ಕರ್ನಾಟಕ ವಿಧಾನ ಪರಿಷತ್ತು

1 ಚುಕ್ಕೆ ಗುರುತಿನ ಪ್ರಶ್ನೆ ಸಂಖ್ಯೆ : 261
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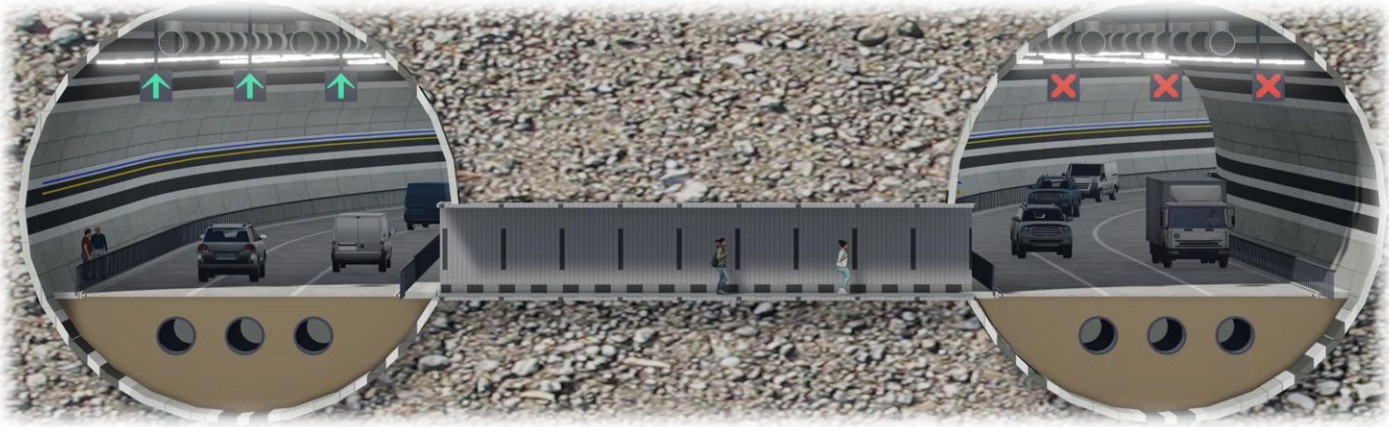
ಕ್ರ ಸಂ	ಪ್ರಶ್ನೆ	ಉತ್ತರ
ಅ	ಬೆಂಗಳೂರು ನಗರದಲ್ಲಿ ಟನಲ್ ರಸ್ತೆ ನಿರ್ಮಾಣ ಮಾಡಲು ಸರ್ಕಾರವು ತೀರ್ಮಾನಿಸಿರುವುದು ನಿಜವೇ ಆಗಿದ್ದಲ್ಲಿ ಈ ಯೋಜನೆಯ ವಿಸ್ತೃತ ಯೋಜನಾ ವರದಿಯ ಪ್ರತಿಯನ್ನು ಒದಗಿಸುವುದು;	• ವಿಸ್ತೃತ ಯೋಜನಾ ವರದಿಯ ಪ್ರತಿಯನ್ನು ಸಿ.ಡಿ. ರೂಪದಲ್ಲಿ ಒದಗಿಸಿದೆ.
ಆ	ಈ ಯೋಜನೆಯು ಪರಿಸರಕ್ಕೆ ಹಾನಿಯನ್ನುಂಟು ಮಾಡುವುದೆಂದು ಪರಿಸರ ಪ್ರೇಮಿಗಳು ಹಾಗೂ ಬೆಂಗಳೂರು ನಿವಾಸಿಗಳು ಆಕ್ಷೇಪಿಸಿರುವುದು ಸರ್ಕಾರದ ಗಮನಕ್ಕೆ ಬಂದಿದೆಯೇ; ಬಂದಿದ್ದಲ್ಲಿ ಅವರ ಆಕ್ಷೇಪಣೆಗಳನ್ನು ಸರ್ಕಾರ ಪರಿಗಣಿಸಿದೆಯೇ; (ವಿವರ ನೀಡುವುದು)	• ಪರಿಸರಕ್ಕೆ ಯಾವುದೇ ಹಾನಿಯಾಗದಂತೆ ಈ ಯೋಜನೆಯನ್ನು ಅನುಷ್ಠಾನಗೊಳಿಸಲು ಉದ್ದೇಶಿಸಲಾಗಿದ್ದು, ಈ ಯೋಜನೆಯನ್ನು ಅನುಷ್ಠಾನಗೊಳಿಸುವ ರಿಯಾಯಿತಿದಾರರು ಪರಿಸರಕ್ಕೆ ಹಾನಿಯುಂಟಾಗದಂತೆ ಪೂರ್ವ ಸಿದ್ದತೆ ಮತ್ತು ನಿಯಮಗಳನ್ನು ಪಾಲಿಸಬೇಕೆಂದು ಟೆಂಡರ್‌ನಲ್ಲಿ ನಿರ್ಬಂಧನೆ ಹಾಕಲಾಗಿರುತ್ತದೆ. • **Environmental Impact Assessment** ನಿಯಮ ಮತ್ತು **Environmental Management Plan** ಅನ್ನು ಟೆಂಡರ್ ದಸ್ತಾವೇಜಿನ ನಿರ್ಬಂಧನೆಯಲ್ಲಿ ಅಳವಡಿಸಲಾಗಿದೆ.
ಇ	ಈ ಯೋಜನೆಗೆ ಮೀಸಲಿಟ್ಟ ಅನುದಾನವೆಷ್ಟು ಹಾಗೂ ಯಾವ ಕಾಲಮಿತಿಯೊಳಗೆ ಪೂರ್ಣಗೊಳಿಸಲಾಗುವುದು;	• ಡಿ.ಪಿ.ಆರ್‌ಅನ್ವಯ ಯೋಜನೆಯ ಅಂದಾಜು ವೆಚ್ಚ ರೂ.17780.00 ಕೋಟಿಗಳು • ಸದರಿ ಯೋಜನೆಯನ್ನು ಕಾರ್ಯಾದೇಶದ ದಿನಾಂಕದಿಂದ 50 ತಿಂಗಳ ಅವಧಿಯಲ್ಲಿ ಪೂರ್ಣಗೊಳಿಸಲು ಉದ್ದೇಶಿಸಲಾಗಿದೆ.
ಈ	ಈ ಯೋಜನೆಯು ಸಾರ್ವಜನಿಕರಿಗೆ ಎಷ್ಟು	• ಬೆಂಗಳೂರು ನಗರದ ಸಂಚಾರ ದಟ್ಟಣೆಯನ್ನು ಕಡಿಮೆಯಾಗುವುದು.

	ಉಪಯೋಗವಾಗಲಿದೆ; ಮತ್ತು ಯಾವ ಯಾವ ವರ್ಗದ ಜನರಿಗೆ ಅನುಕೂಲವಾಗಲಿದೆ; (ವಿವರ ನೀಡುವುದು)	• ಸುಮಾರು 17.00 ಕಿ.ಮೀ ನಷ್ಟು ಹೊಸ ರಸ್ತೆಯನ್ನು ಭೂಗತವಾಗಿ ನಿರ್ಮಿಸುವುದರಿಂದ ಮೇಲ್ಮೈ ರಸ್ತೆಗಳು ಸ್ಥಳೀಯ ವಾಹನ ಸಂಚಾರಕ್ಕೆ ಮತ್ತು ಸುರಂಗ ಮಾರ್ಗವು ನಗರದ ಒಳಭಾಗದಿಂದ ಹೊರಭಾಗಕ್ಕೆ ನೇರ ಸಂಪರ್ಕ ಸಾಧಿಸುವುದರಿಂದ ಬೃಹತ್ ಮಟ್ಟದಲ್ಲಿ ಎಲ್ಲ ಸಾರ್ವಜನಿಕರಿಗೆ ಉಪಯೋಗವಾಗುವುದೆಂದು ನಿರೀಕ್ಷಿಸಲಾಗಿರುತ್ತದೆ. • ಸದರಿ ಸುರಂಗ ಮಾರ್ಗದಲ್ಲಿ 03 ಪಥವನ್ನು ಅಳವಡಿಸಲಾಗಿದ್ದು, ಒಂದು ಪಥವನ್ನು ಸಾರ್ವಜನಿಕ ಸಾರಿಗೆಗಾಗಿ ಮೀಸಲು ಇಡಲಾಗಿರುತ್ತದೆ. ಈ ವ್ಯವಸ್ಥೆಯಿಂದ ಖಾಸಗಿ ಹಾಗೂ ಸಾರ್ವಜನಿಕ ಸಾರಿಗೆ ವ್ಯವಸ್ಥೆಯನ್ನು ಕಲ್ಪಿಸಲಾಗಿದ್ದು, ಸುರಕ್ಷತಾ ದೃಷ್ಟಿಯಿಂದ ದ್ವಿ-ಚಕ್ರ ಮತ್ತು ತ್ರಿ-ಚಕ್ರ ವಾಹನಗಳನ್ನು ಹೊರತುಪಡಿಸಿ ಎಲ್ಲಾ ವರ್ಗದ ವಾಹನ ಸವಾರರಿಗೆ ಅನುಕೂಲವಾಗಲಿದೆ.

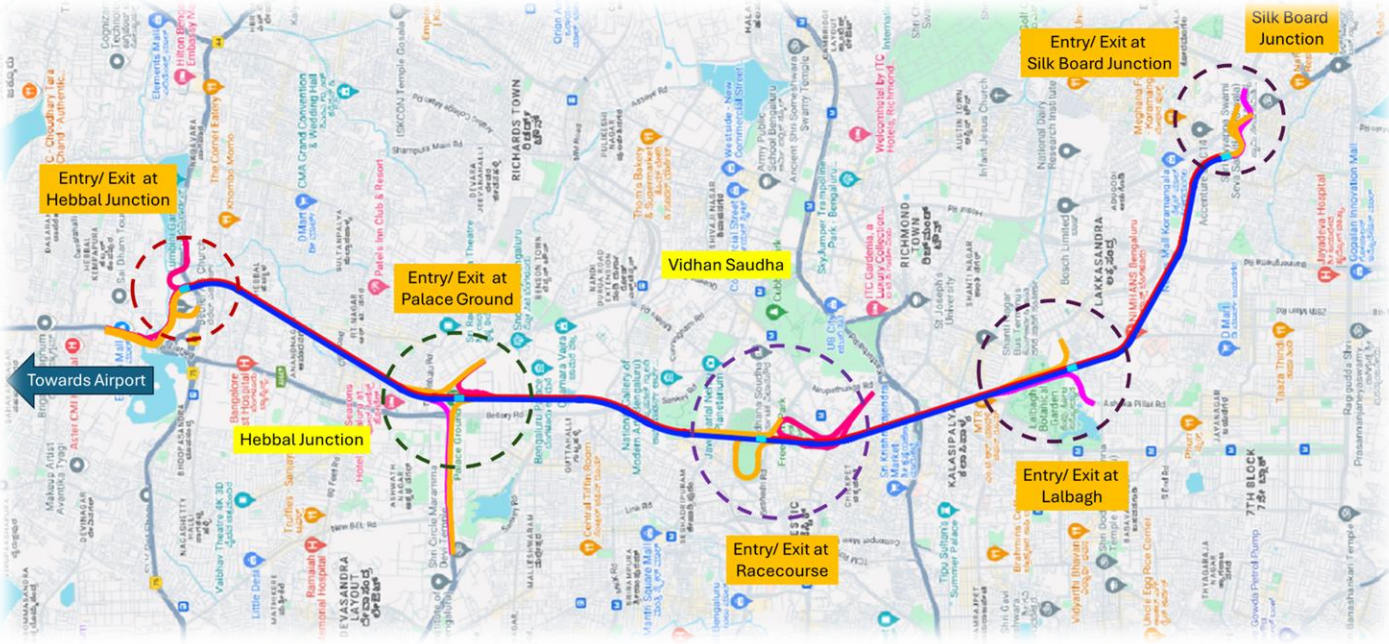
ನಅಇ 113 ಎಂಎನ್‌ವೈ 2026 (ಇ)

(ಡಿ.ಕೆ. ಶಿವಕುಮಾರ್)
ಉಪ ಮುಖ್ಯಮಂತ್ರಿ

GOVERNMENT OF KARNATAKA



CONSULTANCY SERVICES FOR PREPARATION OF DPR FOR THE WORK OF CONSTRUCTION OF UNDERGROUND VEHICULAR TUNNEL FROM HEBBAL ESTEEM MALL JUNCTION TO SILK BOARD KSRP JUNCTION



FINAL DETAILED PROJECT REPORT

VOLUME - I - MAIN REPORT WITH ANNEXURE

February 2025

Rodic
ENGINEERING.PASSION

RODIC CONSULTANTS PVT. LTD

BRUHAT BENGALURU MAHANAGARA PALIKE

TABLE OF CONTENTS

CHAPTER 1: EXECUTIVE SUMMARY 20
1.1 General 20
1.2 Project Background 20
1.3 Need for Tunnel 21
1.4 Project Benefits 22
1.5 Social and Economic Profile 22
1.5.1 Bengaluru Urban District 22
1.5.2 Geography 23
1.5.3 Geology 23
1.5.4 Topography 25
1.5.5 Climate 25
1.5.6 Seismicity 25
1.5.7 Land use 25
1.5.8 Demographic Profile of the District 25
1.5.9 Economy 26
1.5.10 Transport 26
1.5.11 Education 27
1.6 Project Location and Alignment 30
1.5.1 Packaging of the project 30
1.5.2 Salient Features of Northern Package 1: 30
1.5.2.1 Details of Package 1 32
1.5.3 Salient Features of Southern Package 2 33
1.5.3.1 Details of Package 2 35
1.5.4 Infringement with proposed alignment 38
1.6 Engineering Surveys and Investigations 38
1.6.1 Existing Features of Project 38
1.6.2 Reconnaissance Survey 39
1.6.3 Road Inventory 39
1.6.4 Existing Carriageway 39
1.6.5 Existing Road Alignment and Geometry 39
1.6.6 Terrain and Land Use 39
1.6.7 Traffic Survey at Site 39
1.6.8 Topography Survey: 40
1.6.9 Geotechnical & Geophysical Investigation 40
1.6.10 Traffic Surveys Analysis 41
1.6.11 Current level of Service in the project Influence Area 43

1.6.12 Traffic Volume Counts at Cordon Points....44
1.6.13 Traffic Modelling and Level of Service on Project alignment....46
1.6.14 Estimated Travel Time with Tunnel or Without Tunnel on Existing Road....48
1.7 Development Proposals....48
1.7.1 Design Standards....49
1.7.2 Main Tunnel....49
1.7.2.1 For NATM (new Austrian Tunneling Method) Tunnel....50
1.7.2.2 Cut and Cover Section....51
1.7.2.3 Open Cut Section....52
1.7.3 Typical Cross Section and TCS Schedule....53
1.7.3.1 Proposed Typical Cross Sections and TCS Schedule of Package 1....53
1.7.3.2 Proposed Typical Cross Sections and TCS Schedule of Package 2....54
1.7.4 Tunnel clear space....55
1.7.5 Cross Passages....56
1.7.6 Launching and Retrieval Shafts (TBM Shafts)....57
1.7.7 Inter Model Interchange Hubs:....57
1.7.7.1 Need for the Intermediate Stations....58
1.7.7.2 Details about the Facilities....58
1.7.7.3 Facilities Inside the Shaft....59
1.7.7.4 Conceptual Layout plan of intermediate stations (at Shaft Location):....59
1.7.7.5 EV Buses....64
1.7.7 Design Proposal....64
1.7.8 Safety Measures....65
1.7.9 Traffic Control and Safety Measures....65
1.7.10 Ventilation....65
1.7.11 Fire safety....66
1.7.12 SCADA System:....66
1.8 Preconstruction Activities....67
1.9 Environmental Impact Assessment....67
1.10 Construction Time and Phasing....68
1.11 Cost Estimate....68
1.11.1 General....68
1.11.2 Methodology....69
1.11.3 Unit Rates of Materials....69
1.11.4 Summary of Cost Estimate....69
1.12 Financial Analysis....71
1.13 Economic Analysis....72
1.14 Conclusion and Recommendation....72

