.

16.8.3. DIFFERENT PHASES OF SECURITY

There are three different phases associated with the security system in the metro:

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 taken 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 mitigate the impacts. Staff must be trained accordingly. The results of the risk assessment will give the basis for such plans.

Recovery

The procedures/instructions ought to be laid down for the quick recovery of normal service after an incident. Prompt recovery operation is important for the Financial health besides sending out a clear message to the public, reassuring passengers, and giving people the confidence to continue using the system.

Communication is key to quick restoration after such incidents. Restoration should also include an evaluation process for the lessons learnt.

16.8.4. RESPONSIBILITIES AND PARTNERSHIPS

The responsibility of security lies with the state. Security in public transport requires clear governance. Responsibilities should be clearly defined. In the present scenario, it is the responsibility of the State Government to ensure secured travel in Pune Metro corridors.

16.8.5. PROPOSED PROVISIONS FOR THE SECURITY SYSTEM

For providing an efficient security system in metro station areas, the following provisions are suggested:

1. CCTV coverage of all metro stations with the 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 (landline and EPBX) for proper functioning, cluster viewing for stations.
2. A minimum of one baggage scanner at all entry points (one per AFC array). Additional baggage scanners at heavily crowed stations, i.e., at interchange may also be required.
3. A minimum of three Multi-Zone Door Frame Metal Detectors (DFMD) per entry (two per AFC array). The number can increase depending on the footfall at overcrowded stations.
4. Hand-held Metal Detectors (HHMD) as per the requirement of the security agency, and a minimum of two per entry, varying from station to station, with at least 1.5 per DFMD installed at the station.
5. Bomb detection equipment as per the requirement of the security agency.
6. At least one bomb blanket per station and depot.
7. Wireless sets (static and handheld) as per the requirement of the agency.
8. At least one dragon light per metro station.
9. Mobile phones, landlines and EPBX phone connections for senior security officers and control room, etc.
10. Dog squads or at least one sniffer dog for four metro stations. Dog kennels along with dog handlers and MI room will also be provided by the metro train depot administration, including land at suitable places line-wise.
11. One bulletproof morcha per security checkpoint (i.e., AFC array) and entry gate for the metro train depot administration.

12. Bulletproof jackets and helmets for Quick Response Teams (QRTs) and riot control equipment, including space at nominated stations. One QRT will look after 5-6 metro stations, as per the present arrangement. One QRT will consists of five personnel and perform their duty in three shifts.
13. Furniture for each security room and checking point, at every entry point at stations. One office table with three chairs for the security room and office, and one steel top table with two chairs for the checking point.
14. One frisking booth for ladies per security checkpoint (AFC)
15. One wooden ramp per DFMD for security checkpoints.
16. Wall mounted/pedestal fan at security checkpoints, ladies frisking booths and bulletproof morcha, as per requirement.
17. Physical barriers for anti-scaling at ramp areas, low height of viaduct by providing an iron grill of appropriate height and design/concertina wire.
18. An adequate number of ropes, queue managers, cordoning tapes, and dragon search lights for contingencies.
19. Iron grill at station entrance staircases, proper segregation of paid and unpaid areas by providing appropriately designed grills, etc.
20. Proper design of emergency staircases and firemen entry to prevent unauthorized entry.

CHAPTER 17: DETAILED PROJECT COST ESTIMATES

17.1 CAPITAL COST ESTIMATE

17.1.1 COVERAGE

Cost estimate for the Pune Metro Phase II Corridors has been undertaken covering Civil, Electrical, Signalling and Telecommunication works, Rolling Stock, Environmental Protection, Rehabilitation etc. considering 25kV AC Overhead Traction System at July 2022 price level.

While preparing the capital cost estimates, various items have generally been grouped under the three (03) major heads on the basis of

(i) route km length of alignment,
(ii) number of units of that item and
(iii) item being an independent entity.

All items related with alignment, construction, permanent way, OHE, signalling & telecommunication, whether in main lines or in maintenance depot have been estimated at rate per route km basis.

Cost of the station structures, other electrical services at these stations and Automatic Fare Collection (AFC) installations at all stations have been assessed. Similarly, for the items like rolling stock, costs have been estimated in terms of the number of units required for each item. In remaining items viz. land utility diversions, rehabilitation, etc. costs have been assessed on the basis of each item, taken as independent entity.

In order to arrive at the realistic cost of the various items, costs have been assessed based on the following;

- MoHUA Report on the Benchmarking of the Cost Estimation of the Metro Rail Projects and suitably escalated to July 2022 prices,
- Market Research i.e. the recently awarded rates, other metro DPR's prepared post 2018 and suitably escalated to July 2022 prices
- Detailed Bill of Quantities

Taxes and Duties such as Custom Duty, CGST, SGST and IGST etc., wherever applicable, have been worked out on the basis of prevailing rates and included in the cost separately. GST which is applicable to the Metro Project with effect from 01.07.2022 has also been included in the cost estimates.

The details of the Line 2A and Line 2B extension corridors of Line 2 of Pune Metro Phase 1 are mentioned in the Table 17-1

TABLE 17-1: DETAILS OF LINE 2A AND LINE 2B

S. No.	Name of the Corridor	Route Length (Kms)	No. of Stations
1	Line 2A: Vanaz to Chandani Chowk	1.12	2
2	Line 2B: Ramwadi to Wagholi/ Vitthalwadi	11.63	11
	Total Length (Kms)	**12.75**	**13**

17.1.2 LAND

Finalization of alignment, location of stations, entry / exits etc. has been done with the objective of keeping land requirement to the bare minimum. For this purpose, alignment, stations and depots have been planned along the available road RoW.

Rate of the Government Land required on permanent basis has been taken at the Reday Recoker Rates. No Solatium has been applied to the basic land cost. In case, State Govt. is in a position to provide its land free of cost or at reduced rates, it will further improve the financial statistics of the project.

Rate of Private Land required on permanent basis has been taken @ 2.5 times of the Reday Recoker Rate. No administrative cost is added towards land acquisition activities, as it is understood that this activity shall be carried out by State Govt. from its own resources.

Since, majority of the land requirement is within the available RoW, no private structures are being affected except for the boundary/compound walls of the private properties and BRTS corridor on Nagar road. The cost of the re-construction of 374 mts of compound/boundary wall along the Line 2A and Line 2B has been considered under R&R cost along with the 4.5km of dismantling and reconstruction of BRTS on Nagar road.

The total cost of Land at July 2022 prices is worked out to be Rs. 22.15 Crore for Line 2A and Line 2B of the Phase 2 MRTS corridors.

17.1.3 ITEMS OTHER THAN LAND

The basis of rates for items other than land has been represented in the Table 17-2.

TABLE 17-2: BASIS OF RATES

Sl. No.	Item	Unit	Unit Cost (Rs. in Cr.)	Basis of Rates
1	**Alignment & Formation**			
1.1	*Elevated Section (Viaduct) including in station portion*	*RKM*	*44.062*	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*

Sl. No.	Item	Unit	Unit Cost (Rs. in Cr.)	Basis of Rates
1.2	*Additional Viaduct for connectivity to Future Extension near Kharadi Bypass Station (single Track)*	*RKM*	33.047	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices. 75% of Benchmarking cost considered for single track structure*
2	**Station Building**			
2.1	*Elevated Stations (Civil including Finishes) excluding viaduct in station portion*	*Per Station*	*30.962*	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
2.2	*Elevated Stations (E&M including lift and escalator)*	*Per Station*	*9.527*	
2.3	*Additional Platform at Kharadi Bypass Stations - Civil*	*Per Station*	*7.741*	*Kharadi Bypass Station is designed as 3 Platform Station considering the future extension towards Hadapsar. Based on the Station Typology, the total area of the Kharadi Bypass Station is 25% more than the typical Elevated Metro Station. Hence additional 25% on Civil and E & M Cost has been considered for this station on the escalated prices as mentioned above.*
2.4	*Additional Platform at Kharadi Bypass- E&M*	*Per Station*	*2.382*	
3	**Permanent Way**			
3.1	*Ballast less track*	*RKM*	*7.860*	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
3.2	*Ballasted Track for Depot At Grade Section*	*TKM*	*4.644*	
3.3	*Ballast less track Single track for connectivity to Future Extension near Kharadi Bypass Station*	RKM	**3.930**	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices. 50% cost is considered*
4	**Traction and Power Supply**			
4.1	*25 kv Overhead Catenary System (OCS)*			
4.1.1	*Elevated Section*	*RKM*	*8.931*	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7*
4.1.2	*Depot*	*TKM*	*2.382*	
4.1.3	*RSS cum TSS*	*Each*	*53.588*	

Sl. No.	Item	Unit	Unit Cost (Rs. in Cr.)	Basis of Rates
				Months) at 5% p.a to arrive at July 2022 prices
4.1.4	*Single track for connectivity to Future Extension near Kharadi Bypass Station*	*RKM*	**4.465**	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices. 50% cost is considered*
5	**Signalling and Telecom**			
5.1	***Signalling***			
5.1.1	*Main line including OCC/BCC*	*RKM*	*5.240*	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
5.1.2	*Depot including DCC*	*TKM*	*3.811*	
5.1.3	*On Board Equipment*	*Per Train*	*2.024*	
5.1.4	*Single track for connectivity to Future Extension near Kharadi Bypass Station*	RKM	**2.620**	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices. 50% cost is considered*
5.2	***Telecommunication***			
5.2.1	*Station*	*Per Station*	*5.359*	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
5.2.2	*Depot*	*Per Depot*	*4.168*	
6	**Automatic Fare Collection (AFC) System**	**Per Station**	***4.168***	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices.*
7	**Platform Screen Door (PSD) (Half Height)**	**Per Station**	***2.68***	*Half Height PSD are considered in the DPR. Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects for Full Height PSD. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices, For Half Height PSD 75% of the Full Height PSD at July 2022 prices has been applied.*

Sl. No.	Item	Unit	Unit Cost (Rs. in Cr.)	Basis of Rates
8	**Shifting of Miscellaneous Utilities**			
8.1	*Civil*	*RKM*	***3.573***	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
8.2	*E&M*	*RKM*	***3.573***	
9	**Multimodal Integration and Last Mile Connectivity**	**Per Station**	***3.573***	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
9.a	**FOB @ Kharadi Bypass Station**	**Lump sum/Unit (150 mts)**	***7.635***	*Per meter Cost Estimated for FoB considering one lift and one staircase. Rates as per PWD SSR for Year 2022-23. Cost Basis attached as Annexure 17.1Based on the MMI & DDC Works of Pune Metro Phase 1*
9.b	**FOB @ Chandani Chowk Station**	**Lump sum/Unit (500 mts)**	***25.450***	
10	**Depot, Admin Building and Operation and Control Centre**			
10.3	*Augmentation of Depot at Vanaz*		***25.050***	*Rates from CPWD SOR for year 2019 escalated to July 2022 prices.*
11	**Staff Quarters**			
11.1	*Civil & EM*	*RKM*	***2.000***	*Rate as per the MoHUA letter No. K-14011/7/2024-MRTS-II dated 02.07.2024.*
12	**Rolling Stock**	**Per Coach**	***8.000***	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects.* *Escalation on this rate has not been considered as per the MoHUA letter No. K-14011/7/2024-MRTS-II dated 02.07.2024.*
13	**Security**	**Per Station**	***0.441***	*Base Cost based on the Report on Benchmarking for Cost Estimation of Metro Rail Projects. The rates have been escalated by 3.58 years (3 Years and 7 Months) at 5% p.a to arrive at July 2022 prices*
14	**Cyber Security**	**Lump sum**	***5.000***	*Since, this is a new component added, with no base reference cost. A Lump sum cost has been assumed.*
15	**Environmental Management Plan**	**Details mentioned in Chapter 15**		

Sl. No.	Item	Unit	Unit Cost (Rs. in Cr.)	Basis of Rates
16	**Land**	**Details mentioned in Chapter 5**		**As per the actual rates**
17	**R & R**			
17.1	*R & R including hutments*	Details mentioned in Chapter 15		
17.2	*BRT Dismantling and Restoration of Works*	Per Kms	***12.724***	*Pune BRTS Cost for the Civil Items have been estimated for 15 Kms stretch based on the Pune SOR - 2015 - 16. The cost per km works out to be Rs 11.17 Crore. The prices has been duly extrapolated to 2021-22 SOR prices, with an average escalation of 5% p.a to Rs 14.97 Crore per km. Considering 15% of the components would be reused, the cost per km for dismantling and restoration of BRTS works have been reworked at Rs 12.724 Crores*

17.2 INNOVATIONS PROPOSED TO REDUCE THE COST

All efforts have been made to reduce the capital cost. Rates for various components involved in Metro Rail Systems like Civil works, E&M works, Traction & Power supply, Signalling & Telecommunication etc. costs have been assessed comparing the awarded rates of Pune Metro Phase 1, benchmarking costs and other Metro systems across the country.

The average interstation distance for Vanaz to Chandani Chowk (Line 2A) and Ramwadi to Wagholi/Vitthalwadi (Line 2B) is worked out to be 878.614m and 1068.045m respectively. Thus reduction in overall cost of metro system (excluding rolling stock) on account of interstation distance is not required as per Report on “Benchmarking for Cost Estimation of Metro Rail Projects”, by MoHUA.

17.3 DETAILED PROJECT COST ESTIMATES

Corridor Wise Project Cost Estimates with unit rate, quantities and cost of each item is represented Table 17-3 and Table 17-4. Amounts are rounded off to two decimals.

TABLE 17-3: DETAILED COST ESTIMATE FOR LINE 2A – VANAZ TO CHANDANI CHOWK

Line 2A: Vanaz to Chandani Chowk;
Length (Kms) - 1.122 Kms, At Grade - 0.000 Kms, Elevated - 1.122 Kms;
Stations - 02, At Grade - 00, Elevated – 02

July,2022 Price Level (Rs in Crores)

Item No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2A	
				Quantity	Amount (Rs.in Crores)
1	**Land**				
1a	Government Land (GoM) - Permanent	Sq Mts	As per the actuals	0.000	0.00
1b	Government Land (PMC) - Permanent	Sq Mts		0.000	0.00
1c	Private Land - Permanent	Sq Mts		106.260	2.18
1d	Government Land (GoM)- Temporary	Sq Mts		25000.00	2.64
1e	Government Land (PMC)- Temporary	Sq Mts		0.00	0.00
1f	Private Land - Temporary	Sq Mts		115.98	0.10
	Sub Total of Item 1				**4.92**
2	**R & R**				
2a	R & R including hutments	Details As mentioned in Chapter 15			0.04
	Sub Total of Item 2				**0.04**
3	**Environmental Management Plan**	**Details As mentioned in Chapter 15**			0.67
	Sub Total of Item 3				**0.67**
4	**Alignment and Formation**				
4.1	Elevated Section (Viaduct) including in station portion and elevated ramp	RKM	44.062	1.122	49.44
	Sub Total of Item 4				**49.44**
5	**Station Buildings**				
5.1	Elevated Stations Civil Works - (Civil including Finishes) excluding viaduct in station portion	Each	30.962	2	61.92
5.2	Elevated Stations (E&M including lift and escalator)	Each	9.527	2	19.05
	Sub Total of Item 5				**80.97**
6	**Permanent Way**				
6.1	Ballastless track	RKM	7.860	1.122	8.82
	Sub Total of Item 6				**8.82**

Item No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2A	
				Quantity	Amount (Rs.in Crores)
7	**Traction and Power Supply**				
	25 v Overhead Catenary System (OCS)				
7.1	Elevated Section	RKM	8.931	1.122	10.02
	Sub Total of Item 7				**10.02**
8	**Signalling and Telecommunication**				
8.1	**Signalling**				
	Main line including OCC/BCC	RKM	5.24	1.122	5.88
	On Board Equipment	Per Train	2.024	1	2.02
8.2	**Telecommunication**				
	Station	Per Station	5.359	2	10.72
	Sub Total of Item 8				**18.62**
9	**Automatic Fare Collection System**				
9.1	Automatic Fare Collection System	Per Station	4.168	2.00	8.34
	Sub Total of Item 9				**8.34**
10	**Platform Screen Doors**				
10.1	Platform Screen Doors @ Half Height	Per Station	2.680	2.00	5.36
	Sub Total of Item 10				**5.36**
11	**Shifting of Miscellaneous Utilities**				
11.1	Civil	RKM	3.573	1.122	4.01
11.2	E&M	RKM	3.573	1.122	4.01
	Sub Total of Item 11				**8.02**
12	**Multi Modal Integration & Last Mile Connectivity**				
12.1	MMI Facilities for Wayside/Intermediate Stations	Per Station	3.573	2.00	7.15
12.2	*FOB at Chandani Chowk Station 500 m*	Lump sum			25.45
	Sub Total of Item 12				**32.6**
13	**Staff Quarters**				
13.1	Civil & EM	RKM	2.000	1.122	2.24
	Sub Total of Item 13				**2.24**
14	**Security**				
	Security	Per Station	0.441	2.00	0.88
	Sub Total of Item 14				**0.88**

Item No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2A	
				Quantity	Amount (Rs.in Crores)
15	**Cyber Security**	Lump sum			0.5
	Sub Total of Item 15				**0.5**
16	**Rolling Stock**				
	Rolling Stock	Per Coach	8.000	3	24.00
	Sub Total of Item 16				**24.00**
17	**Total on all items except Land and R&R (except Item 1 & 2)**				**250.48**
18	**General Charges incld. Design Charges @ 5% on all items except Land and R&R (i.e. on Item. No. 17)**				**12.52**
19	**Contingencies @3% on all items except Land and R & R (i.e. on Item No. 17)**				**7.51**
20	**Total of all items including G. Charges & Contingencies (Sum of Item No 17, Item No 18 and Item No. 19)**				**270.51**
21	**Total including Contingencies & including Land and R&R (Sum of Item No 20, Item No. 1 and Item No. 2)**				**275.47**
22	**Central and State Taxes (at July 2022 Price Level)**				**50.42**
23	**Total Cost Including Taxes and Duties with Land and R&R (sum of Item No. 21 & 22)**				**325.89**
24	**Escalation @5% per annum on the above (Item No. 23)**				**51.74**
25	**Total Completion Cost incld. Land and R & R Costs (sum of Item No. 23 and Item No. 24)**				**377.63**
26	**Interest During Construction (IDC)**				**18.99**
27	**Total Completion Cost incld. IDC (sum of Item No. 25 and Item No. 26)**				**396.62**

TABLE 17-4: DETAILED COST ESTIMATE FOR LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI

Line 2B: Ramwadi to Wagholi/Vitthalwadi
Length (Kms) – 11.633 Kms, At Grade - 0.000 Kms, Elevated – 11.633 Kms;
Stations - 11, At Grade - 00, Elevated – 11

July,2022 Price Level (Rs in Crores)

Sl. No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2B	
				Quantity	Amount (Rs. in Crores)
1	**Land**				
1a	Government Land - Permanent (GoM)	Sq Mts	As per the actuals	5000	5.27
1b	Government Land - Permanent (PMC)	Sq Mts		190.35	0.19
1c	Private Land - Permanent	Sq Mts		520.99	8.54
1d	Government Land - Temporary (GoM)	Sq Mts		25000	2.64
1e	Government Land - Temporary (PMC)	Sq Mts		132.43	0.02
1f	Private Land - Temporary	Sq Mts		948.84	0.57
	Sub Total of Item 1				**17.23**
2	**R & R**				
2a	R & R including hutments	Details As mentioned in Chapter 15			0.34
2b	BRT Dismantling and Restoration of Works	RKM	12.724	4.5	57.26
	Sub Total of Item 2				**57.60**
3	Environmental Management Plan	Details As mentioned in Chapter 15			2.14
	Sub Total of Item 3				**2.14**
4	**Alignment and Formation**				
4.1	Elevated Section (Viaduct) including in station portion and elevated ramp	RKM	44.062	11.633	512.57
4.2	Additional Viaduct for connectivity to Future Extension near Kharadi Bypass Station (*75% Cost Considered for single Track)	RKM	33.047	0.70	23.13
	Sub Total of Item 4				**535.70**
5	**Station Buildings**				
5.1	Elevated Stations Civil Works - (Civil including Finishes) excluding viaduct in station portion	Each	30.962	11	340.58

Sl. No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2B	
				Quantity	Amount (Rs. in Crores)
5.2	Elevated Stations (E&M including lift and escalator)	Each	9.527	11	104.8
5.3	Additional Cost for Kharadi Bypass Station (3 Platform)- Civil Works	Each	7.741	1	7.74
5.4	Additional Cost for Kharadi Bypass Station (3 Platform) - E & M Works	Each	2.382	1	2.38
	Sub Total of Item 5				**455.50**
6	**Permanent Way**				
6.1	Ballastless track	RKM	7.86	11.633	91.44
6.2	Ballasted track at Depot (Augmentation of Vanaz Depot)	TKM	4.644	0.22	1.02
6.3	Ballastless Track- Single track for connectivity to Future Extension near Kharadi Bypass Station (*Single track of 700m Length)	RKM	7.86	0.35	2.75
	Sub Total of Item 6				**95.21**
7	**Traction and Power Supply**				
	25 v Overhead Catenary System (OCS)				
7.1	Elevated Section	RKM	8.931	11.633	103.89
7.2	RSS cum TSS	Each	53.588	1	53.59
7.3	Depot	TKM	2.382	0.22	0.52
7.4	Single track for connectivity to Future Extension near Kharadi Bypass Station (*Single track of 700m Length)	RKM	8.931	0.35	3.13
	Sub Total of Item 7				**161.13**
8	**Signalling and Telecommunication**				
8.1	**Signalling**				
	Main Line including OCC/BCC	RKM	*5.24*	*11.633*	60.96
	*Single track for connectivity to Future Extension near Kharadi Bypass Station (*Single track of 700m Length)*	RKM	*5.24*	*0.350*	1.83
	Depot including DCC	TKM	*3.811*	*0.220*	0.84
	On Board Equipment	Per Train	*2.024*	*14.000*	28.34
8.2	**Telecommunication**				

Sl. No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2B	
				Quantity	Amount (Rs. in Crores)
	Station	Per Station	*5.359*	*11.000*	58.95
	Depot	Per Depot	*4.168*	*1.000*	4.17
	Sub Total of Item 8				**155.09**
9	**Automatic Fare Collection System**				
9.1	Automatic Fare Collection System	Per Station	4.168	11.50	47.93
	Sub Total of Item 9				**47.93**
10	**Platform Screen Doors**				
10.1	Platform Screen Doors @ Half Height	Per Station	2.68	11.50	30.82
	Sub Total of Item 10				**30.82**
11	**Shifting of Miscellaneous Utilities**				
11.1	Civil	RKM	3.573	11.633	41.56
11.2	E&M Works	RKM	3.573	11.633	41.56
	Sub Total of Item 11				**83.12**
12	**Multi Modal Integration & Last Mile Connectivity**				
12.1	MMI Facilities for Wayside/Intermediate Stations	Per Station	3.573	11.00	39.3
12.2	*FOB at Kharadi Bypass Station 150m*	*Lump sum*			7.64
	Sub Total of Item 12				**46.94**
13	**Depot, Admin Buildings and Operation and control center**				
13.1	Augmentation of Vanaz Depot	Lump sum	25.05	1	25.05
	Sub Total of Item 13				**25.05**
14	**Staff Quarters**				
14.1	Civil & EM	RKM	2.000	11.633	23.27
	Sub Total of Item 14				**23.27**
15	**Security**				
15.1	Security	Per Station	0.441	11.00	4.85
	Sub Total of Item 15				**4.85**
16	Cyber Security	Lump sum			4.5
	Sub Total of Item 16				**4.5**
17	**Rolling Stock**				
	Rolling Stock	Per Coach	8.00	42.00	336.00

Sl. No.	Components	Unit	Rate (Rs in Cr. per Unit)	Line 2B	
				Quantity	Amount (Rs. in Crores)
	Sub Total of Item 17				**336.00**
18	**Total on all items except Land and R&R (except Item No 1 & 2)**				**2007.25**
19	**General Charges incld. Design Charges @ 5% on all items except Land and R&R (i.e. on Item No 18)**				**100.36**
20	**Contingencies @3% on all items except Land and R & R (i.e. on Item. No. 18)**				**60.22**
21	**Total including Contingencies & excluding Land and R&R (Sum of Item No. 18, Item No. 19, & Item No. 20)**				**2167.83**
22	**Total including Contingencies & including Land and R&R (Sum Item No 21 ,Item No. 1 and Item No. 2)**				**2242.66**
23	**Central and State Taxes (at July 2022 Price Level)**				**411.72**
24	**Total Cost Including Taxes and Duties with Land and R&R (sum of Item No. 22 & Item No. 23)**				**2654.38**
25	**Escalation @5% per annum on the above (Item No. 24)**				**420.60**
26	**Total Completion Cost incld. Land and R & R Costs (sum of Item No. 24 and 25)**				**3074.98**
27	**Interest During Construction (IDC)**				**154.64**
28	**Total Completion Cost incld. IDC (sum of Item No. 26 and Item No.27)**				**3229.62**

Note: In Sr. No. 9 and Sr. No. 10 additional quantity of 0.5 Nos has been considered for additional platform at Kharadi Bypass Station

17.4 TAXES AND DUTIES

Taxes and Duties are worked out based on the Current rates of GST i.e. 18% and have been applied as per prevalent practice. Components of Taxes and Duties considered for calculation are represented in Table 17-5.

TABLE 17-5: TAXES AND DUTIES COMPONENTS

Sl. No.	Tax Component	Percentage
1	GST on Construction, Erection, Commissioning or Installation of Original Metro/Mono Rail Works	18.000%
1.a	CGST	9.000%
1.b	SGST	9.000%
2	Tax Leviable on Import – Effective	27.735%
2.a	BCD = Basic Custom Duty	8.250%
2.b	CGST	9.7425%
2.c	SGST	9.7425%
3.	GST on Consultancy Services	18.000%
3.a	CGST	9.000%

Sl. No.	Tax Component	Percentage
3.b	SGST	9.000%

The summary of Taxes and Duties calculated are mentioned in the Table 17-6

TABLE 17-6: SUMMARY OF TAXES AND DUTIES FOR LINE 2A AND LINE 2B

Sl. No.	Taxes	Percentage(%)	Taxes (Rs in Crores)		
			Line 2A	Line 2B	Total
1	**Taxes on Imported Items**	**27.7350%**	**8.76**	**92.32**	**101.08**
1.a	*Basic Customs Duty (BCD)*	8.2500%	2.60	27.48	30.08
1.b	*CGST- Custom Duty*	9.7425%	3.08	32.42	35.5
1.c	*SGST - Custom Duty*	9.7425%	3.08	32.42	35.5
2	**Taxes on Indigenous Items**	**18.0000%**	**41.66**	**319.4**	**361.06**
2.a	General CGST	**9.0000%**	20.83	159.7	180.53
2.b	General SGST	**9.0000%**	20.83	159.7	180.53
	Total (1+2)		**50.42**	**411.72**	**462.14**

TABLE 17-7: DETAILS OF TAXES AND DUTIES FOR LINE 2A – VANAZ TO CHANDANI CHOWK

Sl. No.	Item Description	Total Capital Cost (Rs In Cr)	Procurement		Taxes (Rs in Crore)							Total Taxes & Duties
			Import Comp-onent	Local Comp-onent	BCD (8.25%)	IGST (CGST Portion) (9.7425%)	IGST (SGST Portion) (9.7425%)	Total Taxes on Import	CGST (9%)	SGST (9%)	Total Taxes on Indigeneous	
					(A)	(B)	(C)	(D = A+B+C)	(E)	(F)	(G=E+F)	(H=D+G)
1	Alignment and Formation	49.44	0%	100%	0.00	0.00	0.00	0.00	4.45	4.45	8.90	8.90
2a	Stations_Civil	61.92	0%	100%	0.00	0.00	0.00	0.00	5.57	5.57	11.14	11.14
2b	Stations_E & M	19.05	10%	90%	0.16	0.19	0.19	0.54	1.54	1.54	3.08	3.62
3	Permanent Way	8.82	10%	90%	0.07	0.09	0.09	0.25	0.71	0.71	1.42	1.67
4	Traction and Power Supply	10.02	40%	60%	0.33	0.39	0.39	1.11	0.54	0.54	1.08	2.19
5	Signaling and Telecommunication	18.62	50%	50%	0.77	0.91	0.91	2.59	0.84	0.84	1.68	4.27
6	Automatic Fare Collection System	8.34	40%	60%	0.28	0.33	0.33	0.94	0.45	0.45	0.90	1.84
7	Platform Screen Door (Half Height)	5.36	40%	60%	0.18	0.21	0.21	0.60	0.29	0.29	0.58	1.18
8	Shifting of Utilities	8.02	0%	100%	0.00	0.00	0.00	0.00	0.72	0.72	1.44	1.44
9	Multi Modal Integration & Last Mile Connectivity	32.60	0%	100%	0.00	0.00	0.00	0.00	2.93	2.93	5.86	5.86
10	Staff Quarters	2.24	0%	100%	0.00	0.00	0.00	0.00	0.20	0.20	0.40	0.40
11	Security	0.88	0%	100%	0.00	0.00	0.00	0.00	0.08	0.08	0.16	0.16
12	Cyber Security	0.50	50%	50%	0.02	0.02	0.02	0.06	0.02	0.02	0.04	0.10
13	Rolling Stock	24.00	40%	60%	0.79	0.94	0.94	2.67	1.30	1.30	2.60	5.27
14	Environmental Management Plan	0.67	0%	100%	0.00	0.00	0.00	0.00	0.06	0.06	0.12	0.12
15	General Charges @ 5% on all items except Land and R&R	12.52	0%	100%	0.00	0.00	0.00	0.00	1.13	1.13	2.26	2.26
Total		263.00			2.60	3.08	3.08	8.76	20.83	20.83	41.66	50.42
											Total Central GST & Basic Custom Duty	**26.51**
											Total State GST	**23.91**
											Total Taxes & Duties	**50.42**
											Total Taxes & Duties incl. Escalation	**58.44**

TABLE 17-8: DETAILS OF TAXES AND DUTIES FOR LINE 2B – RAMWADI TO WAGHOLI/VITTHALWADI

Sl. No.	Item Description	Total Capital Cost (Rs In Cr)	Procurement		Taxes (Rs in Crore)							Total Taxes & Duties
			Import Comp-onent	Local Comp-onent	BCD (8.25%)	IGST (CGST Portion) (9.7425%)	IGST (SGST Portion) (9.7425%)	Total Taxes on Import	CGST (9%)	SGST (9%)	Total Taxes on Indigeneous	
					(A)	(B)	(C)	(D = A+B+C)	(E)	(F)	(G=E+F)	(H=D+G)
1	Alignment and Formation	535.70	0%	100%	0.00	0.00	0.00	0.00	48.21	48.21	96.42	96.42
2a	Stations_Civil	348.32	0%	100%	0.00	0.00	0.00	0.00	31.35	31.35	62.70	62.70
2b	Stations_E & M	107.18	10%	90%	0.88	1.04	1.04	2.96	8.68	8.68	17.36	20.32
3	Permanent Way	95.21	10%	90%	0.79	0.93	0.93	2.65	7.71	7.71	15.42	18.07
4	Traction and Power Supply	161.13	40%	60%	5.32	6.28	6.28	17.88	8.70	8.70	17.40	35.28
5	Signalling and Telecommunication	155.09	50%	50%	6.40	7.55	7.55	21.50	6.98	6.98	13.96	35.46
6	AFC System	47.93	40%	60%	1.58	1.87	1.87	5.32	2.59	2.59	5.18	10.50
7	Platform Screen Door (Half Height)	30.82	40%	60%	1.02	1.20	1.20	3.42	1.66	1.66	3.32	6.74
8	Shifting of Utilities	83.12	0%	100%	0.00	0.00	0.00	0.00	7.48	7.48	14.96	14.96
9	MMI & Last Mile Connectivity	46.94	0%	100%	0.00	0.00	0.00	0.00	4.22	4.22	8.44	8.44
10	Augmentation of Vanaz Depot	25.05	10%	90%	0.21	0.24	0.24	0.69	2.03	2.03	4.06	4.75
11	Staff Quarters	23.27	0%	100%	0.00	0.00	0.00	0.00	2.09	2.09	4.18	4.18
12	Security	4.85	0%	100%	0.00	0.00	0.00	0.00	0.44	0.44	0.88	0.88
13	Cyber Security	4.50	50%	50%	0.19	0.22	0.22	0.63	0.20	0.20	0.40	1.03
14	Rolling Stock	336.00	40%	60%	11.09	13.09	13.09	37.27	18.14	18.14	36.28	73.55
15	Environmental Management Plan	2.14	0%	100%	0.00	0.00	0.00	0.00	0.19	0.19	0.38	0.38
16	General Charges @ 5% on all items except Land R&R	100.36	0%	100%	0.00	0.00	0.00	0.00	9.03	9.03	18.06	18.06
Total		2107.61			27.48	32.42	32.42	92.32	159.70	159.70	319.40	411.72
											Total Central GST & Basic Custom Duty	**219.60**
											Total State GST	**192.12**
											Total Taxes & Duties	**411.72**
											Total Taxes & Duties incl. Escalation	**477.25**

17.5 SUMMARY OF CAPITAL COST

Component Wise summary abstract of the project cost estimates is represented in the Table 17-9

TABLE 17-9: ABSTRACT OF CAPITAL COST FOR LINE 2A AND LINE 2B

Sl. No.	Components	Rs. In Crore		
		Line 2A	Line 2B	Total
		RL - 1.122 Kms	RL – 11.633 Kms	RL – 12.755
1	**Alignment and Formation**	**49.44**	**535.70**	**585.14**
2	**Stations**	**80.97**	**455.50**	**536.47**
2a	Stations_Civil	61.92	348.32	**410.24**
2b	Stations_E & M	19.05	107.18	**126.23**
3	**Permanent Way**	**8.82**	**95.21**	**104.03**
4	**Traction and Power Supply**	**10.02**	**161.13**	**171.15**
5	**Signaling and Telecommunication**	**18.62**	**155.09**	**173.71**
6	**Automatic Fare Collection System**	**8.34**	**47.93**	**56.27**
7	**Platform Screen Door (Half Height)**	**5.36**	**30.82**	**36.18**
8	**Shifting of Utilities**	**8.02**	**83.12**	**91.14**
9	**Multi Modal Integration & Last Mile Connectivity**	**32.60**	**46.94**	**79.54**
10	**Augmentation of Vanaz Depot**	**0.00**	**25.05**	**25.05**
11	**Staff Quarters**	**2.24**	**23.27**	**25.51**
12	**Security**	**0.88**	**4.85**	**5.73**
13	**Cyber Security**	**0.50**	**4.5**	**5.00**
14	**Rolling Stock**	**24.00**	**336**	**360.00**
15	**Land**	**4.92**	**17.23**	**22.15**
15a	Government Land (GoM) - Permanent	0.00	5.27	**5.27**
	Government Land (PMC) - Permanent	0.00	0.19	**0.19**
15b	Private Land - Permanent	2.18	8.54	**10.72**
	Government Land (GoM)- Temporary	2.64	2.64	**5.28**
15c	Government Land (PMC)- Temporary	0.00	0.02	**0.02**
15d	Private Land - Temporary	0.10	0.57	**0.67**
16	**R & R**	**0.04**	**57.60**	**57.64**
16a	R & R including hutments	0.04	0.34	**0.38**
16b	BRT Dismantling and Restoration of Works	0.00	57.26	**57.26**
17	**Environmental Management Plan**	**0.67**	**2.14**	**2.81**
18	**Total on all items except Land and R&R (except Item No 15 & 16)**	**250.48**	**2007.25**	**2257.73**

Sl. No.	Components	Rs. In Crore		
		Line 2A	Line 2B	Total
		RL - 1.122 Kms	RL – 11.633 Kms	RL – 12.755
19	General Charges incld. Design Charges @ 5% on all items except Land and R&R (i.e. on Item No 18)	12.52	100.36	112.88
20	Contingencies @3% on all items except Land and R & R (i.e. on Item. No. 18)	7.51	60.22	67.73
21	Total including Contingencies & excluding Land and R&R (Sum of Item No. 18, Item No. 19, & Item No. 20)	270.51	2167.83	2438.34
22	Total including Contingencies & including Land and R&R (Sum Item No 21 ,Item No. 15 and Item No. 16)	275.47	2242.66	2518.13
23	Central and State Taxes (at July 2022 Price Level)	50.42	411.72	462.14
24	Total Cost Including Taxes and Duties with Land and R&R (sum of Item No. 22 & Item No. 23)	325.89	2654.38	2980.27
25	Escalation @5% per annum on the above (Item No. 24)	51.74	420.60	472.34
26	Total Completion Cost incld. Land and R & R Costs (sum of Item No. 24 and 25)	377.63	3074.98	3452.61
27	Interest During Construction (IDC)	18.99	154.64	173.63
28	Total Completion Cost incld. IDC (sum of Item No. 26 and Item No.27)	396.62	3229.62	3626.24

TABLE 17-10: COMPONENT WISE ESCALATION FOR LINE 2A

Year	FY	Cost Phasing	Land Phasing	Cost at July 2022 Price Level (Rs. in Cr.)					Escalation Factor (5% p.a)	Completion Cost (Rs. in Cr.)				
				Component Cost without taxes, Land and R&R	Central Taxes	State Taxes	Land & R&R	Total Cost excl IDC		Component Cost without taxes, Land and R&R	Central Taxes	State Taxes	Land and R&R	Total Cost excl IDC
1	FY2022-23								1.025					
2	FY 2023-24	20.00%	20.00%	54.10	5.30	4.78	0.99	65.17	1.075	58.16	5.70	5.14	1.06	70.06
3	FY 2024-25	30.00%	50.00%	81.15	7.95	7.17	2.48	98.75	1.128	91.50	8.96	8.08	2.80	111.34
4	FY 2025-26	30.00%	30.00%	81.15	7.95	7.17	1.49	97.76	1.183	95.97	9.40	8.48	1.76	115.61
5	FY 2026-27	15.00%		40.58	3.98	3.59	0.00	48.15	1.241	50.34	4.94	4.45		59.73
6	FY 2027-28	5.00%		13.53	1.33	1.20	0.00	16.06	1.301	17.60	1.73	1.56		20.89
Total		**100.00%**	**100.00%**	**270.51**	**26.51**	**23.91**	**4.96**	**325.89**		**313.57**	**30.73**	**27.71**	**5.62**	**377.63**

TABLE 17-11: COMPONENT WISE ESCALATION FOR LINE 2B

Year	FY	Cost Phasing	Land Phasing	Cost at July 2022 Price Level (Rs. Cr.)					Escalation Factor (5% p.a)	Completion Cost (Cr.)				
				Component Cost without taxes, Land and R&R	Central Taxes	State Taxes	Land and R&R	Total Cost excl IDC		Component Cost without taxes, Land and R&R	Central Taxes	State Taxes	Land and R&R	Total Cost excl IDC
1	FY2022-23								1.025					
2	FY 2023-24	20.00%	20.00%	433.57	43.92	38.42	14.97	530.88	1.075	466.09	47.21	41.30	16.09	570.69
3	FY 2024-25	30.00%	50.00%	650.35	65.88	57.64	37.42	811.29	1.128	733.27	74.28	64.99	42.19	914.73
4	FY 2025-26	30.00%	30.00%	650.35	65.88	57.64	22.44	796.31	1.183	769.12	77.91	68.17	26.54	941.74
5	FY 2026-27	15.00%		325.17	32.94	28.82		386.93	1.241	403.38	40.86	35.75		479.99
6	FY 2027-28	5.00%		108.39	10.98	9.60		128.97	1.301	141.05	14.29	12.49		167.83
Total		**100.00%**	**100.00%**	**2167.83**	**219.60**	**192.12**	**74.83**	**2654.38**		**2512.91**	**254.55**	**222.70**	**84.82**	**3074.98**

17.6 ESTIMATIONS OF OPERATION AND MAINTENANCE COSTS

Operation and Maintenance costs for Line 2A and Line 2B has been worked out under three major heads:

- Staff cost
- Maintenance cost which includes expenditure towards upkeep and maintenance of the system and consumables and
- Energy cost

17.6.1 STAFF COST

The O&M staff for the metro is assumed to be provided @ 28 persons per kilometre and the annual cost on this account is estimated considering average staff salary of Rs. 10 Lakh per annum in the Financial Year 2022-23. The escalation factor used for staff costs is 9% per annum to provide for growth in salaries. The estimated staff cost is Rs. 35.80 Crore in FY 2022-23.