CHAPTER 2: SCOPE OF WORK 73
2.1. Objective and Broad Scope of Work 73
2.2. Stages of Deliverables 73
2.3. Final Detailed Project Report 74
CHAPTER 3: SOCIAL AND ECONOMIC PROFILE 76
3.1 Introduction 76
3.1.1 General 76
3.2 Karnataka State 76
3.2.1 Geography 76
3.2.2 Rainfall 77
3.2.3 Climate 77
3.2.4 Flora and fauna 77
3.2.5 Forests 78
3.2.6 Demographic Profile 78
3.2.6.1 Population 78
3.2.6.2 Religion 78
3.2.6.3 Languages 79
3.2.7 Districts of Karnataka 79
3.3 Bangalore Urban District 80
3.3.1 Geography of Bangalore Region 81
3.3.2 Geology 82
3.3.3 Topography 82
3.3.4 Climate 83
3.3.5 Seismicity 83
3.3.6 Land use 83
3.3.7 Demographic Profile of the District 84
3.3.8 Economy 84
3.3.9 Economic sectors 85
3.3.10 Education 88
CHAPTER 4: AVAILABLE DATA PLANS 89
4.1 Comprehensive Mobility Plan-2020 prepared by Infrastructure Development Corporation (Karnataka) Limited 89
4.2 Feasibility Study Report (North-South Corridor) prepared by Altinok Consulting Engineering Inc. in JV with Lion Group. 89
4.3 Existing Project in Bangalore 89
4.3.1 Satellite Town Ring Road: 90
4.3.2 Peripheral Ring Road: 90
4.3.3 Inner Ring Road: 90

4.3.4 Namma Metro 91
CHAPTER 5: ALIGNMENT STUDY 92
5.1 General 92
5.2 Design Consideration 96
5.3 The start Point of Project 96
5.4 First Intermediate Ramps 97
5.5 Second Intermediate Ramps 97
5.6 Third Intermediate Ramps 98
5.7 The End point of Project 99
5.8 Packaging of Project 99
5.8.1 Details of Package 1 100
5.8.2 Details of Package 2 101
CHAPTER 6: ENGINEERING SURVEYS AND INVESTIGATION 102
6.1 General 102
6.2 Existing Features of Project 102
6.3 Reconnaissance Survey 102
6.4 Field Surveys 102
6.4.1 Road Inventory 102
6.4.2 Existing Carriageway 102
6.4.3 Alignment and Geometry 103
6.4.4 Terrain and Land Use 103
6.5 Traffic Survey 103
6.6 Topography Survey: 104
6.7 Geotechnical & Geophysical Investigation: 104
CHAPTER 7: TRAFFIC STUDY AND ANALYSIS 108
7.1 Approach & Methodology 108
7.1.1 Approach 108
7.1.2 About Software 108
7.1.3 Methodology 108
7.1.4 Stage 1 - Data Collection 109
7.1.5 Stage 2 - Data Analysis and Inferences 110
7.1.6 Stage 3 - Base year model development 110
7.1.7 Stage 4 - Model calibration and validation 111
7.1.8 Stage 5 - Projections 112
7.1.9 Stage 6 - Updating demand and network in model 112
7.1.10 Stage 7 – Traffic Demand Estimation 112
7.2 Study area 112
7.2.1 Zoning 112

7.2.2 Road Network 113
7.3 Review of City Urban Transport Scenario and Secondary Data Information 114
7.3.1 City Profile 114
7.3.2 Population 114
7.3.3 Road Network 114
7.4 Overview of Public Transport 115
7.4.1 Bus 115
7.4.2 Metro 116
7.4.3 Sub-Urban Rail 116
7.5 Vehicle Growth in the City 116
7.6 Transport and Infrastructure Proposals 117
7.6.1 Road 117
7.6.2 Metro 117
7.7 Travel Characteristics 119
7.7.1 Mode Share Motorized trips 119
7.7.2 Mode-wise Distribution of Average Trip Length 119
7.8 Travel Demand Assessment 120
7.8.1 Population Forecasting 120
7.8.2 Scenarios 120
7.9 Primary Data Collection and analysis 121
7.9.1 Classified Traffic Volume Count 122
7.9.2 Traffic Volume Counts at Cordon Points 123
7.9.3 Turning Movement Counts at Intersections 130
7.9.4 Speed and Delay 133
7.10 Travel Behavior 133
7.10.1 Origin-Destination Survey at Cordon Points 133
7.10.2 Average Trip lengths 134
7.10.3 Trip Purpose 134
7.11 Base Year Travel Demand Model 134
7.11.1 Introduction 134
7.11.2 Methodology for Base year model development 135
7.11.3 Network Development 135
7.11.3.1 Road (Links/Nodes) 135
7.11.3.2 Link Types 136
7.11.4 Base Year Travel Demand Analysis 137
7.11.5 Base Year Outputs 141
7.11.5.1 Trip Length Frequency Distribution 141
7.11.5.2 Estimated Trips 143

7.11.6 Summary 143
7.12 Traffic Projections and Horizon year model Assessment 143
7.12.1 Planning Period 143
7.12.2 Planning Parameters 143
7.12.3 Scenario Building 144
7.12.3.1 Scenario 1 (S1) 144
7.12.3.2 Scenario 2 (S2) 144
7.12.3.3 Scenario 3 (S3) 144
7.13 Projections 145
7.13.1 Key Assumptions 145
7.13.2 Demand Projections 145
7.13.2.1 Zones within BBMP Area 145
7.13.2.2 Zones outside the BBMP Area 146
7.13.2.3 Freight Vehicles 146
7.13.3 Estimating Horizon year OD Matrices 146
7.13.4 Model Results 146
7.13.4.1 Horizon Year Model Outputs – Without Tolls – Alignment Option 1 147
7.13.4.2 Horizon Year Model Outputs with Tolls – Alignment Option 2 148
7.13.4.3 Horizon Year Model Outputs with Tolls – Alignment Option 3 150
7.14 Inferences and Summary 151
7.14.1 Impact of North-South Corridor on Critical Junctions 154
7.14.2 Estimated Travel Time Comparison - Without Corridor and With Corridor 158
7.15 Annexure 160
7.15.1 TMC Diagrams of Surveyed Locations during peak hour 160
7.16 Level of Service Maps 164
7.16.1 Level of Service - Base Year 164
7.16.2 Level of Service – Do Nothing Scenario 2 for 2031 and 2041 (Without Corridor) 165
7.16.3 Corridor Level of Service –Scenario 2 for 2031 and 2041 168
7.17 Section and Ramp Volumes for morning peak hour in the proposed North-South Corridor for 2031 and 2041 (Without Toll) (Alignment Option 2) 171
7.18 Origin-Destination (OD) Pairwise Ramp Volumes for morning peak hour in the proposed North-South Corridor for 2027-28, 2031, 2037-38, 2041, 2047-48, 2051 and 2057-58 (Alignment Option 3) 172
7.19 Section and Ramp-wise volumes for Horizon Years with Level of Service 174
CHAPTER 8: IMPROVEMENT PROPOSALS 177
8.1 General 177
8.2 Design Standards 177
8.2.1 Geometric Design 177
8.2.1.1 General 177

8.2.1.2 Design Speed....177
8.2.1.3 Levels of Service (LOS)....177
8.3 Main Tunnel....178
8.3.1 For Bored Tunnels....178
8.3.2 For NATM Tunnel....179
8.3.3 Cut and Cover Section....179
8.3.4 Open Cut Section....179
8.4 Proposed Typical Cross Section and TCS Schedules....179
8.4.1 TCS Schedules for Package 1....180
8.4.2 Proposal of Structures for Package 1....183
8.4.3 TCS Schedules for Package 2....183
8.5 Tunnel spacing....208
8.6 Cross Passage....208
8.7 Water Proofing....209
8.7.1 TBM bored tunnels....209
8.7.2 b. NATM Tunnels....209
8.7.3 Cut & Cover and Ramps....209
8.8 Tunnel Drainage System....209
8.8.1 Drain and sumps in Open Ramp zone:....209
8.8.2 Drainage in Cut & Cover tunnels:....209
8.8.3 Drainage in NATM tunnels:....210
8.8.4 Drainage in TBM bored tunnels:....210
8.9 Vertical Shaft....210
8.9.1 Refuge Parking....210
8.9.2 Control buildings....210
8.10 Traffic Control and Safety Measures....211
8.11 Inter Model Interchange Hubs....211
8.11.1 Need of Intermediate Stations....212
8.11.2 Existing situation analysis at the five locations....212
8.11.2.1 Hebbal Junction....212
8.11.2.2 Mekhri Circle....214
8.11.2.3 Race Course....216
8.11.2.4 Lalbagh....217
8.11.2.5 Central Silk Board....219
8.11.3 Requirements at the Terminal / Intermediate Stations....221
8.11.4 Details about the Facilities....221
8.11.5 Facilities Inside the Shaft....222
8.11.6 Transit-Oriented Development (TOD)....222

8.11.6.1 Need for TOD in the Tunnel Project 222
8.11.6.2 Application of TOD in the Project 224
8.11.7 Codes and Applicable Bye-laws 224
8.11.7.1 Bengaluru Development Authority (BDA) Guidelines 224
8.11.7.2 Transit-Oriented Development (TOD) Guidelines 226
CHAPTER 9: PROJECT IMPLEMENTATION AND SCHEDULING 227
9.1 Construction Time and phasing 227
9.2 Implementation Schedule 227
CHAPTER 10: PRELIMINARY COST ESTIMATION 230
10.1 Methodology 230
10.2 Unit Rates of Materials: 231
10.3 Labour Rates: 231
10.4 Plant & Machinery Rates 231
10.5 Centage Charges: Overheads, Contractor's Profit, and Other Components: 231
10.6 Assumptions: The estimate is based on following assumptions: 232
10.7 Construction Time and Phasing 233
10.8 Summary of Cost Estimate 233
CHAPTER 11: FINANCIAL ANALYSIS 236
11.1 Financial Analysis 236
11.2 Overview of implementation modes 236
11.3 Project section 238
11.3.1 Project Packaging 238
11.4 Capital Costs and Its Phasing 238
11.4.1 Base Project Cost 238
11.4.2 Escalation Cost 239
11.4.3 Financing Cost on Debt 239
11.4.4 Interest during Construction (IDC) 239
11.4.5 Landed Project Cost (TPC) 239
11.4.6 Tax rate 239
11.5 Approach to Financial Evaluation on BOT Basis 239
11.6 Assumption for Financial Analysis 239
11.7 Adopted Growth Rates 239
11.8 Traffic Details 240
11.9 Tollable road/ structure Length Details 241
11.10 Revenue Streams 242
11.10.1 Toll Rates 242
11.10.2 Toll Fee 243
11.10.3 Other Revenues 245

11.11 Proposed Sources of Finance 245
11.12 Resource Mobilization Schedule 246
11.13 Operations & Maintenance Cost 246
11.14 Minimum Return Criteria 246
11.15 Financial Viability 246
11.16 Results and Analysis 246
11.17 Sensitivity Analysis 247
CHAPTER 12: ECONOMIC ANALYSIS 249
12.1 General 249
12.1.1 Analysis Period 249
12.2 Traffic parameters considered for Economic Analysis 249
12.3 Quantification of Economic Cost & benefits 250
12.3.1 Capital 250
12.3.2 Shadow Pricing and Use of Conversion Factors 250
12.3.3 Benefits 251
12.3.4 Value of Time Cost 251
12.3.5 Vehicle Operating Cost 251
12.3.6 Employment Benefits 251
12.3.7 Network Benefits 252
12.3.8 Economic Cost 252
12.4 Economic Benefits 252
12.5 Sensitivity Analysis 253
12.6 Conclusion 254
CHAPTER 13: OPERATION AND MAINTENENCE 255
13.1 Operation and Maintenance of the Project 255
13.2 Operations 255
13.3 Traffic Related Functions 255
13.4 Maintenance of Tunnel 256
13.5 Maintenance Manual 256
13.5.1 Functional Control 256
13.5.2 Status Report 257
13.6 Operation and Maintenance Activities for Tunnel 258
13.6.1 Inspection 258
13.6.2 Status Reports 260
13.6.3 Monitoring and Immediate Actions 260
13.6.4 Vehicle Control in Tunnel 261
13.7 Capacity Development for the Tunnel 261
13.7.1 Violation of traffic rules (coordination with traffic police) 261

13.7.2 Traffic accident (coordination with traffic police) 261
13.7.3 Fire incident (coordination with Fire Department) 261
13.7.4 Vehicle control (coordination Traffic Department and Police Department) 262
13.7.5 Lane regulation and Road closing (coordination with traffic police) 262
13.8 Inspection and Maintenance Work 262
13.9 Information Leaflets 263
CHAPTER 14: CODES AND REFERENCES 265

LIST OF TABLES

Table 1: Demographic profile of Bengaluru urban Districts 26
Table 2: Alignment Details of Main Tunnel 30
Table 3: Brief Details of Package 1 32
Table 4: Entry Exit Details at Hebbal Junction 32
Table 5: Ramps Details at Palace Ground/Mekri Circle 33
Table 6: Brief Details of Package 2 35
Table 7: Ramps Details at Race Course/ Vidhan Saudha 35
Table 8: Ramps Details at Lal Bagh Botanical Garden 37
Table 9: Ramps Details at Silk Board 38
Table 10: Existing Carriageway 39
Table 11: Traffic Survey Locations 42
Table 12: Traffic Survey Locations (CVC and OD) 42
Table 13: Traffic Survey Locations (Turning Moment Count) 43
Table 14: LOS as per-IRC 43
Table 15: LOS on the traffic cordon points on existing road 43
Table 16: Traffic Volume Counts at Cordon Locations 44
Table 17: Estimated Total trips during morning peak hour. 46
Table 18: Assignment Results - Scenario 2 (Morning Peak Hour PCU) for 2031 and 2041 (with toll) 47
Table 19: The Level of Service on the Project Corridor during Morning Peak Hour 47
Table 20: Estimated Travel Time Comparison - Without and With Corridor 48
Table 21: TCS Schedule of Package 1 53
Table 22: TCS Schedule of Package 2 54
Table 23: TBM Shaft Locations 57
Table 24: Geometric Design Criteria adopted (IRC 86-2018) 64
Table 25: Summary of Cost for Package 1 69
Table 26: Summary of Cost for Package 2 70
Table 27: Results in BOT Mode for following Concession period – Package 1 71
Table 28: Results in BOT Mode for following Concession period – Package 2 71
Table 29: Economic Benefits 72
Table 30: Description of data and reference locations 74
Table 31: Languages and Religions of the State at the Census 78
Table 32: Details of Religion 79
Table 33: List of Karnataka Districts 79
Table 34: Demographic profile of Bangalore urban Districts 84
Table 35: Geometric Design Criteria adopted (IRC 86-2018) 96
Table 36: Existing Carriageway 103
Table 37: Location of Seismic Refraction test 105