TABLE 17-12: STAFF COSTS

Particulars	Nos/km	Nos	Rs Cr/staff	Amount (Rs. in Cr)	Escalation
Staff Cost	28	358	0.1	**35.80**	9%

17.6.2 MAINTENANCE EXPENSE

The maintenance expenses are taken @ Rs 37.80 Crore per annum at July 2022 Prices (Refer Table 17-13) Escalation of 5% has been assumed.

TABLE 17-13: MAINTENANCE COSTS

SN	Cost Description	Amount (Rs. in Cr.) PA	
1	Station,OCC & Depot maintenance cost (civil & elect)	₹ 10.73	2% of Station Capital Cost
2	RS repairs & maintenance cost	₹ 4.50	Rs 10 lakh per car
3	S&T, AFC maintenance cost	₹ 13.00	Rs 1 cr per station
4	Track Maintenance cost	₹ 2.08	2% of P-Way Cost
5	Traction & Power Supply	₹ 3.42	2% of Power Supply & Electrification
6	**Sub-total**	**₹ 33.73**	
7	Other misc costs @10%	₹ 3.37	
8	Cyber Security & Audit	₹ 0.7	
9	**Maintenance & Repair Cost per annum (Rs cr)at July 2022 Prices**	**₹ 37.80**	

17.6.3 ENERGY CHARGES

The energy consumption to meet the traction and non-traction power requirement is based on traffic demand for different horizon years. Table 17-14 represents the estimated power consumption per year on the Line 2A and Line 2B.

TABLE 17-14: ESTIMATED POWER CONSUMPTION (IN CR KWH) ON LINE 2A AND LINE 2B

	Power Consumption (in Cr KwH)			
	2027	2037	2047	2057
Line 2A West Extension (Vanaz to Chandani Chowk)	0.34	0.38	0.46	0.50
Line 2B East Extension (Ramwadi to Vitthalwadi)	2.29	2.67	3.37	3.70
Total Energy Consumption (Traction+ Auxiliary)	**2.63**	**3.05**	**3.83**	**4.20**

The cost of electricity is a significant part of O&M charges. It is assumed that 80% of the traction power requirement shall be drawn from the grid, whereas the remaining 20% from the solar as per the RESCO model. The traction power tariff is taken @ Rs. 6 per unit and Rs 4 per unit in the year FY 2022-23 for Grid and Solar power respectively. The power tariffs have been escalated @ 5% every 3 year of operation.

17.6.4 ADDITIONAL INVESTMENT AND REPLACEMENT COST

Capital replacement cost includes cost of the equipment comprising electrical, rolling stock and signalling & telecom. Replacement cost is added during the operation period.

To cater to the increased traffic demand, additional investment needs to be made for the purchase of the additional coaches.

The additional investment is for 3 coaches in 2037-38, 45 coaches in 2047-48 and 24 coaches in 2057-58. The estimated costs are escalated at 5% per annum

The replacement costs for Electrical and Telecommunication equipment are provided for meeting the cost on account of replacement of equipment due to wear and tear.

With the nature of equipment proposed to be provided for the corridor, it is expected that about 25% of the equipment comprising Electrical and 50% of Telecom would require replacement/ rehabilitation after 15 years of operation.

It also includes the Cost of the Satellite Depot Land Rs 88.62 Cr and Satellite Depot Development Charges Rs 141.71 Crore, at July 2022 price level. The depot is anticipated to developed and operational by the end of year 2047-48. Escalation of 5% per annum is considered for land and depot.

TABLE 17-15:ADDITIONAL INVESTMENT AND REPLACEMENT COST

Escalated Replacement Cost (Rs. In Cr.)	2037-38	2042-43	2046-47	2047-48	2057-58
Additional Rolling Stock	60.81			1486.00	1290.97
50% of Signaling& Telecom and 25% of Electrical Works		344.00			715.15
Satellite Depot Land Cost [1] (100%)			285.81		
Depot Development Charges (70%)			216.15	340.43	
Total	**60.81**	**344.00**	**501.96**	**1826.43**	**2006.12**

As the O&M period starts from June 2027 thus, O&M Cost for FY 2027-28 is considered for 10 months. The summary of O & M Costs during Operation period of 30 years is represented in Table 17-16

TABLE 17-16: SUMMARY OF THE O & M COSTS (RS IN CRORES)

Financial Year	(Rs. in Crore)				
	Staff Cost (Esc. @9%)	Maintenance Cost (Esc. @5%)	Energy Cost (Esc @5%)	Total O & M Cost	Additional Cost & Replacement Costs[2]
2027-28	45.9	40.2	12.88	98.98	
2028-29	60.04	50.66	16.46	127.16	
2029-30	65.44	53.19	16.71	135.34	
2030-31	71.33	55.85	16.96	144.14	
2031-32	77.75	58.64	18.08	154.47	
2032-33	84.75	61.57	18.35	164.67	
2033-34	92.38	64.65	18.62	175.65	
2034-35	100.69	67.88	19.85	188.42	
2035-36	109.76	71.28	20.14	201.18	
2036-37	119.63	75.49	20.45	215.57	
2037-38	130.4	79.27	21.79	231.46	60.81
2038-39	142.14	83.23	22.3	247.67	
2039-40	154.93	87.39	22.81	265.13	
2040-41	168.87	91.76	24.51	285.14	
2041-42	184.07	96.35	25.07	305.49	
2042-43	200.64	101.17	25.65	327.46	344
2043-44	218.7	106.23	27.56	352.49	
2044-45	238.38	111.54	28.19	378.11	
2045-46	259.83	117.12	28.85	405.8	
2046-47	283.22	138.94	30.99	453.15	501.96
2047-48	308.71	145.88	31.71	486.3	1826.43
2048-49	336.49	153.18	32	521.67	

[1] Details given in Chapter 14 Section 14.1.2
[2] Refer Chapter 17 section 17.6.4

Financial Year	(Rs. in Crore)				
	Staff Cost (Esc. @9%)	Maintenance Cost (Esc. @5%)	Energy Cost (Esc @5%)	Total O & M Cost	Additional Cost & Replacement Costs[2]
2049-50	366.77	160.84	33.91	561.52	
2050-51	399.78	168.88	34.22	602.88	
2051-52	435.76	177.32	34.54	647.62	
2052-53	474.98	186.19	36.6	697.77	
2053-54	517.73	195.5	36.94	750.17	
2054-55	564.33	205.27	37.28	806.88	
2055-56	615.12	215.54	39.51	870.17	
2056-57	670.48	240.18	39.88	950.54	
2057-58	121.8	42.03	6.71	170.54	2006.12

The same is further discussed in Chapter 19.

ANNEXURE 17.1

CONSTRUCTION OF FOB (STEEL)			
Contruction of FOB of Length 100 m.			
FOB - STEEL			
Prepared By-			
SR.NO.	**DESCRIPTION**	**AMOUNT (In INR)**	**Percentage**
A	Excavation & Dismantling	387671.13	0.78
B	Foundation & Drain	11277550.71	22.81
C	Structural Steel, Flooring,Staircase & Roofing	35432808.27	71.67
D	Miscellaneous	494029.20	1.00
E	Lifts	1848446.00	3.74
	Total Amount	**49,440,505.31**	100.00
	Contengency @ 3%	1,483,215.16	
	Total	**50,923,720.47**	**5.09 Cr.**
Note-1. Reference mentioned As per relevant to PWD/MCGM & MORT&H Specification			
2. Utilities shifting given in Abstract sheet taken as actual			

CONSTRUCTION OF FOB (STEEL)

Contruction of FOB of Length 100 m.

FOB - STEEL

Prepared

SR.NO.	Refference	ITEM DESCRIPTION	UNIT	RATE	QTY.	AMOUNT
		A. Excavation & Dismantling				
1	PWD SSR 2022-23 12.06 Page No.	Excavation for foundation in hard murum and boulders including shoring and strutting, dewatering as necessary and disposing off excavated stuff as directed etc. complete. a) Upto 1.50m lift Normal Rate b) 1.50m to 3.00m lift, Add 10% c) 3.00m to 4.50m lift, Add 20% d) 4.50m to 6.0m lift, Add 30%	CUM	300.30	254.00	**76276.2**
2	PWD SSR 2022-23 12.08 Page No.	Excavation for foundation in soft rock including shoring and strutting, dewatering as necessary and disposing off excavated stuff as directed etc. complete. a) Upto 1.50m lift Normal Rate b) 1.50m to 3.00m lift, Add 10% c) 3.00m to 4.50m lift, Add 20% d) 4.50m to 6.0m lift, Add 30%	CUM	643.34	254.00	**163407.09**
3	PWD SSR 2022-23 12.09 Page No.	Excavation for foundation in hard rock by blasting including shoring and strutting, dewatering as necessary and disposing off excavated stuff as directed etc. complete. a) Upto 1.50m lift Normal Rate b) 1.50m to 3.00m lift, Add 10% c) 3.00m to 4.50m lift, Add 20% d) 4.50m to 6.0m lift, Add 30%	CUM	1422.96	104.00	**147987.84**
					Sub Total	**387671.13**

SR.NO.	Refference	ITEM DESCRIPTION	UNIT	RATE	QTY.	AMOUNT
		B. Foundation				
4	PWD SSR 2022-23 24.04 Page No.	Providing and laying Cast in situ/Ready Mix cement concrete in M15 of trap/ granite/quartzite/gneiss metal for foundation and bedding / steps including steel centering, formwork, laying/pumping, compacting, roughening them if special finish is to be provided, finishing uneven and honeycombed surface and curing etc. complete. The Cement Mortar 1:3 plaster is considered for rendering uneven and honeycombed surface, only. Newly laid concrete shall be covered by gunny bag, plastic, tarpaulin etc. (Wooden centering will not be allowed.),with fully automatic micro processor based PLC with SCADA enabled reversible Drum Type mixer/concrete Batch mix plant (Pan mixer) etc. complete. With fine aggregate (Crushed sand VSI Grade)	CUM	6676.95	31.20	**208320.84**
5	PWD SSR 2022-23 26.05 Page No.	Providing and laying Cast in situ/Ready Mixcement concrete M-20 of trap/ granite/ quartzite/ gneiss metal for R.C.C. chajja as per detailed design and drawings including steel centering, formwork, cover blocks, laying/pumping, compacting and roughening the surface if special finish is to be provided and curing complete. (Excluding reinforcement and structural steel). with fully automatic micro processor based PLC with SCADA enabled reversible Drum Type mixer/ concrete Batch mix plant (Pan mixer) etc. complete. With fine aggregate (Crushed sand VSI Grade)	CUM	14628.60	410.01	**5997843.03**
6	PWD SSR 2022-23 26.34 Page No.	Providing and fixing in position HCRM / CRS (Corrosion Resistant Steel) bar reinforcement of various diameters for R.C.C. pile caps, footings, foundations, slabs, beams columns, canopies, staircase, newels, chajjas, lintels pardis, copings, fins, arches etc. as per detailed designs, drawings and schedules. including cutting, bending, hooking the bars, binding with wires or tack welding and supporting as required complete.	Metric Tonns	98842.80	51.31	**5071386.85**
					Sub Total	**11277550.71**

SR.NO.	Refference	ITEM DESCRIPTION	UNIT	RATE	QTY.	AMOUNT
		D. Miscellaneous				
13	PWD SSR 2022-23 6.36 Page No.	Providing and fixing board displaying information, such as 'Name of work, Tender cost, Name of Contractor, Work completion and liability period etc', having rectangular shape of 1.20m x 0.90m size made out 18 gauge (1.25mm) thick mild steel sheet painted with one coat of Zinc chromate stoving primer and two coats of enamel paint on front side and grey stove enamel on back side and border / messages / symbols etc. with approved colour shade paint complete, on M.S.angle of size 35 x 35 x 3 mm frame with properly cross braced M.S. angles of size 35mmx35mmx3mm duly painted including Two M.S. angle iron posts of size 65 mm x 65 mm x 6 mm, 3.65 m long painted with alternate black and white bands of 25 cm width including all fixtures etc.and fixing the boards in 1:4:8 concrete block of size 60 cm x 60 cm x 75 cm including, excavation, refilling, transportation, and labour etc complete. Spec. No. As directed by Engineer in Charge	NOS	10461.15	8.00	83689.20
14	PWD SSR 2022-23 17.71 Page No.	Providing and removing barricading with the help of portable fencing along the running track where the work is to be done in close vicinity of the track. Fencing shall consist of self supporting steel angles of size 50 x50x6mm, 1.5m long provided with hooks etc. and embedded in CC 1:2:4 block of size 0.23x0.23x0.23M placed at c/c distance of 2.0 M along the track. 12 mm dia rods in three horizontal layers tack welded with the angle posts including providing Retro-reflective tapes in Horizontal & vertical direction. Note : Released material will be the property of the contractor after the completion of work. Cost of cement to be paid separately.	RMT	616.35	100.00	61635.00
15	PWD SSR 2022-23 50.46 a Page No.	Providing Heavy Duty Fibre Glass Reinforced Plastic Temporary Barricade of 1.75 m hight, with base width of 430 mm as a provision to accept water ballasting of 101 ltrs-110 Ltrs approx. and arrangement for traffic diversion such as traffic signals during construction at site, for day and night as per requirement. The raw material shall be UV stabilized Linear Low Density Polyethylene and should meet the requirements stipulated in standard IS: 10146-1982, IS:10141-1982 and should also comply to FDA:CFR Title 21.177.1520. Olefin Polymers , with specific FRP Grade 300-104 reinforced during moulding process to the permissible extent for improved impact strength. Qualification Criteria: For qualifying the sample , few tests shall be performed at Government Lab OR NABL Accredited Lab on Site Safety Fence sample, failure or deviations in test results of sample shall be disqualified.The tests and qualifying results are as under, (a) tensile strength at yield by ASTM D 638 =20.93 mPA, (b) Elongation at break ASTM D 638 = 121.66 mPA (c) Flexural Modulus ASTM D 790 = 633.76 mPA (d) Izod Impact Strenth (Notched) ASTM D 256 = 4.41Kilogram/ One Square Metre (e) Izod Impact Strenth (Un-Notched) ASTM D 256 = 67.04Kilogram/ One Square Metre (f) Drop Impact strength 25KilogramLoad from 1 m, 2 m & 5m height the weight of empty single Rotomoulded Plastic Barricade without water ballasting shall be 34 Kilograms approx. & total weight after water allasting shall be 135 Kilograms -140 Kilograms +/- 5 Kilograms (tolarance)The main Barricade body of hight 1750 mm approx is connected with the Extension body through 4 set of nut bolt washers .extenstion body through 4 set of nut bolt washers. Extension body is designed with 9 Nos kiss offs on rear side; the dimension of Extension body are 1500 mm (length),70 mm (width),250 mm (effetive height after fixing) & dimension of its male collarare 1420 mm (length),25 mm (width),30 mm approx (height), it is inserted in U groove provisioned on top of main body Barricade Model for interlconnecting.the minimum thickness of all over surface of plastic barricaed shall be 5 mm +/- 20%.the rear bottam shall have to provision to fix two brackets at both end in corner for anchoring purpose .each rear bracket is constructed through rod of Dia.60 mm with curvature welded with MS strip of 3 mm thick ,50 mm width and 90 mm length at its top and base ,effective bracket shall be 410 mm approx. the anchoring hole in each bracket shall be 18 mm dia. for routine the MS bolts of 16 mm thickness and 150 mm length with sharp pointed edge at one end .the upper part of each bracket shall have a slot size of 30 mm x 10 mm for connecting it with barracade model through bolts.similarly front bracket for site safety fence is 3 mm thick ,50 mm width, feective height after single bend is 230 mm and anchoring in each bracket shall be dia 18 mm unique safety feature for firm gripping to prevent from displacement and falling when inter connected even without water filling . There shall be 7 no's premoulded inserts on site Safety Fence for following application: 2no's for safety latches interconnectivity, 2 no's for fixing rear brackets for anchoring, one One Number at front side for fixing the front bracket for higher stability, and 2 nos on Extension top for holding light brackets / Rod for cloth holding. The plastic barricades has a strong vertical rib of 1740 mm length at the rear centre & 72 No's of kiss offs spread on entire rear surface , the water container (bottom) will also be equipped with 2 additional ribs on top to withstand nominal load if applied over its surface. The Fibre glass Reinforced Plastic Site Safety Fence shall have one drain bung insert moulded with plastic plug , two injection moulded water caps/ lids for base tank, and one yellow black zebra reflective tape as integrated accessories. Please refer the detailed drawing of Site Safety Fence. During construction barricading and arrangement for traffic diversion has to be kept contonuously and maintained properly till the completion of all the activities. All required Project details as per standards shall be screen printed on each board. Other requirements as per Specification in Contract. with prior approval of concerned Superitending Engineer.				
		a) For 725 mm height (LType Jersey Barrier) ,Empty Weight:6.67 Kilogram/ Rgm,Weight Full : 35.89Kilogram/ Rgm approx. (After Water / Sand Filling)	RMT	1938.3	0.00	0.00

SR.NO.	Refference	ITEM DESCRIPTION	UNIT	RATE	QTY.	AMOUNT
16	PWD SSR 2022-23 42.62 Page No.	Providing and fixing reinforced cement concrete cover of size 90 cm x 45 cm with frame over inspection chamber etc. complete. Heavy duty (225 Kilogram)	NOS	5923.05	0.00	0.00
17	PWD SSR 2022-23 Sr. No.56 Page No.546	Providing traffic wardens for regulation of traffic during construction as per the requirement of traffic police, etc. complete and as directed by Engineer-incharge.	Shift	645.75	540.00	348705.00
					Sub Total	**494029.20**
		E. Lifts				
18	MMRDA Rates	Design, Manufacture, Supply, Installation, Testing and Commissioning including comprehensive maintainance during DLP of Heavy Duty Machine room less elevators (Lifts)	NOS	1848446.00	1.00	**1848446.00**
		Utility Shifting				
	AS ACTUAL	Electric Box	NOS			
	AS ACTUAL	Traffic Signal	NOS			
	AS ACTUAL	Telephone Box	NOS			
	AS ACTUAL	Sign Board	NOS			
	AS ACTUAL	Elec. Transformer	NOS			
	AS ACTUAL	Gpost, Mall Post Box	NOS			

CONSTRUCTION OF FOB (STEEL)

Contruction of FOB of Length 100 m.

FOB - STEEL

Prepared by-

SR.NO.	DESCRIPTION	UNIT	NOS	L	B	H	QUANTITY
	A. Excavation & Dismantling						
1	Excavation for foundation in hard murum and boulders including shoring and strutting, dewatering as necessary and disposing off excavated stuff as directed etc. complete. a) Upto 1.50m lift Normal Rate b) 1.50m to 3.00m lift, Add 10% c) 3.00m to 4.50m lift, Add 20% d) 4.50m to 6.0m lift, Add 30%	CUM	26.00	2.00	2.00	1.00	**254.00**
2	Excavation for foundation in soft rock including shoring and strutting, dewatering as necessary and disposing off excavated stuff as directed etc. complete. a) Upto 1.50m lift Normal Rate b) 1.50m to 3.00m lift, Add 10% c) 3.00m to 4.50m lift, Add 20% d) 4.50m to 6.0m lift, Add 30%	CUM	26.00	2.00	2.00	1.00	**254.00**
3	Excavation for foundation in hard rock by blasting including shoring and strutting, dewatering as necessary and disposing off excavated stuff as directed etc. complete. a) Upto 1.50m lift Normal Rate b) 1.50m to 3.00m lift, Add 10% c) 3.00m to 4.50m lift, Add 20% d) 4.50m to 6.0m lift, Add 30%	CUM	26.00	2.00	2.00	1.00	**104.00**
	C. Foundation, Drain & Lift Block						
4	Providing and laying Cast in situ/Ready Mix cement concrete in M15 of trap/ granite/quartzite/gneiss metal for foundation and bedding / steps including steel centering, formwork, laying/pumping, compacting, roughening them if special finish is to be provided, finishing uneven and honeycombed surface and curing etc. complete. The Cement Mortar 1:3 plaster is considered for rendering uneven and honeycombed surface, only. Newly laid concrete shall be covered by gunny bag, plastic, tarpaulin etc. (Wooden centering will not be allowed.),with fully automatic micro processor based PLC with SCADA enabled reversible Drum Type mixer/concrete Batch mix plant (Pan mixer) etc. complete. With fine aggregate (Crushed sand VSI Grade)	CUM	26.00	2.00	2.00	0.30	**31.20**
5	Providing and laying Cast in situ/Ready Mixcement concrete M-20 of trap/ granite/ quartzite/ gneiss metal for R.C.C. chajja as per detailed design and drawings including steel centering, formwork, cover blocks, laying/pumping, compacting and roughening the surface if special finish is to be provided and curing complete. (Excluding reinforcement and structural steel). with fully automatic micro processor based PLC with SCADA enabled reversible Drum Type mixer/ concrete Batch mix plant (Pan mixer) etc. complete. With fine aggregate (Crushed sand VSI Grade)						
	For Foundation, Drain & Lift Block	CUM	26.00	2.00	2.00	2.00	326.80
	For Concrete Pedestal	CUM	26.00	1.20	1.20	0.70	26.21
	For Walk way	CUM		100.00	3.00	0.15	45.00
	For Staircase & Landing	CUM		80.00	3.00	0.05	12.00
						Sub Total	**410.01**
6	Providing and fixing in position HCRM / CRS (Corrosion Resistant Steel) bar reinforcement of various diameters for R.C.C. pile caps, footings, foundations, slabs, beams columns, canopies, staircase, newels, chajjas, lintels pardis, copings, fins, arches etc. as per detailed designs, drawings and schedules. including cutting, bending, hooking the bars, binding with wires or tack welding and supporting as required complete.	Metric Tonns					**51.31**
	D. Structural Steel, Flooring, Staircase & Roofing						

7	Providing. detailing, fabricating and fixing at desired location using hot rolled sections and M S Plates (E350 Grade) of high grade steel as per specifications and approved fabrication drawings (which are to be prepared by Contractor and goi approved from Engineer), transporting to site and erecting/launching structural steel members/girders for all heights & at all levels including provision of necessary erection/ launching acsessaries and machinary for erection/ launching, bolts, fixing bolts, nuts, washers, cleats, stiffeners, gussets, baseplate and all necessary fixtures and operations like preheating as per specifications, straightening, bending, cutting, drilling, grinding, machining if specified, welding, grinding and removing the welding burr and preparing surface for painting with Sand blasting, metalizing and painting of loose fabricated components and girders with sprayed aluminium followed by protective coating of painting outside running line complete with contractor's own point, other material, labour, scaffolding, consumable.	Metric Tonns					**120.00**
8	Providing and fabricating structural steel work in rolled sections like joists, channels, angles, tees etc. as per detailed design and drawings or as directed including cutting, fabricating, hoisting, erecting, fixing in position making riveted / bolted /welded connections without connecting plates, braces etc. and including one coat of anticorrosive paint and over it two coats of oil painting of approved quality and shade etc. complete.	Metric Tonns					
						Sub Total	**30.00**
9	Providing sacrificial shuttering for deck slab made up with galvanised Cold Rolled Cold Annealed (CRCA) steel of 310 MPA Grade with all Contractor's material, labour, erection fixing, welding etc. (Decking Sheet) (For Walk way)	Metric Tonns					**3.84**
10	Providing and fixing machine cut machine polished 18 mm to 20 mm thick telephone black / Amba White / Cat bary brown / RBI red / Ocean Brown granite stone for treads and risers of steps and staircases of approved colour and shade with full moulding and three grooved line for the treads on bed of 1:4 Cement mortar including float filling joints with neat cement slurry curing polishing and cleaning etc. complete.						
	For Walk way	SQM		100.00	3.20		320.00
	For Staircase & Landing	SQM		80.00	3.20		256.00
						Sub Total	**720.00**
11	Providing and fixing UPVC Roof made up of 3 layers roofing material of thickness 2mm having width of 1130 mm and of required Length having Tensile strength not less than 330 Kilogram/cm2, including fastening with self drilling screw having washers made of stainless steel etc. complete.	SQM		660.00	3.50		**2887.50**
12	Providing and Fixing mat finish stainless steel (of 302 grade) railing with top pipe of 50 mm dia. and vertical pipe of 38 mm dia at 0.60 m c/c or as required and horizontal pipes of 25 mm dia in three rows, all pipes of 2 mm thick including buffing,fabricating fixtures and fastening including pipe base of appropriate diameter and ball base of 75 mm dia above newel post of 75 mm diameter etc. complete (Prior approval of sample and brand by Ex.Engineer is necessary before use)	RMT		396.00			**495.00**
	E. Miscellaneous						
13	Providing and fixing board displaying information, such as 'Name of work, Tender cost, Name of Contractor, Work completion and liability period etc', having rectangular shape of 1.20m x 0.90m size made out 18 gauge (1.25mm) thick mild steel sheet painted with one coat of Zinc chromate stoving primer and two coats of enamel paint on front side and grey stove enamel on back side and border / messages / symbols etc. with approved colour shade paint complete, on M.S.angle of size 35 x 35 x 3 mm frame with properly cross braced M.S. angles of size 35mmx35mmx3mm duly painted including Two M.S. angle iron posts of size 65 mm x 65 mm x 6 mm, 3.65 m long painted with alternate black and white bands of 25 cm width including all fixtures etc.and fixing the boards in 1:4:8 concrete block of size 60 cm x 60 cm x 75 cm including, excavation, refilling, transportation, and labour etc complete. Spec. No. As directed by Engineer in Charge	NOS	8.00				**8.00**
14	Providing and removing barricading with the help of portable fencing along the running track where the work is to be done in close vicinity of the track. Fencing shall consist of self supporting steel angles of size 50 x50x6mm, 1.5m long provided with hooks etc. and embedded in CC 1:2:4 block of size 0.23x0.23x0.23M placed at c/c distance of 2.0 M along the track. 12 mm dia rods in three horizontal layers tack welded with the angle posts including providing Retro-reflective tapes in Horizontal & vertical direction. Note : Released material will be the property of the contractor after the completion of work. Cost of cement to be paid separately.	RMT		200.00			**200.00**

15	Providing Heavy Duty Fibre Glass Reinforced Plastic Temporary Barricade of 1.75 m hight, with base width of 430 mm as a provision to accept water ballasting of 101 Itrs-110 Ltrs approx. and arrangement for traffic diversion such as traffic signals during construction at site, for day and night as per requirement. The raw material shall be UV stabilized Linear Low Density Polyethylene and should meet the requirements stipulated in standard IS: 10146-1982, IS:10141-1982 and should also comply to FDA:CFR Title 21.177.1520. Olefin Polymers , with specific FRP Grade 300-104 reinforced during moulding process to the permissible extent for improved impact strength. Qualification Criteria: For qualifying the sample , few tests shall be performed at Government Lab OR NABL Accredited Lab on Site Safety Fence sample, failure or deviations in test results of sample shall be disqualified.The tests and qualifying results are as under, (a) tensile strength at yield by ASTM D 638 =20.93 mPA, (b) Elongation at break ASTM D 638 = 121.66 mPA (c) Flexural Modulus ASTM D 790 = 633.76 mPA (d) Izod Impact Strenth (Notched) ASTM D 256 = 4.41Kilogram/ One Square Metre (e) Izod Impact Strenth (Un-Notched) ASTM D 256 = 67.04Kilogram/ One Square Metre (f) Drop Impact strength 25KilogramLoad from 1 m, 2 m & 5m height the weight of empty single Rotomoulded Plastic Barricade without water ballasting shall be 34 Kilograms approx. & total weight after water allasting shall be 135 Kilograms - 140 Kilograms +/- 5 Kilograms (tolarance)The main Barricade body of hight 1750 mm approx is connected with the Extension body through 4 set of nut bolt washers .extenstion body through 4 set of nut bolt washers. Extension body is designed with 9 Nos kiss offs on rear side; the dimension of Extension body are 1500 mm (length),70 mm (width),250 mm (effetive height after fixing) & dimension of its male collarare 1420 mm (length),25 mm (width),30 mm approx (height), it is inserted in U groove provisioned on top of main body Barricade Model for interlconnecting.the minimum thickness of all over surface of plastic barricaed shall be 5 mm +/- 20%.the rear bottam shall have to provision to fix two brackets at both end in corner for anchoring purpose .each rear bracket is constructed through rod of Dia.60 mm with curvature welded with MS strip of 3 mm thick ,50 mm width and 90 mm length at its top and base ,effective bracket shall be 410 mm approx. the anchoring hole in each bracket shall be 18 mm dia. for routine the MS bolts of 16 mm thickness and 150 mm length with sharp pointed edge at one end .the upper part of each bracket shall have a slot size of 30 mm x 10 mm for connecting it with barracade model through bolts.similarly front bracket for site safety fence is 3 mm thick ,50 mm width, feective height after single bend is 230 mm and anchoring in each bracket shall be dia 18 mm unique safety feature for firm gripping to prevent from displacement and falling when inter connected even without water filling . There shall be 7 no's premoulded inserts on site Safety Fence for following application: 2no's for safety latches interconnectivity, 2 no's for fixing rear brackets for anchoring, one One Number at front side for fixing the front bracket for higher stability, and 2 nos on Extension top for holding light brackets / Rod for cloth holding. The plastic barricades has a strong vertical rib of 1740 mm length at the rear centre & 72 No's of kiss offs spread on entire rear surface , the water container (bottom) will also be equipped with 2 additional ribs on top to withstand nominal load if applied over its surface. The Fibre glass Reinforced Plastic Site Safety Fence shall have one drain bung insert moulded with plastic plug , two injection moulded water caps/ lids for base tank, and one yellow black zebra reflective tape as integrated accessories. Please refer the detailed drawing of Site Safety Fence. During construction barricading and arrangement for traffic diversion has to be kept contonuously and maintained properly till the completion of all the activities. All required Project details as per standards shall be screen printed on each board. Other requirements as per Specification in Contract. with prior approval of concerned Superitending Engineer.						
	a) For 725 mm height (LType Jersey Barrier) ,Empty Weight:6.67 Kilogram/ Rgm,Weight Full : 35.89Kilogram/ Rgm approx. (After Water / Sand Filling)	RMT		0.00			**0.00**
16	Providing and fixing reinforced cement concrete cover of size 90 cm x 45 cm with frame over inspection chamber etc. complete. Heavy duty (225 Kilogram)	NOS	0.00				**0.00**
17	Providing traffic wardens for regulation of traffic during construction as per the requirement of traffic police, etc. complete and as directed by Engineer-incharge.	Shift	2.00	270.00			**540.00**
	F. Lifts						
18	Design, Manufacture, Supply, Installation, Testing and Commissioning including comprehensive maintainance during DLP of Heavy Duty Machine room less elevators (Lifts)	NOS	1.00				**1.00**

CHAPTER 18. TRANSIT ORIENTED DEVELOPMENT

Transit-Oriented Development is essentially a development concept, 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 or cycle and use public transportation over personal modes of transport. It could be located within a quarter-to half-km radius of a transit station that offers a mix of housing, offices, shopping, and transportation choices within a neighbourhood or business district. The primary goals of TOD are to:

- Reduce/discourage private vehicle dependency and induce public transport use – through design, policy measures & enforcement.
- 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, TODs 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.

TOD implies high quality, thoughtful planning and design of land use and built forms to support, facilitate and prioritize not only the use of transit, but the most basic modes of transport - walking and cycling

18.1. OBJECTIVES OF TRANSIT ORIENTED DEVELOPMENT

The primary objectives of the transit oriented development include -

- 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
- Pedestrian and NMT friendly environment
- Manage parking for bus and vehicular traffic, and prioritizing parking for PT/IPT and NMT modes at-grade and on-street, within the station vicinity area.
- Design for pedestrian safety, comfort and convenience on all street's connectivity
- Design infrastructure to ensure rapid and comfortable transfers
- Provide value for both new and existing residents

18.2. NATIONAL TOD POLICY

National TOD policy is aimed to serve as guideline and play a catalytic role in formulating state/city level policies for the promotion of transit oriented development. This would help state and cities to recognize public transport infrastructure as the core around which future expansion of the city should be planned and investments in public transport be directed accordingly. This shall also help in the active participation of all relevant stakeholders for implementation of TOD.

The vision of TOD policy is to:

- **Enable Transformation:** to assist transformation from private mode dependency to public transport
- **Accessible Public Transport:** to promote usage of PT by making it more accessible, promotion of green and active modes of transport, at the same time to reduce the negative impacts of motorization on environment
- **Compact Walkable Communities:** create liveable and affordable communities

18.2.1. APPROACH TO TOD IMPLEMENTATION

TOD Policy suggests that the influence area should be demarcated and notified through master plan and local area plans before implementation, with principles of delineating the influence area clearly mentioned to avoid speculations and confusions. TOD policy promotes the following strategies for the influence area:

- High density compact development
- Mixed use development
- Inclusive housing
- Multi modal integration
- Focus on pedestrians, cyclists and NMT users

- Street oriented building and vibrant public spaces
- Managed parking

18.3. NEED OF DETAILED STUDY

TOD proposal will increase the accessibility of the transit stations by creating pedestrian and non-motorized 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.

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 live-able communes with high density mixed land-use.

Along with this, 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. Value Capturing Financing (VCF) mechanisms give opportunity to capture the value of these benefits from the beneficiaries. In TOD influence area, premium levy can be charged on incremental FAR proposed. Thus, this amount shall be used to fund the transit system. Thus, in order to identify TOD potential in the study area, station wise detailed assessment is done.

18.4. TOD PROPOSAL FOR PUNE METRO LINE 2 EXTENSIONS

18.4.1. INFLUENCE AREA DEMARCATION

The area in the immediate vicinity of the transit station 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. Influence zone is established along the transit stations here. The planning area for TOD implementation has been delineated as zone of about 500m around the transit station boxes as per the Pune TOD Policy. For stations beyond the PMC limits, which fall under the PMRDA area, the

same has been considered *(Unified Development Control and Promotion Regulation for Maharashtra State, 2020, Section 14.2.2).*

18.4.2. TOD PRINCIPLES

18.4.2.1. COMPACT DEVELOPMENT AND 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.

Image Courtesy - southsydneyherald.com.au

To ensure sustainable development, the minimum FSI proposed is 2 and maximum goes up to 4, depending on the plot size and abutting right of way. 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, decreased pollution and reduced congestion.

18.4.2.2. MIXED USE DEVELOPMENT

Mixed land use is stipulated for development/ redevelopment in the TOD zone as it would reduce the need to 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 also ensure better utilization of transit fleet by distributing loads in both directions, rather than creating unidirectional peak hour flows.

To promote such development, high grade commercial development is proposed along the existing arterial road i.e. Pune Ahmednagar Highway to minimize the requirement of road widening. Existing arterial road with ROW > 30m can easily serve the high-density commercial development with FSI in the range - 3 to 4. 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'. Following the commercial belt, high density residential development is envisaged.

18.4.2.3. IMPROVE CONNECTIVITY AND ACCESSIBILITY

Achieving high level of connectivity ensures a successful TOD. As each station increases its reach, it serves larger community, and thereby access to the region's economy is improved. Better connectivity can be achieved through:

- Developing neighbourhoods that promote walking by good pedestrian facilities;
- Prioritizing non-motorised transport;
- Creating dense network of streets and paths

18.4.3. INVENTORY OF THE TOD ZONES & OVERALL ACTIVITY PATTERN

The general land use mix observed for the TOD zones from Viman Nagar Station to Vitthalwadi Station is majorly commercial, industrial, public and semi-public, and residential mix. High rise residential is also observed near Wagheshwar Temple Station and Wagholi Station. Figure 18-1 provide general details of land use in the TOD Zones of the transit stations from Viman Nagar to Vitthalwadi.

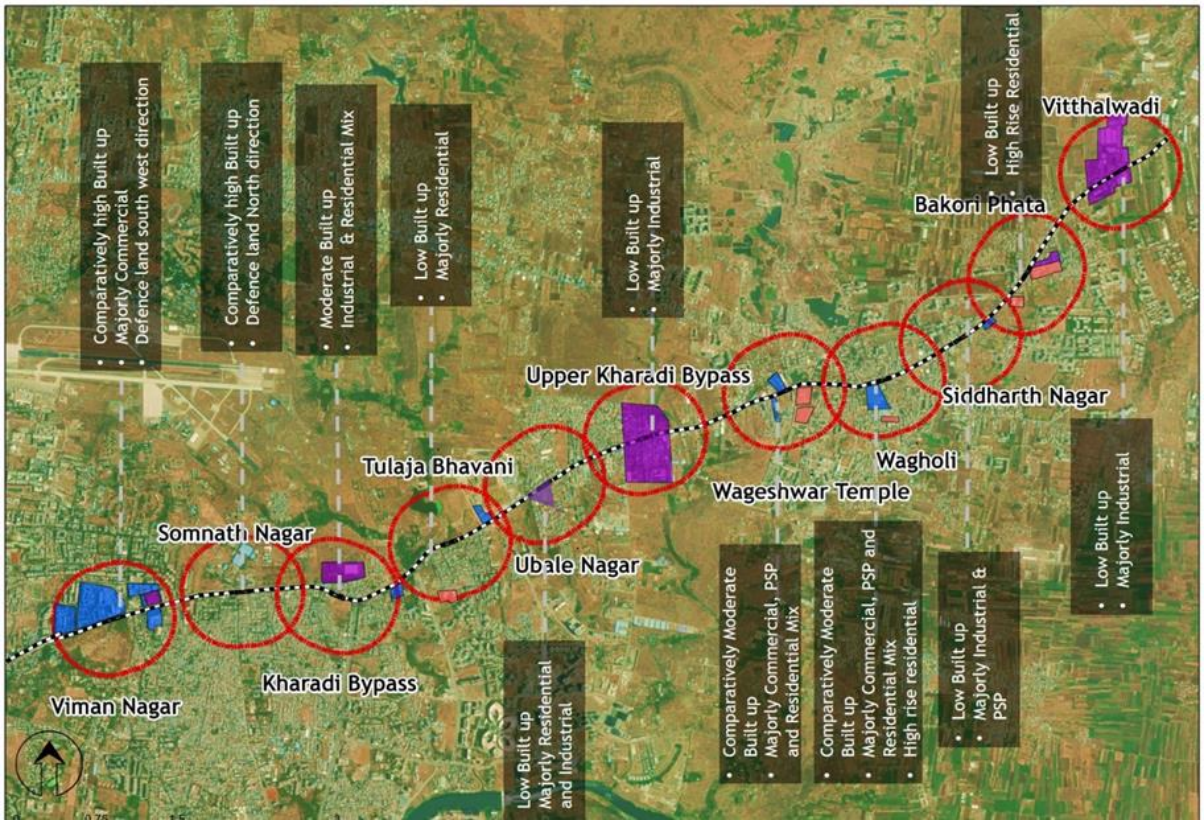
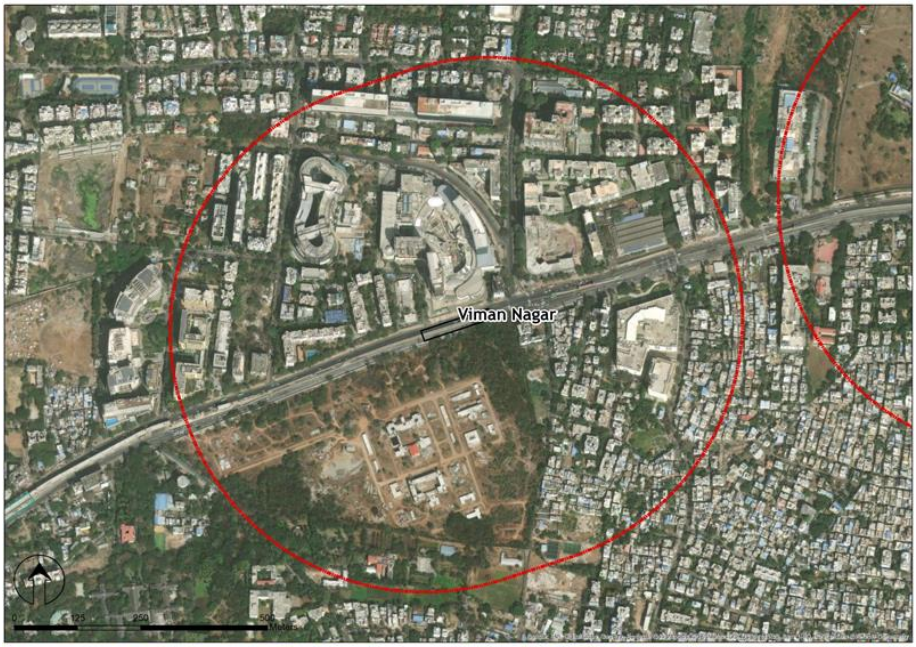
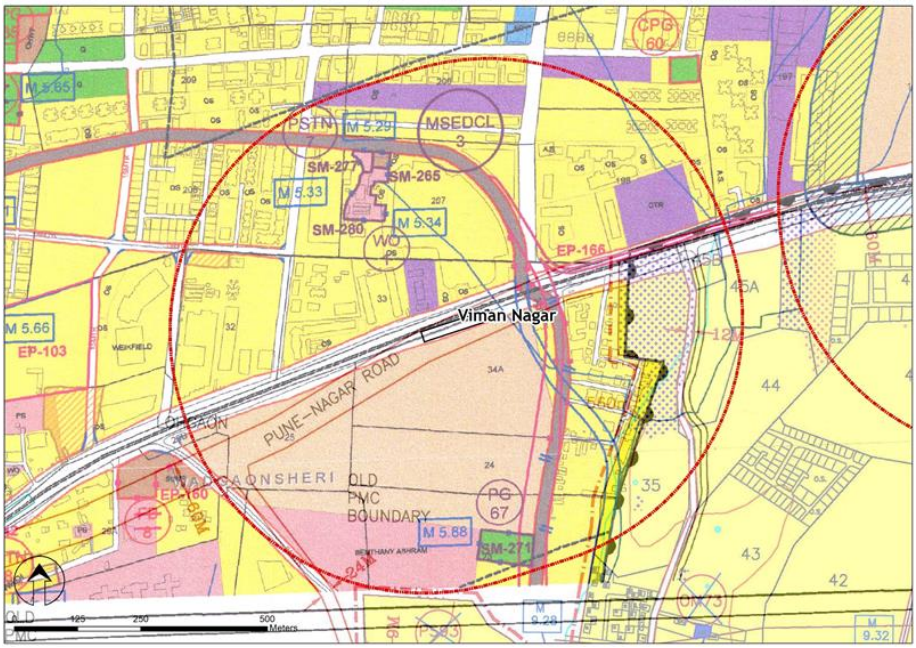


FIGURE 18-1: TOD ZONES FOR VIMAN NAGAR TO VITTHALWADI STATIONS

The following section details each of the station TOD zones -

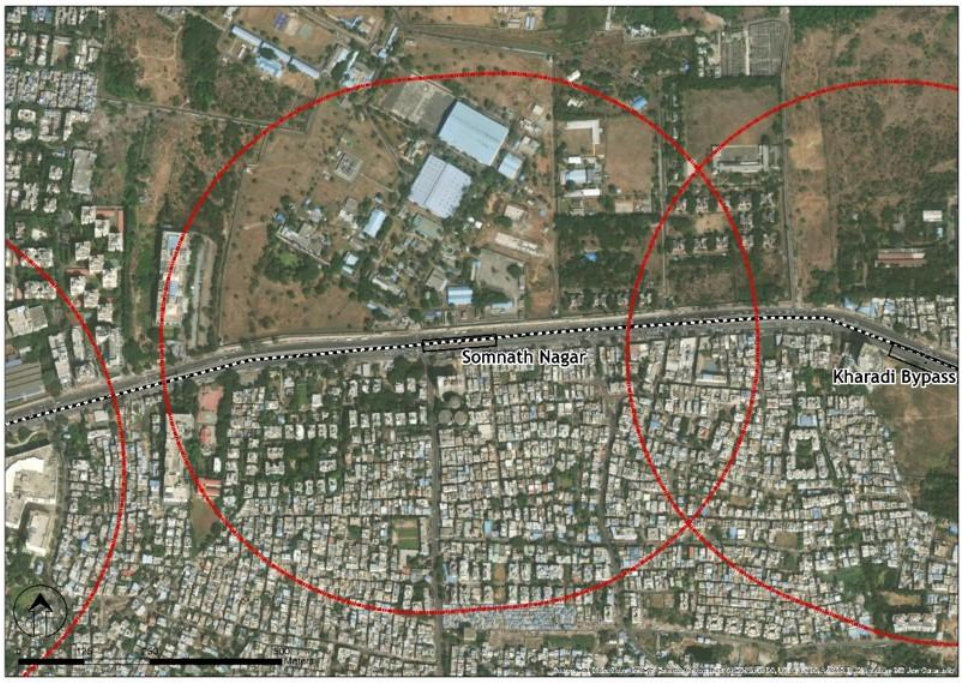
Station 1: Viman Nagar

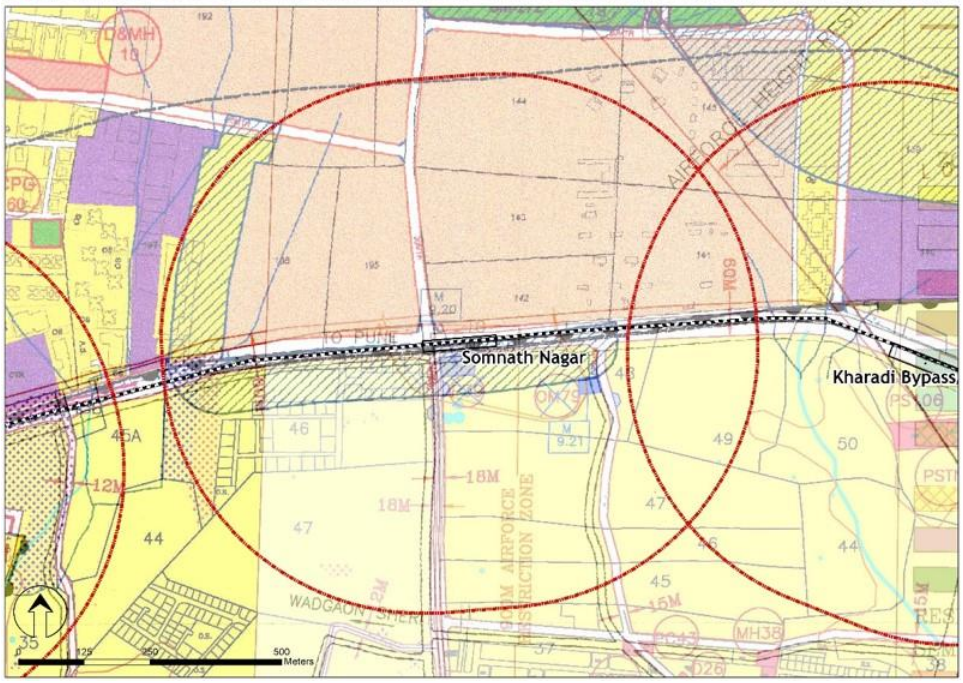




Influence Area	Current Dynamics	Development Potential
Influence area comprises of Phoenix mall, Hyatt Regency, Somnath Nagar	• Station area characterized by moderately high built up • Major mix of commercial, industrial and residential land use • Defence land in south west direction	As per the DP, the major landuse of the influence area is residential. The vacant/under – development land belongs to the defence. There is no vacant land plot available in the zone

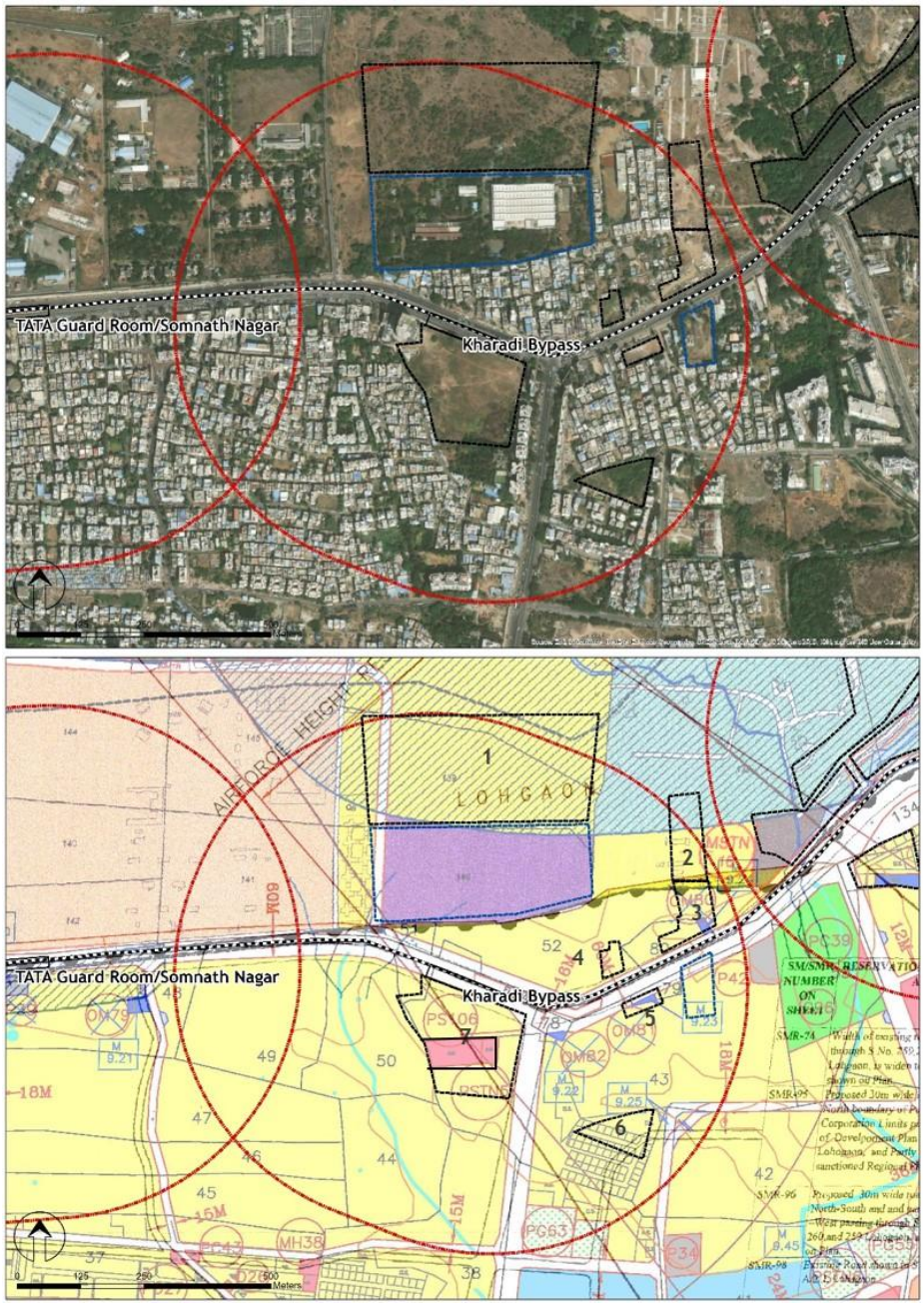
Station 2 – Somnath Nagar





Influence Area	Current Dynamics	Development Potential
Influence area comprises of TATA nagar, Agar Nagar, Preet nagar, Sunita Nagar	• Station area characterized by moderately high built up in the southern end • Defence land in north direction	As per the DP, the major landuse of the influence area is residential and defence. There is no vacant land plot available in the zone

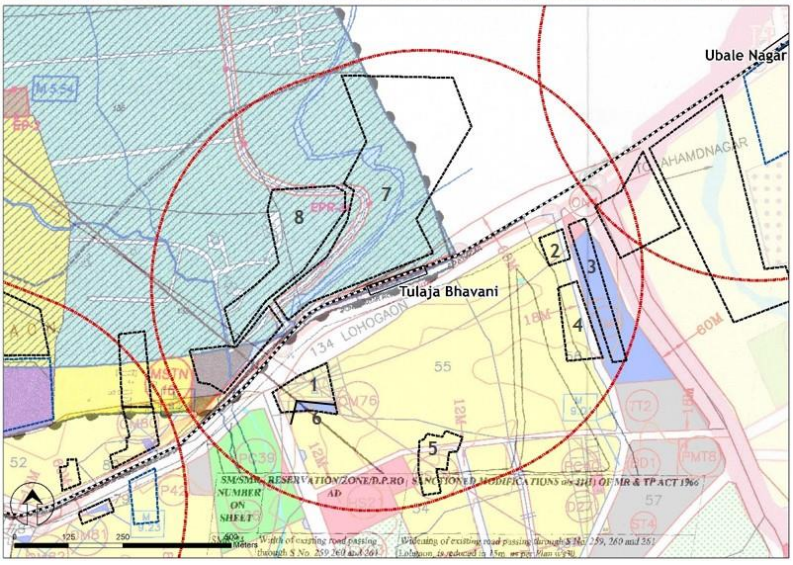
Station 3 – Kharadi Bypass



Influence Area	Current Dynamics	Development Potential
Influence area comprises of Chandan Nagar, Shree Park Society	• Station area characterized by moderate built up • Majorly residential and industrial use observed	• As per the DP, the major landuse of the influence area is residential. Large industrial plot is also available. • Since it is in close proximity to the airport and falls within the funnel zone, there are height restrictions. • 7 potential vacant plots are identified in this zone of 13.2 Ha. These are majorly proposed to be residential.

Influence Area	Current Dynamics	Development Potential
		The details of the plots are – Plot 1 – 7 Ha Plot 2 – 1.1 Ha Plot 3 – 0.8 Ha Plot 4 – 0.2 Ha Plot 5 – 0.2 Ha Plot 6 – 0.8 Ha Plot 7 – 3.1 Ha

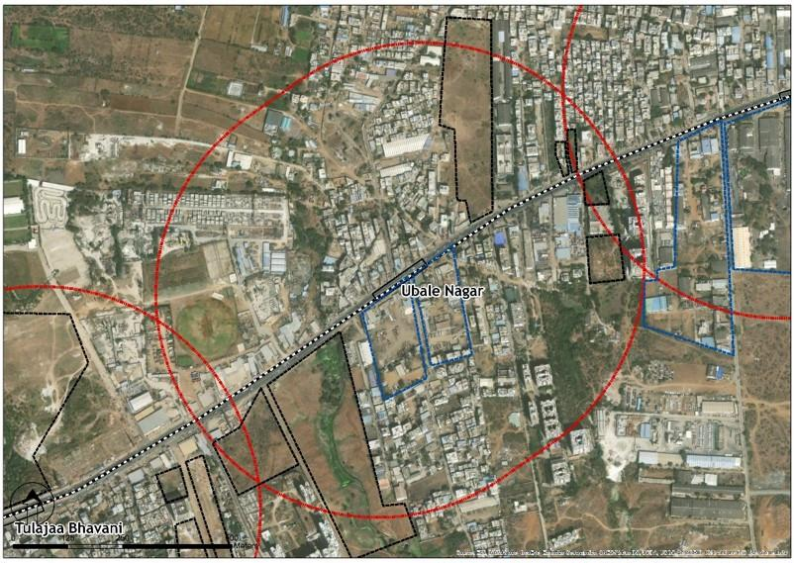
Station 4- Tulaja Bhavani

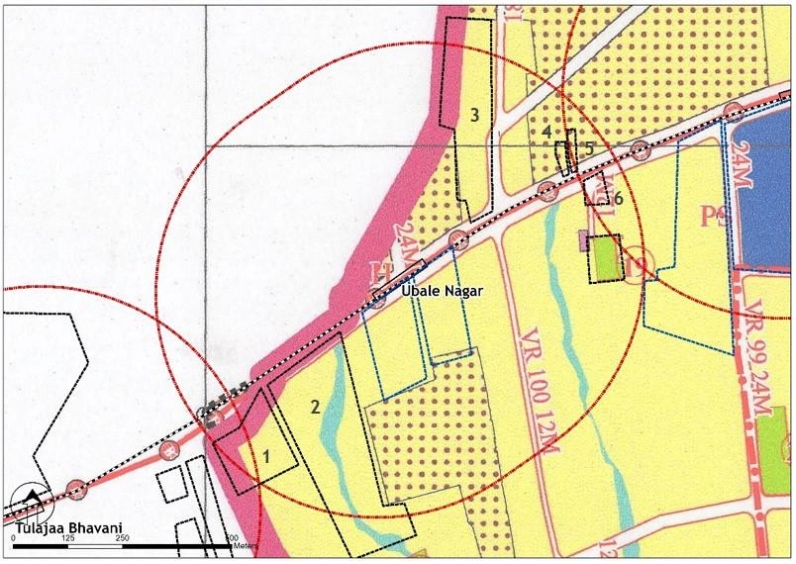


Influence Area	Current Dynamics	Development Potential
Influence area comprises of Aaple Ghar Society, Tulaja Bhavani Nagar	• Station area characterized by low built up	• As per the DP, the major landuse of the influence area is residential and commercial mix.

Influence Area	Current Dynamics	Development Potential
	• Majorly residential use observed	• 8 potential vacant plots have been identified of 19.3 which majorly is proposed to be residential or commercial. The details of the identified plots are – Plot 1 – 0.9 Ha Plot 2 – 0.4 Ha Plot 3 – 1.3 Ha Plot 4 – 1.1 Ha Plot 5 – 0.9 Ha Plot 6 – 0.3 Ha Plot 7 – 10.9 Ha Plot 8 – 3.5 Ha

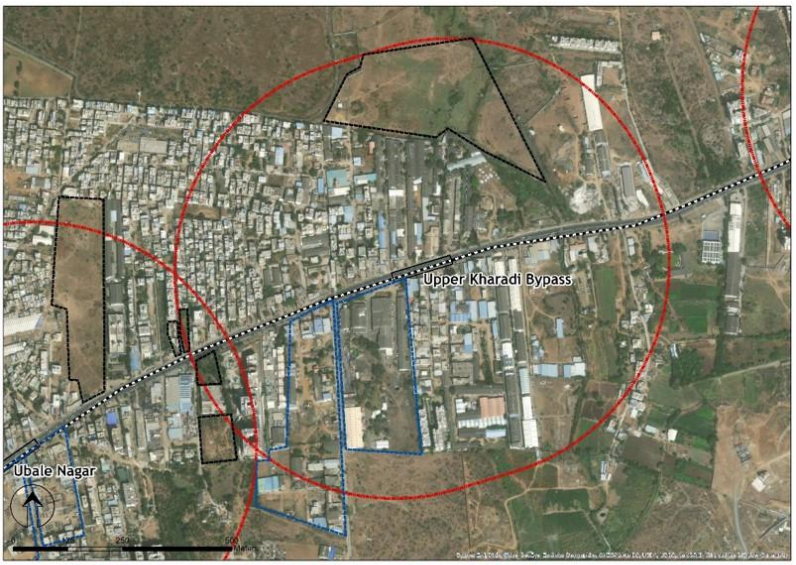
Station 5 – Ubale Nagar

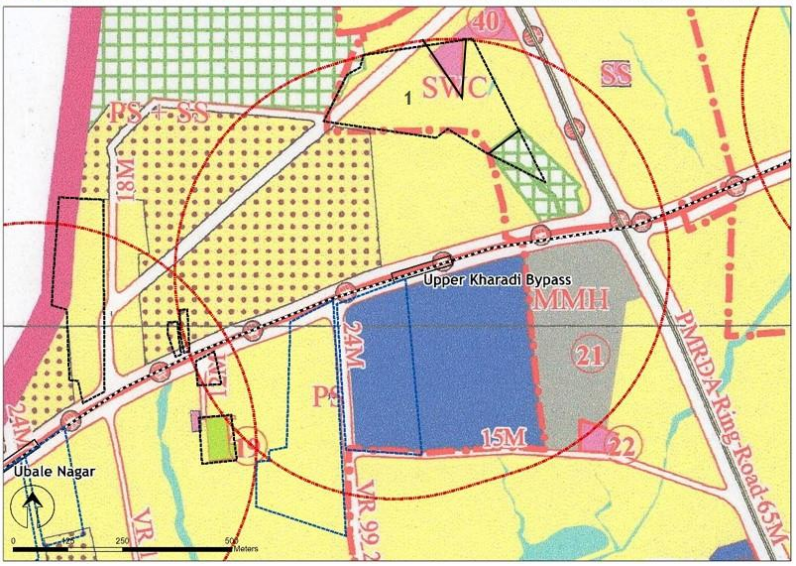




Influence Area	Current Dynamics	Development Potential
Influence area comprises of Mahalaxmi cricket ground, Khandve Nagar, Ubale Nagar	• Station area characterized by low built up • Majorly residential and industrial use observed	• As per the DP, the major landuse of the influence area is residential. • 6 potential plots have been identified in this zone of 15 Ha which are proposed to be residential. The details of the plots are – Plot 1 – 2.4 Ha Plot 2 – 7.5 Ha Plot 3 – 4.4 Ha Plot 4 – 0.2 Ha Plot 5 – 0.2 Ha Plot 6 – 0.3 Ha

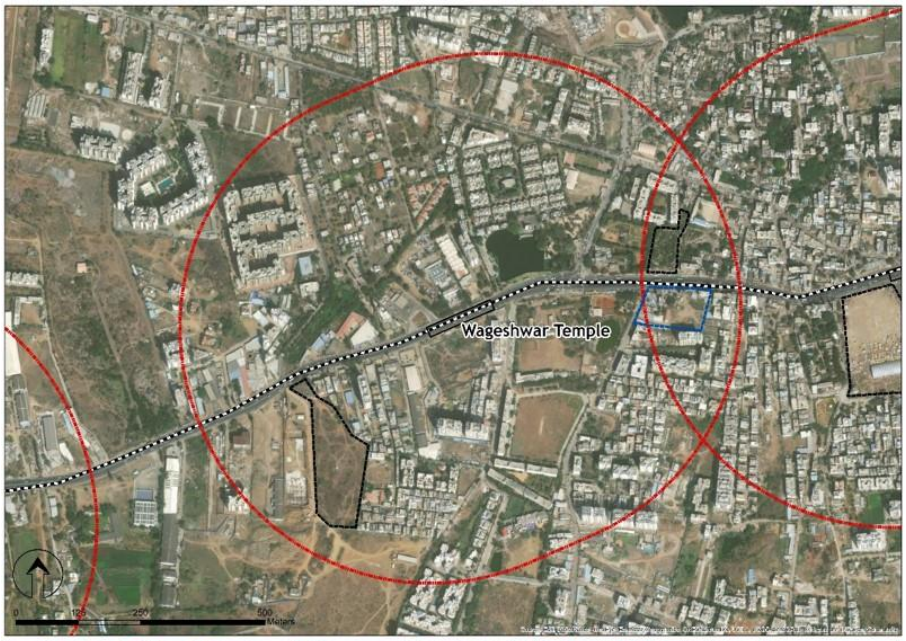
Station 6- Upper Kharadi Road

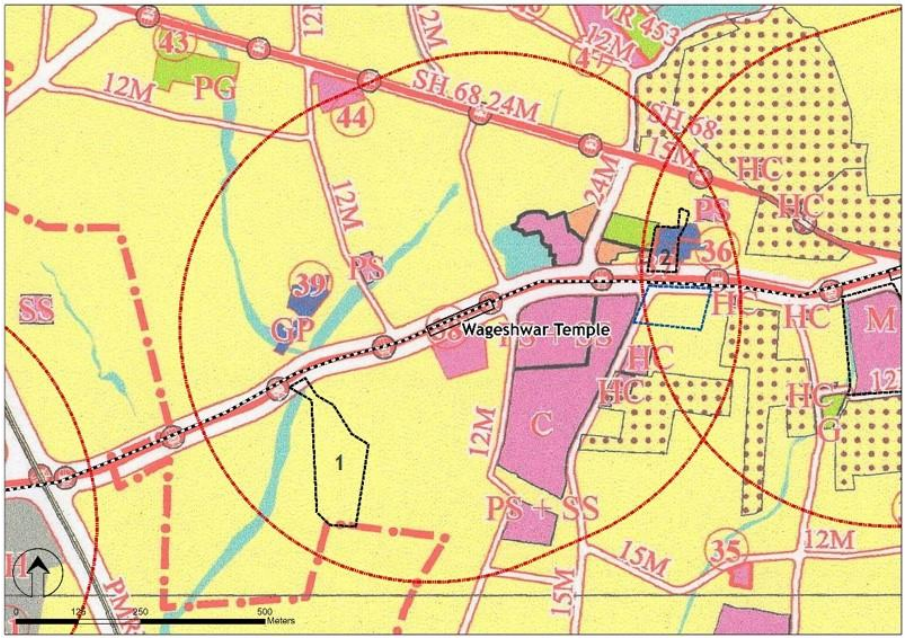




Influence Area	Current Dynamics	Development Potential
Influence area comprises of Vastupauram Co-op Society, industrial units etc.	• Station area characterized by low built up • Majorly residential and industrial use observed	• As per the DP, the major landuse of the influence area is residential. • 1 potential vacant plot of 6.6 Ha is identified, which is proposed to be residential.

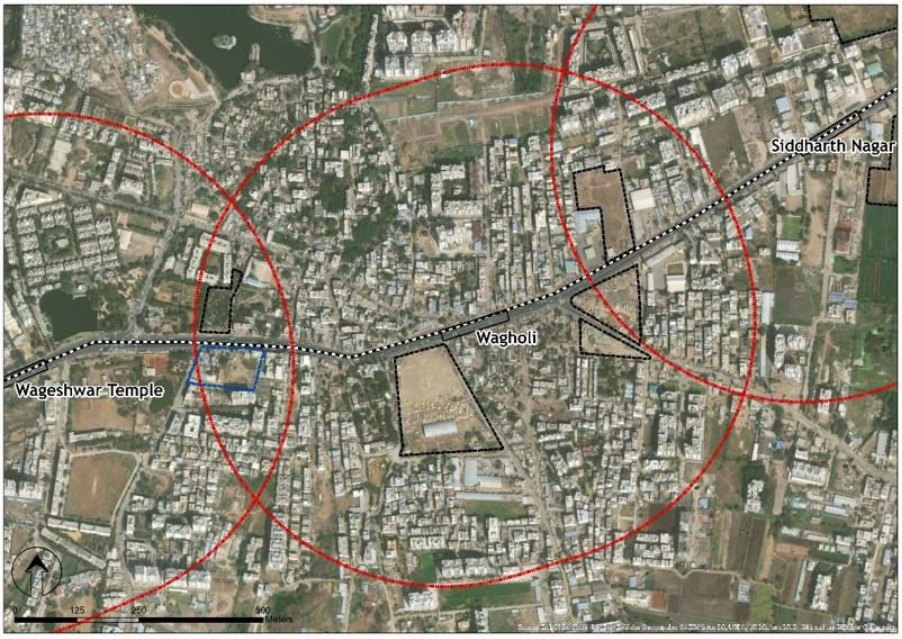
Station 7 – Wagheshwar Temple

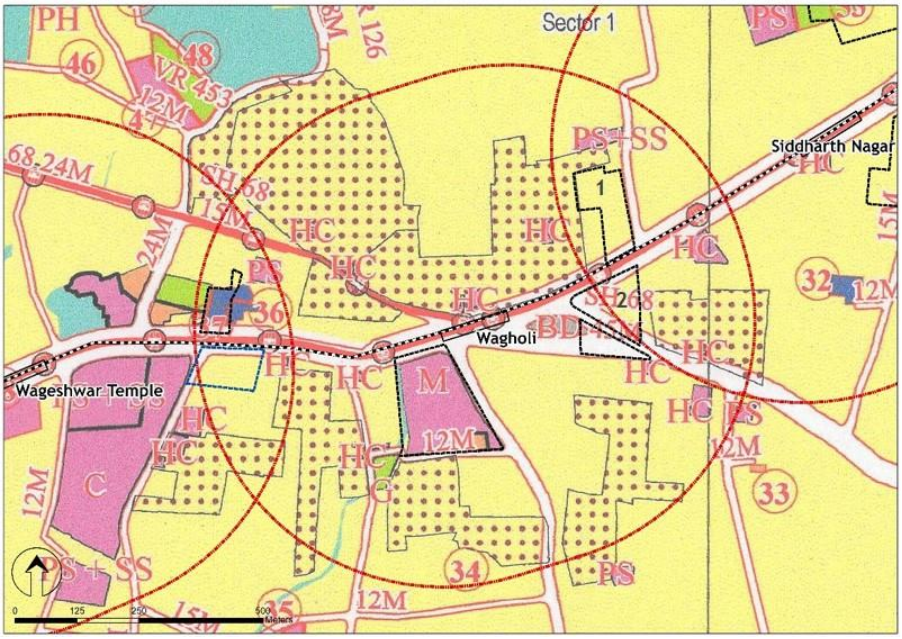




Influence Area	Current Dynamics	Development Potential
Influence area comprises of Amrit Nagari, Kamalbaug Scoiety Rd, Parvatibai Genba Moze College, Wagheshwar Temple	• Station area characterized by moderate built up • Majorly commercial, public semi-public and residential use observed	• As per the DP, the major landuse of the influence area is residential and public-semi public • 2 potential vacant plot of 2.7 Ha is identified, which is proposed to be residential and commercial. The details of the plot are - Plot 1 – 2.2 Ha Plot 2 – 0.5 Ha

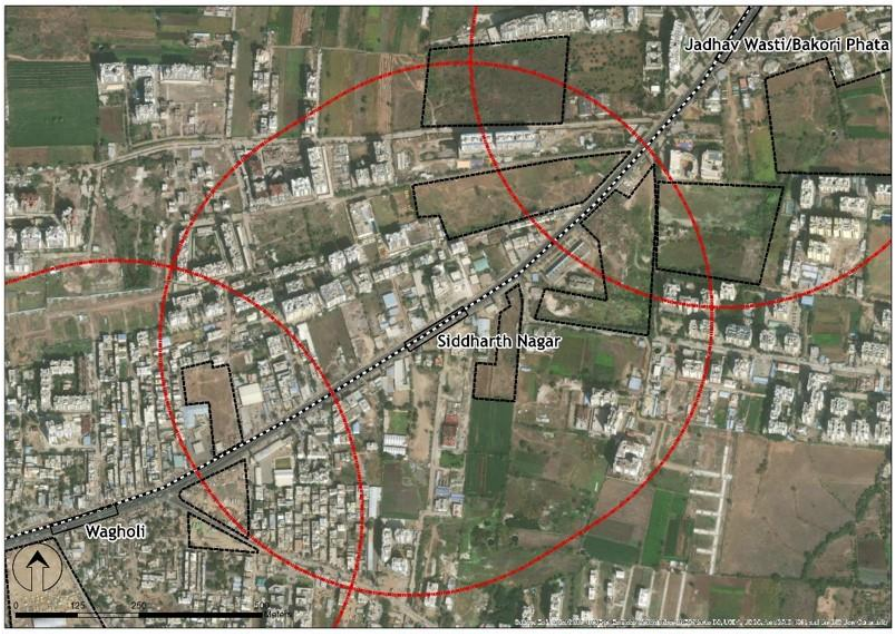
Station 8 – Wagholi

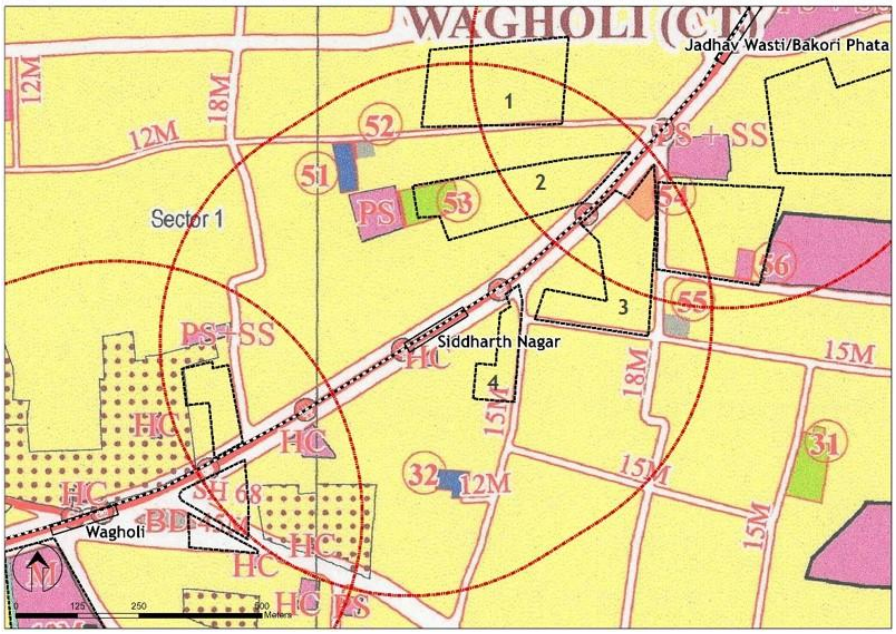




Influence Area	Current Dynamics	Development Potential
Influence area comprises of Kalubai Nagar, Siddhartha Nagar, Multispecialty Hospitals	• Station area characterized by moderate built up • Majorly commercial, public semi-public and residential use observed. High rise residential also observed.	• As per the DP, the major landuse of the influence area is residential and public-semi public • 2 potential vacant plots of 2.5 Ha have been identified which is proposed to be residential. The details of the plots are – Plot 1 – 1.3 Ha Plot 2 – 1.2 Ha