Table 38: Location of Multichannel Analysis of Surface Wave (MASW) 106
Table 39: Bore Hole List 106
Table 40: Bus Performance in Bengaluru 115
Table 41: Metro Corridors along with Stretches and their Status 116
Table 42: Metro Operational Projects 118
Table 43: Metro Ongoing Projects 118
Table 44: Metro Upcoming Projects 118
Table 45: Modal Share (Motorized Trips) 119
Table 46: Mode Wise Average Trip Length 119
Table 47: Forecasted population in CMP Study Area 120
Table 48: Comparison of Travel Characteristics between Base Year and Horizon Year 120
Table 49: Forecast Mode Share – Scenario 2 121
Table 50: Forecast Mode Share – Scenario 3 121
Table 51: Forecast Mode Share – Scenario 4 121
Table 52: Survey Details 121
Table 53: PCU Values for Different Categories of Vehicles 122
Table 54: Daily Traffic Volume Counts at Cordon Locations (24 hours) 123
Table 55: Morning Peak hour Volume at Surveyed Locations 126
Table 56: Evening Peak hour Volume at Surveyed Locations 128
Table 57: Traffic Volume at Intersections 131
Table 58: Average Trip Lengths (in km) 134
Table 59: Model Results 141
Table 60: Synthetics Validation of Base Year Network – Peak Hour 141
Table 61: Total no. of Trips (Mode-wise) - Morning Peak 143
Table 62: BBMP Population Projections 143
Table 63: Forecasted Modal Share for 2031 144
Table 64: Estimated Total Vehicle trips during morning peak hour for study area 145
Table 65: Assignment Results (Morning Peak Hour PCU) for 2031 and 2041 (S2 without toll) 148
Table 66: Assignment Results - Scenario 2: Morning Peak Hour PCU for 2031 and 2041 (with toll) (Alignment Option 2) 149
Table 67: Average Cross section traffic on Each Section (Peak Hour) – With Toll (Alignment Option 2) 150
Table 68: Assignment Results - Scenario 2 (Morning Peak Hour PCU) for 2031 and 2041 (with toll) (Alignment Option 3) 150
Table 69: Average Cross section traffic on Each Section (Peak Hour) Scenario 2 – With Toll (Alignment Option 3) 151
Table 70: Vehicles using the corridor during morning peak hour in Scenario 2 (Alignment Option 3) 151
Table 71: Estimated Travel Time Comparison - Without and With Corridor 158
Table 72: Total Travel Time Savings – Morning Peak Hour 160
Table 73: Projected Traffic on the corridor (alignment option 2) 171

Table 74: OD Pair wise projected traffic volumes 172
Table 75: Level of service on the corridor (morning peak) 174
Table 76: Level of service on the corridor (Morning peak) 175
Table 77: Design Speed Standards 177
Table 78: Standards for Level of Service 177
Table 79: Brief Details of Package 1 178
Table 80: Brief Details of Package 2 178
Table 81: TCS Schedule at Hebbal Junction 181
Table 82: TCS Schedule at Mekri Circle/Palace Ground 182
Table 83: TCS Schedule at Racecourse 185
Table 84: TCS Schedule at Lalbagh 186
Table 85: TCS Schedule for TBM Tunnel and Ramps at Silk Board 186
Table 86: round coverage and FAR ratio for Public and Semi Public Zone as per BDA 2031 224
Table 87: Summary of Cost for Package 1 (Km 0+000 to Km 8+748) 233
Table 88: Summary of Cost for Package 2 (Km 8+748 to Km 16+745) 234
Table 89: Total Project Cost Details Package 1 238
Table 90: Total Project Cost Details Package 2 239
Table 91: Average vehicular growth rate 240
Table 92: Tollable Vehicle Details for the year 2027-28 240
Table 93: Tollable road/structure length details in kms for package 1 241
Table 94: Tollable road/structure length details in kms for package 2 242
Table 95: Toll Capping Rates 242
Table 96: Toll rate in Rs. for entry & exits for single trip for the year 2030-31 for Package 1 243
Table 97: Toll rate in Rs. for entry & exits for single trip for the year 2030-31 for Package 2 244
Table 98: Rental rate per Sq. ft for renting Intermodal Nodes for Package 1 245
Table 99: Rental rate per Sq. ft for renting Intermodal Nodes for Package 2 245
Table 100: Naming rights for Package 1 245
Table 101: Naming rights for Package 2 245
Table 102: Routine and Periodic Maintenance cost 246
Table 103: Results in BOT Mode for following Concession period – for Package 1 247
Table 104: Results in BOT Mode for following Concession period – for Package 2 247
Table 105: Sensitivity analysis for 4+25 Years of concession period (for Package 1) 247
Table 106: Sensitivity analysis for 4+30 Years of concession period (for Package 1) 247
Table 107: Sensitivity analysis for 4+25 Years of concession period (for Package 2) 247
Table 108: Sensitivity analysis for 4+30 Years of concession period (for Package 2) 248
Table 109:Traffic data for the year 2027-28 249
Table 110: Economic Conversion Factors 250
Table 111: Value of time cost 251

Table 112: Vehicle Operating cost 251
Table 113: Employment Benefits 251
Table 114: Volume of pollutants emitted (gram per km) for different modes 252
Table 115: fuel cost and applicable taxes in Karnataka 252
Table 116: Construction cost in crores and investment schedule 252
Table 117: Economic Benefits 253
Table 118: Year wise costs & benefits in Cr. – Base Scenario 253
Table 119: Sensitivity Analysis results wrt to cost and benefits 254
Table 120: Typical Inspection items for civil work components and electrical/communication 258
Table 121: Table for Routine Maintenance 259

LIST OF FIGURES

Figure 1: Project Location in Bangaluru Administrative Boundary 20
Figure 2: Project Key Benefit 22
Figure 3: Bengaluru Districts Map 23
Figure 4: Project Alignment 29
Figure 5: Package 1 Alignment 31
Figure 6: Entry and Exit at Hebbal Junction 32
Figure 7: Entry and Exit Ramps at Palace Ground 33
Figure 8: Package 2 Alignment 34
Figure 9: Entry and Exit Ramps at Racecourse and Vidhan Soudha 36
Figure 10: Entry and Exit Lalbagh Botanical Garden 37
Figure 11: Traffic Surveys conducted at Project Location 40
Figure 12: Topography Survey on Site 40
Figure 13: Geophysical and Intrusive Geotechnical investigation on Site 41
Figure 14: Map Showing Locations of Traffic Volume Count Surveys 42
Figure 15: Existing Traffic Count at Survey Locations 46
Figure 16: Sections for Level of Service Analysis 48
Figure 17: Typical Cross Section of TBM Tunnel 50
Figure 18: Typical Cross Section of NATM Tunnel 51
Figure 19: Typical Cross Section of Cut and Cover Section 52
Figure 20: Typical Cross Section of Open Cut Section 52
Figure 21: Typical Cross Section for Tunnel Cross Passage 56
Figure 22: Typical Cross Section for Tunnel Cross Passage 56
Figure 23: Conceptual Layout at Hebbal 59
Figure 24: Shaft 1 at Hebbal 60
Figure 25: Conceptual Layout at Mekri Circle 60
Figure 26: Shaft 2 at Mekri Circle 61
Figure 27: Conceptual Layout at Race-Course 61
Figure 28: Shaft 3 at Race-Course 62
Figure 29: Conceptual Layout at Lalbagh 62
Figure 30: Shaft 4 at Lalbagh 63
Figure 31: Conceptual Layout at Silk Board 63
Figure 32: Shaft 5 at Silk Board 64
Figure 33: State Authority Letter Reg. Environment Clearance 68
Figure 34: Phasing and Construction Time 68
Figure 35: Districts of Karnataka 80
Figure 36: Bangalore Districts Map 81
Figure 37: Three Road Projects that are Sanctioned in Bengaluru 90

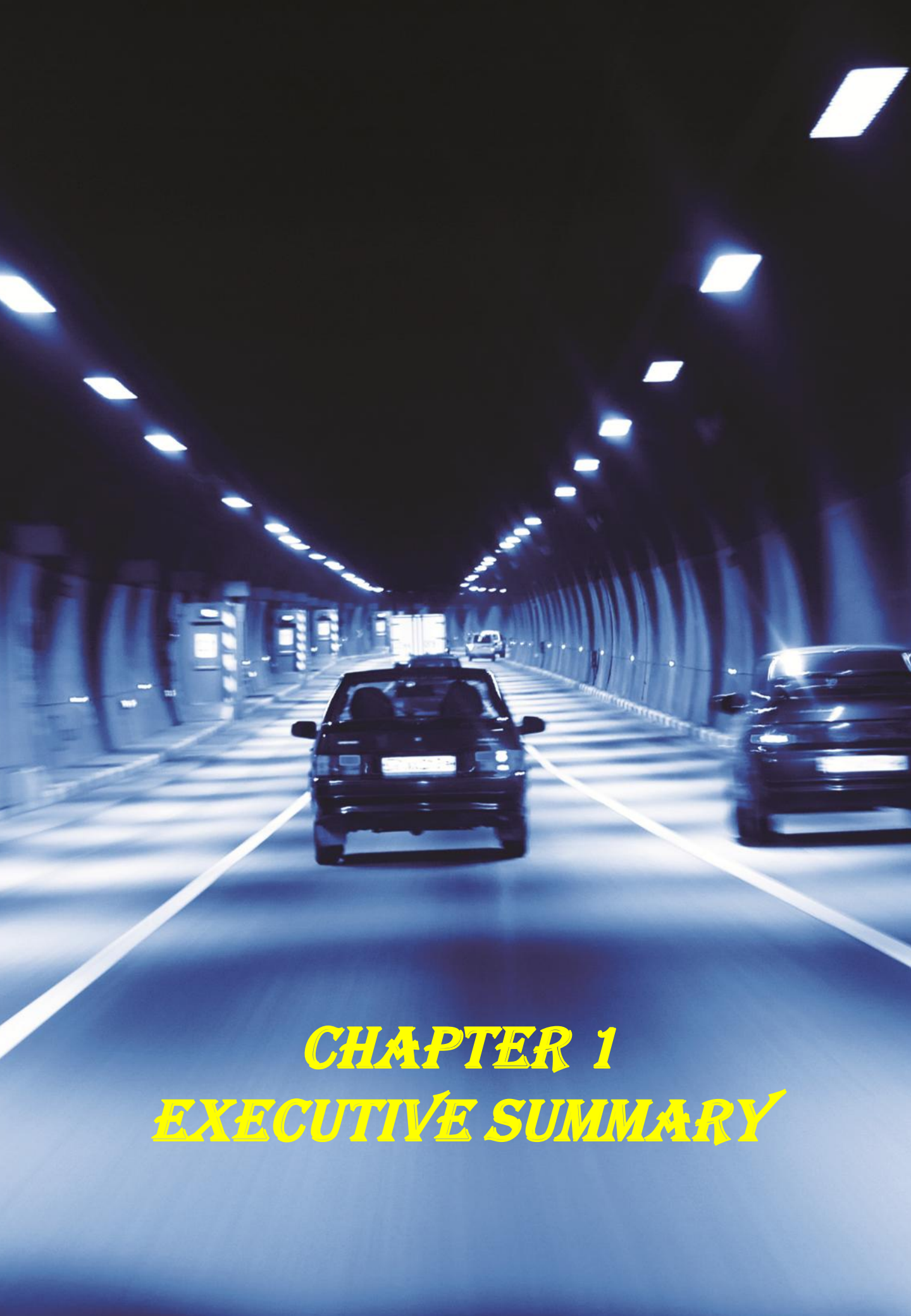
Figure 38: Existing Metro Connectivity 91
Figure 39: Project Alignment (At Inception Stage) 93
Figure 40: Project Alignment (At Draft DPR Stage) 94
Figure 41: Final Approved Project Alignment 95
Figure 42: Entry and Exit at Hebbal Junction 96
Figure 43: Entry and Exit Ramps at Palace Ground 97
Figure 44: Entry and Exit Ramps at Race Course and Vidhan Soudha 98
Figure 45: Entry and Exit Lalbagh Botanical Garden 99
Figure 46: End Point of Project Alignment 99
Figure 47: Entry and Exit at Hebbal Junction 100
Figure 48: Alignment of Package 2 101
Figure 49: Traffic Surveys conducted at Project Location 104
Figure 50: Topography Survey on Site 104
Figure 51: Geophysical Survey on Site 105
Figure 52: Ongoing Borehole along proposed tunnel alignment 107
Figure 53: Overall Methodology 109
Figure 54: Model Development 111
Figure 55: Fuzzy Procedure 111
Figure 56: Study Area 112
Figure 57: Zoning of Study Area 113
Figure 58: Bengaluru Road Network 113
Figure 59: Growth of Population in BMA 114
Figure 60: Road Network of Bengaluru City 115
Figure 61: Vehicular growth in Bengaluru 116
Figure 62: Proposed Roads in Bengaluru 117
Figure 63: Bengaluru metro network (Existing and Proposed) 119
Figure 64: Survey Locations 122
Figure 65: Map Showing Daily Traffic Volume at Count Locations. 124
Figure 66: Overall Average traffic composition 125
Figure 67: Temporal Daily Traffic at Surveyed cordon points 125
Figure 68: Cordon wise Peak hour Traffic Composition 130
Figure 69: Temporal Distribution of traffic at Intersections 132
Figure 70: Map Showing Total Daily Traffic at Junctions in PCU 132
Figure 71: Speed and Delay 133
Figure 72: Purpose wise Distribution of Trips during peak hour 134
Figure 73: Methodology for base year development 135
Figure 74: Road network developed in PTV Visum 136
Figure 75: Traffic assignment, Study Areas (Base Year) 137

Figure 76: Count Locations for validation of base year assignment (a) 138
Figure 77: Count Locations for validation of base year assignment (b) 139
Figure 78: Count Locations for validation of base year assignment (c) 140
Figure 79: TLFD for Car Trips 142
Figure 80: TLFD for Two-Wheeler Trips 142
Figure 81: TLFD for Autorickshaw Trips 143
Figure 82: Estimated Total Vehicular Trips Comparison with Base Year (Morning Peak Hour) 145
Figure 83: North-South Corridor: Entry/Exit Ramps Coding – Alignment Option 1 147
Figure 84: North-South Corridor: Entry/Exit Ramps Coding – Alignment Option 2 149
Figure 85: North-South Corridor: Entry/Exit Ramps Coding – Alignment Option 3 150
Figure 86: Traffic Speeds on the Corridor (Morning Peak -2031) 152
Figure 87: Traffic Speeds on the Corridor (Morning Peak -2041) 153
Figure 88: Road network with reduced volume after corridor (2031) 154
Figure 89: Critical Junctions impacted by N-S Corridor (A) 155
Figure 90: Critical Junctions impacted by N-S Corridor (B) 156
Figure 91: Critical Junctions impacted by N-S Corridor (C) 157
Figure 92: Estimated Travel Time Comparison for Hebbal - Silkboard Junction (With and Without Corridor) 158
Figure 93: Estimated Travel Time Comparison for Silkboard - Hebbal Junction (With and Without Corridor) 159
Figure 94: Estimated Travel Time Comparison for Hebbal – Vidhan Soudha (With and Without Corridor) 159
Figure 95: TMC at CN Rao Underpass Junction 160
Figure 96: TMC at Bengaluru Cantt Junction 161
Figure 97: TMC at Basaveshwara Circle 161
Figure 98: TMC at KR Circle 162
Figure 99: TMC at Cubbon Park Junction 162
Figure 100: TMC at Shoolay Circle 163
Figure 101: TMC at Lalbagh Chowk 163
Figure 102: Level of Service - Base Year (Morning Peak) 164
Figure 103: LOS - Road Network (S2 – Without Corridor 2031) 165
Figure 104: LOS - Road Network (S2 – Without Corridor 2041) 166
Figure 105: LOS - Road Network (S3 – Without Corridor 2031) 167
Figure 106: LOS - Road Network (S3 – Without Corridor 2041) 168
Figure 107: Level of Service on Corridor - S2 Morning Peak Hour (2031) 169
Figure 108: Level of Service on Corridor - S2 Morning Peak Hour (2041) 170
Figure 109: Package 1 Alignment 180
Figure 110: Ramps at Hebbal Junction 181
Figure 111: Ramps at Mekri Circle/Palace Ground 182
Figure 112: Package 2 Alignment 183
Figure 113: Ramps at Racecourse 184