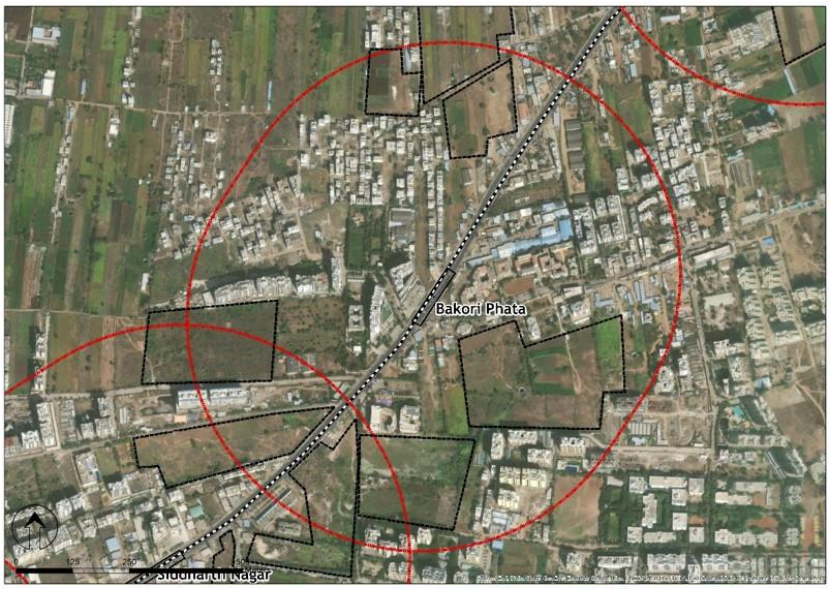
Station 9 – Siddharth Nagar

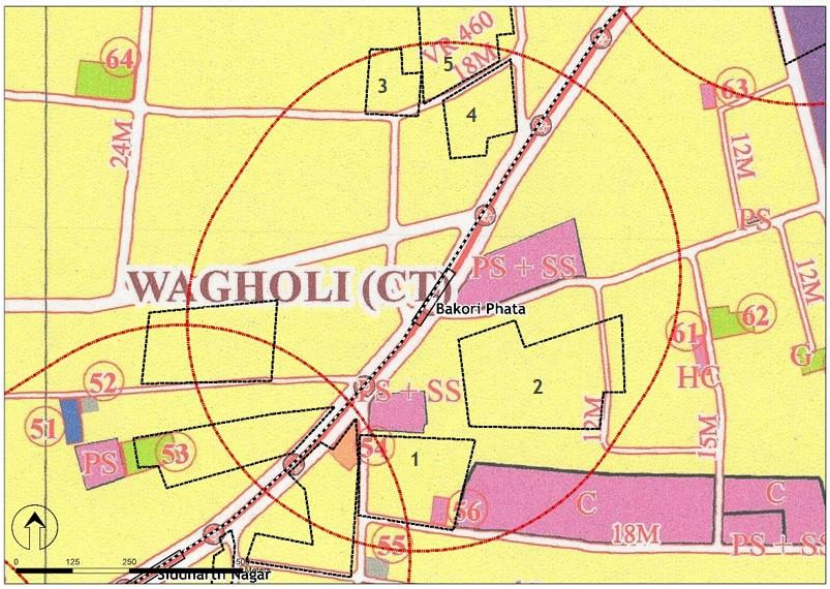




Influence Area	Current Dynamics	Development Potential
Influence area comprises of Sanskriti School, Wagheshwar Palace, Anshul Kanvas Society	• Station area characterized by low built up • Majorly residential use observed. High rise residential also observed.	• As per the DP, the major landuse of the influence area is residential • 4 potential vacant plots of 13.3 Ha identified which is proposed to be residential. The details of the plots are – Plot 1 – 4.7 Ha Plot 2 – 3.4 Ha Plot 3 – 4 Ha Plot 4 – 1.2 Ha

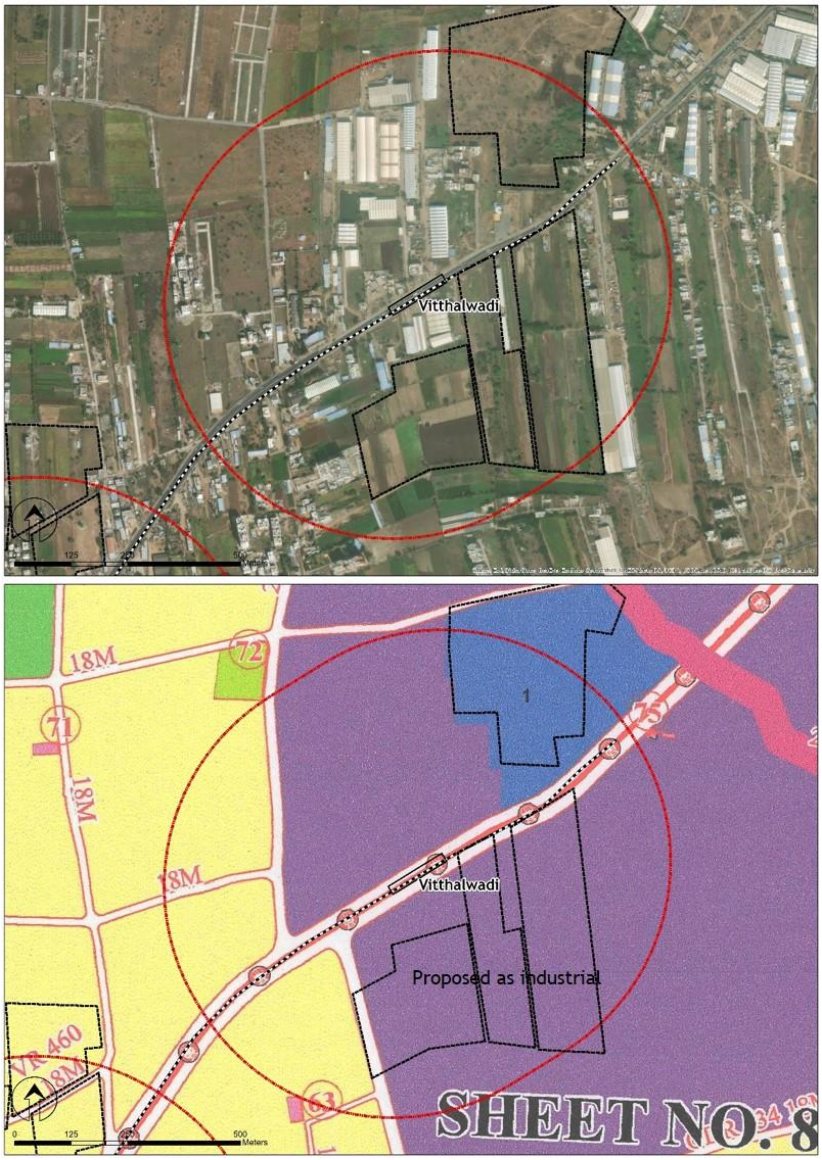
Station 10 – Bakori Phata





Influence Area	Current Dynamics	Development Potential
Influence area comprises of Majestique City Society, Lexicon Internal School, Bharatiya Jain Sanghatana's Arts, Oxy Valley Phase 1	• Station area characterized by low built up • Majorly industrial, public semi-public, residential use observed.	• As per the DP, the major landuse of the influence area is residential • 5 potential vacant plots of 19.2 Ha identified which is proposed to be residential. The details of the plots are – Plot 1 – 4.4 Ha Plot 2 – 7.2 Ha Plot 3 – 1.5 Ha Plot 4 – 2.3 Ha Plot 5 – 3.8 Ha

Station 11 – Vitthalwadi



Influence Area	Current Dynamics	Development Potential
Influence area comprises of industrial units and warehouses	• Station area characterized by low built up • Majorly industrial use observed.	• As per the DP, the major landuse of the influence area is industrial and commercial • 1 potential vacant plot of 10.6 Ha identified which is proposed to be commercial

The details of land use mix observed for the TOD zoned from Vanaz to Chandani Chowk is majorly residential use. The residential typology mainly includes plotted houses. Figure 18-2 provide general details of land use in the TOD Zones of the transit stations from Vanaz to Chandani Chowk.

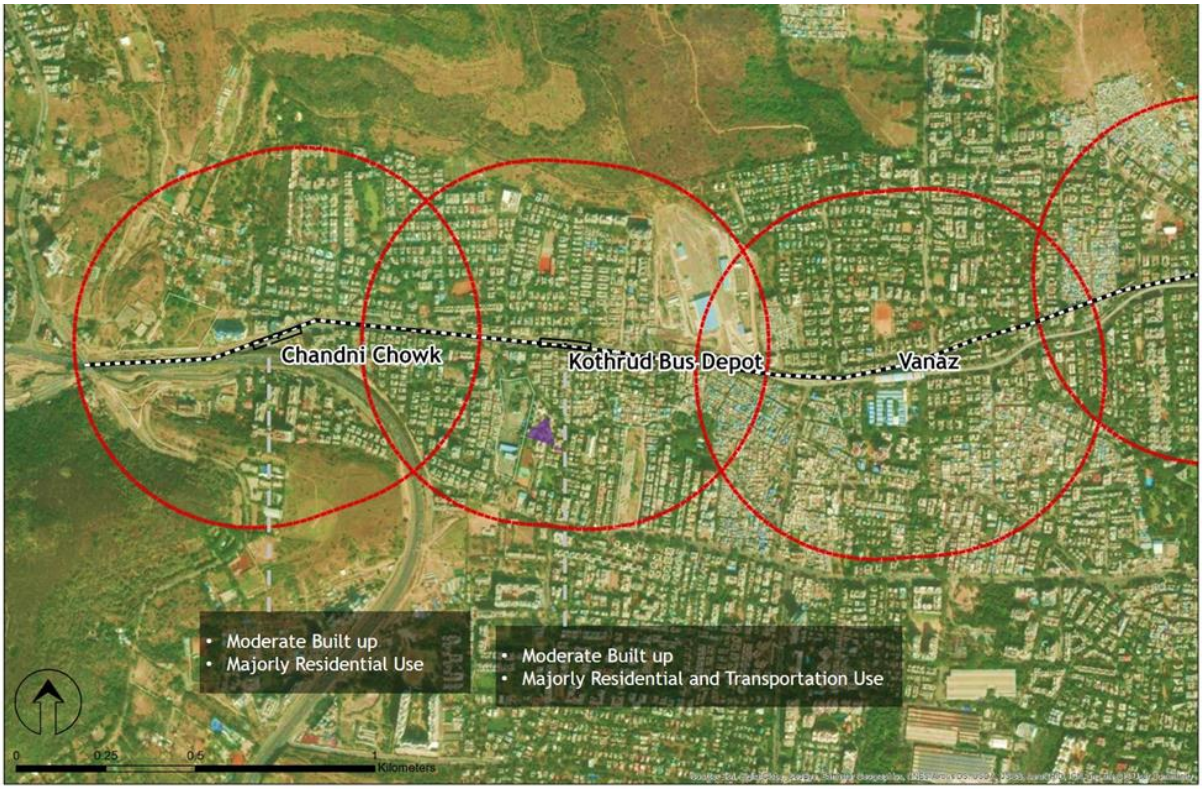
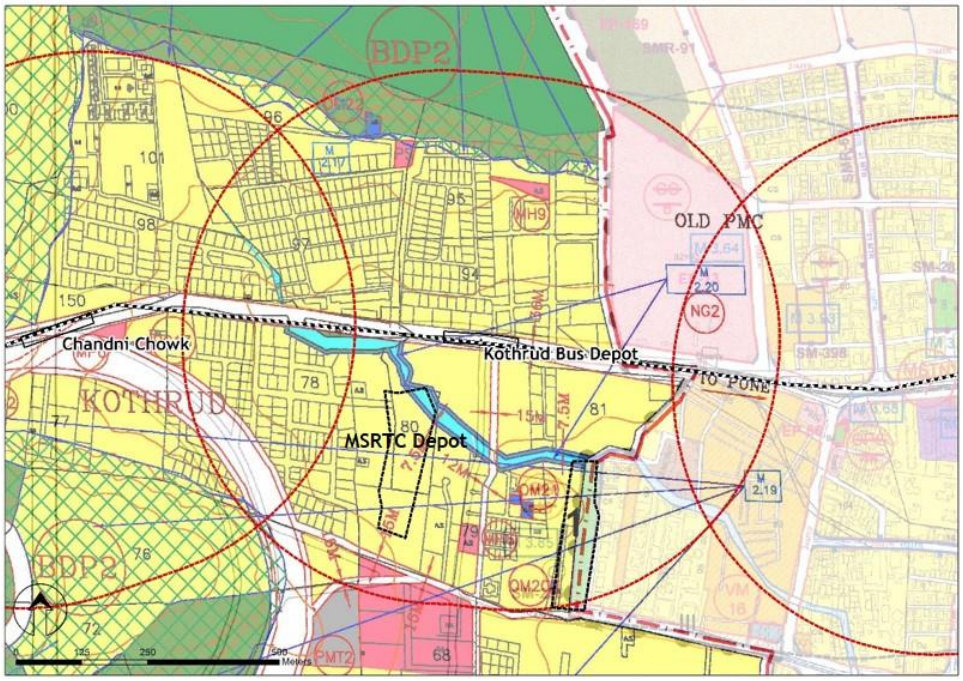


FIGURE 18-2: TOD ZONES FOR VANAZ TO CHANDANI CHOWK

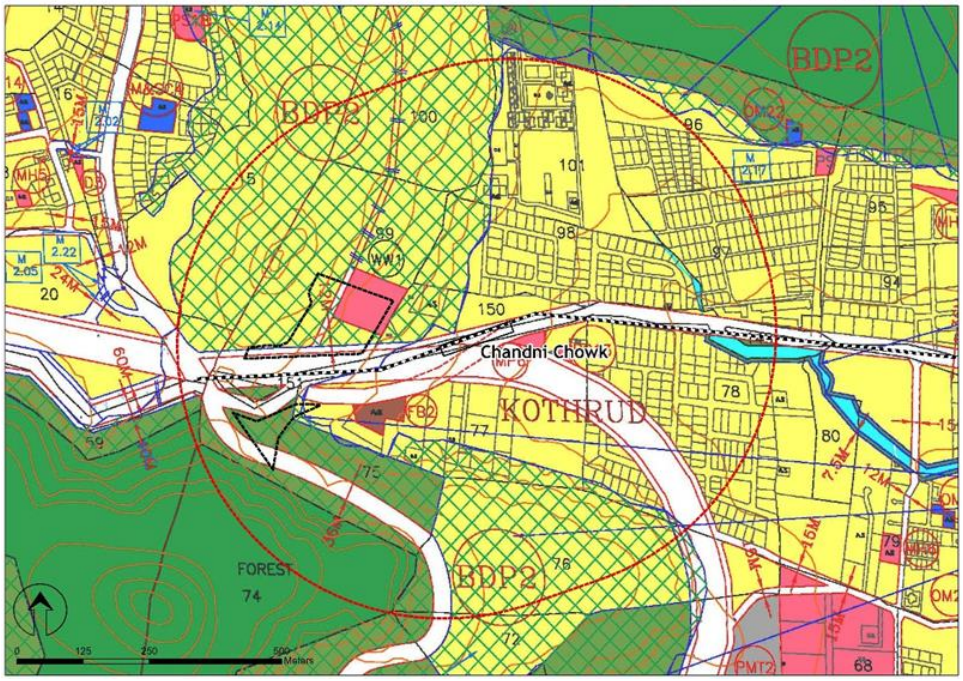
The following section details each of the station TOD zones -

Station 1– Kothrud Bus Depot



Influence Area	Current Dynamics	Development Potential
Influence area comprises of Bharti Nagar, Eklavya Colony, Syash Society	• Station area characterized by moderate built up • Majorly residential use observed	• As per the DP, the major landuse of the influence area is residential • 1.7 Ha of vacant land identified which is proposed to be residential

Station 2– Chandani Chowk



Influence Area	Current Dynamics	Development Potential
Influence area comprises of Lohia Jain IT Park, Westend Vollage, Bhusari Colony	• Station area characterized by moderate built up • Majorly residential use observed	• As per the DP, the major landuse of the influence area is residential • No potential vacant land identified in this zone

18.5. STATUTORY REGULATIONS & COMPLIANCES

18.5.1. CONCEPT OF TOD, PREMIUM ON FSI AND PREMIUM TDR

1. TOD Policy for Pune

The revised Pune TOD regulation was sanctioned and introduced in the Development Control and Promotion Regulation (DCPR) of Pune Municipal Corporation vide. Government notification dated 10/10/2022 (**Annexure 18.1**). The notified Pune TOD policy will be applicable for Pune city limits and PMRDA area as per the Unified Development Control and promotion Regulations for Maharashtra State, 2020 (Section 14.2.2).

The maximum permissible total FSI in TOD zone shall be 4, including the base permissible FSI, subject to condition that, the additional FSI over and above the base permissible FSI shall be allowed within the overall limit of maximum permissible FSI, as given in Table 18-1.

TABLE 18-1: MAXIMUM PERMISSIBLE FSI - REGULATIONS

Sl.no	Road width in mt.	Maximum Permissible FSI
1	9 m and up to 12 m	2.5
2	12 m and up to 15 m	3
3	15 m and up to 24 m	3.5
4	24 m and above	4

Thus, the maximum permissible FSI is based on the right of way of the abutting road only.

2. Additional Premium to be Paid

Additional FSI over and above the base permissible FSI of respective land use zones as per Principal DCPR may be permitted on the payment of premium

Rate of premium for the additional FSI, as mentioned in the Column No. 3 above shall be 30% for FSI to be used for tenements of size equal to or less than 60 sqm and 35% for remaining FSI to be used for residential and/or commercial use, of the rate of the said land mentioned in Annual Statement of Rates without considering the guidelines therein.

In the area of Planning authority, 50% of the amount of premium collected should be paid to the planning authority in the area concerned with the Urban Transport Project and remaining 50% to the Project Implementing Authority.

In the area of regional plans, 50% of the amount of premium collected should be paid to the government through the district offices of Town planning and Valuation Department and remaining 50% to the Project Implementing Authority.

As per DCPR, the basic FSI for residential and residential with mixed-uses in non-congested areas is 1.1. For congested areas, for residential and residential with mixed uses, the basic FSI is 1.5.

3. TOD Policy for Pune

For any development or redevelopment within TOD zones, size of tenement shall be minimum 25 sqm and maximum 120 sqm of carpet area and out of the total proposed tenements, the tenements equivalent to atleast 50% of the total FSI shall be of size equal to or less than 60 sqm.

18.5.2. PROPERTY TAX

Incremental property tax benefit can be accured from the project in two-ways:

- Better infrastructure facilities in the form of Metro as an incremental benefit on the users of the facility as well as the land values, which in-turn improve rentals.
- Larger Development Area – Property Tax is levied on the built-up component of property, development of built up space due to additional FSI shall promote the collection of additional property tax.

18.5.3. CHANGE IN LAND USE

Land conversion charges for changing land usage from industrial to residential/commercial is 20% of the ready reckoner rates as per the Notification - TPS - 1812/981/CR-250/213/UD-13 Dt 11-01-2017 by Government of Maharashtra. To utilize potential from premium FSI in the region, developers, as well as small dwelling owners, may opt for purchase of industrial land parcels which are available near the TOD zone and convert them into residential/commercial usage by paying the applicable premium.

18.5.4. STAMP DUTY AND REGISTRATION CHARGES

As per the section 149 B of the Maharashtra Municipal Corporations Act, projects notified by City Corporations as “Vital Important Urban Transport Projects” can charge an additional levy of 1% over and above the existing stamp duty charges. At present, stamp duty including the surcharge for Metro Rail Project in Pune is charged at 5% and Registration Charge at 1% capped at Rs. 30,000 of the agreement value or the ready reckoner values, whichever is higher.

18.5.5. APPLICABLE CIRCLE RATES ACROSS THE TOD ZONES

Table 18-3 highlights the current circle rates in the TOD Zones.

TABLE 18-2: CIRCLE RATES IN THE TOD ZONE

Station Name	Ready Reckoner Rates (Rs/sqm)		
	Land	Residential	Commercial
Viman Nagar to Vitthalwadi			
Kharadi Bypass	7870	51250	58940
Tulaja Bhavani	13615	71146	90550
Ubale Nagar	6480	43720	68270
Upper Kharadi Road	9740	55210	80875
Wagheshwar Temple	11835	55210	80875
Wagholi	11835	55210	80875
Siddharth Nagar	13460	55210	80875
Bakori Phata	8825	52890	75895
Vitthalwadi	9270	55210	80875
Vanaz to Chandani Chowk			
Kothrud Depot	29660	90590	108710

Note: Forecast rate of 5% is considered for every 3rd year based on the previous land rate trend for the estimation of revenue.

18.6. NON-FARE BOX REVENUE ESTIMATION

18.6.1. VALUE CAPTURE MECHANISM

The concepts of fiscal reform and urban infrastructure investment are to a certain extent connected, given the fact that urban infrastructure investments often induce escalations in land value in the subject area. It is therefore possible to recover part of the capital cost incurred as part of the urban investment by capturing some or all of the incremental benefits in land value resulting from the investment.

This could be done via different fiscal mechanism such as tax, premiums, development agreements, etc. The search for such alternative and flexible methods of revenue generation and the development of the fiscal framework is a continuous process within local authorities. Therefore, the role of land value capture finance is crucial.

Land Value Capture finance (LVC) is not merely a one-off mechanism for recouping the costs of public infrastructure investments; instead, it can also be a grouping of various methods and techniques that, in fact, enable local authorities to trade anticipated future income for the present benefit.

With regard to part-financing transport infrastructure projects using LVC mechanisms, it is important not only to understand the urban context of the project, but also to be informed about the country where LVC tools are being proposed, such as the condition of the

economy, taxation and planning systems, public and political attitude towards funding, and how coordination between key players is undertaken.

The introduction of LVC should not be limited in scope to the implementation of a land tax, because LVC approach have a wider role to play in supporting efficient planning and urban management systems. Four imperatives could be listed to support the case for LVC as an urban management tool. These are:

- The need to reduce costs in the land development process; promoting more efficient and productive capital flows;
- The need to fund the management of urban and economic development, including preserving access to the planning system for a range of interest groups;
- The need to acknowledge the role public sphere investment has in 'overheating' inner-city property markets, and recoup the costs of this investment;
- The need to redistribute the globalization 'dividend' from inner to outer parts of the metropolitan area.

The potential advantage of land value capture is that the revenue (e.g. – a tax) can be used to fund public projects that may subsequently increase the net earnings for the landowners.

Therefore, a land tax that captures some portion of the increased value of this infrastructure might be an appropriate way of funding the investment.

Value Capture Realization by Time

Most Tax based LVC tools can be applied throughout the lifecycle of the project whereas development-based mechanisms have relevance only after the project has been approved.

Key Enabling Factors for Success of LVC Strategies are:

- **Inclusive value creation -** Development based LVC is creating and sharing incremental value amongst the government, transit agencies, developers, business and resident enabling property development.
- **Macro Fundamentals -** Demographic and economic fundamentals are paramount when applying development based LVC leading to a higher demand for land and subsequently growth in property prices.
- **Flexible Zoning -** Zoning course and site design parameters around stations should be flexible enough to meet changing market demands and diverse local needs.
- **Intergovernmental collaboration -** Multiple government entities to work together on transit related projects.
- **Public land ownership is preferred -** Municipalities and transit agencies can acquire land through incentive-based techniques such as land readjustment or Urban Development.

- **Visionary master plans -** Needs to provide long term vision on development plans. Policymakers must emphasize transit infrastructure as the spine of spatial development in their visionary plans.
- **Multiple funding sources -** Given the capital-intensive nature of transit systems and negative externalities government should close their financial gaps by mobilizing diverse funding sources.
- **Clear fair and transparent rules -** For sharing cost benefits and risk among stakeholders to ensure commitment of public and private agencies and maximize benefits in and around stations.

18.6.2. ESTIMATION OF NON-FARE REVENUE POTENTIAL

For the purpose of estimation of non – fare box revenue potential expected on account of development of Metro System, following steps were carried out:

As part of this exercise, vacant land parcels across the influence area were identified. Parameters such as road width, permissible usage based on the DP, base applicable FSI etc. were assessed. The objective of this assessment is to evaluate the potential for new development in the TOD zones. The potential vacant land identified in the TOD zones is given in Table 18-3.

TABLE 18-3: IDENTIFIED VACANT LAND PARCELS

Sl.no	Station	Total Vacant Land (Ha)	Usage Mix		Base FSI	Potential FSI	
			Residential (Ha)	Commercial (Ha)		Residential	Commercial
LINE 2A							
1	Kothrud Bus Depot	1.7	1.7	-	1.1	4	-
LINE 2B							
2	Kharadi Bypass	13.2	13.20	-	1.1	3.5	-
3	Tulaja Bhavani	19.3	3.30	16	1.1	3.5	4
4	Ubale Nagar	15	15.00	-	1.1	4	-
5	Upper Kharadi Road	6.6	6.60	-	1.1	4	-
6	Wagheshwar Temple	2.7	2.20	0.5	1.1	4	4
7	Wagholi	2.5	2.50	-	1.1	4	-
8	Siddharth Nagar	13.3	13.3	-	1.1	4	-
9	Bakori Phata	19.2	19.20	-	1.1	3.5	-
10	Vitthalwadi	10.6	0	10.6	1.1	-	3.5
Total		**104.1**	**77**	**27.1**			

Approximately, 104.1 Ha of potential vacant land has been identified in all the zones combined which are proposed for residential or commercial.

18.5.2.1. COMPACT DEVELOPMENT AND DENSIFICATION

1. Residential Development Potential

The developable area is converted to the total built up area based on the potential FSI. Total built up area of 290 Ha will be available for residential.

2. Commercial Development Potential

The developable area is converted to the total built up area based on the potential FSI. Total built up area of 103 Ha will be available for commercial. Table 18-4 gives the FSI potential and Premium FSI across the TOD zones. The revenue will be calculated for the premium built up area. For this, premium FSI is assessed for each of the TOD zone.

Premium FSI = Maximum Potential FSI – Base FSI

TABLE 18-4: POTENTIAL FOR PREMIUM FSI

SN	Station	Total Vacant Land	Residential (Ha)	Commercial (Ha)	Base FSI	Potential FSI		Calculated Premium FSI	
						Residential	Commercial	Residential	Commercial
Line 2A									
1	Kothrud Bus Depot	1.7	1.7	-	1.1	4	-	2.9	-
LINE 2B									
2	Kharadi Bypass	13.2	13.2	0.0	1.1	3.5	-	2.4	-
3	Tulaja Bhavani	19.3	3.3	16.0	1.1	3.5	4	2.4	2.9
4	Ubale Nagar	15	15.0	0.0	1.1	4	-	2.9	-
5	Upper Kharadi Road	6.6	6.6	0.0	1.1	4	-	2.9	-
6	Wagheshwar Temple	2.7	2.2	0.5	1.1	4	-	2.9	2.9
7	Wagholi	2.5	2.5	0.0	1.1	4	0	2.9	-
8	Siddharth Nagar	13.3	13.3	0.0	1.1	4	-	2.9	-
9	Bakori Phata	19.2	19.2	0.0	1.1	3.5	-	2.4	-
10	Vitthalwadi	10.6	0.0	10.6	1.1	-	3.5	-	2.4
Total			**77**	**27.1**					

18.5.2.2. ASSESSMENT OF NON-FARE BOX REVENUE

Premium FSI

A detailed review of current DP for the proposed metro corridor is undertaken considering the following matters:

Levy of premium for additional FSI.

a) Establishing applicable base and premium FSI for the various identified revenue yielding uses of land.
b) Understanding the applicable premium for purchasing additional FSI in congested and non-congested areas.
c) Scrutiny of ready reckoner values for the TOD influence areas.
d) Calculation of premium on additional FSI along each corridor, which is calculated as per the equation below:
   $(FSI_{(max)} - FSI_{(base)} \times A_{(vacant)} \times RR_{(weighted\ average)}$
   - $FSI_{(max)}$ – Maximum permissible FSI as per TOD Policy
   - $FSI_{(base)}$ – Base FSI (as per DCPR)
   - $RR_{(weighted\ average)}$ – Weighted average ready reckoner value of land along the corridor

Average ready reckoner rates were calculated through weighted average method based on the vacant land parcel availability across the proposed stations and are presented in **Section 18.5.5**. The rates are escalated at 5% every 3rd year considering the past trends in the land rates based on the ready reckoner values. FSI premium charges are levied at 30% of ready reckoner values for residential/commercial units upto size 60 sqm and 35% for residential/commercial for unit size greater than 60 sqm as per revised TOD notification. Also, as per the policy the share of revenue from the premium FSI between planning authority and project implementing authority is 50-50%.

Based on the assumptions above, revenue potential from premium FSI is calculated. It is safe to assume that all of the potential will not get absorbed in the stipulated project years, thus a conservative scenario is considered, with absorption rate of 50%. Also, the absorption rate in the project years will follow a bell curve, with increasing rate in the initial years, reaching a peak and then at decreasing rate. The first 20 years (including the construction phase) will have total absorption of 95%. For first 2 years, the absorption rate is assumed is 0.7%, slowing increasing to 0.8%, 0.9%, 2.5 % and so on.

The revenue calculation for the year 2023-2024 is shown below as an example:

TABLE 18-5: REVENUE CALCULATION FROM PREMIUM FSI

Sl.no	Station	Total Vacant Land	Residential (Ha)	Commercial	Calculated Additional FSI		Additional Built up (sqm)		Ready Reckoner Value		Total Revenue* (in Rs crore)		Conservative Scenario
					Residential	Commercial	Residential	Commercial	Residential (Rs/sqm)	Commercial (Rs/sqm)	Residential	Commercial	At 50%
1	Kothrud Bus Depot	1.7	1.7	0	2.9	0	49300	0	90590	108710	78	0	39
2	Kharadi Bypass	13.2	13.2	0.0	2.4	0	316800	0	51250	58940	284	0	142
3	Tulaja Bhavani	19.3	3.3	16.0	2.4	2.9	79200	464000	71146	90550	99	735	417
4	Ubale Nagar	15	15.0	0.0	2.9	0	435000	0	43720	68270	333	0	166
5	Upper Kharadi Bypass	6.6	6.6	0.0	2.9	0	191400	0	55210	80875	185	0	92
6	Wagheshwar Temple	2.7	2.2	0.5	2.9	2.9	63800	14500	55210	80875	62	21	41
7	Wagholi	2.5	2.5	0.0	2.9	0	72500	0	55210	80875	70	0	35
8	Siddharth Nagar	13.3	13.3	0.0	2.9	0	385700	0	55210	80875	373	0	186
9	Bakori Phata	19.2	19.2	0.0	2.4	0	460800	0	52890	75895	427	0	213
10	Vitthalwadi	10.6	0.0	10.6	0	2.4	0	254400	55210	80875	0	360	180
Total													**1513**

* Total Revenue for Residential = Additional Built up* Ready Reckoner Rate *35%*50%
* Total Revenue for Commercial = Additional Built up* Ready Reckoner Rate *35%*50%

- The total revenue estimated in the conservative scenario is Rs. 1804 crores.
- For year 2023-2024, absorption rate of 0.7% is considered.
- Thus, revenue for 2023-2024 is Rs 9.8 Crore

Similarly, absorption rates have been assigned for each year and escalation of 5% is applied every 3rd year. Thus the Revenue from premium FSI is as shown in Table 18-6.

TABLE 18-6: REVENUE THROUGH ADDITIONAL PREMIUM FSI

Financial Year		Revenue from Premium FSI (Rs. in Crores)
2023	2024	9.8
2024	2025	10.6
2025	2026	11.9
2026	2027	12.7
2027	2028	13.5
2028	2029	41.6
2029	2030	83.2
2030	2031	138.1
2031	2032	153.1
2032	2033	165.3
2033	2034	153.1
2034	2035	150.7
2035	2036	136.1
2036	2037	127.1
2037	2038	113.5
2038	2039	104.0
2039	2040	94.5
2040	2041	78.7
2041	2042	59.0
2042	2043	39.3
2043	2044	27.6
2044	2045	10.2
2045	2046	5.1
2046	2047	5.3
2047	2048	5.3
2048	2049	5.3
2049	2050	5.5
2050	2051	5.5
2051	2052	5.5
2052	2053	5.7
2053	2054	5.7

Financial Year		Revenue from Premium FSI (Rs. in Crores)
2054	2055	5.7
2055	2056	5.9
2056	2057	5.9
2057	2058	4.7
Total		1804.4

Additional Stamp Duty

The levy on stamp duty is a standard share of the transaction/guideline value, whichever is more. The study reflects an estimate of revenue from levy of an additional cess on the stipulated stamp duty dedicated towards Metro project. The same shall apply to the transactions arising out of sale/purchase of transfer of land/property.

Base Assumptions and Considerations

a) The 1% additional stamp duty is levied on the transactions basis average ready reckoner rates.
b) The Maharashtra State Government has reduced its total stamp duty to 5% in urban areas of the state as per Notification No: MRD/3320/CR-24/UD 7.
c) The project is assumed to get the status of Essential Urban Transport Project, providing it the option to levy an additional 1% stamp duty.
d) It is decided by the department of Urban Development that share of revenue between the Pune Metro (Maha Metro) and PMRDA would be based on the ratio of the project cost (**Annexure 18.2**).

Firstly, based on the previous metro cess collected in the PMC, revenue from stamp duty has been projected for the project years considering the previous growth rate. The total revenue through additional stamp duty (metro cess) is given in Table 18-7.

TABLE 18-7: TOTAL REVENUE THROUGH ADDITIONAL STAMP DUTY IN THE CITY (RS CRORE)

Financial Year		Revenue from Stamp Duty in the city (Rs. in Crores)
2023	2024	344.4
2024	2025	365.8
2025	2026	388.5
2026	2027	412.6
2027	2028	438.3
2028	2029	465.5

Financial Year		Revenue from Stamp Duty in the city (Rs. in Crores)
2029	2030	494.4
2030	2031	525.1
2031	2032	557.7
2032	2033	592.4
2033	2034	629.2
2034	2035	668.3
2035	2036	709.8
2036	2037	753.9
2037	2038	800.7
2038	2039	850.4
2039	2040	903.3
2040	2041	959.4
2041	2042	1019.0
2042	2043	1082.2
2043	2044	1149.5
2044	2045	1220.9
2045	2046	1296.7
2046	2047	1377.2
2047	2048	1462.8
2048	2049	1553.7
2049	2050	1650.2
2050	2051	1752.7
2051	2052	1861.5
2052	2053	1977.2
2053	2054	2100.0
2054	2055	2230.4
2055	2056	2369.0
2056	2057	2516.1
2057	2058	2672.4

Note: The Stamp Duty collection for Pune MRTS Phase - 1 has begun in February 2019 and was put on hold from April 2020 to April 2022 due to the ongoing Covid-19 pandemic.

The share of revenue through additional stamp duty between Pune Metro (Maha Metro) and PMRDA, will be based on the ratio of the project costs. Considering the ongoing and planned projects under both the agencies, year wise share of the revenue is assessed and presented in Table 18-8.

TABLE 18-8: SHARE RATIO OF REVENUE FROM ADDITIONAL STAMP DUTY BETWEEN MAHA METRO AND PMRDA

Year	Maha Metro				PMRDA				Maha Metro Share (%)	PMRDA Share (%)
	Corridor Length (in Km)**	Total length (in Km)	Project cost (in Cr)	Total Project cost (in Cr)	Corridor Length (in Km)##	Total length (in Km)	Project cost (in Cr)	Total Project cost (in Cr)		
2023	31.254	31.25	11420	11420	23.33	23.33	7947	7947	59%	41%
2024		31.25		11420		23.33		7947	59%	41%
2025		31.25		11420		23.33		7947	59%	41%
2026	4.413	35.67	910	12330	29.14	52.47	7381	15328	45%	55%
2027	5.464	41.13	3668	15998		52.47		15328	51%	49%
2028	12.753	53.88	3626	19624		52.47		15328	56%	44%
2029	75.600	129.48	13598	33222		52.47		15328	68%	32%
2030		129.48		33222		52.47		15328	68%	32%
2031		129.48		33222		52.47		15328	68%	32%
2032		129.48		33222		52.47		15328	68%	32%
2033		129.48		33222		52.47		15328	68%	32%
2034		129.48		33222		52.47		15328	68%	32%
2035		129.48		33222		52.47		15328	68%	32%
2036		129.48		33222		52.47		15328	68%	32%
2037		129.48		33222		52.47		15328	68%	32%
2038		129.48		33222		52.47		15328	68%	32%
2039		129.48		33222		52.47		15328	68%	32%
2040		129.48		33222		52.47		15328	68%	32%
2041		129.48		33222		52.47		15328	68%	32%

Year	Maha Metro				PMRDA				Maha Metro Share (%)	PMRDA Share (%)
	Corridor Length (in Km)**	Total length (in Km)	Project cost (in Cr)	Total Project cost (in Cr)	Corridor Length (in Km)##	Total length (in Km)	Project cost (in Cr)	Total Project cost (in Cr)		
2042		129.48		33222		52.47		15328	68%	32%
2043		129.48		33222		52.47		15328	68%	32%
2044		129.48		33222		52.47		15328	68%	32%
2045		129.48		33222		52.47		15328	68%	32%
2046		129.48		33222		52.47		15328	68%	32%
2047		129.48		33222		52.47		15328	68%	32%
2048		129.48		33222		52.47		15328	68%	32%
2049		129.48		33222		52.47		15328	68%	32%
2050		129.48		33222		52.47		15328	68%	32%
2051		129.48		33222		52.47		15328	68%	32%
2052		129.48		33222		52.47		15328	68%	32%
2053		129.48		33222		52.47		15328	68%	32%
2054		129.48		33222		52.47		15328	68%	32%
2055		129.48		33222		52.47		15328	68%	32%
2056		129.48		33222		52.47		15328	68%	32%
2057		129.48		33222		52.47		15328	68%	32%

** Corridors considered under Maha Metro –

- Year 2023 - PCMC - Swargate (Line 01), Vanaz - Ramwadi (Line 02)
- Year 2026 - PCMC – Nigdi
- Year 2027 - Swargate – Katraj
- Year 2028 - Vanaz - Chandani Chowk, Ramwadi - Wagholi/Vitthalwadi
- Year 2029 - Kharadi - Hadapsar - Swargate - Khadakwasla, SNDT - Warje/Manik Baug, HCMTR

Corridors considered under PMRDA –

- Year 2023 - Hinjawadi - Shivajinagar (Line 03)
- Year 2026 - Shivajinagar - Loni Kalbhor / Saswad road

Considering the share presented in Table 18-8, the revenue collection estimated through additional stamp duty under Maha metro is estimated and is shown in Table 18-9.

TABLE 18-9: REVENUE COLLECTED FROM ADDITIONAL STAMP DUTY FOR MAHA METRO

Financial Year		Revenue from Additional Stamp Duty for Maha Metro (Rs. in Crores)
2023	2024	203.1
2024	2025	215.7
2025	2026	229.1
2026	2027	184.0
2027	2028	223.8
2028	2029	261.4
2029	2030	338.3
2030	2031	359.3
2031	2032	381.7
2032	2033	405.4
2033	2034	430.5
2034	2035	457.3
2035	2036	485.7
2036	2037	515.9
2037	2038	547.9
2038	2039	581.9
2039	2040	618.1
2040	2041	656.5
2041	2042	697.3
2042	2043	740.6
2043	2044	786.6
2044	2045	835.4
2045	2046	887.3

Financial Year		Revenue from Additional Stamp Duty for Maha Metro (Rs. in Crores)
2046	2047	942.4
2047	2048	1001.0
2048	2049	1063.2
2049	2050	1129.2
2050	2051	1199.3
2051	2052	1273.8
2052	2053	1353.0
2053	2054	1437.0
2054	2055	1526.3
2055	2056	1621.1
2056	2057	1721.7
2057	2058	1828.7

The year wise revenue for the considered Line 2 extensions is estimated on the basis of the stamp duty collected per km and the operational kms. The revenue from Line 2 extensions is shown in Table 18-10.

TABLE 18-10: REVENUE COLLECTED FOR LINE 2A AND LINE 2B THROUGH STAMP DUTY

Financial Year		Revenue from Additional Stamp Duty for Maha Metro (Rs. in Crores)	Operational Metro line (in Km)	Stamp Duty per Km (in Cr)	Revenue from Stamp Duty for Line 2 Extensions (Rs. in Crores)
2028	2029	261.4	53.88	4.9	61.9
2029	2030	338.3	129.48	2.6	33.3
2030	2031	359.3	129.48	2.8	35.4
2031	2032	381.7	129.48	2.9	37.6
2032	2033	405.4	129.48	3.1	39.9
2033	2034	430.5	129.48	3.3	42.4
2034	2035	457.3	129.48	3.5	45.0
2035	2036	485.7	129.48	3.8	47.8
2036	2037	515.9	129.48	4.0	50.8
2037	2038	547.9	129.48	4.2	54.0
2038	2039	581.9	129.48	4.5	57.3
2039	2040	618.1	129.48	4.8	60.9
2040	2041	656.5	129.48	5.1	64.7

Financial Year		Revenue from Additional Stamp Duty for Maha Metro (Rs. in Crores)	Operational Metro line (in Km)	Stamp Duty per Km (in Cr)	Revenue from Stamp Duty for Line 2 Extensions (Rs. in Crores)
2041	2042	697.3	129.48	5.4	68.7
2042	2043	740.6	129.48	5.7	72.9
2043	2044	786.6	129.48	6.1	77.5
2044	2045	835.4	129.48	6.5	82.3
2045	2046	887.3	129.48	6.9	87.4
2046	2047	942.4	129.48	7.3	92.8
2047	2048	1001.0	129.48	7.7	98.6
2048	2049	1063.2	129.48	8.2	104.7
2049	2050	1129.2	129.48	8.7	111.2
2050	2051	1199.3	129.48	9.3	118.1
2051	2052	1273.8	129.48	9.8	125.5
2052	2053	1353.0	129.48	10.4	133.3
2053	2054	1437.0	129.48	11.1	141.5
2054	2055	1526.3	129.48	11.8	150.3
2055	2056	1621.1	129.48	12.5	159.7
2056	2057	1721.7	129.48	13.3	169.6
2057	2058	1828.7	129.48	14.1	180.1

Consolidated Revenue

The consolidated revenue from the two source are given in Table 18-11.

TABLE 18-11: CONSOLIDATED REVENUE FROM PREMIUM FSI AND STAMP DUTY FOR THE LINE 2 EXTENSIONS FROM THE YEAR 2023 TO YEAR 2057

Financial Year		Revenue from Premium FSI (Rs. in Crores)	Revenue from Stamp Duty (Rs. in Crores)
2023	2024	9.8	-
2024	2025	10.6	-
2025	2026	11.9	-
2026	2027	12.7	-
2027	2028	13.5	-
2028	2029	41.6	61.9
2029	2030	83.2	33.3
2030	2031	138.1	35.4

Financial Year		Revenue from Premium FSI (Rs. in Crores)	Revenue from Stamp Duty (Rs. in Crores)
2031	2032	153.1	37.6
2032	2033	165.3	39.9
2033	2034	153.1	42.4
2034	2035	150.7	45.0
2035	2036	136.1	47.8
2036	2037	127.1	50.8
2037	2038	113.5	54.0
2038	2039	104.0	57.3
2039	2040	94.5	60.9
2040	2041	78.7	64.7
2041	2042	59.0	68.7
2042	2043	39.3	72.9
2043	2044	27.6	77.5
2044	2045	10.2	82.3
2045	2046	5.1	87.4
2046	2047	5.3	92.8
2047	2048	5.3	98.6
2048	2049	5.3	104.7
2049	2050	5.5	111.2
2050	2051	5.5	118.1
2051	2052	5.5	125.5
2052	2053	5.7	133.3
2053	2054	5.7	141.5
2054	2055	5.7	150.3
2055	2056	5.9	159.7
2056	2057	5.9	169.6
2057	2058	4.7	180.1

18.6.3. SUMMARY OF NON-FARE REVENUE ESTIMATION

Sale of Premium FSI and premium TDR: Charges on the sale of premium FSI would be levied on account of the transit system. However, the regulatory framework and collection of the same would be under the Municipal Corporation's jurisdiction. The revenue estimation in the section above has been done considering the share of premium charges, that is, 35% for residential and commercial. The share of Pune Metro (Maha Metro) was considered as 50% of the total.

Stamp Duty: For this assignment, the additional cess of 1% on Stamp Duty has been considered, which is exclusively reserved for the project with "Vital Urban Transport

Project" status. Therefore, the total revenue generated on account of Additional Cess as part of the Stamp Duty has been assumed to be passed on to the SPV.

Table 18-13 gives the non-fare revenue estimation.

TABLE 18-12: NON-FARE REVENUE ESTIMATION FOR THE PROJECT YEAR (RS. IN CRORE)

Value Capture Finance Mechanism	Estimated Revenue (Rs. Crore)
Premium FSI	1804.4
Stamp Duty	2605.1
Total	4409.5

18.7. PROPERTY DEVELOPMENT

As part of the estimation of revenue through property development, land parcels with potential for development have been identified along the Metro corridor, and is listed and shown in Table 18-13.

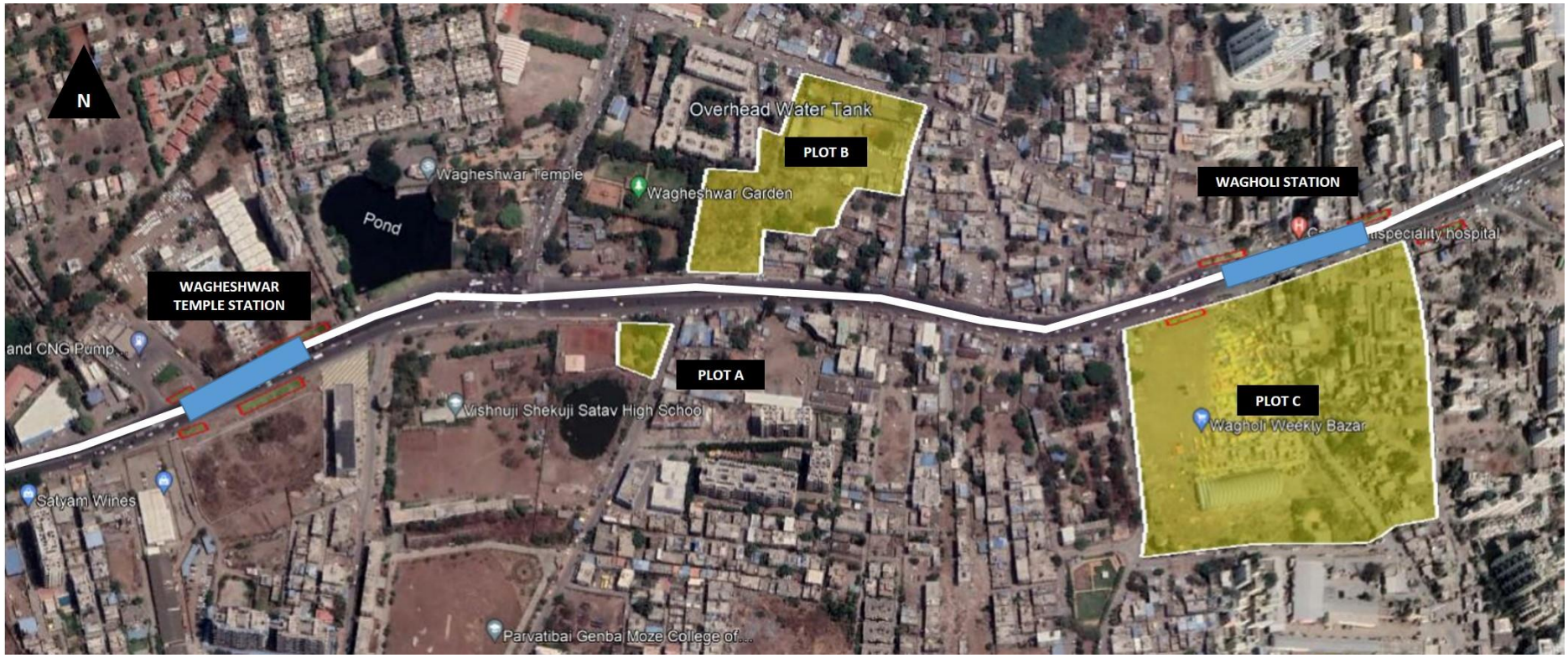


FIGURE 18-3: IDENTIFIED PLOTS FOR THE PROPERTY DEVELOPMENT UNDER TOD

TABLE 18-13: PLOTS IDENTIFIED FOR PROPERTY DEVELOPMENT

SN	Land Plot	Survey No	Area (Sqm)	Ownership	Nearest Metro Station
1	Plot A	1176	1,800	Govt	Wagheshwar Temple
2	Plot B	1417	19,400	Govt	Wagheshwar Temple/ Wagholi
3	Plot C	1123	59,700	Govt	Wagholi
Total			80,900		

The maximum permissible FSI based on the size of the plot and abutting ROW is identified and the total built-up area is estimated for the revenue potential.

TABLE 18-14: ESTIMATED BUILT UP FOR IDENTIFIED LAND PARCELS

Sl. no	Land Plot	Plot Size (sqm)	Plot size category	Abutting ROW	Max. Permissible FSI	Total Built-up (sqm)
1	Plot A	1,800	1000-2000sqm	>24m	4	7,200
2	Plot B	19,400	>4000 sqm	>24m	4	77,600
3	Plot C	59,700	>4000 sqm	>24m	4	2,38,800
Total Built Up (Sqm)						**3,23,600**
Total Built Up (Sq. ft.)						**34,83,201**

A total of 3,23,600 Sqm (34,83,201 Sq. ft.) built up area available for development at the identified plots (A, B & C). It was however observed that in these plots, few settlements/encroachments are present in Plot B & Plot C whereas few Government Offices are present in Plot A & Plot B. The clearance of these settlements and relocation of offices would be required before the initiation of the development of these Plots.

It is proposed that cost implication towards clearance of the settlements and relocation of public offices (if any) are assumed to be within the scope of the PPP developer. Alternatively, the option of utilizing entire plot permissible built up area, in the available vacant land can also be considered.

One of the best ways to realize upfront revenues for the project is by giving the land to a private developer on lease for 30 years.

TABLE 18-15: LAND VALUE

Particulars	Unit	Plot A	Plot B	Plot C
Commerical B/U Area	Sq Ft	77,500	835,279	2,570,422
Rental per month *	Rs/Sq Ft	80	80	80
Annual Rental	Rs Cr	7.44	80.19	246.76
Operating Profit/Rev		95%	95%	95%
Annual Operating Profit	Rs Cr	7.07	76.18	234.42
Cap Rate/Annualized Rental Yield#		10%	10%	10%
Property Value	Rs Cr	70.68	761.77	2,344.22
Construction Cost @Rs. 3500 per sqft.	Rs Cr	27.13	292.35	899.65
Land Value	Rs Cr	**43.56**	**469.44**	**1,444.58**
Total Land Value	Rs Cr	**1,957.58**		

Note: * Based on Primary sources from Property Brokers and Secondary Source
Based on Market norms for Commercial Properties

The potential revenue expected from the PD development is 60% of the Total Land Value (1957.58 Cr) which works out to be 1174.54 Crores.This amount is expected to be realized in FY 29-30 when the metro becomes operational. The same is considered as one of the non-fare box revenue in the Financial modeling and the further details are detailed out in the Chapter 19 – Financial Analysis and Non-Fare Box Revenue

Notes:

- Revenue potential has been estimated at an overall level on total land area available for development highlighted in Table 18-14 & Table 18-15 (i.e. 3,23,600 sqm) and no separate assessment has been undertaken for specific land parcels.
- Maximum permissible FSI of 4 is considered for land parcels in Table 18-13 based on the plot size & ROW
- It is assumed that the said development will be purely commercial – Office or retail
- As per the Pune TOD Policy, for commercial spaces, parking can be provided parcel, the following assumptions have been considered.

Annexure 18.1

Revised TOD Policy

NOTIFICATION

Government of Maharashtra

Urban Development Department

Madam Kama Marg, Hutatma Rajguru Chowk,

Mantralaya, Mumbai – 400 032.

Date : 10.10.2022

The Maharashtra Regional & Town Planning Act, 1966

No.TPS-1818/950/C.R.158/19/UD-13 :- whereas, Government in Urban Development Department, under the provisions of section 31(1) the Maharashtra Regional and Town Planning Act, 1966 (hereinafter referred to as "the said Act") has sanctioned Development Control and Promotion Regulations of Pune Municipal Corporation vide Notification No.TPS-1815/209/C.R.69/15/D.P.Pune-Sanction/UD-13, dated 05.01.2017. Also sanctioned the Development Control Regulations for Pimpri-Chinchwad Municipal Corporation vide Notification No.TPS-1890/699/C.R.89/90/UD-13, dated 17.12.1990. (hereinafter referred to as "the said the then Regulations");

And whereas, in order to facilitate the implementation of the Government's Transit Oriented Development (TOD) Policy in the interest of the larger public, the Government has published a Notice No.TPS-1818/950/CR.No.158/19/Ud-13, dated 30.06.2020 under Section 37(1AA) and Section 20(3) of the said Act (hereinafter referred to as "the said Notice") to make applicable T.O.D. Regulations, as mentioned in **Appendix-A** appended to the said Notice, in the then Regulations of Pune Municipal Corporation and include this Regulations in the then Regulations of Pimpri-Chinchwad Municipal Corporation (hereinafter referred to as "the said proposed Modification") and appointed the Joint Director, Town Planning, Pune Division, Pune as an "Officer" to hear the suggestions / objections received from the public regarding the said proposed Modification and to complete the proceedings prescribed under Section 37(1AA) of the said Act and submit the report thereon to the Government. Also Regulations published vide said Notice have been immediately implemented vide Order dated 30.06.2020 under Section 154 of the said Act;

And whereas, the Government has sanctioned the Unified Development Control and Promotion Regulations (hereinafter referred to as "the said UDCPR") for remaining Planning Authorities, excluding some Planning Authorities and Regional Plan Areas in the State vide Government Notification No.TPS-1818/C.R.236/18/D.P. & R.P./Sec.37(1AA)(c) & Sec.20(4)/ UD-13, dated 02.12.2020 which has come into effect from 03.12.2020. The Regulation No.14.2.1 - T.O.D. Regulation for Pune Municipal Corporation in said Regulation has been Kept in abeyance;

And whereas, the appointed Officer has submitted his report to the Government after hearing the suggestions / objections received from the public in pursuance of the said Notice and taking the say of the Planning Authority and after completing the necessary statutory proceedings;

URBAN DEVELOPMENT DEPTT. MANTRALAYA MUMBAI 32

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And Whereas, after considering the report of the said appointed Officer and consulting with the Director of Town Planning and making necessary enquiries and as the said the then Regulations are not in force, the Government is of the opinion that, it is necessary to include the said proposed Modification, with some changes, as mentioned in **Appendix-A** appended herewith, in the Regulation No.14.2.1 of the said UDCPR;

Now therefore, in accordance with the powers conferred under Section 37(1AA)(c) and Section 20(4) of the said Act, the Government hereby -

A. Sanctions to include Regulations of T.O.D., as mentioned in **Appendix-A** appended herewith, in the Regulation No.14.2.1 of the sanctioned Unified Development Control and Promotion Regulations.

B. Fixes the date of publication of this Notification in Government Gazette, as the date of coming into force of the said modification.

1) This incorporated Regulation will be available for inspection to the public at the following offices during office hours for a period of one month..

1. The Commissioner, Pune Municipal Corporation, Pune.
2. The Commissioner, Pimpri-Chinchwad Municipal Corporation, Pimpri, Pune.
3. The Metropolitan Commissioner and Chief Executive Officer, Pune Metropolitan Region Development Authority, Pune.

2) This Notification alongwith Appendix will be available on Government website www.maharashtra.Gov.in (Acts / Rules).

By order and in the name of the Governor of Maharashtra,

URBAN DEVELOPMENT DEPTT. MANTRALAYA, MUMBAI-32

(Kishor V. Gokhale)
Under Secretary to Government

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Accompaniment of Govt. Notification bearing No.TPS-1818/950/CR.158/19/ Sec.37(1AA)(c) & Sec.20(4)/UD-13, Dated 10/10/2022

APPENDIX – 'A'
(Regulation No.14.2.1)

TOD Regulations inserted in the Unified Development Control and Promotion Regulations (UDCPR) as mentioned below.

14.2.1 TRANSIT ORIENTED DEVELOPMENT (TOD)

The planning authority shall ensure execution of complete street design for the success of TOD and enable construction of street oriented buildings while achieving optimum densities in residential, commercial and office buildings.

The Planning authority shall also ensure complete pedestrianisation in the TOD zones for easy movement of the pedestrians to & from station within a period of 1 year from ***sanction*** of this regulation.

14.2.1.1 Definitions

(i) TOD zone: - It is the area 500 mt. around the proposed Metro-station boundary as will be delineated by the Planning Authority with the approval of the State Government. Wherever any reservation / amenity space within such distance is utilized for the purpose of transportation as prescribed in these regulations, and the distance of 500 mtr shall stand relaxed up to 30%. The TOD zone shall be delineated on ground by the Planning Authority in time bound manner i.e. within 2 months from this notification.

(ii) Base permissible FSI: - It is the FSI that is otherwise permissible on any land with respect to zone shown as per the sanctioned development plan and the relevant provision of the Principal DCPR excluding the TDR and the premium FSI, redevelopment incentive FSI that can be received.

(iii) Gross plot area: - Gross Plot Area means total area of land after deducting area under reservation or deemed reservation like amenity space if any, area under D.P. Road and Road widening.

(iv) Principal DCPR: - Principal DCPR means the ***UDCPR sanctioned vide notification dt.02.12.2020 and as amended from time to time.***

14.2.1.2 Maximum Permissible FSI :- The maximum permissible total FSI in TOD zone shall be 4.00 including the base permissible FSI, subject to condition that, the additional FSI over and above the base permissible FSI shall be allowed within the overall limit of maximum permissible FSI, as given in the Table below -

Sr. No.	Road width in mt.	Maximum Permissible FSI
1	2	3
1	9 m. and up to 12 m.	2.50
2	12 m. and up to 15 m.	3.00
3	15 m. and up to 24 m.	3.50
4	24 m. and above	4.00

URBAN DEVELOPMENT DEPTT. MANTRALAYA, MUMBAI-32

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Note : The Regulations as pertaining to Ancillary FSI as listed in the principle DCPR shall be applicable on the above mentioned FSI. The Built-up Area Calculation shall be in accordance with Regulation 6.6 of UDCPR.

14.2.1.2.1 Premium to be Paid - *Additional FSI Over and above the base permissible FSI of respective land use zones as per principal DCPR may be permitted on the payment of premium*

Rate of premium for the additional F.S.I., as mentioned in Column No.3 above shall be 30% for FSI to be used for tenements of size equal to or less than 60 sq.mt. and 35% for remaining FSI to be used for residential and / or commercial use, of the rate of the said land mentioned in Annual Statement of Rates without considering the guidelines therein.

In the area of Planning Authority, 50% of the amount of premium collected should be paid to the Planning Authority in the area concerned with the Urban Transport Project and remaining 50% to the Project Implementing Authority.

In the area of Regional Plans, 50% of the amount of premium collected should be paid to the Government through the District offices of Town Planning and Valuation Department and remaining 50% to the Project Implementing Authority.

14.2.1.2.2 **Impact Assessment and Integrated Mobility Plan:-**

Such additional FSI over and above the base permissible FSI, shall be granted by *the Authority* from where the Metro Rail is passing through, after taking into account the Impact Assessment of the implementation of these regulations, regarding the impact on the city and sector level infrastructure and amenities as well as traffic and environment. Such Impact Assessment shall also contain measures to be undertaken to mitigate its likely impact and the Action Plan for implementation of such measures in a time bound manner.

There shall be an Integrated Mobility Plan envisaging inter-linkages between different modes of mass transport, parking management, traffic management and *pedestrianisation, non-motorized transport network, last mile connectivity, traffic calming, inter-connected street networking etc.*

The impact assessment analysis shall be done by ***Planning Authority*** within 4 months containing the remedial measures required regarding upgradation of infrastructure etc. taking into consideration the impact analysis and provisions of sanctioned Development Plan and need of such area falling in TOD Zone. Local Area Plans shall be prepared by ***Planning Authority*** with participation of local residents within a period of four (4) months. Such Local Area Plans shall contain complete street design to achieve optimum densities and also to ensure complete pedestrianisation.

14.2.1.2.3 ***Entire area of plot may be considered for calculating the potential of plot in respect of premium FSI + TDR, but not the basic FSI. Basic FSI shall be calculated on area of the plot remaining with the owner after deducting area under D.P. road / road widening / reservations and amenity space. This shall be applicable in cases where reservation area or amenity space is handed over to the authority.***

URBAN DEVELOPMENT DEPT. MANTRALAYA, MUMBAI

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14.2.1.2.4 - In case of plot / plots falling partly within the TOD zone, the FSI permissible shall be as follows, provided that the total area of the plot (plot falling within TOD zone plus plot falling outside TOD zone) shall be as prescribed in the table in regulation no.14.2.1.2 :-

(i) Where 50% or more area of such plot / plots falls within TOD zone, these regulations including FSI shall apply to the total area of such plot / plots.

(ii) Where less than 50% area of such plot / plots falls within TOD zone, these regulations including FSI shall be applicable to the part of plot / plots falling within TOD zone, whereas for the part of plot / plots falling outside TOD zone, these regulations except provisions regarding FSI shall be applicable. The FSI permissible for the part falling outside TOD zone shall be as per Principal DCPR.

Notwithstanding anything contained in any other provisions of these regulations, TDR shall be allowed to be received on the plots within TOD zone, irrespective of its location in congested area / non-congested area as per the Development Plan of Pune subject to condition that it shall be utilised in 1/4 share with premium FSI at every stage of utilization. Such share shall be calculated on the potential remaining after utilizing the in-situ FSI towards Development Plan road, reservation, amenity space, if any, on such land. ***_However in case of non -availability / shortage of TDR, the Authority, after considering the local situation, may allow utilisation of entire potential with premium FSI.*** The ***Planning Authority*** shall compensate for the same to Metro Project Implementing Authority as per the sharing formula decided by the Government from time to time.

(iii) In case of plot / plots which marginally fall in TOD Zone i.e. less than 10% or 500 sq.mt., whichever is less, the land owner / developer shall decide to follow this TOD Regulations or Principal DCPR.

14.2.1.3 Tenement Size

For any development or redevelopment within TOD zone, size of tenement shall be minimum 25 sq.mt. and maximum 120 sq.mt. of carpet area and out of total proposed tenements, the tenements equivalent to at least 50% of total FSI shall be of a size equal to or less than 60 sq.mt. carpet area except the projects in which rehabilitation of existing tenements is undertaken. In case of redevelopment scheme, size of tenement can be relaxed for Rehab Component subject to other provisions of Principal DCPR. However for free sale component 50% of residual FSI shall be utilise for tenements of size equal to or less than 60 sq.mt. carpet area. These tenements shall not be allowed to be clubbed / amalgamated in any case. ***However, this restriction for the residual FSI shall not be necessary in case of single building redevelopment projects on plots below 1000 sq.mt.***

In case of building with mixed use, 50% of FSI utilized for residential purpose shall be considered for calculating requirement of tenements of a size equal to or less than 60 sq.mt. carpet area.

If the holder / owner of the property needs to build this 50% component at some other location(s) within the same TOD zone / circle, the difference between rate of sale of

URBAN DEVELOPMENT DEPTT. MANTRALAYA, MUMBAI 32

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tenements as mentioned in Annual Statement of Rates shall be paid by the developer to the Municipal Corporation as premium.

14.2.1.4 Permissible mixed use in TOD zone : Mixed use in the form of residential and commercial may be permissible on the residential plot in TOD zone fronting on the road width of 12 mt., and above and mix use on plot / plots in commercial ***plot in TOD zone*** shall be permissible as per the Principal DCPR and the maximum permissible FSI under ***this regulation*** shall be allowed on the payment of premium. Purely Mercantile building ***office building, schools, colleges, hospitals, hotels, assembly buildings will be permissible on independent plot*** & Information Technology building will be permissible on independent plot subject to payment of premium. For I.T. Buildings the rate of premium for additional FSI up to 200 % shall be as per regulation no. ***7.8*** of Principal DCPR and for additional FSI over it shall be as required under ***this regulation***.

14.2.1.5 Marginal Distances :- ***Marginal Distances Shall be applicable as per provisions in principle DCPR.***

14.2.1.6 Parking :- ***Parking provisions in the TOD Zone shall be at 50% of those as mentioned in UDCPR.***

Note : No on-street parking shall be permissible, unless specifically allowed in the integrated mobility plan report.

14.2.1.6.1 Incentive for providing Public Parking in the area falling within the radius of 200 mt. from the Metro/MRTS Station.

If the owner / developer of the plot falling within the radius of 200 mt. from the Metro Station is willing to provide Public Parking space over and above the parking spaces required as per regulation No.***14.2.1.6*** of this regulation, the same shall be allowed without charging premium for such additional area and in that case the overall premium shall be discounted on 50 **%** of such parking area while calculating premium for additional FSI allowed over and above the base FSI, subject to following conditions :-

a) Such parking area shall be in the built-up form and shall be handed over to Planning Authority free of cost before granting the Occupation Certificate to the project. The Planning Authority should enter into an agreement with owner / developer for such parking space at the time of granting Commencement Certificate to the project. Such Public Parking area shall be clearly shown on the proposed building plan / layout and a condition to above effect shall be incorporated in the Commencement Certificate.

b) The parking area shall have independent access from major road adjacent to the plot and with proper entry and exits.

c) The parking area to be made available at individual site shall be at minimum 100 sq.mt. at one place either at Ground floor / Stilt floor or first floor.

d) The maximum parking area that can be provided shall be decided by the ***Authority***, as the case may be, on considering the location of such site and the parking requirement.

e) A board showing the location of such public parking space should he displayed at suitable places by the Planning Authority.

URBAN DEVELOPMENT DEPTT. MANTRALAYA MUMBAI

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f) Area covered under such parking shall not be counted towards FSI consumption.

g) Concerned land owner / developer / society / public company shall not be allowed to operate the public parking.

h) The proposed development shall be further subject to such conditions as may be decided by the ***Authority***.

14.2.1.7 In case of development or redevelopment, proposed by the Authority / individual applicant / any other Planning Authority, from the edge of the Metro Rail, within 20 mt. distance on its either side, the concerned Planning Authority before granting such permission for development / redevelopment shall seek prior NOC from the concerned Metro Railway Authority as required under the Metro Railways (Construction of Works) Act, 1978 from the point of view of safety of the Metro Railway and such other related matters.

14.2.1.8 For the matters not provided in this regulation, the relevant provisions of Principal DCPR shall apply. However, in case of any conflict between this Regulation and any other Regulation/s of the *Principal DCPR*, this Regulation shall prevail for the TOD zone.

14.2.1.9 No Compound wall / fencing shall be permissible on the boundary of plot *facing the* road and 50% front marginal distance (subject to minimum of 3.0 mt.) shall be kept accessible to the pedestrians to be used as foot paths. However, it shall be permissible for the applicant to construct / erect fencing, on the receded boundary, after leaving the space for pedestrians as specified above.

14.2.1.10 Large wholesale stores ***having built-up area of more than 500 sq.mt.,*** car dealer showrooms, warehouses / storages, auto service centers, Garages etc. shall not be permissible in TOD zone.

14.2.1.11 Provision of Inclusive housing shall not be applicable in TOD zone.

14.2.1.12 For Gunthewari development regularized under the provisions of Maharashtra Gunthewari Development Act, 2001 and falling in TOD zone, seeking permission for *development* / redevelopment, these regulations shall apply.

14.2.1.13 In case of independent unit / Bungalow for self use, such Development / Redevelopment may be allowed within base FSI subject to Principal DCPR.

Notwithstanding anything contained in this regulation, if any development on plot in TOD zone is proposed within base permissible FSI (without TDR or Premium FSI) as per provisions of Principal DCPR, all other provisions of Principal DCPR shall be applicable.

14.2.1.14 The layout of building / group housing layout or standalone building on a plot / plots situated in TOD zone / Circle, over which ***any development permission granted or any development proposal for which any action is taken*** and for which occupancy certificate is not granted, may be revised and balance potential, ***as per this regulation,*** if any, may be allowed subject to structural stability criteria and ***provisions in Regulation 1.5 of Principle DCPR*** and subject to following.

URBAN DEVELOPMENT DEPTT. MANTRALAYA, MUMBAI

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a) **Parking** - For the ongoing buildings, the requirement of parking as per this regulation shall be applicable for the balance building potential.

b) **Tenement size** - For the ongoing buildings, the requirement of tenement size as per this regulation shall be applicable for the balance building potential.

14.2.1.15 The Amount received as scrutiny fee, hardship premium, and premium for additional FSI etc. in TOD zone / circle shall be kept in separate head at ***Authority*** level and shall be utilized for development of metro project as per directives issued by Government from time to time.

14.2.1.16 These TOD provisions will also be made applicable to other MRTS projects such as BRTS. The scale of FSI availability will be notified later by the Government for such other projects.

By order and in the name of the Governor of Maharashtra

URBAN DEVELOPMENT DEPTT. MANTRALAYA, MUMBAI-32 सत्यमेव जयते

(Kishor Gokhale)
Under Secretary to Government

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Annexure 18.2

मुंबई महानगरपालिका अधिनियम-१८८८ व महाराष्ट्र महानगरपालिका अधिनियम-१९४९ मधील तरतूदीनुसार वसूल होणारी एक टक्का मुद्रांक शुल्क अधिभाराची रक्कम नगर विकास विभागांतर्गत राबविण्यात येणा-या मुंबई, नागपूर व पुणे मेट्रो रेल्वे या महत्वाकांक्षी नागरी परिवहन प्रकल्पांच्या अंमलबजावणी यंत्रणेस वितरीत करण्यासाठीचे धोरण निश्चितीबाबत.

महाराष्ट्र शासन
नगर विकास विभाग
शासन निर्णय क्रमांक : एमआरडी-३३१९/प्र.क्र.६१/नवि-७
मादाम कामा रोड, हुतात्मा राजगुरु चौक,
मंत्रालय, मुंबई-४०० ०३२.
दिनांक: १० सप्टेंबर, २०२०

संदर्भः- १. महाराष्ट्र शासन राजपत्र अधिसूचना असाधारण क्र. ५६ दि. २१.०८.२०१५
२. महाराष्ट्र शासन राजपत्र अधिसूचना असाधारण क्र. ११९ दि. १७.१२.२०१८
३. महाराष्ट्र शासन राजपत्र अधिसूचना असाधारण क्र. १६ दि. ०८.०२.२०१९
४. महाराष्ट्र शासन राजपत्र अधिसूचना असाधारण क्र. १७ दि. ०८.०२.२०१९

प्रस्तावना:-

महाराष्ट्र महानगरपालिका अधिनियम-१९४९ व मुंबई महानगरपालिका अधिनियम-१९८८ मधील तरतूदीनुसार महत्वाकांक्षी नागरी परिवहन प्रकल्प राबविण्यात येत असलेल्या महानगरपालिका क्षेत्रात स्थावर मालमत्तेची अनुक्रमे विक्री, दान व फलोपभोग गहाण या संबंधीच्या संलेखांवर मुद्रांक शुल्क अधिनियमान्वये आकारावयाच्या मुद्रांक शुल्कात एक टक्का दराने अधिभार आकारुन वाढ करणे व सदर अधिभारापोटी वसुल केलेल्या रक्कमेएवढे सहायक अनुदान अशा प्रकाराचे प्रकल्प हाती घेतलेल्या अभिकरणाला/प्रकल्प अंमलबजावणी संस्थेला प्रदान करण्याबाबत तरतूद करण्यात आली आहे. सदर तरतुदीनुसार अतिरिक्त मुद्रांक शुल्क ज्या दिनांकापासून वा नंतर आकारले जाईल त्यासाठी दिनांक ८ फेब्रुवारी, २०१९ हा दिनांक विनिर्दिष्ट करण्यात आला आहे.

नगर विकास विभागांतर्गत मुंबई, नागपूर व पुणे महानगर क्षेत्रात मुंबई महानगर प्रदेश विकास प्रधिकरण (एमएमआरडीए), मुंबई मेट्रो रेल कॉर्पोरेशन लि. (एमएमआरसीएल), महाराष्ट्र मेट्रो रेल कॉर्पोरेशन लि.(महामेट्रो), पुणे महानगर प्रदेश विकास प्रधिकरण (पीएमआरडीए) अशा प्रकल्प अंमलबजावणी संस्थेमार्फत विविध मेट्रो रेल्वे प्रकल्प राबविण्यात येत असून सदर प्रकल्प मुंबई महानगरपालिका अधिनियम-१८८८ व महाराष्ट्र महानगरपालिका अधिनियम-१९४९ मधील तरतूदीच्या प्रयोजनार्थ महत्वाकांक्षी नागरी परिवहन प्रकल्प म्हणून घोषित करण्यात आले आहेत. मुंबई महानगरपालिका अधिनियम-१८८८ व महाराष्ट्र महानगरपालिका अधिनियम-१९४९ मधील तरतूदीनुसार वसूल होणारी एक टक्का मुद्रांक शुल्क अधिभाराची रक्कम नगर विकास विभागांतर्गत राबविण्यात येणा-या मुंबई, नागपूर व पुणे मेट्रो रेल्वे या महत्वाकांक्षी नागरी परिवहन प्रकल्पांना वितरीत करण्यासाठीचे धोरण निश्चित करण्याची बाब शासनाच्या विचाराधीन होता. यानुषंगाने शासनाने पुढीलप्रमाणे निर्णय घेतला आहे.

शासन निर्णय क्रमांकः **एमआरडी-३३१९/प्र.क्र.६१/नवि-७**

शासन निर्णय :-

मुंबई महानगरपालिका अधिनियम-१८८८ व महाराष्ट्र महानगरपालिका अधिनियम-१९४९ मधील तरतूदीनुसार नगर विकास विभागांतर्गत राबविण्यात येणा-या मुंबई, नागपूर व पुणे मेट्रो रेल्वे या महत्वाकांक्षी नागरी परिवहन प्रकल्पांशी संबंधित महानगरपालिका क्षेत्रात स्थावर मालमत्तेची अनुक्रमे विक्री, दान व फलोपभोग गहाण संबंधीच्या संलेखांवर मुद्रांक शुल्क अधिनियमान्वये आकारावयाच्या मुद्रांक शुल्कावरील एक टक्का अधिभारापोटी वसूल होणारी रक्कम संबंधित मेट्रो प्रकल्प अंमलबजावणी संस्थेला वितरीत करण्याची कार्यप्रणाली खालीलप्रमाणे राहीलः-

१. सदर एक टक्का मुद्रांक शुल्कावरील अधिभाराची वसूली नोंदणी महानिरिक्षक व मुद्रांक नियंत्रक विभागामार्फत दि. ८ फेब्रुवारी, २०१९ पासून करण्यात यावी. सदर वसूल होणारी रक्कम राज्याच्या एकत्रित निधीमध्ये या प्रयोजनार्थ घेण्यात येणा-या लेखाशिर्षाखाली जमा करण्यात यावी.

२. सदर एक टक्का अधिभारापोटी राज्याच्या एकत्रित निधीमध्ये जमा होणा-या रक्कमेचा तपशील नोंदणी महानिरिक्षक व मुद्रांक नियंत्रक, महाराष्ट्र राज्य, पुणे यांनी नगर विकास विभागाकडे सादर केल्यानंतर वित्त विभागाने खालील लेखाशिर्षाखाली अर्थसंकल्पीय तरतूदीद्वारे नगर विकास विभागास निधी उपलब्ध करून द्यावा.

मागणी क्रमांक एफ-५ ४२१७-नगर विकासावरील भांडवली खर्च, ६०- नगर विकास विभाग इतर योजना, १९०, सार्वजनिक क्षेत्रातील व इतर उपक्रमातील गुंतवणूका	
१.	(०१)(०१) मुंबई मेट्रो रेल्वे प्रकल्पास मुद्रांक शुल्क अधिभाराचे प्रदान (४२१७०८०१) (अनिवार्य), ५४-गुंतवणुका
२.	(०१)(०२) नागपूर मेट्रो रेल्वे प्रकल्पास मुद्रांक शुल्क अधिभाराचे प्रदान (४२१७०८१९) (अनिवार्य), ५४-गुंतवणुका
३.	(०१)(०३) पुणे मेट्रो रेल्वे प्रकल्पास मुद्रांक शुल्क अधिभाराचे प्रदान (४२१७०८२८) (अनिवार्य) ५४-गुंतवणुका

३. सदर महत्वकांक्षी नागरी परिवहन प्रकल्प राबविण्यात येत असलेल्या शहरांमध्ये एक टक्का मुद्रांक शुल्क अधिभारापोटी शासनाकडे जमा होणारी रक्कम वित्त विभागाच्या सहमतीने संबंधित शहराध्ये राबविण्यात येणा-या मेट्रो रेल्वे प्रकल्पांच्या अंदाजित प्रकल्प पुर्णत्व खर्चाच्या प्रमाणात संबंधित मेट्रो रेल्वे प्रकल्प अंमलबजावणी यंत्रणांच्या -नागरी वाहतूक निधी- मध्ये नगर विकास विभागामार्फत उपलब्ध करून देण्यात येईल.