Figure 114: Ramps at Lalbagh....185
Figure 115: Ramps at Silk Board....186
Figure 116: TCS-1, TBM Tunnel Cross-Section....188
Figure 117: TCS-2, 3 lane Open Cut Section....189
Figure 118: TCS-3, 2 lane Cut & Cover Section....190
Figure 119: TCS-03A, 2 lanes Cut and Cover....191
Figure 120: TCS-4, 2 lane Open Cut Section....192
Figure 121: TCS-5, 2 Lane NATM Section....193
Figure 122: TCS-6, 3 Lane Cut and Cover Section....194
Figure 123: TCS-6A, 3 Cut and Cover Section....195
Figure 124: TCS-7, 2+2 lane Open Cut Section....196
Figure 125: TCS-8, 2+2 Lane Cut and Cover Section....197
Figure 126: TCS-9, 2+3 Lane Cut and Cover Section....198
Figure 127: TCS-10, 3+3 Lane Open Cut Section....199
Figure 128: TCS-11, 2 x Intermediate Lane Open Cut Section....200
Figure 129: TCS-12, 2 x Intermediate Lane Open Cut and Cover Section....201
Figure 130: TCS-12A, 2 x Intermediate Lane Open Cut and Cover Section....202
Figure 131: TCS-13, Intermediate Lane Cut and Cover Section....203
Figure 132: TCS-14, 3+3 Lane Cut & Cover Section....204
Figure 133: TCS-15, Intermediate Lane NATM Section....205
Figure 134: Typical Cross Section for Cross Passages....206
Figure 135: Typical Cross Section for merger section of Entry/ Exit Ramps & Main Tunnel....207
Figure 136: Typical Cross Section for Tunnel Cross Passage....208
Figure 137: TCS for Tunnel Cross Passage....208
Figure 138: Shaft at Hebbal Junction....212
Figure 139: Shaft at Mekri Cirle....214
Figure 140: Shaft at Race-Course....216
Figure 141: Shaft at Lalbagh....217
Figure 142: Shaft at Silk Board....219
Figure 143: TOD Components....223
Figure 144: Located shafts in Land Use Pattern(1)....225
Figure 145: Located shafts in Land Use Pattern (2)....225
Figure 146: Phasing and Construction Time....227
Figure 147: Phasing and Construction Time....233
Figure 148: Implementation modes overview....236
Figure 149: Flow chart of financial viability....237
Figure 150: Comparative Analysis of Implementation Modes....237
Figure 151: Maintenance As per IRC:SP:91-2019....258

Figure 152: Information Leaflet as per IRC:SP:91-2019. 263

Figure 153: Traffic Signs as per IRC:SP:91-2019..... 264



CHAPTER 1
EXECUTIVE SUMMARY

CHAPTER 1: EXECUTIVE SUMMARY

1.1 General

Bruhat Bengaluru Mahanagara Palike (BBMP) intends to Construct an Underground Vehicular Tunnel for the North – South Corridor starting from Hebbal Esteem Mall junction to Silk Board KSRP Junction. In pursuance of the above, Rodic Consultants Pvt Ltd., New Delhi have been appointed as consultants to carry out Consultancy Services for Preparation of DPR for the work of Construction of Underground Vehicular Tunnel from Hebbal Esteem Mall junction to Silk Board KSRP junction.

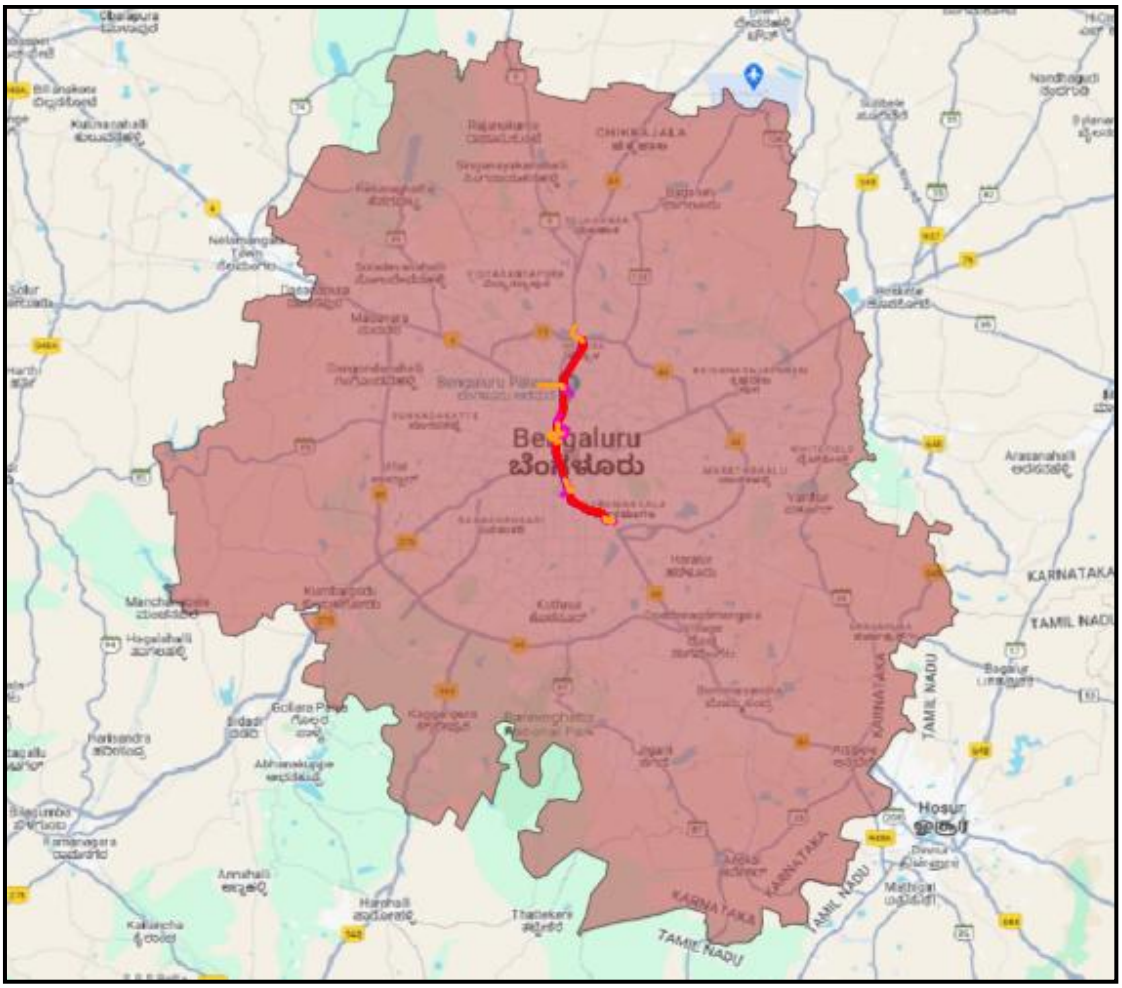


Figure 1: Project Location in Bangaluru Administrative Boundary

1.2 Project Background

Bengaluru, known as the Silicon Valley of India, has been facing a persistent challenge with vehicular congestion due to its rapid urbanization and population growth. To address this issue, the Government of Karnataka has initiated an ambitious tunnel infrastructure project aimed at easing traffic congestion and improving connectivity across key nodes of the city. This tunnel project is part of a comprehensive urban mobility plan to ensure efficient transportation while minimizing the environmental impact.

The proposed tunnel alignment spans crucial parts of Bengaluru, connecting Hebbal Junction in the north to Silk Board Junction in the south. This alignment traverses major commercial, residential, and institutional zones, providing seamless connectivity for commuters. The tunnel project will significantly reduce travel times, enhance road safety, and offer an alternative to the heavily congested surface roads.

Bengaluru's population has grown dramatically, and the city now ranks among the top metropolitan areas in the country, both in terms of population and in terms of economic activity. The city has undergone rapid urbanization and has transformed into one of the fastest growing economic centers of the world which has attracted millions of job-seeking individuals from different part of countries and world.

However, the city road networks have not seen major improvements either in terms existing roadway capacity or creation of new road networks to reduce traffic congestion. Bengaluru City has a total registered vehicle count of approximately 1 crore vehicles in 2023, vehicles have grown at an average growth rate of 8% over the past 10 years. Increasing traffic volume and its associated adverse impacts on traffic congestion and noise pollution is a key problem in Bengaluru. Without the intervention of planned construction to decongest the traffic hot spots along with promotion public transport/metro the situation is likely to deteriorate further. Reference from CMP 2020 (by BMRCL and DULT) has been taken to integrate our traffic studies and simulations for forecasting the future demand model.

Due to poor level of services (mostly section in LOS 'F') of the present route of North – South corridor, the passenger travelling from North to South part & vice versa for work trip & travel trip faces huge congestion during travel. This leads to an increase in VOC (vehicle operation cost) & VOT (Value of time cost) accumulating higher economical loss.

For decongestion of the Bengaluru city, BBMP had earlier assigned the work of "Consultancy services for preparation of Comprehensive Bengaluru city road infrastructure plan to decongest traffic and to prepare comprehensive traffic management plan for proposal of vehicular tunnel / Grade separator /Road widening in selected corridors in the State of Karnataka" to *M/S Altinok Consulting Engineering Inc. In Jv With M/S Lion Engineering Consultants Pvt. Limited*. The feasibility study has identified North South corridor as the high traffic density corridor of the Bangaluru city. The decongestion of North-South corridor has been suggested in the feasibility study by providing underground tunnel from Hebbal to Silk Board. The major problem statement identified in feasibility studies are as under:

- In peak hours and even most of the day the traffic runs at an average speed of 15-20 Kmph
- The Level of Service is between LOS-E and LOS-F i.e., 15 to 20 Kmph resulting in huge loss of fuel
- The city roads have exhausted their lane capacity and there is no land available to widen the roads due to heavy built-up areas and higher price of land.

One of the corridors that has been taken up for this assignment is **North South Corridor** which we have studied. The road sections connecting the electronic city (Southern part) to Hebbal Junction (Northern Part) is **Hebbal Flyover- Mekri circle-Chalyuka circle-Lalbagh Botanical Garden-Silk Board Jn.** The existing corridor width varies from four lane to six lane. From Hebbal Junction the Airport is connected through NH-4. The North South Corridor is a very important connection and due to traffic congestion, it chokes during peak hour resulting loss of travel time and increase in Vehicle operation cost.

1.3 Need for Tunnel

The proposed North-South corridor is planned to reduce the congestion levels on roads and reduce the travel time of people. The present North South corridor connects the north & south part of Bengaluru and feeds the traffic for work trips, airport trips, tourism trip etc. Most of the residents of the North and eastern part of the city are travelling through this corridor to white field & electronic city area for work/business purposes.

The high traffic during peak hours congests the major junction point and the corridor on the preset route. The existing route traversing from Hebbal- Mekri Circle to Golf Course to Chalukya Circle to Lalbagh to Silk board junction. From that point the traffic divided towards Whitefield & Electronic City. Due to longer trip length, people use private mode of communication for travelling to the offices and others outdoor activities.

During the peak the average speed on the north south corridor is just 15 to 20 km/h. Apart from above the K R Circle, Mother dairy circle also used to be congested during the peak hours. The present Level of service, speed and traffic density is as under-

Level of Service	Speed
The Present LOS is E/F	**Present travel speed is 15-20 Kmph.**

The basic IT hubs and other developments have concentration on outer fringe on the city. This IT sector and other businesses attract lot of trips bound to airport and railways. These trips the user is normally having

baggage along with their travel due to which private vehicle/taxies, in addition to these trips a business trips are getting generated between these hubs. For such longer trips cars/taxies are preferred over public transport which can be seen that even the city is facing a level of service (LOS)- E and F, the trips generated by private car and taxies are not reducing.

During the peak hour the vehicle moves at an average speed of 15 kmph forcing commuters to spend a significant portion of time of their day on roads in congestion. Despite of expansion of metro networks, development of surface infrastructure, the traffic congestion remains persistent problem.

The present section from Hebbal to Golf Course, Golf Course to Chalukya Junction, Chalukya to Lal Bagh and Lal Bagh to Silk Board Junction is the main section traversing through the central part of Bengaluru city. The section traverses through most of the Government Offices, Official Residences of Members of Assembly, Vidhan Soudha, and other prominent administrative blocks along with densely packed residential areas. The traffic from airport to Main city and through traffic also contributes to the congestion of the North South Corridor.

The current road network capacity is already saturated. The capacity of the current road network needs to be increased to cater for the present and future traffic demand.

With the completion of the Tunnel Project, commuters will be able to travel the distance from Hebbal to Silk Board and vice-a-versa in just 35 minutes against the existing travel time of 90 minutes.

1.4 Project Benefits

The main objective of the project is to provide safe and efficient service levels to growing traffic movements and better connectivity between Silk board junction and Esteem mall junction. All road users will be benefited from the proposed improvement on account of comfort, safety and reduced vehicle operating costs. Community will accrue the benefit from proposed development project by way of improvement in the physical infrastructure; social infrastructure; development of economy; reduced pollution, vehicle maintenance, fuel saving; employment potential and other tangible benefits.

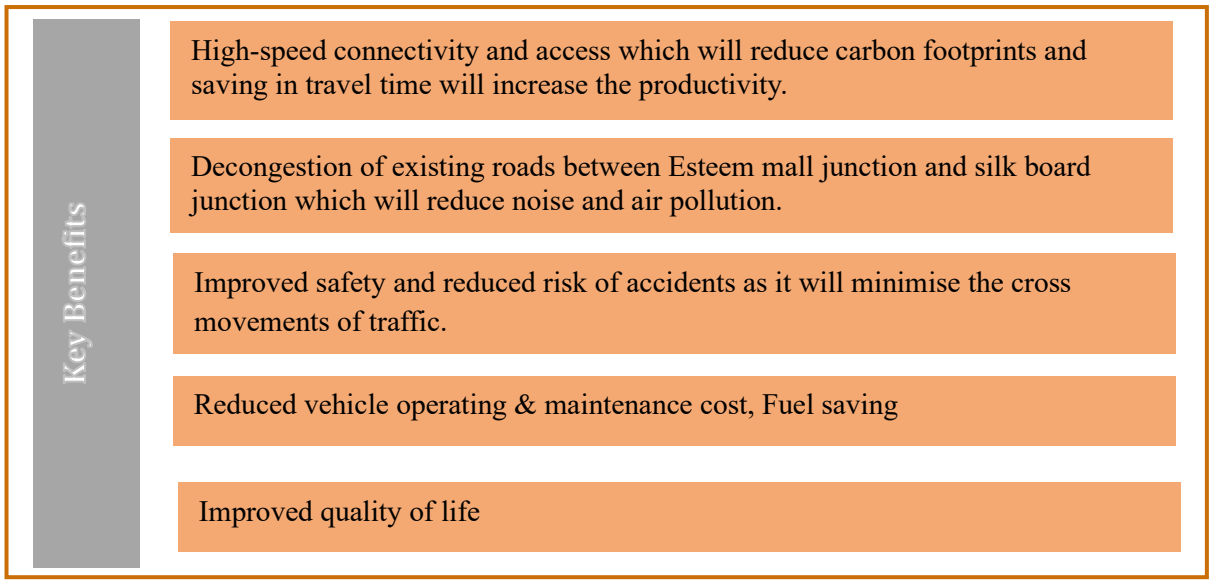


Figure 2: Project Key Benefit

1.5 Social and Economic Profile

1.5.1 Bengaluru Urban District

Bengaluru, officially known as Bengaluru, is the Capital of the Indian State of Karnataka. It has a population of over ten million, making it a megacity and the Third populous City and 5th most populous urban agglomeration in India.