४. मुंबई महानगर प्रदेशात राबविण्यात येत असलेले विविध मेट्रो प्रकल्प हे वेगवेगळ्या यंत्रणांमार्फत राबविण्यात येत असल्याने व अशा प्रकल्पातील राज्य शासनाचा हिस्सा एमएमआरडीए वहन करीत असल्याने मुंबई महानगर प्रदेशातील प्रकल्पांना एक टक्का अधिभारापोटी द्यावयाचा निधी एमएमआरडीएकडे नगर विकास विभागामार्फत वर्ग करण्यात येईल. तद्नंतर एमएमआरडीएने संबंधित प्रकल्पांचा अंदाजित प्रकल्प पुर्णत्व खर्च विचारात

पृष्ठ **५** पैकी **२**

शासन निर्णय क्रमांकः **एमआरडी-३३१९/प्र.क्र.६१/नवि-७**

घेऊन सदरचा निधी त्या त्या प्रमाणात अन्य प्रकल्प अंमलबजावणी यंत्रणेकडे (एमएमआरडीएसह) वर्ग करावा. मुंबई शहर व परिसरातील मेट्रो रेल्वे प्रकल्पांना शासनाकडून वितरीत करण्यात येणा-या निधीचे प्रकल्पनिहाय वाटप एमएमआरडीएच्या स्तरावरून केल्यानंतर त्याबाबतचे लेखे एमएमआरडीएमार्फत ठेवण्यात यावे.

५. नागपूर व पुणे महानगर प्रदेशात राबविण्यात येत असलेल्या मेट्रो प्रकल्पांस मुद्रांक शुल्कावरील एक टक्का अधिभारापोटी द्यावयाचा निधी नगर विकास विभागामार्फत अनुक्रमे महामेट्रो, नागपूर व पीएमआरडीए, पुणे यांचेकडे वर्ग करण्यात यावा. पीएमआरडीएमार्फत, पुणे महानगर प्रदेशात राबविण्यात येणा-या प्रकल्पांचा अंदाजित प्रकल्प पुर्णत्व खर्च विचारात घेऊन, सदरचा निधी त्या त्या प्रमाणात अन्य मेट्रो रेल्वे प्रकल्प अंमलबजावणी यंत्रणेकडे (पीएमआरडीएसह) वर्ग करावा. यासंदर्भात महामेट्रो व पीएमआरडीएने जमा-खर्चाचा ताळेबंद ठेवावा.

६. सदर एक टक्का अधिभारापोटी वितरीत करण्यात येणा-या निधीच्या जमा-खर्चासाठी एमएमआरडीए, महामेट्रो व पीएमआरडीए यांच्या स्तरावर स्वतंत्र राष्ट्रीयकृत बँक खाते उघडण्यात यावे. सदर बँक खात्याचा जमा-खर्चाचा ताळेबंद एमएमआरडीए, महामेट्रो व पीएमआरडीएमार्फत शासनास दरवर्षी सादर करण्यात येईल. सदर निधी वितरण प्रक्रियेचे संनियंत्रण नगर विकास विभागामार्फत करण्यात येईल.

७. सदर एक टक्का अधिभारापोटी संबंधित मेट्रो रेल्वे प्रकल्पांना वितरीत करावयाचा निधी हा संबंधित मेट्रो रेल्वे प्रकल्पाच्या अंमलबजावणीकरिता घेण्यात येणा-या कर्जाची परतफेड होईपर्यंत अथवा यासंदर्भात शासनाच्या पुढील आदेशापर्यंत या पैकी जे आधी घडेल तोपर्यंत वितरीत करण्यात यावा.

०२. सदरचा शासन निर्णय महसूल व वन विभाग अनौपचारिक संदर्भ क्र.५/२०२०/म-१(धोरण) व दि.२८.०२.२०२० वित्त विभाग अनौपचारिक संदर्भ क्र.११८/व्यय-३ व दि.०३.०७.२०२० अन्वये प्राप्त सहमतीनुसार निर्गमित करण्यात येत आहे.

०३. सदर शासन निर्णय महाराष्ट्र शासनाच्या www.maharashtra.gov.in या संकेतस्थळावर उपलब्ध करण्यात आला असून त्याचा सांकेतांक २०२००९१०१४४९३३८२२५ असा आहे. हा आदेश डिजीटल स्वाक्षरीने साक्षांकित करुन काढण्यात येत आहे.

महाराष्ट्राचे राज्यपाल यांच्या आदेशानुसार व नांवाने,

Digitally signed by VIJAY KARBHARI CHAUDHARI
Date: 2020.09.10 18:21:59 +05'30'

(विजय चौधरी)
उप सचिव, महाराष्ट्र शासन

प्रत:-

१. मा. राज्यपाल महोदयांचे सचिव

पृष्ठ **५** पैकी **३**

शासन निर्णय क्रमांकः **एमआरडी-३३१९/प्र.क्र.६१/नवि-७**

२. मा. सभापती, महाराष्ट्र विधानपरिषद, महाराष्ट्र विधानमंडळ सचिवालय, मुंबई.
३. मा. अध्यक्ष, महाराष्ट्र विधानसभा, महाराष्ट्र विधानमंडळ सचिवालय, मुंबई.
४. मा. विरोधी पक्षनेता, विधानपरिषद, महाराष्ट्र विधानमंडळ सचिवालय, मुंबई.
५. मा. विरोधी पक्षनेता, विधानसभा, महाराष्ट्र विधानमंडळ सचिवालय, मुंबई.
६. मा. उपसभापती, महाराष्ट्र विधानपरिषद, महाराष्ट्र विधानमंडळ सचिवालय, मुंबई.
७. मा. उपाध्यक्ष, महाराष्ट्र विधानसभा, महाराष्ट्र विधानमंडळ सचिवालय, मुंबई.
८. मा. मुख्य सचिव, मुख्य सचिव कार्यालय, मंत्रालय, मुंबई.
९. मा. अपर मुख्य सचिव, मा. मुख्यमंत्री कार्यालय, मंत्रालय, मुंबई.
१०. मा. अपर मुख्य सचिव (नियोजन विभाग), मंत्रालय, मुंबई.
११. मा. अपर मुख्य सचिव (वित्त विभाग), मंत्रालय, मुंबई.
१२. मा. अपर मुख्य सचिव (महसूल व वन विभाग), मंत्रालय, मुंबई.
१३. मा. प्रधान सचिव (नवि-१), नगर विकास विभाग, मंत्रालय, मुंबई.
१४. मा. प्रधान सचिव (नवि-२), नगर विकास विभाग, मंत्रालय, मुंबई.
१५. सचिव, मा. उप मुख्यमंत्री कार्यालय, मंत्रालय, मुंबई.
१६. आयुक्त, बृहन्मुंबई महानगरपालिका, मुंबई.
१७. महानगर आयुक्त, मुंबई महानगर प्रदेश विकास प्राधिकरण, मुंबई.
१८. नोंदणी महानिरीक्षक व मुद्रांक नियंत्रक, महाराष्ट्र राज्य, पुणे.
१९. व्यवस्थापकीय संचालक, मुंबई मेट्रो रेल्वे कॉर्पोरेशन लि. मुंबई.
२०. व्यवस्थापकीय संचालक, महाराष्ट्र मेट्रो रेल्वे कॉर्पोरेशन लि. नागपूर.
२१. महानगर आयुक्त, पुणे महानगर प्रदेश विकास प्राधिकरण, पुणे.
२२. महानगर आयुक्त, नागपूर महानगर प्रदेश विकास प्राधिकरण, पुणे.
२३. जिल्हाधिकारी, मुंबई शहर
२४. जिल्हाधिकारी, मुंबई उपनगर
२५. जिल्हाधिकारी, पुणे
२६. जिल्हाधिकारी, नागपूर
२७. जिल्हाधिकारी, ठाणे
२८. जिल्हाधिकारी, पालघर
२९. आयुक्त, पुणे महानगरपालिका, पुणे
३०. आयुक्त, नागपूर महानगरपालिका, नागपूर
३१. आयुक्त, ठाणे महानगरपालिका, ठाणे
३२. आयुक्त, कल्याण-डोंबविली महानगरपालिका
३३. आयुक्त, नवी मुंबई महानगरपालिका
३४. आयुक्त, मीरा-भाईंदर महानगरपालिका
३५. आयुक्त, भिवंडी-निजामपूर महानगरपालिका

पृष्ठ **५** पैकी **४**

शासन निर्णय क्रमांकः **एमआरडी-३३१९/प्र.क्र.६१/नवि-७**

३६.आयुक्त, उल्हासनगर महानगरपालिका
३७.आयुक्त, वसई-विरार महानगरपालिका
३८.आयुक्त, पनवेल महानगरपालिका, पनवेल
३९.सभापती, नागपूर सुधार प्रन्यास, नागपूर.
४०.नोंदणी उपमहानिरीक्षक, मुंबई
४१.नोंदणी उपमहानिरीक्षक, ठाणे.
४२.नोंदणी उपमहानिरीक्षक, नागपूर
४३. नोंदणी उपमहानिरीक्षक, पुणे
४४.सह जिल्हा निबंधक व मुद्रांक जिल्हाधिकारी, ठाणे
४५. सह जिल्हा निबंधक व मुद्रांक जिल्हाधिकारी, पालघर
४६.सह जिल्हा निबंधक व मुद्रांक जिल्हाधिकारी, पुणे
४७.सह जिल्हा निबंधक व मुद्रांक जिल्हाधिकारी, नागपूर
४८.निवड नस्ती, नवि-७.

CHAPTER 19: FINANCIAL ANALYSIS & NON FARE BOX REVENUE

19.1 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 Vanaz to Chandani Chowk on the western side and Ramwadi to Wagholi/Vitthalwadi on the eastern end.

This chapter evaluates the financial feasibility of this extension line.

TABLE 19-1: PROJECT COST DETAILS (RS IN CRORE)

Sr No	Particulars	July 22 Price level (Rs. In Cr)	Completion Cost (Rs. In Cr.)
1	Without Land, R&R and taxes	2438.34	2826.48
2	With Land, R&R and taxes	2980.27	3452.61

Construction period start is assumed in the month June 2023 and period of construction is assumed as four (04) years. Start of operations is assumed as June 2027. The project completion cost is broken down year wise and presented in Chapter 17.

19.1.1 ADDITIONAL INVESTMENT AND REPLACEMENT COST

Additional Investment includes the rolling stock to be added into the system during operation period to cater to the increased demand of metro. To cater to this demand, the additional investment for 3 coaches in FY 2037-38, 45 coaches in FY 2047-48 and 24 coaches in FY 2057-58. The estimated costs are escalated at 5% per annum.

To cater to increased demand, Additional investment also include Satellite Depot Land Cost taken in FY 2046-47 and Cost of Development of Depot is taken in FY 2046-47 and FY 2047-48 in 40:60 basis. The estimated costs are escalated at 5% per annum

Replacement Cost is added during the operation period 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 50% of signalling and telecom and 25% of electrical works would require replacement after 15 years. Escalation is provided @ 5% per annum.

Table 19-2 represents the additional investment and Replacement Cost

TABLE 19-2: ADDITIONAL INVESTMENT AND REPLACEMENT COST (RS IN CRORE)

Escalated Replacement Cost (Rs. In Cr.)	2037-38	2042-43	2046-47	2047-48	2057-58
Additional Rolling Stock	60.81			1486.00	1290.97
50% of Signaling& Telecom and 25% of Electrical Works		344.00			715.15
Satellite Depot Land Cost [1] (100%)			285.81		
Depot Development Charges (70%)			216.15	340.43	
Total	**60.81**	**344.00**	**501.96**	**1826.43**	**2006.12**

19.1.2 O & M COSTS

O & M Costs include the following;

1. Staff Costs
2. Maintenance Costs.
3. Energy Costs

The same has been discussed in detail in the Section 17-6 of Chapter 17.

As the O&M period starts from June 2027 and ends on May 2057, O&M Cost for FY 2027-28 is considered for 10 months. The summary of O & M Costs during Operation period of 30 years is represented in the Table 19-3.

TABLE 19-3: SUMMARY OF OPERATION AND MAINTENANCE EXPENSES(RS. IN CR.)

Financial Year	(Rs. in Crore)				
	Staff Cost (Esc. @9%)	Maintenance Cost (Esc. @5%)	Energy Cost (Esc @5%)	Total O & M Cost	Additional Cost & Replacement Costs[2]
2027-28	45.9	40.2	12.88	98.98	
2028-29	60.04	50.66	16.46	127.16	
2029-30	65.44	53.19	16.71	135.34	
2030-31	71.33	55.85	16.96	144.14	
2031-32	77.75	58.64	18.08	154.47	
2032-33	84.75	61.57	18.35	164.67	
2033-34	92.38	64.65	18.62	175.65	
2034-35	100.69	67.88	19.85	188.42	
2035-36	109.76	71.28	20.14	201.18	
2036-37	119.63	75.49	20.45	215.57	
2037-38	130.4	79.27	21.79	231.46	60.81
2038-39	142.14	83.23	22.3	247.67	
2039-40	154.93	87.39	22.81	265.13	

[1] Details given in Chapter 14 Section 14.1.2
[2] Refer Chapter 17 section 17.6.4

Financial Year	(Rs. in Crore)				
	Staff Cost (Esc. @9%)	Maintenance Cost (Esc. @5%)	Energy Cost (Esc @5%)	Total O & M Cost	Additional Cost & Replacement Costs[2]
2040-41	168.87	91.76	24.51	285.14	
2041-42	184.07	96.35	25.07	305.49	
2042-43	200.64	101.17	25.65	327.46	344
2043-44	218.7	106.23	27.56	352.49	
2044-45	238.38	111.54	28.19	378.11	
2045-46	259.83	117.12	28.85	405.8	
2046-47	283.22	138.94	30.99	453.15	501.96
2047-48	308.71	145.88	31.71	486.3	1826.43
2048-49	336.49	153.18	32	521.67	
2049-50	366.77	160.84	33.91	561.52	
2050-51	399.78	168.88	34.22	602.88	
2051-52	435.76	177.32	34.54	647.62	
2052-53	474.98	186.19	36.6	697.77	
2053-54	517.73	195.5	36.94	750.17	
2054-55	564.33	205.27	37.28	806.88	
2055-56	615.12	215.54	39.51	870.17	
2056-57	670.48	240.18	39.88	950.54	
2057-58	121.8	42.03	6.71	170.54	2006.12

19.1.2.1. 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 unabsorbed 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 noncash item. Salvage value is considered as zero for ease of calculation. In consideration to Income Tax Act the Depreciation is not charged on Land.

19.1.3 REVENUE

The revenue streams for the project are Fare Box Revenue and Non-Fare Box Revenue. The Non-Fare Box Revenue is further classified into Value Capture Finance (VCF) Tools, Property Development and Other sources like Advertisement etc.

19.1.3.1. FARE BOX REVENUE

The trips per day on the Line 2A and Line 2B corridor is detailed in the Table 19-4.

TABLE 19-4: RIDERSHIP (IN LAKHS) OF LINE 2A AND LINE 2B

Year	2026-27	2036-37	2046-47	2056-57
Chandani Chowk – Vanaz – Ramwadi – Vitthalwadi i.e. With Extensions (A)	3,59,080	5,76,880	8,19,250	9,93,380
Vanaz – Ramwadi i.e. Without extension (B)	2,63,080	3,75,770	5,32,260	6,44,460

The trip length distribution observed is represented in the Table 19-5.

TABLE 19-5: TRIP LENGTH DISTRIBUTION

Trip Length (Kms)	%age of Passenger Trips			
	2027	2037	2047	2057
0 to 2	7.32%	7.32%	7.77%	7.76%
2 to 4	18.73%	18.50%	19.09%	19.04%
4 to 6	17.09%	16.46%	18.45%	18.45%
6 to 9	15.90%	16.11%	17.80%	17.78%
9 to 12	10.22%	11.01%	9.08%	9.07%
12 to 15	8.98%	8.35%	7.94%	7.95%
15 to 18	6.65%	6.34%	5.29%	5.31%
18 to 21	5.93%	6.25%	5.40%	5.42%
21 to 24	4.79%	4.82%	4.47%	4.49%
24 to 27	2.20%	2.03%	2.20%	2.21%
27 to 30	1.18%	1.35%	1.40%	1.40%
to >30	1.00%	1.47%	1.11%	1.11%
Total	100%	100%	100%	100%

The fare box revenue has been calculated based on ridership in the full Chandani Chowk to Vitthalwadi corridor, subtracting the farebox from Vanaz to Ramwadi.

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. The escalation in Fare Revenue is considered at 15% after every 3 years for each fare slab, which is rounded off to nearest one rupee.

The fares at 2018-2019 prices are detailed in Table 19-6.

TABLE 19-6: FARE STRUCTURE

Fare Slab(Km)	Fare (Rs.)
0-2	13
2-4	17
4-6	20
6-9	25
9-12	27
12-15	30
15-18	32

Fare Slab(Km)	Fare (Rs.)
18-21	35
21-24	37
24-27	38
27-30	42
>30	45

The change in travel behaviour is a gradual phenomenon. As a result, ridership on any new system takes time to stabilize and reach to the predicted level.

Taking cognizance of this fact, the fare box revenue estimation considers 75% of the projected ridership in first year of operation and then the ridership increases gradually to reach the projected level by FY 2031-32.

As the O&M period starts from June 2027 and ends on May 2057, Revenue for FY 2027-28 is considered for 10 months.

TABLE 19-7: FARE REVENUE (RS IN CRORE)

	2027-28	2037-38	2047-48	2056-57
Fare Revenue (Rs. in Cr.)	81.66	431.33	923.11	1,673.99

19.1.3.2. NON FARE BOX REVENUE

The sources of non-fare box revenue identified in the study are divided into three heads:

1. Value Capture Finance (VCF) tools
2. Property Development
3. Other sources like Advertisement etc.

Value Capture Finance (VCF) Tools:

The following sources have been identified as part of VCF for assessment of revenue in in Metro Phase 2 extension corridors of Line 2A and Line 2B.

- Levying premium on additional Floor Space Index (FSI)
- Additional 1% Cess on the Stamp Duty

The assessment of revenue from VCF tools has been detailed in Chapter 18 – Transit Oriented Development and the same are considered in the Financial Analysis.

Property Development:

The details of identified land parcels (Plot A, Plot B and Plot C) and its permissible FSI details along with the required calculation are presented in Chapter 18 of this Report. A total of 3,23,600Sqm (34,83,201 Sq. ft.) built up area available for development at the identified plots (A, B & C).

One of the best ways to realize upfront revenues for the project is by giving the land to a private developer on lease for 30 years.

TABLE 19-8: CASH FLOW FROM TOD

Particulars	Unit	Plot A	Plot B	Plot C
Commerical B/U Area	Sq Ft	77,500	835,279	2,570,422
Rental per month *	Rs/Sq Ft	80	80	80
Annual Rental	Rs Cr	7.44	80.19	246.76
Operating Profit/Rev		95%	95%	95%
Annual Operating Profit	Rs Cr	7.07	76.18	234.42
Cap Rate/Annualized Rental Yield#		10%	10%	10%
Property Value	Rs Cr	70.68	761.77	2,344.22
Construction Cost @Rs. 3500 per sqft.	Rs Cr	27.13	292.35	899.65
Land Value	Rs Cr	**43.56**	**469.45**	**1,444.57**
Total Land Value	Rs Cr	**1,957.58**		

Note: * Based on Primary sources from Property Brokers and Secondary Source
Based on Market norms for Commercial Properties

The potential revenue expected from the PD development is 60% of the Total Land Value (i.e. Rs.1957.58 Cr) which works out to be Rs. 1174.55 Crores.This amount is expected to be realized in FY 2029-30 when the metro becomes operational. The same is considered as one of the non-fare box revenue in the financial modelling.

Other Sources of Revenue:

The following sources of Advertisement revenue has been considered for assessment of the proposed corridors;

- **Revenue from the Retail Kiosks and ATM's at Metro Stations:** All stations have been designed keeping some space allocated to the Retail Kiosks, ATMs and other Commerical activities.
- **Co-Branding/Naming Rights:** Co-Branding by Suffixing/Prefixing of Brand Name with the Metro Station name may be allowed for selected stations. Co-branding rights may be awarded to the eligible/competent parties through tendering process. The Scope under this type of advertisement may be to suffix the Brand name with the Metro Station name whereas for Stations. Colouring of the station in brand colour as well as inside and outside Advertisement rights for the station may also be permitted. The contract may be awarded generally for tenure of 10 years which may be further be extendable by 5 years on mutually agreeable terms and conditions. The bidders quote the lump sum rate/annum for the total scope offered at the station.
- **Metro Coach/Train Wrapping:** The Metro operator may be allowed Commercial Advertisement on Metro Coaches; by wrapping of coaches.
- **Outdoor Advertisement at the Median:** Commercial Advertisement may be allowed by putting Advertisement boards on Median below the viaduct. Scope of

the Outdoor advertisement may be to put up static advertisement display below the Viaduct. Area of advertisement space may be decided based on type, size of station and footfall of station etc., and as per policy of Urban Local Body.

- The other major sources of Non-fare box revenue may be explored during the operations period are as under;
    - Inside Station Advertisement
    - Advertisement on Smart Card or Tokens
    - Telecom Tower and Telecom Cable
    - Others such as leasing of parking rights at stations, film shootings & special events on Metro premises

The unit rates and rates of increase are tabulated in the Table 19-9; and the Summary Revenues is mentioned in the Table 19-11.

TABLE 19-9: NON FARE BOX REVENUE

Sl. No.	Type of Revenue	Unit Rate at July 2022 Prices (Rs)	Rate of Increase (%)
1	Revenue From Retail Kiosks & ATMS	Rs 150 to Rs 300 Per Sq Ft per month based on the Station Potential and development surrounding it	5% per annum
2	Station Naming Rights	Rs 3.00 Lakhs per month per Station	5% per annum
3	Train Wrapping	Rs 25 Lakh per Train per annum i.e. ~Rs 0.07 Crore/Km	2.5% per annum
4	Advertisement at Medians	Rs200 per sqft per month for 48 Sq Ft including both the sides of display. Assuming that these displays would be occupied for 9 months in a year	5% per annum

TABLE 19-10: ADVERTISING AREA

Sl. No.	Place of Advertisement	Area of Advertising (in Sq Ft)
1	Area for Retail Kiosks and ATM's at the all the 13 elevated stations along Line 2A and Line 2B	14359.07
2	Advertisement at Medians in between 2 spans along Line 2A and Line 2B	61152

TABLE 19-11: SUMMARY OF REVENUES (RS IN CRORES)

Financial Year	Fare Box Revenue	Non - Fare Box Revenue (Rs. in Cr.)								
		Revenue From Retail Kiosks & ATMS	Station Naming Rights	Train Wrapping	Advertisement at Medians	Premium on FSI	Stamp Duty	Cash flow from Property Development	Total Non-Fare Box Revenue	Total Revenue
2027-28	81.66	4.23	4.98	2.54	11.71	34.67	51.55		109.68	191.34
2028-29	120.6	5.33	6.27	3.12	14.75	83.2	33.32		145.99	266.59
2029-30	146.08	5.6	6.59	3.2	15.49	138.11	35.39	1174.55	1378.93	1525.01
2030-31	191.45	5.88	6.91	3.28	16.26	153.09	37.59		223.01	414.46
2031-32	216.99	6.18	7.26	3.36	17.08	165.26	39.92		239.06	456.05
2032-33	233.65	6.48	7.62	3.44	17.93	153.09	42.4		230.96	464.61
2033-34	289.69	6.81	8	3.53	18.83	150.67	45.04		232.88	522.57
2034-35	311.92	7.15	8.4	3.62	19.77	136.14	47.84		222.92	534.84
2035-36	335.86	7.51	8.82	3.71	20.76	127.07	50.81		218.68	554.54
2036-37	416.26	7.88	9.27	5.07	21.79	113.45	53.96		211.42	627.68
2037-38	431.33	8.28	9.73	5.2	22.88	104	57.32		207.41	638.74
2038-39	446.95	8.69	10.22	5.33	24.03	94.54	60.88		203.69	650.64
2039-40	533.23	9.12	10.73	5.46	25.23	78.66	64.66		193.86	727.09
2040-41	552.54	9.58	11.26	5.6	26.49	59	68.67		180.6	733.14
2041-42	572.53	10.06	11.83	5.74	27.82	39.33	72.94		167.72	740.25
2042-43	682.52	10.56	12.42	5.88	29.21	27.57	77.47		163.11	845.63
2043-44	707.22	11.09	13.04	6.03	30.67	10.21	82.28		153.32	860.54
2044-45	732.83	11.64	13.69	6.18	32.2	5.11	87.39		156.21	889.04
2045-46	873.62	12.23	14.37	6.33	33.81	5.29	92.82		164.85	1038.47
2046-47	905.24	12.84	15.09	9.44	35.5	5.29	98.59		176.75	1081.99
2047-48	923.11	13.48	15.85	9.68	37.28	5.29	104.71		186.29	1109.4
2048-49	1082.17	14.15	16.64	9.92	39.14	5.48	111.21		196.54	1278.71
2049-50	1103.52	14.86	17.47	10.17	41.1	5.48	118.12		207.2	1310.72

2050-51	1125.3	15.61	18.35	10.42	43.15	5.48	125.46		218.47	1343.77
2051-52	1319.44	16.39	19.26	10.68	45.31	5.67	133.25		230.56	1550
2052-53	1345.47	17.2	20.23	10.95	47.57	5.67	141.53		243.15	1588.62
2053-54	1372.02	18.06	21.24	11.22	49.95	5.67	150.32		256.46	1628.48
2054-55	1609.83	18.97	22.3	11.5	52.45	5.86	159.66		270.74	1880.57
2055-56	1641.58	19.92	23.41	11.79	55.07	5.86	169.58		285.63	1927.21
2056-57	1673.99	20.91	24.59	14.26	57.83	4.69	180.11		302.39	1976.38
2057-58	327.02	3.66	4.3	2.44	10.12	0.78	31.88		53.18	380.2

19.2 PROJECT FINANCING

19.2.1 PREVALENT FUNDING MODELS FOR METRO PROJECTS IN INDIA

A large number of cities, including Pune and Nagpur, which are operating the Metro systems, i.e., Delhi, Mumbai, Chennai, Bangalore, Kochi, Lucknow, Ahmedabad have all adopted the prevalent model, wherein the Government of India (GoI) and the State Government come together and make equal equity contributions to the Total Project Cost (TPC) through an SPV, formed as a commercial enterprise through a Joint Venture of GoI& the State Government. The GoI contributes 20% of the project cost as its equity contribution. An equal amount can be contributed by the State Government aggregating upto a total equity to 40% of Total Project Cost. With equal ownership, both governments nominate their representatives as Board members, which in turn select functional directors. Such a SPV has a benefit of independent management under the aegis of Indian Companies Act, 2013. The balance cost (60%) is met through loans from bilateral/multi-lateral institutions. The exchange rate fluctuation (at present) has to be borne by the State Government. Cost of land (RoW for Corridor, land for Station and Depot/Workshop etc.) and R&R cost is borne by the State Government or Urban Local Bodies.

TABLE 19-12: ADVANTAGES AND LIMITATIONS - JOINT VENTURE MODEL BETWEEN GOI AND STATE GOVERNMENT

Advantages	Limitations
• GoI (20%) and –GoM) (20%) fund 40% of the Project Cost; • GoI may extend sovereign guarantee for multi-lateral/bi-lateral loan. • Ownership is equally shared by GoI& State Govt	• Loan Repayment responsibility is on SPV & State Govt. whereas GoI will act as guarantor only. • State Govt. to bear fluctuation in forex rate. • O&M cost liability: SPV/State Govt.

19.2.2 EQUITY SHARING MODEL (SPV MODEL)

Under this model, a Special Purpose Vehicle (SPV) is set up as a joint venture between Central Government and State Government for the implementation of the project and for its subsequent Operation & Maintenance. Under this arrangement Government of India and State Government make equal equity contribution. As per the prevalent practice, Central Government contributes 20% of the project cost as their equity contribution. An equal amount can be contributed by State Government aggregating the total equity to 40%. Remaining 60% is arranged as soft loan from funding agencies.

In case of this project, Maha Metro is already functioning as an SPV for Metro projects in Maharashtra. In Pune, Maha-Metro is implementing Line 1 and Line 2 on SPV Model, the proposed corridors i.e., Line 2A and 2B are extensions of the existing Line 2. So it is proposed to consider the same SPV model for implementation of this project also. Accordingly, Financial Analysis has been carried out for the SPV Model.

The funding pattern developed under this model (SPV) is placed in Table 19-13. It is proposed that soft loans may be procured from bilateral/multilateral funding agencies having lowest interest rate and higher moratorium period to keep lower project cost.

TABLE 19-13: FUNDING PATTERN

Particulars	Project Cost with Taxes and Duties (Rs. in Cr.)	
	Amount	% of Contribution
Equity By Govt. of India (GoI)	479.71	15.42%
Equity By Govt. of Maharashtra (GoM)	479.71	15.42%
Subordinate Debt for Central Taxes by GoI (50%)	142.64	4.58%
Subordinate Debt for Central Taxes by GoM (50%)	142.64	4.58%
Bilateral/Multilateral Loan from Funding Agencies	1867.06	60.000%
Sub-Total	**3111.76**	**100.00%**
Subordinate Debt for State Taxes by GoM	250.41	
Subordinate Debt for Land by GoM	24.86	
Subordinate Debt for R&R by GoM	65.34	
Contribution for Land by Pune Municipal Corporation (PMC)	0.24	
Total Cost	**3452.61**	
Subordinate Debt for Interest during Construction (IDC) by GoM	173.63	
Total Project Completion Cost	**3626.24**	

Multilateral funded loan @ 4.5% per annum. (As per prevalent EURIBOR at 3.3% and spread of 1.2%.) This is in line with the Minutes of PIB meeting for Pune MRTS Phase 1 Extension of Swargate-Katraj corridor held on 18.01.2024

TABLE 19-14: REPAYMENT PHASING

S.No.	Parameter	Value
1	Annual Interest rate for loan	4.5%
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 19-15: YEAR WISE BREAKUP OF PROJECT COST (RS. IN CR.)

Particular	Year-wise Contribution (Rs. in Cr.)					Total
	FY 2023-2024	FY 2024-2025	FY 2025-2026	FY 2026-2027	FY 2027-2028	
1. State Government						
State Taxes (SGST)	46.45	73.07	76.64	40.20	14.05	250.41
Central Taxes (CGST)-50%	26.45	41.62	43.66	22.90	8.01	142.64
Land	4.71	12.36	7.79	0.00	0.00	24.86
R&R	12.39	32.51	20.44	0.00	0.00	65.34
Construction Cost	88.98	139.98	146.82	77.01	26.92	479.71
IDC	8.43	27.24	52.30	72.24	13.42	173.63
Sub-total (State Government)	**187.41**	**326.78**	**347.65**	**212.35**	**62.40**	**1136.59**
2. Central Government						
Central Taxes (CGST)-50%	26.45	41.62	43.66	22.90	8.01	142.64
Construction Cost	88.98	139.98	146.82	77.01	26.92	479.71
Sub-total (Central Government)	**115.43**	**181.60**	**190.48**	**99.91**	**34.93**	**622.35**
3. Bilateral/Multilateral Agency						
Construction Cost	346.30	544.81	571.44	299.71	104.80	1867.06
Sub-total (Bilateral/Multilateral Agency)	**346.30**	**544.81**	**571.44**	**299.71**	**104.80**	**1867.06**
4. Pune Municipal Corporation (PMC)						
Land	0.05	0.12	0.07			0.24
Sub-total (PMC)	**0.05**	**0.12**	**0.07**			**0.24**
Total Cost	**649.19**	**1053.31**	**1109.64**	**611.97**	**202.13**	**3626.24**

19.3 FINANCIAL INTERNAL RATE OF RETURN

The financial internal rate of return at completion cost basis with fare box and non-fare box revenue works out to **8.67%.** The project FIRR is provided in Table 19-16.

TABLE 19-16: PROJECT FIRR

SN	Year	Rs. In Cr								
		Completion Cost (A)	O&M Cost (B)	Additional Capital including Replacement (C)	Total Cost (D = A+B+C)	Fare Box Revenue (E)	Non Fare Box Revenue (F)	Total Revenue (G =E+F)	Corporate Tax (H)	Operational Surplus after Corporate Tax (I =G-D-H)
1	2023-24	640.77			640.77					-640.77
2	2024-25	1026.07			1026.07					-1026.07
3	2025-26	1057.36			1057.36					-1057.36
4	2026-27	539.71			539.71					-539.71
5	2027-28	188.70	98.98		287.68	81.66	109.67	191.33	0.00	-96.35
6	2028-29	0.00	127.16		127.16	120.60	146.00	266.60	0.00	139.44
7	2029-30		135.34		135.34	146.08	1378.92	1525.00	0.00	1389.66
8	2030-31		144.14		144.14	191.45	223.01	414.46	0.00	270.32
9	2031-32		154.47		154.47	216.99	239.06	456.05	0.00	301.58
10	2032-33		164.67		164.67	233.65	230.97	464.62	0.00	299.95
11	2033-34		175.65		175.65	289.69	232.87	522.56	0.00	346.91
12	2034-35		188.42		188.42	311.92	222.92	534.84	0.00	346.42
13	2035-36		201.18		201.18	335.86	218.67	554.53	0.00	353.35
14	2036-37		215.57		215.57	416.26	211.43	627.69	44.37	367.75
15	2037-38		231.46	60.81	292.27	431.33	207.40	638.73	72.17	274.29
16	2038-39		247.67		247.67	446.95	203.68	650.63	76.18	326.78
17	2039-40		265.13		265.13	533.23	193.86	727.09	96.00	365.96

SN	Year	Rs. In Cr								
		Completion Cost (A)	O&M Cost (B)	Additional Capital including Replacement (C)	Total Cost (D = A+B+C)	Fare Box Revenue (E)	Non Fare Box Revenue (F)	Total Revenue (G =E+F)	Corporate Tax (H)	Operational Surplus after Corporate Tax (I =G-D-H)
18	2040-41		285.14		285.14	552.54	180.60	733.14	96.74	351.26
19	2041-42		305.49		305.49	572.53	167.71	740.24	97.09	337.66
20	2042-43		327.46	344.00	671.46	682.52	163.11	845.63	104.00	70.17
21	2043-44		352.49		352.49	707.22	153.32	860.54	101.66	406.39
22	2044-45		378.11		378.11	732.83	156.21	889.04	106.32	404.61
23	2045-46		405.80		405.80	873.62	164.86	1038.48	140.11	492.57
24	2046-47		453.15	501.96	955.11	905.24	176.76	1082.00	116.40	10.49
25	2047-48		486.30	1826.43	2312.73	923.11	186.29	1109.40	30.08	-1233.41
26	2048-49		521.67		521.67	1082.17	196.55	1278.72	29.23	727.82
27	2049-50		561.52		561.52	1103.52	207.21	1310.73	46.49	702.72
28	2050-51		602.88		602.88	1125.30	218.47	1343.77	59.79	681.10
29	2051-52		647.62		647.62	1319.44	230.57	1550.01	112.75	789.64
30	2052-53		697.77		697.77	1345.47	243.16	1588.63	119.69	771.17
31	2053-54		750.17		750.17	1372.02	256.47	1628.49	124.42	753.90
32	2054-55		806.88		806.88	1609.83	270.74	1880.57	179.90	893.79
33	2055-56		870.17		870.17	1641.58	285.63	1927.21	180.75	876.30
34	2056-57		950.54		950.54	1673.99	302.39	1976.38	176.92	848.92
35	2057-58		170.54	2006.12	2176.66	327.02	53.18	380.20	0.00	-1796.46
Total		**3452.61**	**11923.54**	**4739.32**	**20115.47**	**22305.62**	**7431.69**	**29737.31**	**2111.06**	**7510.79**
									IRR	**8.67%**

19.4 FIRR SENSITIVITY

A sensitivity analysis of economic analysis is being carried out based on the critical factors such as: Project Cost and Ridership. Summary of FIRRs under various scenarios is given in the Table 19-17 below:

TABLE 19-17: SENSITIVITY ANALYSIS

Particulars	FIRR based on Project Cost	FIRR based on Ridership
Base	8.67%	8.67%
5% Lower	8.74%	8.20%
10% Lower	8.82%	7.69%
5% Higher	8.59%	9.11%
10% Higher	8.52%	9.52%

19.5 ALTERNATIVE SOURCES FOR MEANS OF FINANCE – EXPLORING PRIVATE PARTICIPATION

The basic approach to infrastructure financing is changing rapidly. The transport services have been generally considered social goods to be provided by the Government at free or at subsidized costs. The normal practice has been to provide funds through Government budgetary sources for both capital investments on projects as well to cover the short fall in their O&M costs.

However, over the past few years, the approach towards funding the infrastructure has been changing. The private sector through innovative ways is being invited to not only mobilise financial resources but also to involve in the operations and management of the system.

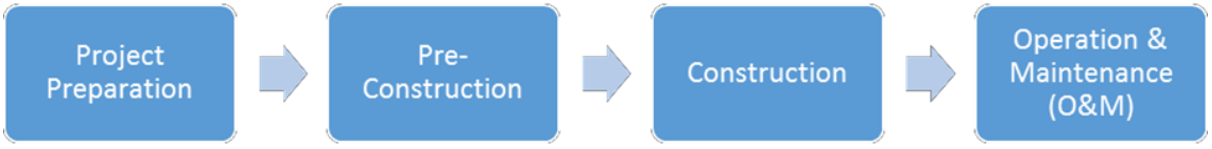
As per circular No. K-14011/08/2017-MRTS-Coord dated 03.10.2023, “any form of PPP of unbundled components which primarily aims and entails deferred payment system should not be entered into by Metro/MRTS companies. Even for the existing PPP contract a proper cost benefit analysis should be done vis-à-vis 100% Government capital infusion.

The fundamental principle underlying Public Private Partnerships (PPPs) as a development option for any infrastructure project is to combine the strengths of the private sector with those of the public sector in order to overcome challenges faced during construction & operation and to achieve superior outcomes.