The Deputy Commissioner, being the head of the District Administration, is officer vested with powers under the Central and State Laws. The D.C. office comes in direct contact with the people and people's representatives at various levels. The office of the Deputy Commissioner apart from having many original

works enumerated under different Acts and Rules has got the supervisory and coordinating roles at the district level. Apart from regulatory functions, the Deputy Commissioner guides and coordinates the developmental activities of the district.

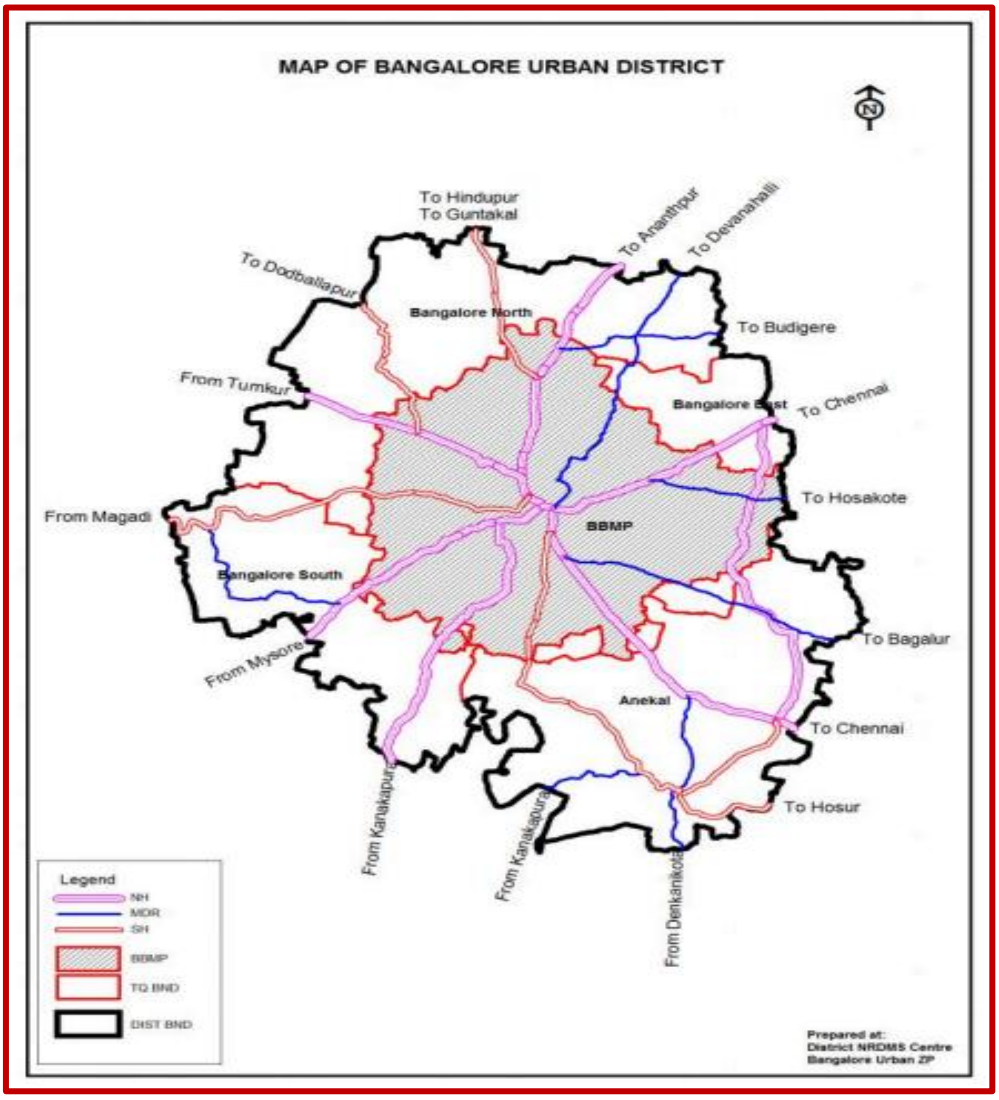


Figure 3: Bengaluru Districts Map

1.5.2 Geography

Bengaluru lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Precambrian Deccan Plateau) at an average elevation of 920 m (3,020 ft). It is positioned at 12.97°N 77.56°E). Most of the city of Bengaluru lies in the Bengaluru Urban district of Karnataka and the surrounding rural areas are a part of the Bengaluru Rural district. The region comprising the Bengaluru Urban and Rural districts is known as the Bengaluru (region).

Bengaluru has a handful of freshwater lakes and water tanks, some of which are Madivala tank, Hebbal Lake, Ulsoor Lake and Sankey Tank. Groundwater occurs in silty to sandy layers of the alluvial sediments. The Peninsular Gneissic Complex (PGC) is the most dominant rock unit in the area and includes granites, gneisses and migmatites, while the soils of Bengaluru consist of red laterite and red, fine loamy to clayey soils.

1.5.3 Geology

The city of Bangalore is located in central part of the Dharwar Craton. As its base, the Basement Gneiss, a polyphase migmatite (Tonalite- trondhjemite-granodiorite-TTG) originated over a period of 3400Ma. Over it the volcano- sedimentary Sargur Supracrustal (green stone belt) rocks were deposited and

metamorphosed, and what was subsequently intruded by another phase of TTG about 3000Ma which is referred to as the Peninsular Granite Suite-1 groups of rocks.

Subsequent tectonic deformations created linear belts of basins for the deposition of the younger volcano-sedimentary deposits and their metamorphism, also referred to as the rocks of the younger Dharwar/ Kolar type Super Group around 2700Ma. These belts comprised of rocks which metamorphosed included grits/arenites, pelites, Bimodal mafic- felsic volcanics, pyro clasts, agglomerates, layers of BIF, local komatiites, Quartzites (locally cross bedded), manganese marble, stromatolitic carbonate, calc- silicate, cordierite bearing pelites, amphibolite etc. This was followed by the next phase of granitic- granodiorite intrusion rich in potassium and mafic constituents about 2350-2600My. The resultant rocks occurring to the East of the Closepet Granite is referred to as Peninsular Gneiss II (Bangalore Supersuite)/ Dharwar Batholith.

The Dharwar Batholith which is characterized by rocks of granites, granodirites, monzonites, diorites and their high strained gneissic equivalents. These rocks are understood to have been uplifted as diapiric structures following a process of anatexis. The melts that intruded the overlying rock, normally had a wedge or elongated dome shapes trending approximately N-S to NW-SE. Swarms of mafic dykes have cut across these granitic plutons during more recent ages.

The exposed rocks have been undergoing weathering processes, and the residual patches are exposed as laterites locally and are identified with the Neogene period and the transported soils of the Quaternary period.

The superimposed folding patterns in the rocks suggest that the entire sequence of the rock groups appears to have deformed in a ductile manner. Throughout the gneissic terrain, small enclaves of reworked older rocks are observed to be signatures of even older deformational, metamorphic and magmatic history in the area.

The Diapiric uplift of the granitic melts was followed up by a prominent transcurrent sinistral Shear. Multiple generations of folding are interpreted in the rock groups at all scales. However, the NNW -SSE trend is the most prominent in the area and appears to represent the strike of the axial plane of a particular generation.

The project alignment is approximately N-S oriented between Esteem Mall Junction to Silk Board Junction. The project alignment takes off from close North of the Hebbal Lake near Esteem Mall. Proceeding southwards, the alignment passes through a topographic depression, thorough which a nalla/drain flows connecting the Hebbal and Nagavara Lakes. The area is suspected have a significant fill material and deeper weathered zone. The bedrock in the area is identified with Grey Granite equivalent to Closepet Granite Formation of Paleo-Proterozoic age.

Further south, near to the Palace Ground, where the proposed link Tunnels are proposed to connect the main tunnel and having the Sankey Tank towards the west of the Main Tunnel Alignment and the Palace Lake over the alignment, a substantial outcropping and thickening of laterite rocks is observed.

Advancing further south, immediately after the Racecourse, the next set of intersections are also set in the same Grey Granite as bedrock. Further south, in the Lal Bagh area, the Bed rock is in a transition zone. The alignment is set to cross a prominent lineament, which the Lal bagh lake in the vicinity and the Grey Granite bedrock in contact with Hornblende Granite. The alignment curves eastward and is set to negotiate through the Hornblende Granite for about 1.5-2Km before crossing into the Hornblede-Biotie Gneiss of Precambrian Geiessic Complex-II.

1.5.4 Topography

Bengaluru has two unique Topography terrains—North Bengaluru taluk and the South Bengaluru taluk. The North Bengaluru taluk is a relatively higher-level plateau and lies between an average of 839 to 962 meters above sea level. The middle of the taluk has a prominent ridge running NNE-SSW. The highest point in the city, Doddabettahalli, (962m) is on this ridge. There are gentle slopes and valleys on either side of this ridge. The low-lying area is marked by a series of water tanks varying in size from a small pond to those of considerable extent, but all shallow.

1.5.5 Climate

Due to its elevation, Bengaluru enjoys a pleasant and equable climate throughout the year with occasional extreme weather events like heatwaves, coldwaves, floods and droughts. The highest temperature ever recorded in Bengaluru is 41.8°C in April 30, 2024 in Kengeri at Bengaluru. Winter temperatures rarely drop below 13 °C and summer temperatures seldom exceed 37 °C.

The hottest summer day on average has a maximum temperature of about 37°c, and the coldest winter day has a temperature of about 13°c. Occasionally, heat waves can cause temperatures of up to 38-40°c. Occasional cold waves will be leading to the temperatures as low as below 9-10°c. Bengaluru receives about 970 mm of rain annually, with the wettest months being August, September and October. The heaviest rainfall recorded in a 24-hour period was 18 cm recorded on 1988.

Most of the rainfall occurs during late afternoon, evening or night and rain before noon is infrequent. November 2015 (290.4 mm) was recorded as one of the wettest months in Bengaluru with heavy rains causing flooding in some areas.

1.5.6 Seismicity

Because it lies in the seismically stable region, Zone II (encompassing parts of Karnataka, Maharashtra, Kerala, Tamil Nadu and Andhra Pradesh), Bengaluru has been untouched by major seismic events. The highest earthquake that has hit Bangalore is reported to have occurred on 7th January 1916. This earthquake had the intensity of VI.

1.5.7 Land use

According to data contained in the Bengaluru Mahanagara Palike Master Plan, 40.4% of the land in the city is used for residential purposes. Transport uses 24.3% of the land, while land used for industrial, and commercial purposes comprise 6.9% and 2.7% respectively. As the city of Bengaluru expands, the BMP expects the percentage of land used for industrial purposes to decrease, while it expects the percentages of land used for residential, commercial and public and semi-public purposes to increase.

1.5.8 Demographic Profile of the District

According to the 2011 census Bengaluru Urban district has a population of 9,621,551, roughly equal to the nation of Belarus. This gives it a ranking of third in India (out of a total of 640). The district has a population density of 4,378 inhabitants per square kilometre (11,340/sq mi). Its population growth rate over the decade 2001-2011 was 46.68%. Bengaluru has a sex ratio of 908 females for every 1000 males, and a literacy rate of 88.48%. 90.94% of the population lives in urban areas. Scheduled Castes and Scheduled Tribes make up 12.46% and 1.98% of the population respectively.

Languages of Bengaluru Urban district (2011)

- Kannada (44.47%)
- Tamil (15.99%)
- Telugu (13.99%)
- Urdu (12.11%)
- Hindi (4.55%)
- Malayalam (2.94%)
- Marathi (1.92%)

- Others (4.82%)

Table 1: Demographic profile of Bengaluru urban Districts

Category	Absolute Figures
Area	2196 Sq.kms
Population- Total	9621551
Male	5022661
Female	4518890
Rural	871607
Urban	8749944
Decadal Population Growth	47.18%
Literacy-Total	87.67%
SC Population – Total	1198385
ST Population – Total	190239
Sex Ratio (females per 1000 males)	916
Child Sex Ratio (0 to 6 years)	944
Occupational pattern of Population Total Workers	3998286

1.5.9 Economy

Bengaluru is one of the fastest-growing metropolises in India. Bengaluru contributes 38% of India's total IT exports. Its economy is primarily service oriented and industrial, dominated by information technology, telecommunication, biotechnology, and manufacturing of electronics, machinery, automobiles, food, etc. Major industrial areas around Bengaluru are Adugodi, Bidadi, Bommanahalli, Bommasandra, Domlur, Hoodi, Whitefield, Doddaballapura, Hoskote, Bashettihalli, Yelahanka, Electronic City, Peenya, Krishnarajapuram, Bellandur, Narasapura, Rajajinagar, Mahadevapura etc. It is the fifth Indian city to host maximum numbers of Fortune Companies, after Mumbai, Delhi, Kolkata and Chennai.

The growth of IT has presented the city with unique challenges. Ideological clashes sometimes occur between the city's IT moguls, who demand an improvement in the city's infrastructure, and the state government, whose electorate is primarily from rural Karnataka. The encouragement of high-tech industry in Bengaluru, for example, has not favoured local employment development, but instead increased land values and forced out small enterprises. The state has also resisted the massive investments required to reverse the rapid decline in city transport, driving new and expanding businesses elsewhere in India. Bengaluru is a hub for Indian biotechnology-related industry and in 2005 was home to around 47% of the 265 biotechnology companies in India, including Biocon, India's largest biotechnology company, giving Bengaluru the nickname of the "Biotech Capital of India". Bengaluru is also the country's fourth largest fast-moving consumer goods (FMCG) market. Forbes considers Bengaluru one of "The Next Decade's Fastest-Growing Cities". The city is the third largest hub for high-net-worth individuals. There were a large number of high-net-worth individuals with a ₹4.5 crore investment surplus in 2007. In the Ease of Living Index 2020, it was ranked the most liveable Indian city with a population of over a million.

1.5.10 Transport

Air

Bengaluru is served by Kempegowda International Airport, located at Devanahalli, about 40 km (25 mi) from the city centre. Formerly Bengaluru International Airport, the airport started operations from 24 May 2008 and is privately managed by a consortium led by the GVK Group. The city was earlier served by the HAL Airport at Vimanapura, a residential locality in the eastern part of the city. The airport is the third busiest in India after Delhi and Mumbai in terms of passenger and airplane traffic. Taxis and air-conditioned Volvo buses operated by BMTC connect the airport with the city.

Railways and Metro

As of 2022, a mass rapid transit system (MRTS) called the Namma Metro is being built in stages. Initially opened with the 7 km (4.3 mi) stretch from Baiyappanahalli to MG Road in 2011, metro lines totalling 42.30 km (26.28 mi) for the north–south and east–west lines were made operational in June 2017. Phase 2 of the metro covering 72.1 km (44.8 mi) is under construction and includes two new lines along with the

extension of the existing north–south and east–west lines. There are also plans to extend the north–south line to the airport, covering a distance of 29.6 km (18.4 mi).

Bengaluru is a divisional headquarters in the South Western Railway zone of the Indian Railways. There are four major railway stations in the city: Krantiveera Sangolli Rayanna Railway Station; Bengaluru Cantonment railway station; Yeshwantapur Junction, Krishnarajapuram railway station and newly inaugurated Sir M. Visvesvaraya Terminus, with railway lines towards Jolarpettai in the east; Guntakal in the north; Kadapa (only operational until Kolar) in the northeast; Tumkur in the northwest; Hassan and Mangalore in the west; Mysore in the southwest; and Salem in the south. There is also a railway line from Baiyappanahalli to Vimanapura, no longer in use. Though Bengaluru has no commuter rail, there have been demands for a suburban rail service because of the large number of employees working in the IT corridor areas of Whitefield, Outer Ring Road and Electronic City. The Rail Wheel Factory is Asia's second-largest manufacturer of wheels and axle for railways and is headquartered in Yelahanka, Bengaluru.

Bus

Buses operated by Bengaluru Metropolitan Transport Corporation (BMTC) are a staple of city public transport. While commuters can buy tickets on boarding these buses, BMTC also provides an option of a bus pass to frequent users. BMTC runs air-conditioned luxury buses on major routes and operates shuttle services from various parts of the city to Kempegowda International Airport. The Karnataka State Road Transport Corporation operates 6,918 buses on 6,352 schedules, connecting Bengaluru with other parts of Karnataka and with neighbouring states. The main bus depots that KSRTC maintains is the Kempegowda Bus Station, locally known as "Majestic bus stand", where most of the buses going out of the city ply from. Some of the KSRTC buses to Tamil Nadu, Telangana and Andhra Pradesh ply from Shantinagar Bus Station, Satellite Bus Station at Mysore Road and Baiyappanahalli satellite bus station. BMTC and KSRTC were the first operators in India to introduce Volvo city buses and intra-city coaches in India.

Taxis

Three-wheeled, yellow and black or yellow and green auto-rickshaws, referred to as autos, are popular for transport. They are metered and can accommodate up to three passengers. Taxis are usually available via phone calls or online services; they are metered and generally more expensive than auto-rickshaws.

Road

Bengaluru is well-connected with national highways with the rest of the country. The highways are National Highway 44 (NH-44), National Highway 48 (NH-48) (also Asian Highway 47 (AH-47)), National Highway 275 (NH-275), National Highway 75 (NH-75), National Highway 648 (NH-648) and National Highway 948 (NH-948), along with state highways and the city's roads total 11,000 km (6,835 mi).

Bengaluru currently has one expressway, the Bengaluru–Mysore Expressway, operational since March 2023, which is part of NH-275. In the coming years, the city will get more expressways, resulting in enhanced connectivity and commutes with the rest of the country. They are as follows:

- Bengaluru–Chennai Expressway: Under construction since August 2019, to be completed by March 2024.
- Pune–Bengaluru Expressway: Proposed, to be completed by 2028.
- Nagpur–Hyderabad–Bengaluru Expressway: Proposed, expected to be completed by before 2030.

An average of 1,750 vehicles are registered daily in Bengaluru Regional Transport Offices (RTOs). The total number of vehicles, as of 2020, are around 8,500,000 vehicles.

1.5.11 Education

Bengaluru has a literacy rate of around 88%, according to the 2011 national census. Primary, middle school and secondary education in Bengaluru is offered by various schools which are affiliated to one of the government or government recognised private boards of education, such as the Secondary School Leaving Certificate (SSLC), Central Board of Secondary Education (CBSE), Council for the Indian School Certificate Examinations (CISCE), International Baccalaureate (IB), International General Certificate of Secondary Education (IGCSE) and National Institute of Open Schooling (NIOS). Schools in Bengaluru are either government run or are private (both aided and un-aided by the government). Bengaluru has a

significant number of international schools due to large number of expats and people employed in the IT sector. After completing their secondary education, students either attend a pre-university course or continue an equivalent high school course in one of three streams – arts, commerce or science – in various combinations. Alternatively, students may enrol in diploma courses. Upon completing the required coursework, students enrol in general or professional degrees in universities through lateral entry.

The Bengaluru University, established in 1886, provides affiliation to over 500 colleges, with a total student enrolment exceeding 300,000. The university has two campuses within Bengaluru – Jnanabharathi and Central College. University Visvesvaraya College of Engineering was established in the year 1917, by Bharat Ratna Sir M. Visvesvaraya, At present, the UVCE is the only engineering college under the Bengaluru University. Bengaluru also has many private Engineering Colleges affiliated to Visvesvaraya Technological University.

Indian Institute of Science, which was established in 1909 in Bengaluru, National Centre for Biological Sciences, National Institute of Mental Health and Neuro-Sciences, Jawaharlal Nehru Centre for Advanced Scientific Research and the Raman Research Institute are the premier institutes for scientific research and study in India. Nationally renowned universities and institutes such as the, National Institute of Design, National Institute of Fashion Technology, National Law School of India University, the Indian Institute of Management, International Institute of Information Technology, Christ University, Brindavan College of Engineering, RV Educational Institutions, University of Agricultural Sciences, Bengaluru, the ICAR-National Institute of Animal Nutrition and Physiology, the Indian Statistical Institute are located in Bengaluru. Bengaluru also has some of the best medical colleges in the country, like St. John's Medical College and Bengaluru Medical College and Research Institute. The M. P. Birla Institute of Fundamental Research has a branch located in Bengaluru. Mount Carmel College, a premier institution for women's education in India is located in Bengaluru. It is affiliated to Bengaluru University, as is Acharya Bengaluru Business School, established in 2008.

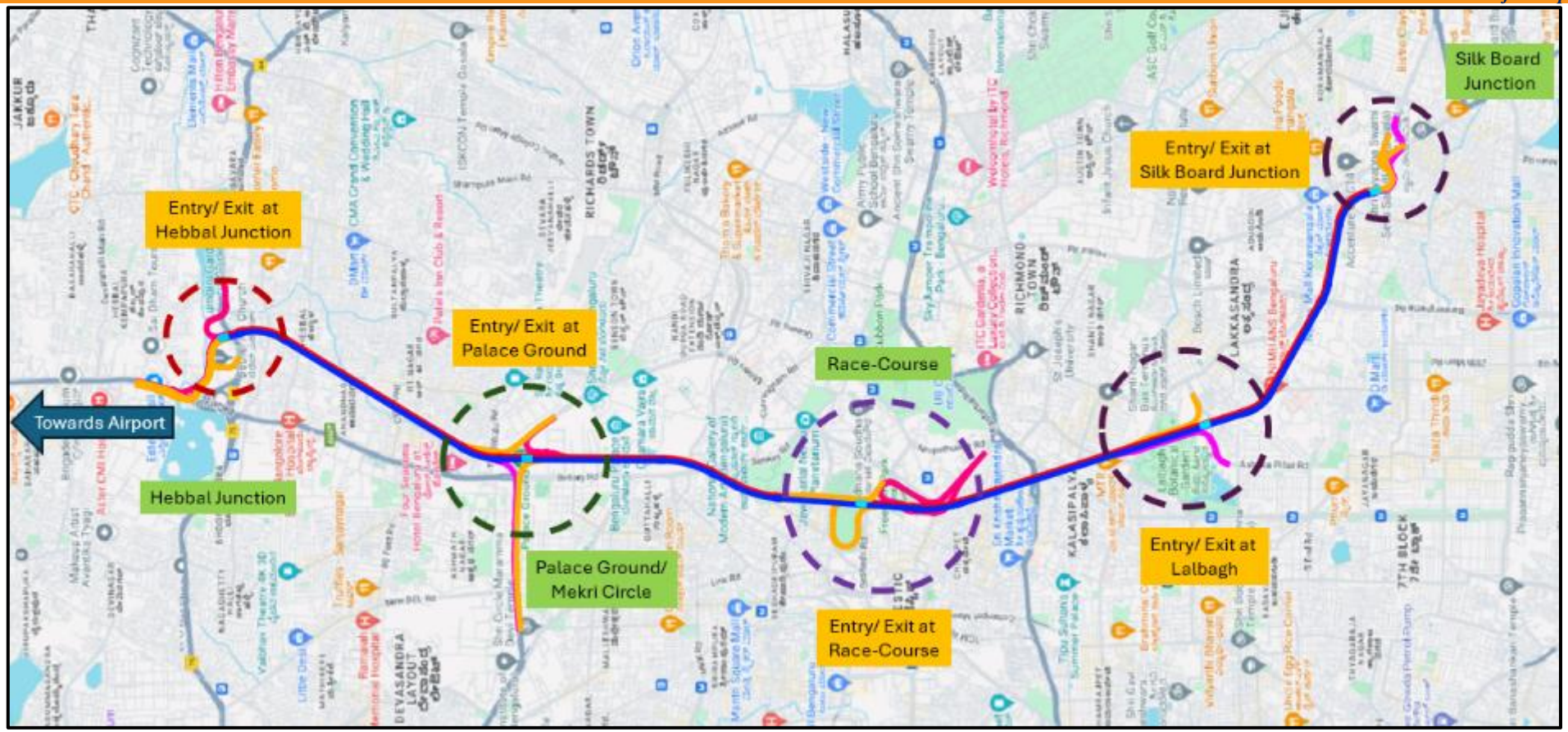


Figure 4: Project Alignment

1.6 Project Location and Alignment

The entire project is in Bengaluru city and connecting the northern part to the southern part of the city.

As per the feasibility report, the North – South Corridor starting from Hebbal Esteem Mall junction to Silk Board KSRP Junction is going to be developed as Underground Vehicular tunnel having 03 intermediate locations connected via ramps for entry & exit into the Main Tunnel.

The alignment has been decided with various discussions held along with Competent Authority. The alignment option has been discussed with competent Authority and suggested modification has been incorporated. The alignment has been approved by the Competent Authority. The proposal has been planned in such a way to minimise the infringement with the planned & ongoing surrounding development project The alignment is connecting the obligatory locations based on the discussion, site facts and traffic studies. This alignment will connect the Hebbal and silk Board Junction and proposed 3 intermediate ramps at Mekri circle (Palace Ground), Race-Course & Lalbagh directly. The travel time will be reduced from about 90 minutes to 35 minutes and Level of Service will enhance from existing LOS of E and F to improved LOS of B and C.

The details of the alignment have been provided in given table.

Table 2: Alignment Details of Main Tunnel

From Hebbal to Silk Board	From Silk Board to Hebbal
Length: 16.745 km	Length: 16.571 km
Lane Configuration: 3 Lane	Lane Configuration: 3 Lane
Start: Approach of Hebbal Flyover	Start: Approach of Hebbal Flyover
End: Hosur Road (Silk Board Junction)	End: Hosur Road (Silk Board Junction)

1.5.1 Packaging of the project

The project has been divided into two number of packages based on discussion with Competent Authority. The packages have been designed by considering the following aspects of the project.

- For the ease and timely construction of the tunnel project.
- Factors such as bid capacity of the leading tunnel construction firms in India and Across Globe,
- Civil construction cost of the project and constructability
- Other administrative and reasons .

The package has been divided into North side and South side. The detail of the project packages is as mentioned below-

- Design and Construction of 3 lane Underground Twin Tunnel Road from Hebbal (Esteem Mall junction) (Km. 0+000) and Silk Board (KSRP Junction) along with 3lane/2-lane entry & exit ramps on Enhanced BOT (Toll) Mode including operation and maintenance in Bangalore City (North South Corridor).
- **Northern Package 1:** Hebbal Near Esteem Mall Junction to Seshadri Road, Freedom Park (8.748 Km
- **Southern Package-2: F**rom Seshadri Road, Freedom Park (Km 8.748) to Silk Board (Km 16.745)

1.5.2 Salient Features of Northern Package 1:

The salient features of package 1 are given below:

Total project Length : 8.748 km
TBM Tunnel length : Tube I: 7206 km & Tube II: 7195 km
Lane Configuration : 3 lanes
Tunnel Diameter : 13.5 m (finished)

Cross passage	: 13 No.
Cross passage	: 10 Nos. (For Electrical Sub Stations)
Shaft	: 2 Nos. for launching & retrieval of Tunnel boring machines
Depth of Tunnel	: Tunnel crown will be varying 15m to 50m (1D to 4D) below the existing ground level.

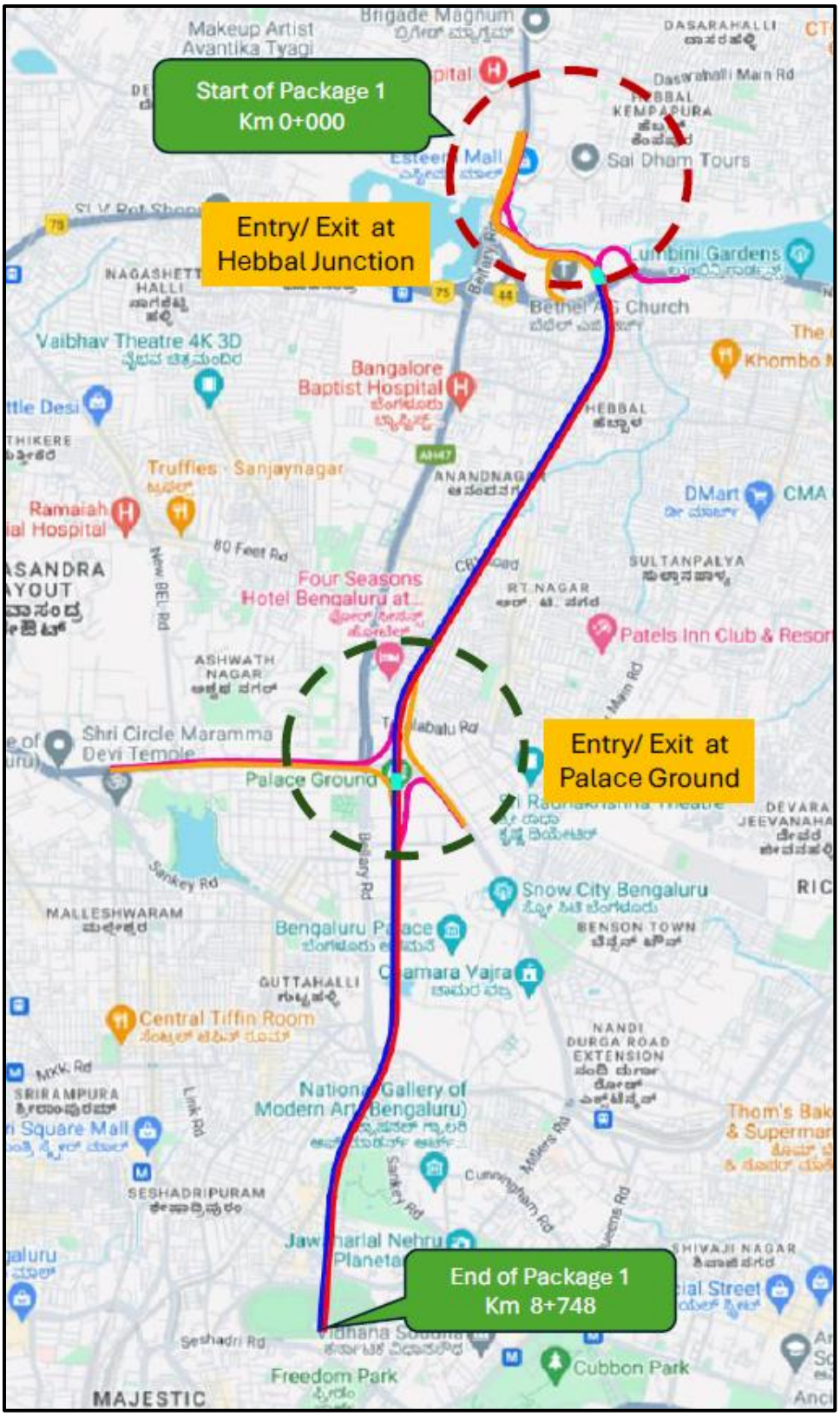


Figure 5: Package 1 Alignment

1.5.2.1 Details of Package 1

Package 1 starts at the Km 0+000 at Hebbal Junction and Ends at Km 8+748 Kms. This package consists of upper half (North portion) of the North-South corridor of our projects. Package consists of twin tube tunnel (Tube 1 and Tube 2), Two TBM Launching and retrieval shafts, Connecting Ramps at Outer Ring Road (ORR) and Intermediate ramps at Place Ground for traffic travelling to CV Raman Road and Jayamahal Road.