The private sector can be expected to contribute to efficiency gains in the development of land, construction, operations and maintenance through the use of technology, better management and construction practices. In addition, the private sector should be expected to bring economies of scale from large projects and by involving a larger number of private partners.

However, the success of PPP will depend critically on designing PPP structures that make an appropriate allocation of risks, responsibilities, rewards and penalties, and create the incentives for value creation. Indeed, this risk allocation is the defining feature of the PPP strategy. The golden principle is that risks should be allocated to the entity best equipped to manage each risk. The expectation is that such an allocation of risks will not only produce the best possible program and project outcomes but also optimize costs. This should lead to good quality outcomes at optimum prices.

Any infrastructure project generally goes through the following phases:



Each phase is susceptible to different types of risks. A PPP can be established in either in Construction phase/Operation & Maintenance phase; and both Construction and O&M phase.

Based on Metro Policy 2017 and PPP models adopted in various sectors in India, the following models of PPP are explored:

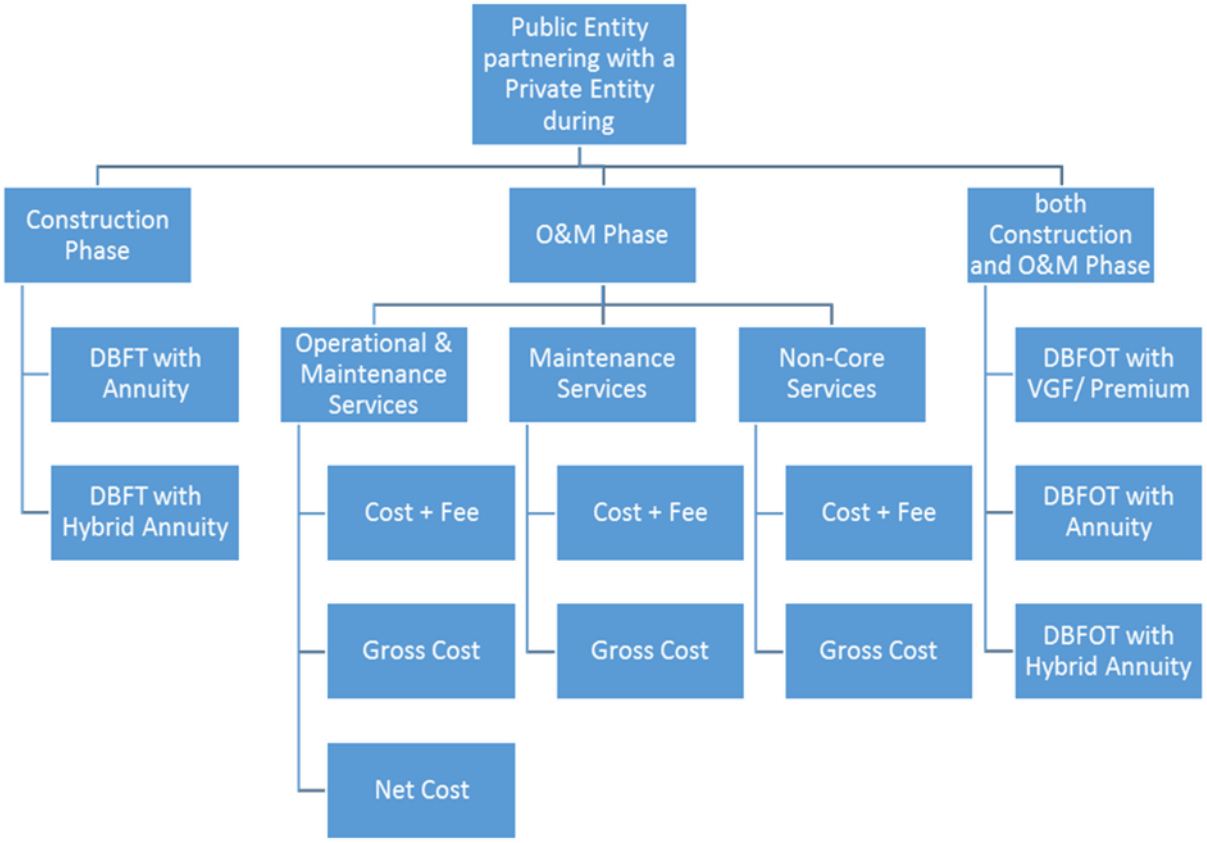


FIGURE 19-1: VARIOUS PPP MODELS

19.5.1 PPP MODESL FOR METRO RAIL DURING CONSTRUCTION PHASE

19.5.1.1. MODEL 1: DEVELOPMENT OF METRO RAIL SYSTEM ON GOVERNMENT LAND BASED DBFT WITH ANNUITY

Under this model, the public authority will provide land to the selected private developer. The private partner will develop the infrastructure with its own funds and funds raised from lenders at its risk (that is, it will provide all or the majority of the financing). The authority shall be responsible for operating (supply and running of rolling stock) and managing the infrastructure life cycle (assuming life-cycle cost risks).

The bid parameter in such projects is generally Annuity which is a fixed amount paid to the private partner post-construction and during O&M period. The Annuity pay-out is generally financed through the funds coming from users after covering O&M expenses and long-term maintenance. If these funds are insufficient to meet the Annuity pay-out, the Authority shall finance the same through State or Central Government budget/exchequer.

19.5.1.2. MODEL 2: DEVELOPMENT OF METRO RAIL SYSTEM ON GOVERNMENT LAND BASED DBFT WITH HYBRID ANNUITY

This model is similar to DBFT with Annuity expect for one major difference – the private entity receives certain amount (% of capital cost) during construction phase while the remaining is paid out as annuity during operation & maintenance phase.

19.5.2 PPP MODELS FOR METRO RAIL DURING O&M PHASE

19.5.2.1. MODEL 1: OPERATION AND MAINTENANCE SERVICES ON COST + FEE MODEL

Under this model, post-construction of civil assets the private partner installs the system (signalling and electrical assets), procures rolling stock and operates and maintains all these assets. The authority collects all the revenue and pays the private entity a monthly/ annual payment for operations and maintenance of the system. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of service provided.

19.5.2.2. MODEL 2: OPERATION AND MAINTENANCE SERVICES ON GROSS COST MODEL

Under this model, post-construction of civil assets the private partner installs the system, procures rolling stock and operates and maintains all the assets. The authority collects all

the revenue and the private entity is paid an agreed fixed sum for the duration of the contract.

19.5.3 MODEL 3: OPERATION AND MAINTENANCE SERVICES IN NET COST MODEL

Under this model, post-construction of civil assets the private entity/partner installs the system, procures rolling stock and operates and maintains all the assets. The private entity collects the complete revenue generated from the services provided. In case, the revenue generated is lower than O&M cost, the Authority may agree to compensate the difference in cost to the private entity while finalizing the agreement.

19.5.4 PPP MODELS FOR METRO RAIL DURING O&M PHASE – MAINTENANCE SERVICES

19.5.4.1. MODEL 1: MAINTENANCE SERVICES ON COST + FEE MODEL

Under this model, post-construction and installation of system including provisioning of rolling stock by public authority, the private partner is awarded the contract to maintain all the assets. The authority collects all the revenue and pays the private entity a monthly/ annual payment for maintenance of the system. The remuneration given could comprise of a fixed fee and a variable component, which would depend on the quality of maintenance.

19.5.4.2. MODEL 2: MAINTENANCE SERVICES ON GROSS FEE MODEL

Under this model, post-construction and installation of system including provisioning of rolling stock by public authority, the private partner is awarded the contract to maintain all the assets. The authority collects all the revenue and the private entity is paid an agreed fixed sum for the duration of the contract.

19.5.5 PPP MODELS FOR METRO RAIL DURING O&M PHASE: NON-CORE SERVICES

19.5.5.1. MODEL 1: NON-CORE SERVOCES ON COST + FEE MODEL

For carrying out certain non-core activities such as Automated Fare Collection system, Housekeeping, Non-Fare Revenue Collection etc., a private entity may be selected who shall be paid a monthly/ annual payment for undertaking these activities. The remuneration or fee given could comprise of a fixed fee and a variable component, which would depend on the quality of service provided.

19.5.5.2. MODELE 2: NON-CORE SERVICES ON GROSS FEE MODEL

For carrying out certain non-core activities such as Automated Fare Collection system, Housekeeping, Non-Fare Revenue Collection etc., a private entity may be selected who shall be paid an agreed fixed sum for the duration of the contract.

19.5.6 PPP MODELS FOR METRO RAIL DURING BOTH CONSTRUCTION AND O&M PHASE

19.5.6.1. MODEL 1: DEVELOPMENT OF METRO RAIL SYSTEM ON GOVERNMENT LAND BASED DBFOT WITH VGF/PREMIUM

Under this model, the public authority will provide land to the selected private developer. The private partner will develop the infrastructure with its own funds and funds raised from lenders at its risk (that is, it will provide all or the majority of the financing). The contractor is also responsible for operating (supply and running of rolling stock) and managing the infrastructure life cycle (assuming life-cycle cost risks) for a specified number of years. To carry out these tasks, the private entity /partner, will usually create an SPV.

The bid parameter in such projects is either premium (as percentage of revenues) if the funds coming from users are sufficient to cover O&M expenses and long-term maintenance with a surplus that can then be used as a source to repay the financing of the construction of the asset, and where no bidder is offering a premium, bidding parameter is the Grant required (as per VGF scheme of Government of India).

19.5.6.2. MODEL 2: DEVELOPMENT OF METRO RAIL SYSTEM ON GOVERNMENT LAND BASED DBFOT WITH ANNUITY

This model is similar to DBFOT with VGF/Premium expect for two major differences –1) User fees/charges are collected by the public authority 2) The private entity receives a fixed amount (called as Annuity payment) for a specified number of years. The fee is generally financed through the funds coming from users and in case the revenue from users is insufficient to meet the Annuity pay-out, the Authority shall finance the same through State/Central Government budget/exchequer.

19.5.6.3. MODEL 3: DEVELOPMENT OF METRO RAIL SYSTEM ON GOVERNMENT LAND BASED DBFOT WITH HYBRID ANNUITY

This model is similar to DBFOT with Annuity expect for one major difference – The private entity receives certain amount (% of capital cost) during construction phase while the remaining is paid out as annuity during operation & maintenance phase.

19.5.7 RISK MATRIX

The transfer of risk from the public entity to the private partner in various PPP models is set out in Table 19-18.

TABLE 19-18: RISK BASED COMPARISON OF PPP MODELS

PPP Model	Construction Risk (Including Design Risk and Financing Risk)	Operation Risk	Maintenance Risk	Non-Core Activities Management Risk	Revenue Risk
DBFT with Annuity	Private	Government.	Government.	Government.	Government.
DBFT with Hybrid Annuity	Private	Government.	Government.	Government.	Government.
O & M Services – Cost +Fee	Government	Shared	Shared	Shared	Government.
O & M Services – Gross Cost	Government	Private	Private	Private	Government.
O & M Services – Net Cost	Government	Private	Private	Private	Private
Maintenance Services - Cost +Fee	Government	Government	Shared	Shared	Government
Maintenance Services - Gross Cost	Government	Government	Private	Private	Government
Non-Core Services – Cost +Fee	Government	Government	Government	Shared	Government
Non-Core Services – Gross Cost	Government	Government	Government	Private	Government
DBFOT with VGF/Premium	Private	Private	Private	Private	Private
DBFOT with Annuity	Private	Private	Private	Private	Government
DBFOT with Hybrid Annuity	Private	Private	Private	Private	Government

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

The parties best suited for various types of risk are provided in Table 19-19.

TABLE 19-19: RISK BASED COMPARISON OF PPP MODELS

Risk Category	Party best suited to manage the risk
Construction Risk	Private
Operation Risk	Private/Government
Maintenance Risk	Private
Non-Core Activities Management Risk	Private
Revenue Risk	Government

From above, all risks except revenue risk can be transferred to private entity owing to private sector efficiency in these areas. In regard to revenue, government is able to manage this risk as revenue depends on i) traffic – which depends on regional growth, connectivity, route, etc. over which government has more control and ii) tariff – which for a public transport is not flexible enough to be transferred to private entity.

Also, though a private entity is better able to manage the construction risk, the cost of financing in PPP model for a private entity is higher than the cost of financing for the government, therefore, by transferring this risk completely in a PPP mode, the government shall end up paying more to the private entity. Therefore, it will be more appropriate to enter into an EPC contract for construction in which case the construction risk excluding financing risk is transferred to the private entity.

Based on above, Maha Metro Pune may explore the possibility of private participation in O&M phase post construction of metro rail duly ensuring cost-effectiveness of available PPP.

CHAPTER 20: ECONOMIC ANALYSIS

20.1. APPROACH & METHODOLOGY FOR ECONOMIC ANALYSIS

The economic appraisal of the Pune Metro has been carried out for the Line 2A - Vanaz to Chandani Chowk and Line 2B - Ramwadi to Wagholi/Vitthalwadi of Pune Phase-2 MRTS, within the broad framework in Appraisal Guidelines for Metro Rail Project Proposals by Ministry of Housing & Urban Affairs (MoHUA), Government of India (GoI). In the analysis, the cost and benefit streams arising under the 'with' and 'without' project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate values as per Appraisal Guidelines for Metro Rail Project Proposals by MoHUA, GoI. The annual streams of project costs and benefit have been compared over the analysis period of 34 years to estimate the net cost/benefit and to calculate the economic viability of the project in terms of Economic Internal Rate of Return (EIRR).

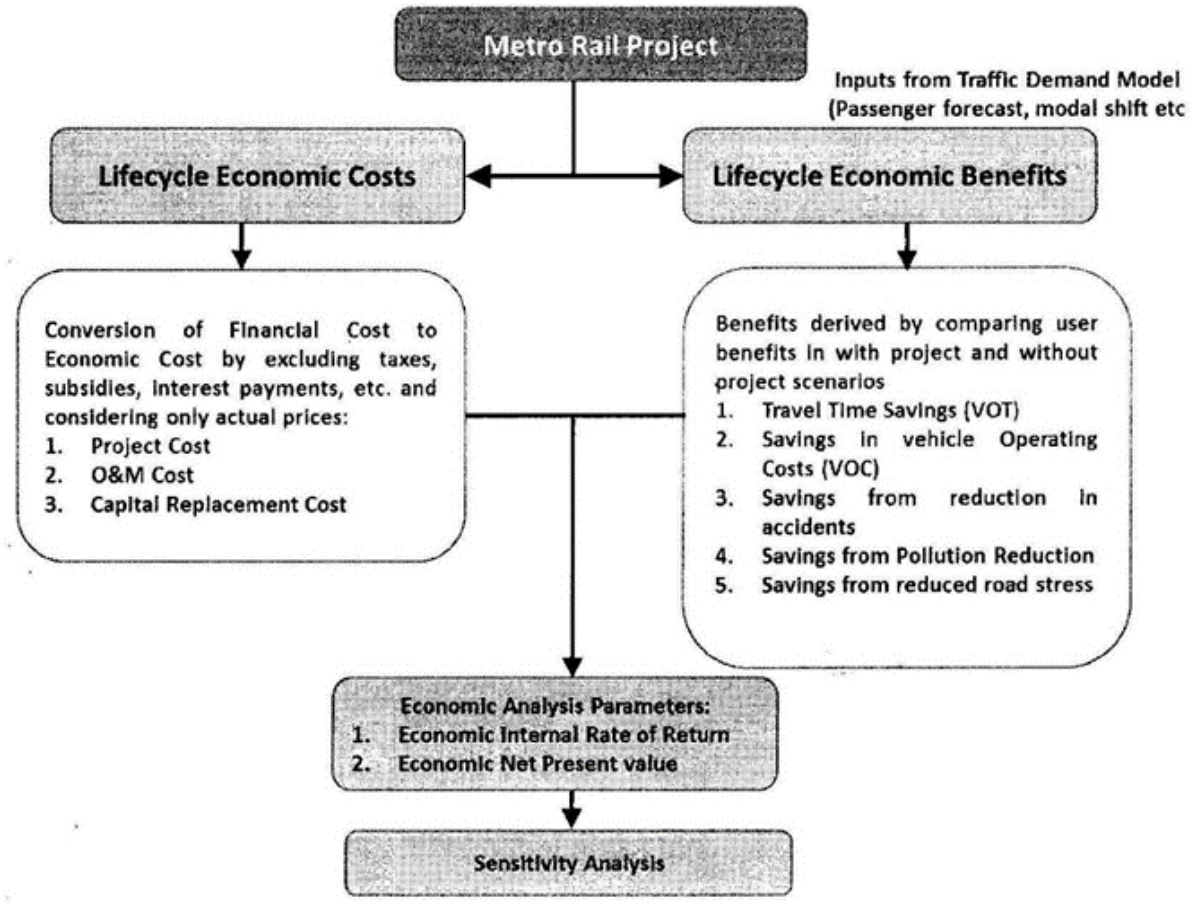


FIGURE 20-1: FRAMEWORK FOR ECONOMIC ANALYSIS

20.1.1 DEVELOPMENT OF ALTERNATIVE SCENARIOS

The development of the two scenario starts with estimating the traffic and modal share in these scenarios for the system. Table 20-1 below gives the estimated traffic and modal share in different horizon years. It can be seen that the total estimated demand in the year 2027 is about 8.29 Lakh which is expected to rise to about 12.497 Lakh in the year 2057. In the year 2027, extension of Metro system is expected to cater to about 0.654 Lakh trips per day which is expected to rise to about 3.462 Lakh in the year 2057 for the extension corridors of Line 2A and Line 2B.

TABLE 20-1: ESTIMATED MODE WISE TRIPS IN 'WITH' AND 'WITHOUT' SCENARIO (PEAK HOUR TRIPS IN LAKHS)

Mode	Trips without Line 2 Extension (in Lakhs)				Trips with Line 2 Extension (in Lakhs)			
	2027	2037	2047	2057	2027	2037	2047	2057
2W	4.424	4.827	4.995	5.092	4.267	4.303	4.195	4.088
3W	0.926	1.175	1.394	1.569	0.756	0.551	0.508	0.496
4W	0.937	1.288	1.332	1.366	0.818	1.077	1.052	1.051
Taxi	0.218	0.250	0.253	0.262	0.167	0.159	0.133	0.127
Bus	1.783	2.513	3.502	4.208	1.626	1.949	2.73	3.273
Metro	-	-	-	-	0.654	2.014	2.858	3.462
Total	8.288	10.053	11.476	12.497	8.288	10.053	11.476	12.497

TABLE 20-2: ESTIMATED MODE WISE TRIPS IN 'WITH' AND 'WITHOUT' SCENARIO (PERCENTAGE)

Mode	Trips without Line 2 Extension (in %)				Trips with Line 2 Extension (in %)			
	2027	2037	2047	2057	2027	2037	2047	2057
2W	53.38%	48.01%	43.53%	40.75%	51.48%	42.80%	36.56%	32.71%
3W	11.17%	11.69%	12.15%	12.56%	9.12%	5.48%	4.42%	3.96%
4W	11.31%	12.82%	11.61%	10.93%	9.87%	10.72%	9.17%	8.41%
Taxi	2.63%	2.48%	2.20%	2.10%	2.02%	1.58%	1.16%	1.02%
Bus	21.51%	25.00%	30.51%	33.66%	19.62%	19.39%	23.79%	26.19%
Metro	-	-	-	-	7.89%	20.03%	24.90%	27.71%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

20.2. ESTIMATION OF ECONOMIC PROJECT COST OF MRTS

Cost components considered for the purpose of this exercise include:

Lifecycle Economic Costs:

The project horizon is 34 years including construction period of 04 years starting from June 2023 and the operation and maintenance period of 30 years starting from June 2027

Estimation of Project Cost:

The economic costs of the capital works and annual operation and maintenance costs have been calculated from the financial cost estimates by excluding:

- Price contingencies/price escalations
- Import duties and taxes
- Sunk costs
- Interest payment, principal payment and interest during construction period

The economic costs have been derived from financial costs using following shadow price factor for each component to take care of the distortions brought by above factors.

TABLE 20-3: FACTORS USED FOR ECONOMIC COSTS

Sl. No.	Component	Factor
1	Capital Cost	0.83
2	Operation and Maintenance Cost	0.87

TABLE 20-4: ECONOMIC COST OF THE PROJECT

Particulars	Amount (Rs. Cr)
Project Cost at July 2022 price level Excluding Price Contingencies, Import duties & taxes, Sunk costs, Interest payment, principal payment and interest during construction period etc.	2518.13
Conversion Factor	0.83
Economic Cost of Project	**2090.05**

Phasing of Project Cost:

The total construction period for the project is four years i.e. from year June 2023 to May 2027. The year wise phasing of project cost and economic capex is presented in Table 20-5.

TABLE 20-5: PHASING OF PROJECT COST

Amount in Rs crore	1	2	3	4	5
Particular	**FY 2023-24**	**FY 2024-25**	**FY 2025-26**	**FY 2026-27**	**FY 2027-28**
Construction Phasing	20.00%	30.00%	30.00%	15.00%	5.00%
Land Phasing	20.00%	50.00%	30.00%		
AFC Cost Phasing				50.00%	50.00%
Economic Capex	**418.01**	**640.26**	**627.02**	**303.57**	**101.19**

Operating and Maintenance Cost of Metro Rail System:

The O&M cost includes the staff cost, routine maintenance cost and energy cost. The details of calculation are provided in Chapter 17. As the O&M period starts from June 2027 and ends in May 2057, O&M for FY 2027-28 is considered for 10 months. Table 20-6

below shows the Economic O&M Cost for FY 2027-28. The year wise economic O&M cost is presented in Table 20-16

TABLE 20-6: ECONOMIC O & M COST

Particular	FY 2027-28 Amount (Rs in Crore)
Staff Cost	**45.90**
Routine Maintenance	**40.20**
Energy Cost	**12.88**
Total Maintenance Cost	**98.98**
Conversion Factor	0.87
Economic O&M cost	**86.11**

Additional Investment for Rolling Stock, Depot Land and Depot Development and Capital Replacement Cost

Additional Investment includes the rolling stock to be added into the system during operation period to cater to the increased demand of metro. To cater to this demand, the additional investment for 3 coaches in FY 2037-38, 45 coaches in FY 2047-48 and 24 coaches in FY 2057-58.

To cater to increased demand, Additional investment also include Satellite Depot Land Cost taken in FY 2046-47 and Cost of Development of Depot is taken in FY 2046-47 and FY 2047-48 in 40:60 basis.

Replacement Cost is added during the operation period 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 50% of signalling and telecom and 25% of electrical works would require replacement after 15 years.

TABLE 20-7: ECONOMIC CAPITAL REPLACEMENT COST AND ADDITIONAL INVESTMENT (RS IN CRORES)

Particulars	2037-38 Additional Rolling Stock (3 no.)	2042-43 50% of Signalling& Telecom and 25% of Electrical Works	2046-47 Satellite Depot Land Cost and Depot Development Charges (40%)	2047-48 Additional Rolling Stock (45no.) and Depot Development Charges (60%)	2057-58 Additional Rolling Stock (24 no.) and 50% of Signalling& Telecom and 25% of Electrical Works
Replacement Cost/Additional Cost	60.81	344.00	501.96	1826.43	2006.12
Conversion Factor	0.83	0.83	0.83	0.83	0.83
Economic Capital Replacement Cost	**50.47**	**285.52**	**416.63**	**1515.94**	**1665.08**

20.3. ECONOMIC BENEFITS OF MRTS

The Project will yield tangible and non-tangible savings due to equivalent reduction in road traffic and certain socio-economic benefits. The introduction of project will result in reduction in number of Buses, IPT, usage of private vehicles, air pollution and increase in the speed of road-based vehicles. This, in turn, will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers. Reduction in accidents, pollution and road maintenance costs are the other benefits to the society in general. The benefit stream includes:

- Savings in capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing modes in case this Metro project is not taken up.
- Savings in operating costs of different modes due to de-congestion including those that would continue to use the existing transport network even after this Metro is introduced.
- Savings in time of commuters using this Metro over the existing transport modes because of faster speed of Metro.
- Time Savings of passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of accidents and pollution with introduction of this Metro corridors.
- Savings in road infrastructure and development costs that would be required to cater to increase in traffic.

20.3.1 QUANTIFIABLE ECONOMIC BENEFITS TO SOCIETY

The following quantifiable benefits are accrued to the society owing to implementation of the metro rail project.

- Travel Time Savings
- Savings in Vehicle Operating Cost
- Savings from Accident Reduction
- Savings from Pollution Reduction
- Savings due to Reduced Road stress

The following factors have been used for converting project benefits to economic costs.

TABLE 20-8: FACTORS USED FOR CONVERTING PROJECT BENEFITS IN TERMS OF ECONOMIC COST[1]

Component	Economic Factor
Time Cost Saving	100%
Vehicle Operating Cost Saving	90%
Emission Saving Cost	100%
Accident reduction Saving	90%
Infrastructure Maintenance Cost Saving	87%

20.3.2 INPUT PARAMETERS

Inputs used for Economic analysis have been collected from primary and secondary data sources. Vehicle Operating cost (VOC) and Value of Travel Time (VOT) are the two important parameters of Economic Analysis.

Various assumptions have been made, while assessing the economic benefits to the society on account of various factors after introduction of project. Following are the assumptions made for each of the factors as shown in Table 20-9.

TABLE 20-9: ASSUMPTIONS FOR VEHICLE OPERATING COST AND VALUE OF TIME

Mode	VOC/Km* (Rs.)	Value of Time ** Passenger/Hour (Rs.)
Bus	26.31	37.00
Car	8.26	82.46
2 Wheeler	2.89	40.00
3 Wheeler	7.31	37.00
Taxi	8.26	70.00
Note: * IRC SP 30 (2009) Values brought to 2022 level ** UMTC Primary Estimates for Pune Metro DPR Phase 2		

Other operational parameters required to assess the savings in VOC and VOT, accidents, pollution for the system are presented in the Table below;

TABLE 20-10: MODE WISE OPERATIONAL PARAMETERS

Mode	Average Lead Kms[2]	Vehicle Km/Day	Average Speed (Km/Hr)		Occupancy
			With Project Corridors	Without Project Corridors	
Bus	8.50	28	18	13	21.99
2 Wheeler	8.50	413	22	20	1.51
Car	8.50	258	22	20	2.62
Auto	8.50	211	22	20	3.21

Other benefits that will accrue to the society include reduction in emission, savings due to reduction in accidents. The input for the benefit estimation from these parameters include

1 Source: Appraisal Guidelines for Metro Rail Project Proposals – September 2017, MoHUA, GoI
2Source: UMTC Primary Surveys 2021

the emission factors by vehicle category as given by CPCB (Table 20-11), vehicle and accident statistics and cost of accidents (Table 20-12) in Pune.

TABLE 20-11: MODE WISE EMISSION FACTORS (GRAM/KM)[3]

Vehicle Type/Pollutant	CO	HC	NOX	PM	CO2
2 Wheeler	1.40	0.70	0.30	0.05	28.58
Auto	1.39	0.15	0.12	0.02	139.52
Cars (incld. Cabs)	2.45	0.75	0.12	0.08	77.89
Bus (incld. BRT)	3.72	0.16	6.53	0.24	787.72
Treatment Cost (Rs/Ton)	1,00,000	1,00,000	1,00,000	1,00,000	500

TABLE 20-12: COST OF ACCIDENTS[4]

Vehicle Type/Pollutant	Accident Cost (Rs)	
	2004 Prices	2022 Prices[5]
Cost of Fatal Accident	4,37,342	10,52,516
Cost of Major Accident	64256	1,54,640
Cost of damage to Two Wheelers	2286	5,502
Cost of damage to Car	9763	23,496
Cost of Damage to buses in road accidents	32818	78,980

20.3.3 ESTIMATION OF PROJECT BENEFITS

Quantifiable benefits accrued to the society owing to implementation of Line 2A and Line 2B as part of the Pune MRTS Phase-2 include;

- Travel Time Savings
  - Travel Time Savings due to higher speed of Medium Metro System project as compared to 'Without' project scenario.
  - Congestion reduction due to modal shift leads to fewer vehicles on roads. This also contributes to time savings of passengers travelling on other modes.
- Savings in VOC
  - Absence of vehicles on road due to modal shift passengers on Medium Metro System
  - Smoother operations of passenger trips of other mode vehicles owing to reduced congestion on roads.
- Savings from Accident Reduction
  - Reduction in fatal and injury accidents due less no of vehicles on roads
  - Savings in damage cost to vehicles involved in accidents.
- Savings from Pollution Reduction
  - Absence of vehicles on road due to modal shift passengers on Metro System

3Source: Appraisal Guidelines for Metro Rail Project Proposals September, 2017, MoHUA, GoI
4Source: Appraisal Guidelines for Metro Rail Project Proposals September, 2017, MoHUA, GoI
5Escalated at 5% per annum

- Less pollution due to reduced congestion on roads.

The above socio-economic benefits have been converted into money as per the Appraisal Guidelines for Metro Rail Project Proposals by MoHUA, GoI.

With input from the above tables, the accrued project benefits for Pune Metro Project have been summarized in Table 20-13 below.

TABLE 20-13: SUMMARY OF ECONOMIC BENEFITS (RS IN CRORES)

Particular	2028-29	2037-38	2047-48	2057-58
Travel Time Saving	91.58	634.34	2728.95	1333.49
Saving in Vehicle Operating Cost	99.46	269.74	610.49	172.93
Saving from Accident Reduction	0.39	2.41	8.90	4.79
Saving from Pollution Reduction	3.26	7.12	10.47	1.87
Saving due to Reduced Road Stress	4.97	10.42	15.47	2.77
Total	**199.66**	**924.03**	**3374.28**	**1515.85**

20.4. EIRR FOR 30 YEARS

Considering the economic lifecycle cost and economic benefits over the project horizon, the economic internal rate of return (EIRR) for the corridor from Line 2A and Line 2B comes out to be 17.93% for the duration of 30 years which is above the established cut-off criterion of 14% as per Appraisal Guidelines for Metro Rail Project Proposals by MoHUA, GoI.

This implies that the economic benefits accruing out of this project are substantial and will yield high savings to the economy as a whole.

20.5. OUTCOME ON ECONOMIC VIABILITY

The outcome of economic viability is given in the Table 20-14 below;

TABLE 20-14: OUTCOMES OF ECONOMIC VIABILITY

Economic Internal Rate of Return	Economic Net Present Value (ENPV) @ 14% Discount Rate (Rs in Crores)
17.93%	**1778.45**

20.6. SENSITIVITY ANALYSIS

A sensitivity analysis of economic analysis is being carried out based on the critical factors such as:

1. Cost overruns due to delay or other factors.
2. Increase in Maintenance Cost.
3. Reduction in Ridership.
4. Reduction in benefits.
5. Combination of reduction in benefits and increase in cost.

The summary of EIRRs under various scenarios is given in Table 20-15;

TABLE 20-15: SUMMARY OF SENSITIVITY ANALYSIS

S.No.	Factor	Range		
		5%	10%	15%
1	Cost overruns due to delay or other factors	17.58%	17.25%	16.93%
2	Increase in Maintenance Cost	17.82%	17.70%	17.585%
3	Reduction in Ridership	17.52%	17.66%	17.80%
4	Reduction in Benefits	16.34%	16.89%	17.42%
Combination of Reduction in Benefits and Increase in Cost				
Project Cost		**Benefits**		
		5% Reduction	**10% Reduction**	**15% Reduction**
5% Higher		17.08%	16.55%	16.01%
10% Higher		16.75%	16.24%	15.70%
15% Higher		16.44%	15.94%	15.41%

TABLE 20-16: EIRR ANALYSIS (RS IN CRORE)

Period		Life Cycle Cost (Rs. In Cr.)				Revenue (Rs. in Cr.)						Net Benefits
		Economic Capex	Economic O&M Cost	Economic Capital Replacement Cost	Life Cycle Cost	Travel Time Saving	Saving in Vehicle Operating Cost	Saving from Accident Reduction	Saving from Pollution Reduction	Saving due to Reduced Road Stress	Total Benefits	
2023	2024	**418.01**			418.01						0	-418.01
2024	2025	640.26			640.26						0	-640.26
2025	2026	627.02			627.02						0	-627.02
2026	2027	303.57			303.57						0	-303.57
2027	2028	101.19	86.11		187.30	54.96	71.98	0.28	2.38	3.64	133.24	-54.06
2028	2029		110.63		110.63	91.58	99.46	0.39	3.26	4.97	199.66	89.03
2029	2030		117.75		117.75	124.43	114.54	0.65	3.67	5.62	248.91	131.16
2030	2031		125.40		125.40	163.40	131.86	0.74	4.14	6.34	306.48	181.08
2031	2032		134.39		134.39	217.23	158.15	0.89	4.90	7.50	388.67	254.28
2032	2033		143.26		143.26	266.14	174.62	1.04	5.22	7.98	455	311.74
2033	2034		152.82		152.82	323.85	193.00	1.18	5.56	8.50	532.09	379.27
2034	2035		163.93		163.93	391.73	213.37	1.64	5.92	9.05	621.71	457.78
2035	2036		175.03		175.03	469.33	236.11	1.86	6.31	9.64	723.25	548.22
2036	2037		187.55		187.55	560.14	261.41	2.12	6.71	10.26	840.64	653.09
2037	2038		201.53	50.47	252.00	634.34	269.74	2.41	7.12	10.42	924.03	672.03
2038	2039		215.62		215.62	743.39	292.94	2.67	7.40	10.83	1057.23	841.61
2039	2040		230.82		230.82	868.15	318.21	3.02	7.70	11.26	1208.34	977.52
2040	2041		248.24		248.24	1011.36	345.65	3.41	8.00	11.70	1380.12	1131.88
2041	2042		265.95		265.95	1174.90	375.42	4.34	8.30	12.16	1575.12	1309.17
2042	2043		285.07	285.52	570.59	1362.83	408.29	4.91	8.63	12.64	1797.3	1226.71
2043	2044		306.86		306.86	1575.69	443.91	5.51	8.97	13.13	2047.21	1740.35
2044	2045		329.16		329.16	1819.08	482.65	6.23	9.33	13.65	2330.94	2001.78
2045	2046		353.25		353.25	2098.44	524.92	7.01	9.69	14.19	2654.25	2301.00
2046	2047		394.46	416.63	811.09	2416.48	570.81	7.77	10.07	14.74	3019.87	2208.78

Period		Life Cycle Cost (Rs. In Cr.)				Revenue (Rs. in Cr.)						Net Benefits
		Economic Capex	Economic O&M Cost	Economic Capital Replacement Cost	Life Cycle Cost	Travel Time Saving	Saving in Vehicle Operating Cost	Saving from Accident Reduction	Saving from Pollution Reduction	Saving due to Reduced Road Stress	Total Benefits	
2047	2048		422.92	1515.94	1938.86	2728.95	610.49	8.90	10.47	15.47	3374.28	1435.42
2048	2049		453.70		453.70	3058.10	645.25	10.96	10.55	15.60	3740.46	3286.76
2049	2050		488.36		488.36	3421.51	681.94	12.31	10.64	15.73	4142.13	3653.77
2050	2051		524.34		524.34	3826.52	720.73	13.57	10.73	15.86	4587.41	4063.07
2051	2052		563.26		563.26	4274.66	761.91	15.18	10.83	16.00	5078.58	4515.32
2052	2053		606.89		606.89	4768.71	805.12	16.80	10.91	16.13	5617.67	5010.78
2053	2054		652.47		652.47	5316.52	851.03	18.80	11.00	16.27	6213.62	5561.15
2054	2055		701.80		701.80	5925.29	899.58	20.79	11.09	16.40	6873.15	6171.35
2055	2056		756.86		756.86	6595.74	950.76	23.25	11.18	16.54	7597.47	6840.61
2056	2057		826.77		826.77	7338.90	1004.87	25.72	11.28	16.68	8397.45	7570.68
2057	2058		148.34	1665.08	1813.42	1333.49	172.93	4.79	1.87	2.77	1515.85	-297.57
Total		**2090.05**	**10373.54**	**3933.64**	**16397.23**	**64955.84**	**13791.65**	**229.14**	**243.83**	**361.67**	**79582.13**	**63184.90**
											EIRR	**17.93%**

CHAPTER 21: IMPLEMENTATION PLAN

21.1. PROJECT IMPLEMENTATION PLAN

Based on the important milestones given in Table 21-1 and Figure 21-1, as soon as the approval is accorded at the state level, the appointment of General Consultants (GC) and Detailed Design Consultants (DDC) may be initiated for the preparation of tender documents as well as project management. As the land acquisition is a time consuming activity, the process to acquire the land for the Project may also start simultaneously.

TABLE 21-1: ANTICIPATED IMPLEMENTATION SCHEDULE OF THE PROJECT

SN	Tasks	Anticipated Timelines
1	Submission of the DPR	July 2022
2	Approval of DPR by PMC	September 2022
3	Approval of DPR by GoM	October 2022
4	Final Approval by GoI	January 2023
5	Packaging and invitation of bids	April 2023
6	Commencement of civil works	June 2023
7	Commencement of operation	June 2027

Line 1 and Line 2 of Pune MRTS Phase-1 are being implemented on SPV Model by Maha-Metro. The proposed metro corridors (i.e. Line 2A-Vanaz to Chandani Chowk and Line 2B-Ramwadi to Wagholi/Vitthalwadi), as stated in the relevant chapters of this DPR, may also be implemented on SPV model The commercial operation of these corridors may start from June 2027 after about 4 years of construction including land acquisition.

21.2. CONTRACTS

21.2.1. CIVIL WORKS

It is proposed to carry out the civil works through new construction contracts:

a) **Viaduct cum Station Construction Contracts:** As some of the stations are Island types, and a synchronous approach is required to have seamless construction sequence, it will be important that each contract should integrate Viaduct and Stations and further, these can be limited to 4 to 5 Kms in length, including 4 to 5 stations. Architectural finishes, firefighting arrangements, and general electrification will be part of civil contracts.