Table 3: Brief Details of Package 1

Description (LHS)	Details	Description (RHS)	Details
Start km	0+000	Start km	0+000
End km	8+748	End km	8+725
Length	8748 m	Length	8725 m
TBM Length Tube 1	7206 m	TBM Length Tube 2	7195 m
Shaft Length at Hebbal and Palace Ground	205 m	Shaft Length at Hebbal and Palace Ground	200 m
Cut and Cover Length Tube 1	837 m	Cut and Cover Length Tube 2	830 m
Open Cut Length Tube 1	500 m	Open Cut Length Tube 2	500 m

Start point at Hebbal

The Entry at the start location has been planned near esteem mall for connecting traffic from Airport flyover and another entry has been provided from service road for the traffic coming from Sahakar Nagar & Yelahanka to the main tunnel for conflict free movement at junction. Another entry ramps have been proposed at the Outer Ring Road (traffic from KR Puram to Silk Board). Similarly, two exits have been proposed, one towards the Ring Road (traffic coming from Silk Board towards K R Puram) and another on the service road (traffic coming from Silk Board towards Sahakar Nagar & Yelahanka).

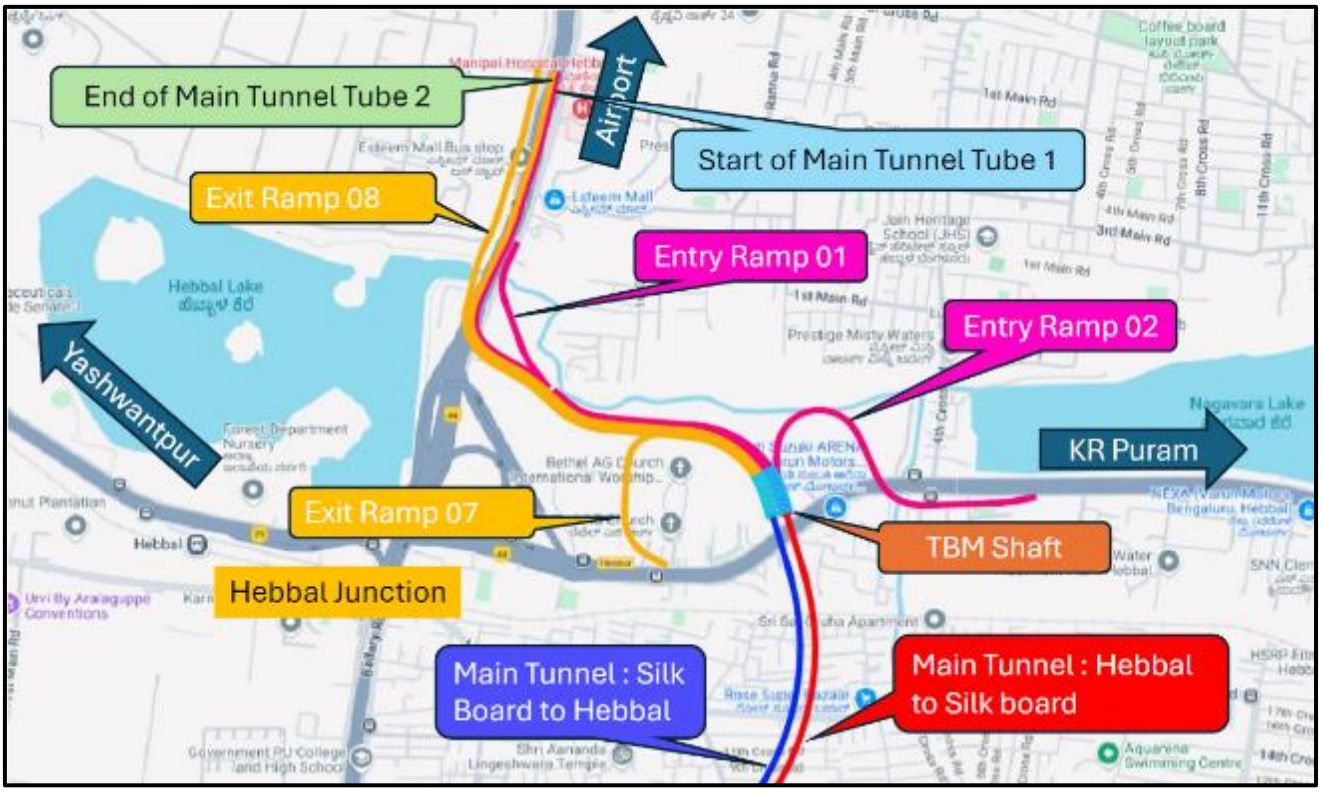


Figure 6: Entry and Exit at Hebbal Junction

Table 4: Entry Exit Details at Hebbal Junction

Sr. No.	Location	Description	Length (m)	Direction Of Traffic	Lane Configuration
Ramps at Start of Main Tunnel					
1	Hebbal	Entry Ramp 1 into	341	From Service Road Airport to	2 Lane

Sr. No.	Location	Description	Length (m)	Direction Of Traffic	Lane Configuration
	Junction	Main Tunnel		Bangaluru City	
2		Exit Ramp 08 from Main Tunnel	548	To Service Road towards Sahakar Nagar, Yelahanka	2 Lane
3		Entry Ramp 2 into Main Tunnel	814	From KR Puram on Outer Ring Road	2 Lane
4		Exit Ramp 07 from Main Tunnel	415	Towards Yeswanthpur on Outer Ring Road	2 Lane

Intermediate Ramp at Place Ground

The first intermediate location has been planned near Mehkri circle. There are a total of 2 entry & 2 exits Ramps at this location from each tunnel.

- Two ramps have been proposed on Jayamahal Road: One exit ramp for the traffic coming from Hebbal Side, and one entry ramp for traffic going to Silk Board side from Jayamahal Road.
- Two Ramps have been proposed on CV Raman Road: One exit Ramp on CV Raman Road for the traffic coming from Silk board side and one entry ramp for the traffic going to Hebbal side from CV Raman Road.

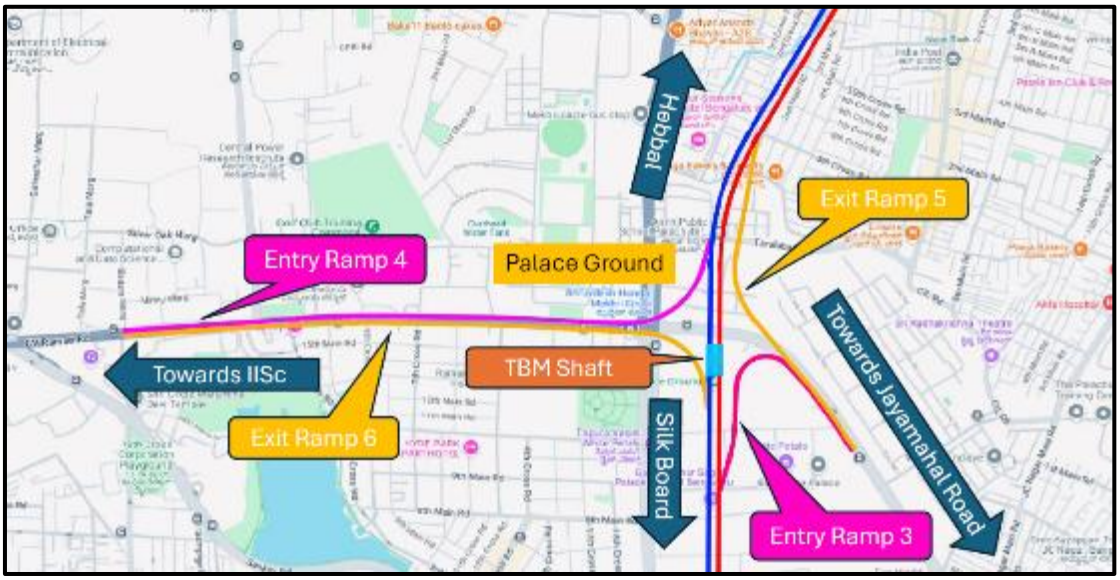


Figure 7: Entry and Exit Ramps at Palace Ground

Table 5: Ramps Details at Palace Ground/Mekri Circle

Sr. No.	Location	Description	Length (m)	Direction Of Traffic	Lane Configuration
Intermediate Ramps					
1	Near Palace Ground/ Mekri Circle	Entry Ramp 03 into Main Tunnel	871	From Jayamahal Road towards Silk Board	Intermediate Lane
2		Exit Ramp 06 from Main Tunnel	1942	Towards CV Raman Road	Intermediate Lane
3		Entry Ramp 4 into Main Tunnel	1945	Entry from CV Raman Road towards Hebbal	Intermediate Lane
4		Exit Ramp 05 from Main Tunnel	1110	Exit Towards Jayamahal Road	Intermediate Lane

1.5.3 Salient Features of Southern Package 2

The salient features of package 2 are given below:

Total project Length	: 7.997 km
TBM Tunnel length	: Tube I: 7042 km & Tube II: 7044 km
Lane Configuration	: 3 lanes
Tunnel Diameter	: 13.5 m (Finished)
Cross passage	: 13 No. (Vehicular)
Cross passage	: 08 Nos. (For Electrical Sub Stations)
Shaft	: 3 Nos. for launching & retrieval of Tunnel boring machines
Depth of Tunnel	: Tunnel crown varies 15m to 50m (1D to 4D) below the existing ground level.

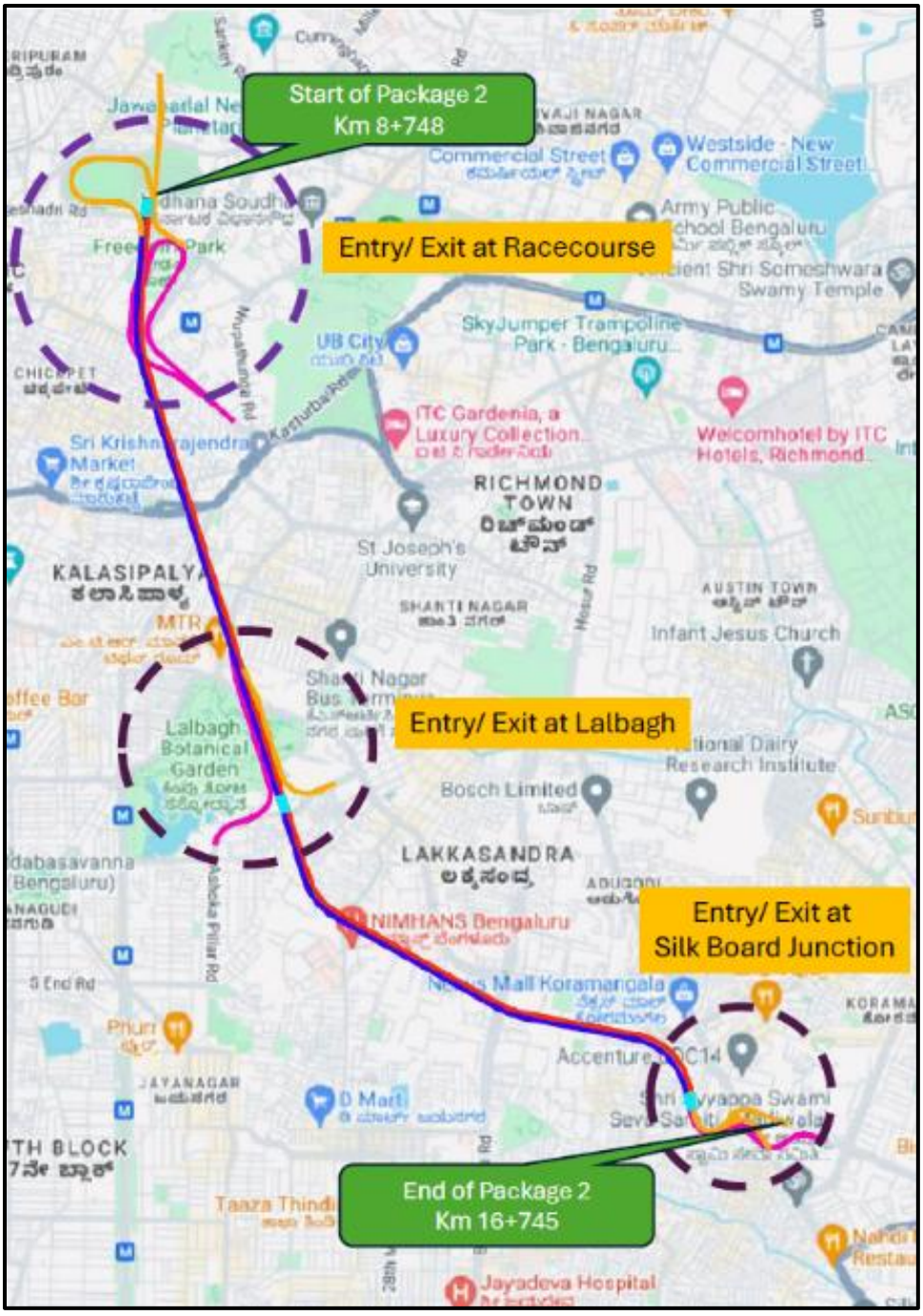


Figure 8: Package 2 Alignment

1.5.3.1 Details of Package 2

Package 2 starts at the Km 8+748 (near Racecourse) and Ends at Km 16+745 Kms. Package consists of twin tube tunnels (Tube 1 and Tube 2), three TBM Launching and retrieval shafts, and Intermediate ramps at Racecourse, Lal Bagh and Silk Board Junction.

Table 6: Brief Details of Package 2

Description (LHS)	Details	Description (RHS)	Details
Start km	8+748	Start km	8+725
End km	16+745	End km	16+571
Length Tube 1	7997 m	Length Tube 2	7846 m
TBM Length Tube 1	7042 m	TBM Length Tube 2	7044 m
Shaft Length Tube 1	300 m	Shaft Length Tube 2	301 m
Cut and Cover Length Tube 1	425 m	Cut and Cover Length Tube 2	250 m
Open Cut Length Tube 1	230 m	Open Cut Length Tube 2	251 m

Start Point of Package 2: The project starts at Km 8+748 near the racecourse at the start of our TBM Shaft.

Intermediate Ramps at Racecourse:

The Entry and Exit Ramps at Racecourse have been proposed to be part of Package 2.

There are a total of 4 exit and entry ramps at racecourse.

- Two Exit Ramps have been proposed on Seshadri Road for Traffic coming from Hebbal Side and as well as for the traffic coming from Silk board side.
- Two Entry Ramps have been proposed from District Office Road (CSI Hudson Memorial Church) for traffic going to Hebbal side as well as Silk Board side.