21.2.2. SYSTEMS CONTRACT

It is proposed to carry out the systems contract based on the broad technical specifications and performance requirements drawn up by the GCs. The following systems contracts are proposed:

- Extension of the existing contracts for
  - Design - Construct - Installation of Traction and Power Supply
  - Design - Procure - Installation of Signal and Telecommunication Work
  - Installation of Track Works
  - Installation of Depot Track and Main Line Track
- Carryout new contracts for
  - Design - Construct - Installation of Lifts, Escalators, Platform Screen Doors
  - Design - Construct - Commissioning of Automatic Fare Collection System
  - Design - Supply of Rolling Stock
  - Design - Installation of Signage's

21.3. LEGAL & INSTITUTIONAL FRAMEWORK

21.3.1. LEGAL FRAMEWORK

Construction and operation of the proposed corridors of Pune Metro would commence after the approval of the Central Government. The Project would be implemented under the Metro Railways (Construction of Works) Act and the Metro Railways (O&M) Act.

Procedure for safety certification and technical clearance of metro system, December 2015, circulated by RDSO shall be followed for the technical clearance of the MRTS and the system shall be opened for passenger traffic in accordance with 'Opening of Metro Railway for Public Carriage of Passenger Rules, 2020' after safety certification by the Commissioner of Metro Railway Safety. The trains shall be worked on the System in accordance with 'Metro Railway General Rules, 2020'.

21.3.2. INSTITUTIONAL ARRANGEMENTS

The Government of Maharashtra has already created a Special Purpose Vehicle (SPV) for implementing the Pune Metro Rail Project. The SPV, "Maha-Metro" shall be responsible for the implementation of the proposed Pune MRTS Phase-2 Corridors also.

Metro construction is a very specialized and multi-disciplinary job. It is, therefore, extremely difficult to have a single organizational set-up that can be responsible for all aspects of metro implementation, namely investigation, planning, design, drawing up of specifications, preparation of tender documents, fixing of contractors, supervising the contractor's works, ensuring interface fusion between different contractors, ensuring quality and safety during constructions, planning and supervising integration system trials

and getting the project commissioned in time. The appointment of General Consultant (GC) becomes inevitable.

Metro 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 the integration of a number of complex technical systems, and some of the technologies used in these systems are highly complex and sophisticated and hence each one of these 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 the required 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/GC.

21.3.3. HIGH POWER COMMITTEE

During the implementation of the project, several problems with regard to the acquisition of land, diversion of utilities, shifting of structures falling on the project alignment, rehabilitation of project affected persons, etc. will arise. For the 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, Govt. of 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. The Commissioner of Pune Metropolitan Region Development Authority (PMRDA) and Municipal Commissioner of PMC should also be key members of this committee.

21.4. ROLES & RESPONSIBILITY OF CITY GOVERNMENT

21.4.1. UNIFIED METROPOLITAN TRANSPORT AUTHORITY (UMTA)

The National Urban Transport Policy 2014 has recommended the setting up of Unified Metropolitan Transport Authorities (UMTA) in million-plus cities. The policy document stipulates the following on UMTA.

"The current structure of governance for the transport sector is not equipped to deal with the problems of urban transport. These structures were put in place well before the problems of urban transport began to surface in India and hence do not provide for the right coordination mechanisms to deal with urban transport. The central government will, therefore, recommend the setting up of Unified Metropolitan Transport Authorities (UMTA) in all million cities to facilitate more coordinated planning and implementation of urban transport programs and projects and integrated management of urban transport systems.

Such Metropolitan Transport Authorities would need statutory backing in order to be meaningful."

The Metro Rail Policy - 2017 makes it mandatory for the cities to have city-level UMTA, while these are planning to have MRTS to address their mass transport requirements.

For an integrated approach to planning and management of urban transport in the city, State Government shall constitute Unified Metropolitan Transport Authority (UMTA) as a statutory body. This Authority would implement various proposals as per CMP for the city, organize investments in urban transport infrastructure, establish effective coordination among various urban transport agencies, and manage the Urban Transport Fund (UTF) etc.

Pune Unified Metropolitan Transport Authority (PUMTA) has been set up by Government of Maharashtra in 2019 with Pune Divisional Commissioner as the Chairperson. PUMTA consists of members of various stakeholders such as PMC, PCMC, PMRDA, Maha-Metro, Traffic Police, PWD, NHAI, MSRTC etc. PUMTA will have to play active role in the implementation of Pune Metro Phase-2 project, being a city government authority.

21.4.2. STEERING COMMITTEE

Apart from a High Power Committee under the chairmanship of Chief Secretary, Maharashtra, a 'Steering Committee' may be set up under the chairmanship of Divisional Commissioner, Pune. Other members of this Committee may be the District Magistrate, Municipal Commissioner of Pune and other heads of civic bodies who will be connected in one way or the other with the implementation of the project.

During the implementation of the project several problems with regard to the acquisition of land, diversion of utilities, shifting of structures falling on the project alignment, rehabilitation of project affected persons, etc. are likely to arise. The steering committee will work for expeditious resolution of these problems at the local level. This Committee may meet regularly to sort out all problems brought before it by Maha-Metro.

21.4.3. PERFORMANCE MONITORING DURING CONSTRUCTION AND IMPLEMENTATION

The efficiency in standards during construction and implementation will be monitored in the following manner:

1. Constant monitoring in the meeting of the Board of Directors of the company.
2. Monitoring by High Powered Committee (HPC) of the State Government: During the implementation of the project, a High Powered Committee under the chairmanship of the Chief Secretary of the State Government will be set up by the State Government to take expeditious decisions on land acquisition matters, diversion of utilities, shifting of structures in the project alignment, rehabilitation of

Project Affected Persons, multimodal integration and such other matters where the State Government has to facilitate quick action including various conditions of sanction of this project.

3. Audit of the projects accounts to be monitored by the Audit Committee of BoD.

21.4.4. WAY FORWARD

On acceptance of this DPR for the Metro, the following actions may be initiated for implementing the project:

- Approval of DPR by PMC, PUMTA and State Government.
- DPR to be forwarded to the Ministry of Housing and Urban Affairs, Niti Aayog and Finance Ministry with a request for approving the Metro project and for financial participation through equity contribution to the SPV.
- Approval from the Government of India.
- Agreement between the State and Central Government for financing the debt portion of the project along with the setting up of time frame for completing the Project.
- Examination and appraisal of DPR by bilateral/multilateral funding agencies for possible funding.
- Appointment/Extension of Contracts for of General Consultants (GC)
- Appointment of Detailed Design Consultants (DDC).
- Packaging and invitation of bids for various contracts.
- Land acquisition related issues.
- Stakeholder consultation on environmental and social impact of the project.
- Signing of an MOU between Maharashtra State Government and Government of India and SPV, giving all details of the Joint Venture bringing out the financial involvement of each party, liability for the loans raised, the administrative control in the SPV, policy in regard to fare structure etc.
- Loan approval.
- Providing legal cover for construction as well as O&M stages of the Project.
- Memorandum of Understanding between various service providers to provide seamless integration between various transport modes.

Main Activity	2022	2023				2024				2025				2026				2027	
	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun
Approval of DPR by State Govt.																			
Approval of DPR by Central Govt.																			
Appointment of General Consultant/DDC																			
Packaging and Invitation of Bids																			
Land Acquisition																			
Shifting of Utilities																			
GT Survey																			
Construction of Viaduct																			
Construction of Elevated Station																			
Construction of Depot (Agumentation)																			
Track Laying																			
OHE Fixing and Testing																			
S&T works																			
Trial Run & Testing																			
CMRS Inspection and Commissioning																			

FIGURE 21-1: IMPLEMENTATION SCHEDULE FOR MONITORING PROJECT

CHAPTER 22: IT/OT AND CYBER SECURITY

22.1. BACKGROUND

The Ministry of Housing and Urban Affairs, GoI vide letter no K-14011/01/2019-MRTS-Coord dated December 02, 2021, informed the Managing Directors of all Metro Rail Corporations to include a dedicated chapter on IT/OT systems and cyber security in the DPR, which should cover Backup and Disaster Recovery Measures, Anti-virus and Perimeter Security Devices (firewall, IPS/IDS, proxy), Active Directory and Domain Server, Encryption for Data Transmission and SAN Storage Server on a Centralised Network. The chapter should cover Network Security, Identity and Access Management, Application Security, Threat and Vulnerability Management, Security Monitoring, and Incident Management. It may also cover that the vulnerability assessment of all new technologies is required to be carried out at the institutional level, preferably involving C3I (Centre for Cyber Defence of Critical Infrastructure), IIT Kanpur.

Subsequently, UMTC approached C3i at IIT Kanpur and Latter accepted the request and prepared this chapter as brought out in subsequent paragraphs.

22.2. INTRODUCTION

Metro railways are deploying automation technologies/systems both for core rail systems as well as other systems. However, the increasing usage of digital technologies in rail systems are creating new vulnerabilities in the cyber physical domain, making the IT/OT systems susceptible to cyber-attacks. These vulnerabilities can be exploited by threat actors to disrupt operations. Therefore, safeguards are required to be built-in at the preparatory stage of the metro rail project.

Multiple digital technologies are deployed in metro rail, viz.:

- Train control system
- Train control management system (TCMS) in rolling stock
- Telecommunication systems
- Traction and power SCADA system
- Facilities SCADA system
- Tunnel ventilation SCADA system (for Under Ground)
- Automatic Fare Collection System and Platform Screen Door System
- Building management system
- Fire control and alarm system

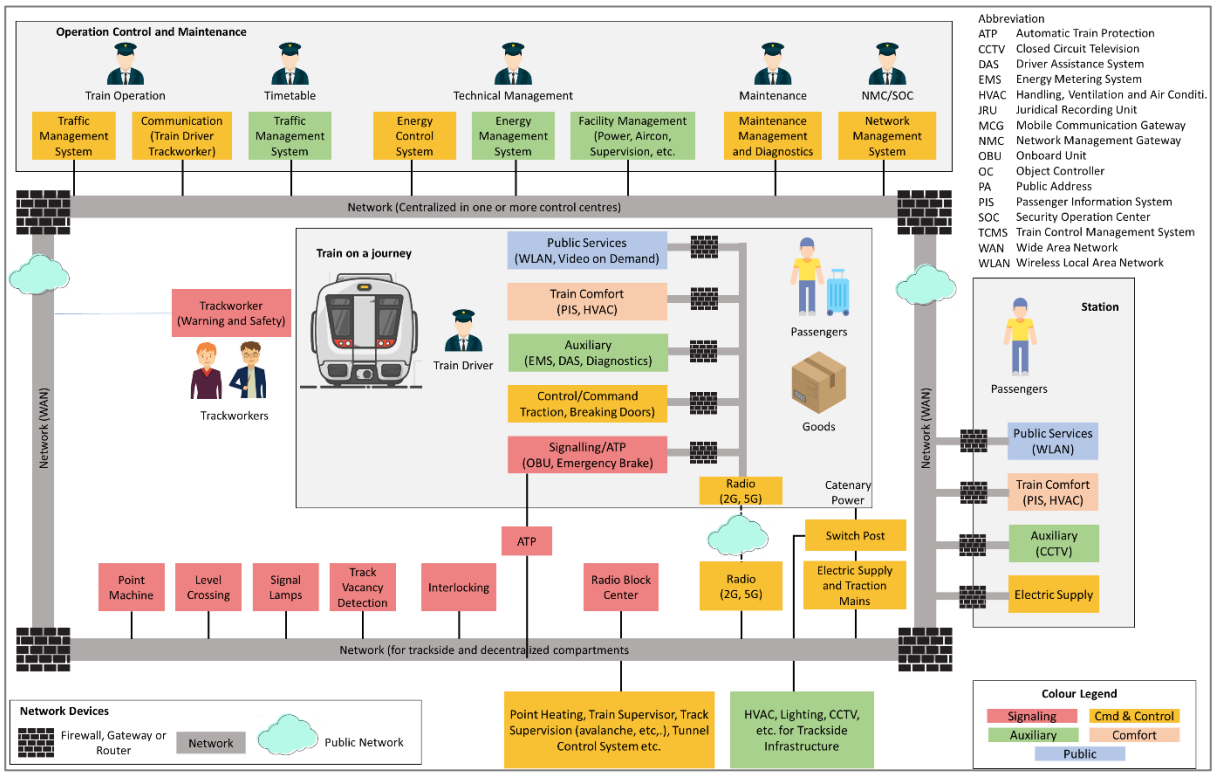


FIGURE 22-1: TYPICAL RAIL SYSTEM OVERVIEW

Additionally, Office Automation/IT system is deployed in metro offices and depots.

A new standard TS 50701 (Railway Cyber Security) has been published in recent times in view of the importance of the matter in the context of the increasing use of digital technologies in rail operation and administration.

TS 50701 elaborates the requirements of cyber security on a lifecycle format, similar to RAMS V-cycle as per EN 50126.

22.3. METRO RAIL IT INFRASTRUCTURE OVERVIEW

The metro system IT infrastructure can be broadly categorized into the following physical and logical autonomous environments:

a) Signalling Communication Network (SCN)
b) Operational Communication Network (OCN)
c) Administrative Communication Network (ACN)
d) Fire and Emergency Network (F&EN)
e) Traffic Light Communication Network (TLCN)

The security solution shall be designed and implemented with all the security means to be ready to absorb the administrative systems, including interfaces to other environments.

As part of the desired functionality and services, some of these core networks shall be expandable and shall provide interconnectivity with external service provider networks and institutions via direct links or dedicated network segments. Implementation decisions for the external connectivity shall follow the security guidelines, as relevant.

Traffic management is composed of three (03) standalone networks physically and logically separated from the Communication Backbone Network (CBN):

a) Traffic Light Controller (TLC) communication network
b) Train Detection (TD) communication network
c) Traffic VSS/CCTV communication network

The figure below is an overview of the metro system's logical architecture and information flow:

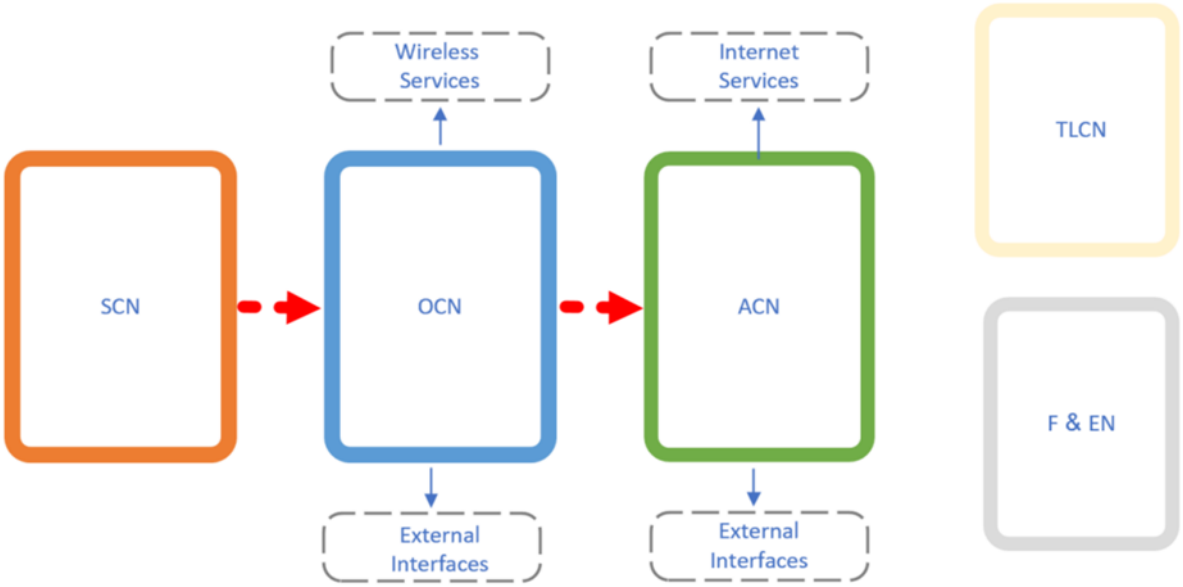


FIGURE 22-2: LOGICAL ARCHITECTURE AND INFORMATION FLOW (CONCEPTUAL)

The subsequent contents of this chapter elaborate on the requirements of cyber security, broken down into tasks and functionalities, for the metro rail system.

22.4. MAIN CONSTITUENTS OF CYBER SECURITY

The following are the main constituents of cyber security implementation in a metro rail organization:

- Initial risk assessment
- Security service and infrastructure
  - Authorization
  - Identification
  - Authorization and access control

  - Network security
  - Firewalls
  - Data security administration
  - Network devices
  - Server, host and end-point security
  - Application security
  - System availability and continuity
  - Technological means to security
  - Equipment security
- Elaboration of security requirements for each network
  - SCN
  - OCN
  - ACN
  - F&EN
  - TLCN
- Security system-specific requirements
  - Railway scheduling system
  - Rolling stock on-board system
  - ATS and SCADA interface
  - Interface between cellular network and Metro CBN
- Security requirements for testbed and pre-production (staging) environment
  - Staging
  - Testbed and model
- Cyber risk assessment and penetration testing
- Periodic cyber risk assessment
- Penetration testing

22.5. NETWORK SECURITY

Network policies are designed to govern how a network should be implemented and configured to streamline operation in ordinary conditions as well as guide how to react during the occurrence of abnormalities. In this context, the following section explains the imposition of policy measures of each term or principles of network security to protect information and systems.

22.5.1. DEVICE SECURITY

It is important to identify different network segments with different security requirements while designing the security for an organization’s network. For instance, some servers will need to be accessible by employees. Some, on the other hand, will be openly accessible. To implement security for different divisions or subdivisions, perimeters need to be erected, which can only be crossed by certain types of traffic, in the form of public network, private network, and semi-private network.

The limitations of such network segments are founded by devices such as a router, gateway, bridge, and switch which are capable of regulating and controlling the flow of packets into and out of the segment. Communication and monitoring devices are typically deployed in the network for various purposes. They must be configured properly according to requirement and accessed on the ground of given privilege and profile of users. Their inbuilt software must also be up to date. Apart from that, the following measures should be taken in the context of device security:

1. The metro authority must sign an NDA with each employee about not disclosing the details of deployed devices inside the perimeter.
2. Patches and security updates released by various OEMs must be regularly applied.
3. Access Control List (ACL) should be maintained to permit or deny Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) traffic.
4. Services must be disabled if they are not in use

22.5.2. INTERNET ACCESS

Internet access policies include automatically blocking all websites identified as inappropriate (especially social media-related sites) for the authority user. Moreover, internet access should be based on the work of the employees. The internet constructs a network topology in itself and connects various crucial assets of the company, for example, server, account sections, etc. Therefore, it must be filtered and monitored properly before wielding.

22.5.3. WIRELESS LAN POLICY

To stop the possible abuse of wireless network, there should be proper user authentication along with the appropriate replacement of Wired Equivalent Privacy (WEP) and anomaly tracking mechanism on wireless LAN. Moreover, 802.11i security measures such as Temporal Key Integrity Protocol (TKIP) and Counter Mode with Cipher Block Chaining Message Authentication Code Protocol (CCMP) should be employed for encryption.

22.5.4. REMOTE CONNECTION POLICY

Data security is becoming vital as more organizations establish network links between their employees to share information and increase productivity. As personnel prefer to work from home more often, security begins with a terminal session between an authorized user and a remote host on a network and the user can perform all functions as if he were actually on the remote host. At the same, mismanagement of user credentials can lead to exploitation too. Hence, direct access to the critical server or system of an organization should be strictly in restricted mode via remote login or Secure Socket Shell (SSH) utility with the exception of authorized users. However, encrypted access could be permitted.

22.6. WEB APPLICATION SECURITY

Web application vulnerabilities account for the largest portion of attack vectors outside of malware. It is crucial that any web application be assessed for vulnerabilities and any vulnerabilities be remediated prior to production deployment.

This policy covers all web application security assessments requested by any individual, group or department for the purposes of maintaining the security posture, compliance, risk management, and change control of technologies in use at the organization.

All web application security assessments shall be performed by delegated security personnel either employed or contracted by the organization. All findings are considered confidential and are to be distributed to persons on a "need to know" basis. Distribution of any findings outside of the organization is strictly prohibited, unless approved by the Chief Information Officer.

Any relationships within multi-tiered applications found during the scope phase will be included in the assessment, unless explicitly limited. Limitations and subsequent justification will be documented prior to the start of the assessment.

22.6.1. WEB APPLICATION SECURITY ASSESSMENT

The assessment provides a point-in-time security analysis and resultant recommendations for improving the security of the application and its environment. It consists of the following activities:

- Information gathering techniques shall be used in conjunction with a review of application and support system documentation in order to gain a deep and thorough understanding of how the application works, what its purpose is, and how it has been implemented.
- Reconnaissance, which involves performing active assessment techniques in order to fingerprint the technologies and versions of software in use, as well as mapping the available functionality of the application.
- Communications security and cryptography implementations shall be analysed in order to ensure that cryptography is appropriately used to protect the confidentiality and integrity of sensitive user data. Cryptographic algorithms, ciphers, key lengths and storage strategies are assessed to ascertain their effectiveness to withstand cryptanalysis attack.
- Authentication mechanisms shall be examined to determine the effectiveness and resilience to subversion techniques.
- Session management implementations shall be assessed and attempts made to violate session state to become another valid user or to escalate privileges.

- Authorization access controls that enforce authorization levels for the application shall be analysed in detail to assess the user segregation methods employed and to validate their effectiveness.
- Data validation routines shall be subjected to tests that consist of supplying unexpected data of various types and lengths, in order to ascertain the potential for exploitation of several classes of vulnerabilities such as: Operating System (Shell and System), Database (SQL), Data (XML) and Scripting (XSS) Injections, Buffer Overflows, Format Strings, etc.

22.7. IDENTITY AND ACCESS MANAGEMENT

Identity and access management refers to the processes and methodologies that are used to ensure the right access to right individuals across various information sources of an organization. This is a discipline that is fast emerging as a critical one on account of the increase in data security and compliance requirements by organizations.

It encompasses a set of policies, procedures and tools required to manage individual access rights, authentication and privileges, including cross border and cross line of business privileges.

To summarize, the key objective of this discipline is to ensure that legitimate parties have the right access to the resources at the right time, while keeping unauthorized parties out of systems.

22.7.1. IDENTITY ACCESS MANAGEMENT

Today, with most organizations operating globally across geographical, political and physical boundaries, compliance and data security measures have grown in prominence.

Identity and access management procedures ensure that organizations can set the right access mechanisms in place to prevent any unintended exposure of sensitive data, thereby, helping them meet rigorous compliance mechanisms. By establishing guidelines and rules for access at various organizational levels, identity management ensures that each user of the system can access and manage the data that he is authorized to view, thereby, imposing stringent monitoring and data protection mechanisms.

22.7.2. ACCESS GOVERNANCE

Access governance provides the guiding principles that determine who has access to what information in an organization.

In the ever-changing IT landscape, involving a plethora of distributed technologies, applications residing in the cloud, and private and public networks, it has become all the more important to set appropriate access levels for various users.

22.7.3. WAYS AND MEANS OF MANAGING IDENTITIES

Identity management is a combination of processes and software/database tools that enable the creation and management of individual identities.

Most identity management functions are based on a strong foundation of unified personnel data. This database is used to create and manage privilege rights of the personnel based on their roles in the organization.

Once an identity is established for an individual, it is modified on an ongoing basis, depending on the roles the person undertakes in the organization. Various ID management systems and tools enable the administrator to create a user ID, track it on an ongoing basis, and make changes as and when required. Periodic audits are mandatory to ensure that the IDs are functioning in the proper manner.

Identity is managed across a wide range of devices that are carried by an individual to their work environment. By creating a single identity and imposing access rights, no matter what device the user logs in, the access rights and criteria remain the same based on the single central identity management system. Identity and Access Management (IAM) tools are designed to manage identities (users) and access (authentication and authorization). The goal of IAM tools is to streamline the management of user accounts and privileges from all aspects.

In most cases, an IAM solution will let a user define a policy. This policy will, in turn, determine the roles of users. Each role defined will have permissions set. These permissions allow access to specific resources. The core features of IAM solutions usually include:

- A database of user identities and their access privileges
- Tools for granting, monitoring, modifying, and revoking access privileges
- A logging and reporting system for auditing and access history

22.8. THREAT AND VULNERABILITY MANAGEMENT

22.8.1. WHAT IS THREAT AND VULNERABILITY MANAGEMENT?

Threat management, or cyber threat management, is a framework often used by cybersecurity professionals to manage the life cycle of a threat in an effort to identify and respond to it with speed and accuracy. Vulnerability management is the practice of identifying, classifying, remediating, and mitigating weaknesses in an IT environment. It also includes discovery, reporting, prioritization, and response to vulnerabilities in a network.

The purpose of a vulnerability management program is to keep the network safe from known exploitation and ensure it stays compliant with any regulatory requirements.

Four Stages of a Vulnerability Program:

Discovery: Building a list of every computing asset the organization has on network and then building a database that vulnerability management solutions can use. This list will be changing constantly so it will need to be refreshed constantly. All assets must be categorized and assessed.

Reporting: This includes all the data from the network assets in their current state. Typically, this is done with a vulnerability scanner which will produce a report of all known vulnerabilities on any assets in the organization's network.

Prioritization: Depending on the size of the organization or the age of its assets, the list of known vulnerabilities can be pages long. In this step, the vulnerabilities will be ranked from highest to lowest risk, depending on multiple factors. The vulnerability management solution should prioritize these by the MITRE Common Vulnerabilities and Exposure (CVE) Score and by the unique risk they pose to the organization.

Response: The goal of discovering, reporting and prioritizing vulnerabilities is to let the team focus its remediation to the largest risks in network. Once these vulnerabilities are remediated or patched, one should conduct a penetration test to ensure that the patch is valid and that there is no longer any issues, before moving on to the next vulnerability.

22.8.2. DEVELOPING A PLAN FOR VULNERABILITY MANAGEMENT

The strategy needs to be converted into a plan with rules and guidelines for the vulnerability management teams. They need to understand what is expected of them and how they will use the resources they have. The planning phase consists of the following steps:

- Define and document the plan
- Define measures of effectiveness
- Define training requirements
- Determine tools aligned to the strategy
- Identify sources of vulnerability information
- Define roles and responsibilities
- Engage stakeholders
- Develop a plan revision process

In this phase of the process, the organization actually implements the vulnerability management plan and conducts vulnerability analysis and resolution activities. It makes use of the methodologies, tools, and sources defined in the previous phases and mitigates

the organization's exposure to the vulnerability based on the timeframes agreed to in the plan.

Throughout the performance of vulnerability analysis and resolution, the organization takes steps to ensure that the vulnerability is tracked, improvement information is collected, and the risk management process is engaged where appropriate.

The following are the foundational steps in the implementation of the vulnerability management plan:

- Provide training and conduct vulnerability assessment activities
- Record discovered vulnerabilities
- Categorize and prioritize vulnerabilities
- Manage exposure to discovered vulnerabilities
- Determine effectiveness of vulnerability dispositions
- Analyse root causes

22.9. SECURITY MONITORING

Security monitoring occurs on both physical areas as well as logical components in many different information system areas. Information security monitoring confirms that appropriate mechanisms and controls are in place to secure systems and applications, that they are effective, and are not being bypassed in any way.

Security monitoring is predicated on audit logs, network security monitoring (using traffic inspection such as snort, and so on), and environmental data (see section on Physical Security above). The requirements for security monitoring are as follows:

- Security monitoring shall be a highly available and hardened service that is accessible internally or remotely in a secure manner.

Security monitoring shall include

- The generation of alerts based on automated recognition that a critical security event or situation has taken place or is detected.
- The delivery of critical alerts via various means in order that security and management are made aware in a timely manner.
- The means for security personnel to investigate and prosecute an unfolding incident or simply to review logs to improve alerting mechanisms or to manually identify security incidents.
- Implement a cloud-wide intrusion and anomaly detection capability and consider expressing this as a service for tenants or users.

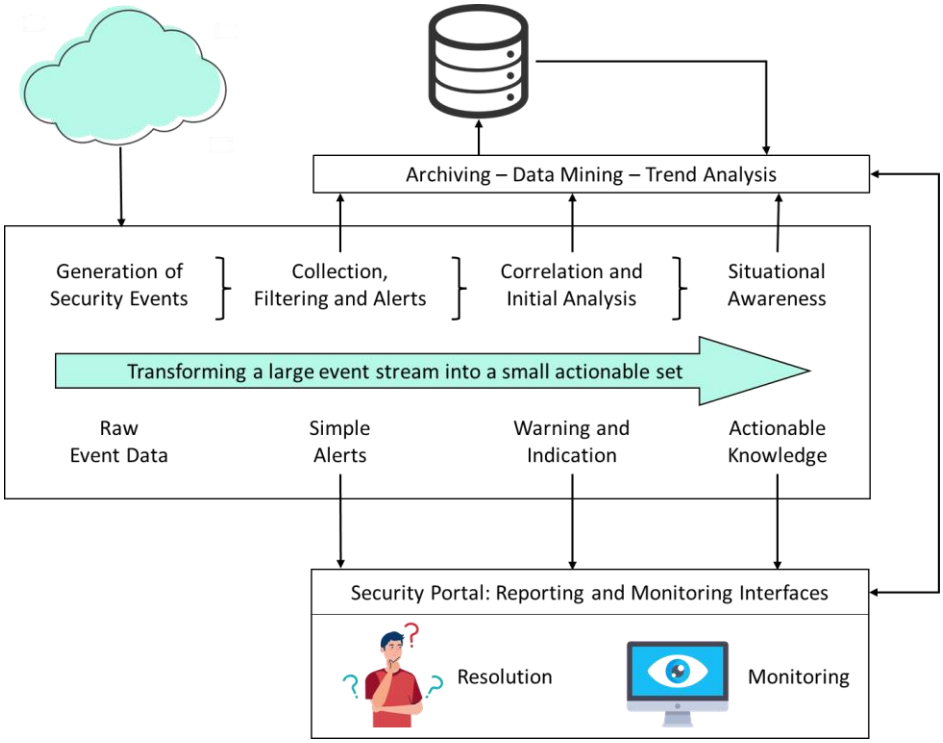


FIGURE 22-3: SECURITY MONITORING

22.9.1. PURPOSE OF SECURITY MONITORING

One of the benefits of security monitoring is the early identification of wrongdoing or new security vulnerabilities. Early identification can help block wrongdoing or vulnerabilities before harm can be done. Other benefits include audit compliance, service level monitoring, performance measuring, limiting liability, and capacity planning. The important aspects of security monitoring are:

- **Threat Detection:** Some exploits may not be preventable and some threats may not be anticipated, and, in this sense, monitoring is the last line of defence. But there is a difference between detecting a security situation and doing something about it.
- **Verification of Security Controls:** Although most security controls are oriented toward enforcing security policy, monitoring is used to verify the correct operation of other security controls. If events which indicate actions prohibited by policy appear in the security event stream, this would indicate that policy is not being correctly enforced by security controls.
- **Exposure of Bugs Security Monitoring:** This identifies vulnerabilities or security bugs that were previously unknown. This can take several forms, including the triggering of monitoring rules, which, when they are subsequently reviewed against the monitoring record, simply do not make sense.
- **A Legal Record of Activity:** Security event data can form a legal record of actions that users or processes performed. To be used in a legal proceeding, this data

must have verifiable integrity (records have not been altered and comprise a complete record) and the organization must be able to demonstrate chain of custody over the data.

- **Enabling Forensics:** Security event data has great value in gaining an understanding of the steps involved in an exploit along with discerning the scope of any resulting damage.

22.9.2. BENEFITS OF CONTINUOUS SECURITY MONITORING (CSM)

1. Continuous Security Monitoring Provides Visibility of Your Digital Footprint

For any organization, it is imperative to fully understand the evolving IT environments. Real-time asset and vulnerability discovery will map known and unknown assets helping to visualize overall security posture to pin-point vulnerabilities accurately. Vulnerabilities can be introduced at any time and the attack surface is constantly in a state of change which reinforces the critical need for a continuous monitoring solution.

2. Assess the Capacity of Organizations to Combat Risk

Full visibility of the threat landscape empowers one to determine digital health and subsequently gauge the ability to manage risks decisions. With the detailed and continuous insight provided by this form of monitoring, one can use the information to adjust their security strategy accordingly and build a more robust security program. For example, if an application is regularly flagging vulnerabilities, it is a trigger for a manual penetration test.

3. Speed Up and Prioritize Remediation

Once the vulnerabilities and other potential attack vectors are located, one can prioritize remediation efforts. The fact that this approach is continuous means one can be notified of risk as soon as it appears, thus allowing one to resolve issues imminently to efficiently optimize the organization's defence. Alerts should also provide full descriptions of discovered vulnerabilities.

4. Taking a Proactive Approach to Cyber Security

Continuous monitoring allows one to secure the external environment before attacks occur, rather than in response to them, minimizing the chance of successful breach taking place.

A productive, forward-thinking measure like Continuous Security Monitoring is much more effective than a reactive one, particularly in light of the rise in cyber-attacks, including data leaks and XSS attacks. Firewalls, anti-virus software, and other traditional protective methods no longer suffice and can be easily nullified by sophisticated attacks.

5. Scaling Security Efforts

New and emerging technology enables processes and operations to be faster and more efficient, which inevitably generates new and inescapable risks. Increasing risk must be addressed through a scalable, continuous security strategy to protect data and systems from attacks 24x7. Scalable security is a strategy and toolset that can increase or decrease in capacity to support a larger or smaller load, subject to variations in demand. In other words, it readily safeguards an organization's systems, even if at the cost of load increase.

6. Process to Create a Continuous Monitoring Plan

It is important to remember that the goal of continuous monitoring is to detect and respond to threats as quickly as possible.

Some of the main considerations to take into account when designing a Continuous Monitoring Plan include:

- Threat type and definition
- Detection method
- Frequency of monitoring

22.9.3. USE OF AUTOMATED TOOLS

Automated tools provide real-time notification of detected wrongdoing and vulnerability exploitation. Where possible, the staff shall develop security baselines and tools to report exceptions. Baselines and tools shall be deployed to monitor:

- Internet traffic and electronic mail traffic
- LAN traffic, protocols, and device inventory
- Operating system security parameters

The following files shall be checked for signs of wrongdoing and vulnerability exploitation:

- Automated intrusion detection system logs
- Firewall logs
- User account logs and network scanning logs
- System error logs and application logs
- Data backup and recovery logs
- Helpdesk trouble tickets
- Telephone activity (e.g., call detail reports), network printer, and fax

22.10. INCIDENT MANAGEMENT

22.10.1. WHAT IS INCIDENT MANAGEMENT?

Incident management (IM) is an IT Service Management (ITSM) process area. The first goal of the incident management process is to restore a normal service operation as quickly as possible and to minimize the impact on business operations, thus ensuring that the best possible levels of service quality and availability are maintained.

22.10.2. PRIMARY OBJECTIVES OF INCIDENT MANAGEMENT

- To automatically detect service-affecting events
- To restore normal service operation as quickly as possible
- To minimize adverse impacts on business operations
- To ensure that agreed levels of service quality are maintained
- To increase visibility and communication of incidents to business and IT support staff

The steps of incident management process as follows:

- Step 1: Incident logging
- Step 2: Incident categorization
- Step 3: Incident prioritization
- Step 4: Incident assignment
- Step 5: Task creation and management
- Step 6: SLA management and escalation
- Step 7: Incident resolution
- Step 8: Incident closure

The main challenges in incident management are:

- Constantly increasing alert and event noise
- Complex and lengthy IT problem resolution process
- Lack of context about the incident and lack of prioritization

The IT-related benefits of incident management are:

- Improved monitoring and measurement of performance against SLAs
- Enhanced management information regarding service quality
- Improved staff utilization/increased efficiency
- Lost/incorrect incidents/service requests eradicated
- Increased user/customer satisfaction

22.10.3. ADVANTAGES OF INCIDENT MANAGEMENT

Scope of Improvement

Incident management software assists in several ways, e.g., how long it takes to find a resolution for an incident, what the approximate time is for resolving an incident, and most importantly, how to minimize the time taken to close the issue. These analytics assist in the closure of tickets at the earliest.

IT Service Management Documentation

Stakeholders need information and documentary proof to know how an incident management software provided assistance in reducing restoring time and ensuring customer satisfaction. Such reports are set up with the complaint ticketing system.

Visibility and Transparency

A ticketing system is a significant part of offering visibility and transparency. It is utilized to facilitate and encourage the interchange of communication between the IT division and any staff or clients who have experienced problem. Enhancing visibility and transparency is needed as it assists in managing realistic expectations.

Enhanced Efficiency

An organization may have countable or too many assets. No matter how resourceful an organization is, incident management software has the ability to increase productivity.

22.11. CYBER SECURITY CASE

TS 50701 indicates the preparation of a cyber-security case (similar to Safety Case). The typical contents of a cyber-security case are elaborated as under:

Introduction (could be a set of references to other documents)	• System under consideration definition (including Zones and Conduits)
	• Threat and risks assessment
	  ○ Assumptions
	  ○ List of threat intelligence sources
	  ○ List of threat scenarios
	• List of sufficiently mitigated risks (with explanation)

Cybersecurity requirements specification (CRS) (could be a set of references to other documents)	• Assumptions • Cyber security needs (including safety-related high-level objectives) • Cyber security requirements • List of open risks (with explanation)

Cyber security management (could be a set of references to other documents)	• Cyber security policy • Cyber security plan • Cyber security process • Vulnerability assessment and management

Cyber security fulfilment (could be a set of references to other documents)	• Implementation of cyber security measures – evidences of fulfilment of CRS
	• Evidence of application of cyber security process
	• Verification and validation results
	  ○ Testing of security measures (e.g., V&V, penetration testing)
	  ○ Traceability of cyber security requirements
	• Related cyber security cases (from included components or subsystems, if any)

Security-related application conditions (could be a set of references to other documents)	• Installation • Maintenance • Operation

CHECKLIST AS PER MOUHA GUIDELINES

S. No	Item	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
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

S. No	Item	Yes/No
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?	No
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
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

S. No	Item	Yes/No
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?	No. PPP Component has not been considered as per MoHUA Letter Dated 03.10.2023
23	Does the proposal include the exploration of PPP models for Operations and/or maintenance of the project?	No
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 providers to provide seamless integration between the various stage modes?	No (To 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
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 0&M to ensure financial	Yes

S. No	Item	Yes/No
	sustainability during the project life cycle including the operations stage?	
34	Has the State Government set up or firmed up the plan for setting up of UMTA for the city?	Yes
35	Is 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 State Government devised any option to enable metro rail implementing agencies to issue corporate bonds	No