Table 7: Ramps Details at Race Course/ Vidhan Saudha

Sr. No.	Location	Description	Length (m)	Direction Of Traffic	Lane Configuration
Intermediate Ramps					
1	Near Racecourse / Vidhan Saudha	Entry Ramp 5 into Main Tunnel	1197	From District Officer Road Towards Hebbal	2 Lane
2		Entry Ramp 6 into Main Tunnel	1783	From District Officer Road Towards Silk Board Junction	2 Lane
3		Exit Ramp 04 from Main Tunnel	1141	On Seshadri Road (Towards KR Circle)	2 Lane
4		Exit Ramp 03 from Main Tunnel	1465	On Seshadri Road (Towards KR Circle)	2 Lane

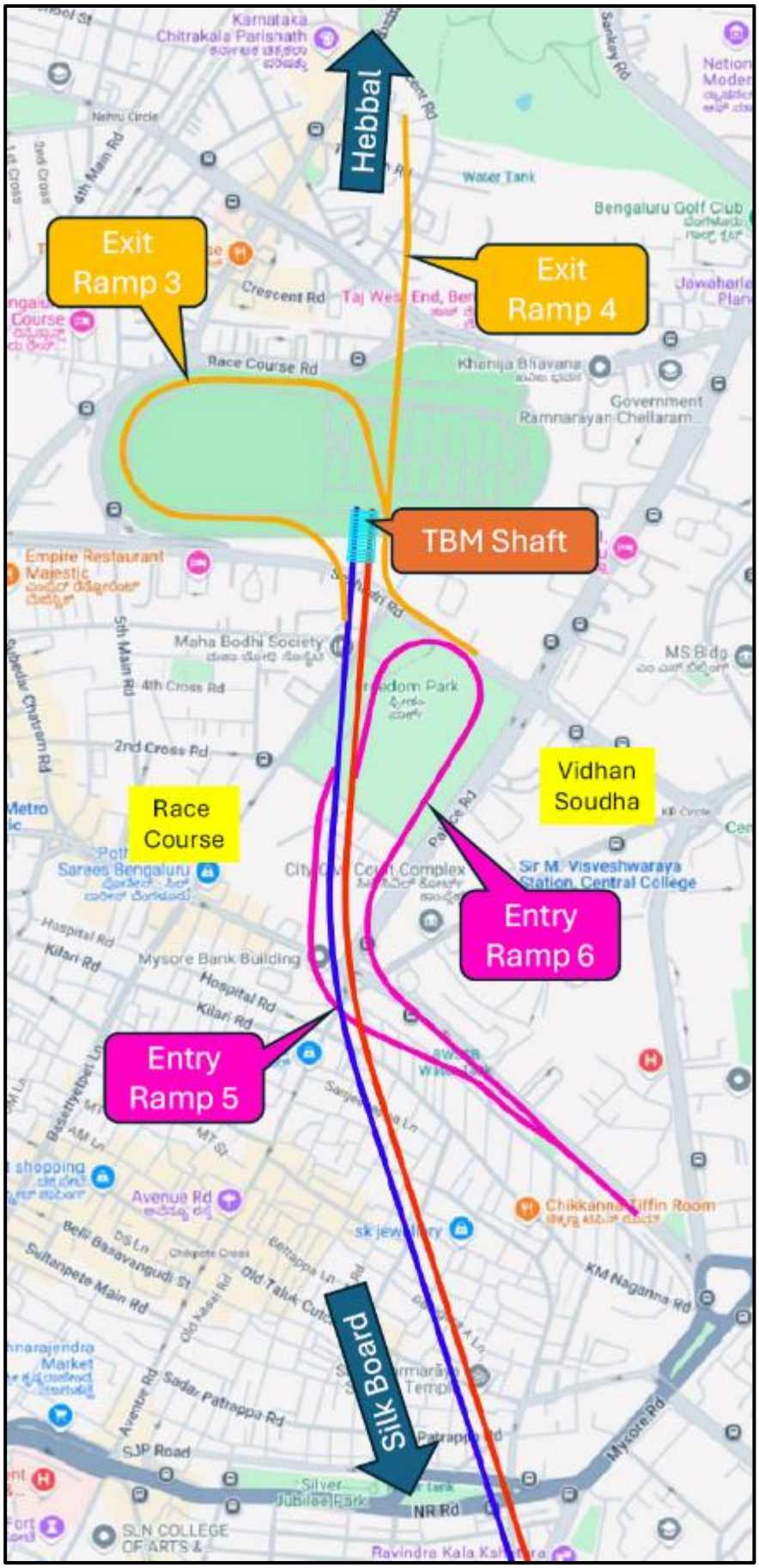


Figure 9: Entry and Exit Ramps at Racecourse and Vidhan Soudha

Intermediate Ramps at Lal Bagh

There are a total of 2 entry and exit ramps at this location.

- One exit ramp on Marigowda road towards Dairy circle at Wilson Garden has been proposed.
- One entry ramp from Ashoka Pillar on Siddapura road for traffic going to Hebbal junction has been proposed.

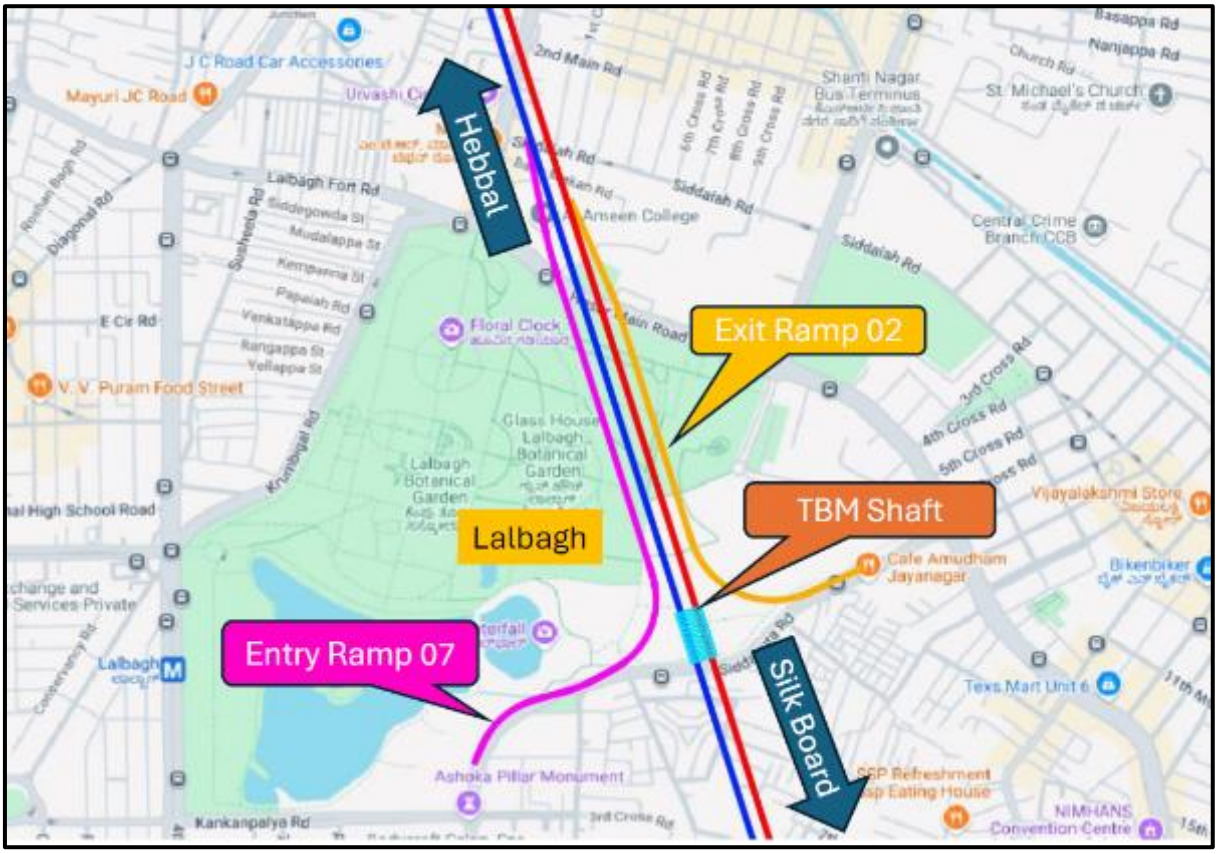


Figure 10: Entry and Exit Lalbagh Botanical Garden

Table 8: Ramps Details at Lal Bagh Botanical Garden

Sr. No.	Location	Description	Length (m)	Direction Of Traffic	Lane Configuration
Intermediate Ramps					
1	Near Lalbagh	Entry Ramp 7 into Main Tunnel	1416	From Siddapura Road (Near Ashoka Pillar).	2 Lane
2		Exit Ramp 2 from Main Tunnel	1081	On Siddapura Road Near Wilson Garden	2 Lane

End Point of Package 2 Near Silk Board Junction.

The Tunnel ends before silk board junction on Hosur road. Both entry and exit ramps have been planned on Hosur Road for the traffic going to electronic city. However, additional, entry & exit ramp has been planned to connect the traffic going to Ring Road/ HSR layout area on Sarjapur road near St. John Hospital.

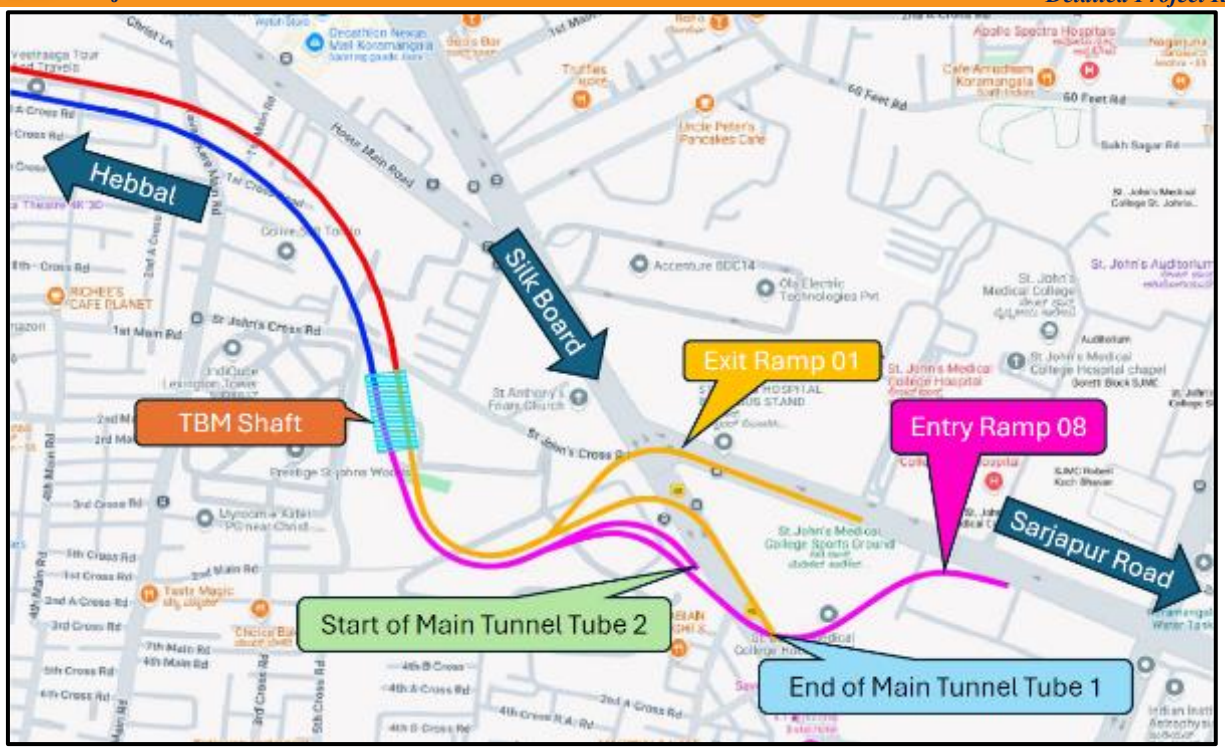


Table 9: Ramps Details at Silk Board

Sr. No.	Location	Description	New Length (m)	Direction Of Traffic	Lane Configuration
Ramps at End of Main Tunnel					
1	Silk Board	Exit Ramp 1 from Main Tunnel	455	On Sarjapur Road / HSR layout (Ring Road)	2 Lane
2		Entry Ramp 8 into Main Tunnel	654	From Sarjapur Road / HSR layout (Ring Road)	2 Lane

1.5.4 Infringement with proposed alignment

Package 1: The proposed tunnel alignment starts from Hebbal and ends at Racecourse, including 2 intermediate ramps in between. The proposed development plan in having infringement with ongoing & planned work of Metro and K-Ride. The concerned offices have been informed and requested for combined GADs preparation.

Package 2: The proposed tunnel alignment of package 2 starts from Racecourse and ends at Silk Board Junction, including 2 intermediate ramps in between. The proposed development plan in having infringement with planned work of Metro The concerned offices have been informed and requested for combined GADs preparation.

1.6 Engineering Surveys and Investigations

Based upon the objectives of the project and with careful planning and efficient use of resources, different tasks have been done simultaneously. Based on the objectives and scope of the consultancy services, an appropriate work methodology has been developed by the consultants to address the other requirements also, especially regarding various intermediate targets and completion period, manning schedule, and TOR.

A work plan was prepared based on the methodology developed. A competent team of suitably qualified key professionals as per the requirements and other supporting staff was selected to carry out the services fieldwork and office work.

1.6.1 Existing Features of Project

The project starts near Esteem Mall Hebbal Junction and Ends at Silk board Junction. The alignment passes through nodal points/ stretch of the Bengaluru city.

First stretch is Hebbal to Golf course whose existing roadway width is 6 lane divided carriageway, then further there is connectivity to Chalukya circle via 4 lane existing divided carriageway road. After that Chalukya circle is connected to Lalbagh and finally Lalbagh to Silkboard junction all the stretches are 4 lane divided carriageway.

The location of entry and exit ramps have been analyzed.

- At the Start End, the road is 6 lanes with a divided carriageway with service road either side. There is a Minor bridge near Esteem mall which channelizes the stream during the period when Hebbal lake saturated or overflows. The construction of metro (Phase 2A, Phase 2, Phase 3 & Phase 3A) is underway/ planned, which affects our project start point.
- At the End Point the road is 4 lanes with divided carriageway. The road has an under-construction double-decker flyover at Silk Board junction and the metro is also under construction at the project end location.

1.6.2 Reconnaissance Survey

A preliminary survey was conducted to gather general information about the project area. The purpose of the reconnaissance survey is to get a broad understanding of the terrain, conditions, Environmental and Social Considerations, Safety and Risk Assessment of the project area.

1.6.3 Road Inventory

Road inventory was carried out in the first week of August 2024 over the possible locations of the project alignment. The road conditions are found to be good, some of the roads have undergone strengthening of bitumen surface through the provision of White Topping. Metro is being constructed at the starting point of our project alignment. The traffic volume in the project influence area is quite high.

1.6.4 Existing Carriageway

The existing road infrastructure includes lane configurations of 4 lanes, and 6 lanes in various segments. Furthermore, it is observed that several metro routes intersect with these corridors. The road stretches and lane details are as follows:

Table 10: Existing Carriageway

Stretch	Lane Configuration
1. Hebbal to Golf course	6 lanes
2. Golf course to Chalukya	4 lanes
3. Chalukya to Lalbagh botanical garden	4 lanes
4. Lalbagh botanical garden to silk board	4 lanes

1.6.5 Existing Road Alignment and Geometry

The existing road is of 4 to 6 lane capacity. Due to heavy traffic especially in peak hour the average travel speed is about 15-20 km/hr in the project stretch. This leads to traffic congestion. because The proposed tunnel will be with improved geometry and designed with the speed of 80 KMPH

1.6.6 Terrain and Land Use

Project area lies in plain terrain in entire length. The land-use pattern for the project area is densely populated builtup of Bengaluru City.

1.6.7 Traffic Survey at Site

For the evaluation of the traffic demand estimation on the proposed North – South corridor in Bengaluru and impact on the road network in study area, traffic model was developed in PTV Visum 2024. Macro simulation analysis were conducted to understand the overall travel pattern in the study area. PTV Visum 2024 helps to understand the existing traffic and travel patterns and bottlenecks in the transportation system. Further it was used for scenario testing according to the changes in demand and infrastructure. Comprehensive data collection was done to understand the existing traffic and travel pattern and for development of the base year model.

The traffic survey location were planned along the proposed corridor, the location of traffic survey mainly

for classified Volume count, O-D Survey and Turning movement survey along with detailed analysis are described in later in this report.

Figure 11: Traffic Surveys conducted at Project Location

1.6.8 Topography Survey:

The topography survey was carried out using Drone LiDAR, DGPS (Differential Global Positioning System) and Total Station equipment as per the requirement of site for development of Topographical maps.

Figure 12: Topography Survey on Site

1.6.9 Geotechnical & Geophysical Investigation

Initial assessment of corridors has been done which includes desk studies, study of any earlier investigation,

any geological research, geological maps, remote sensing inputs etc. Apart from it, walkover geological survey has been carried out to study the ground condition and to corroborate with the existing information/data. Further Geophysical Investigation (MASW-Multichannel Analysis of Surface Wave and SRT-Seismic Refraction Test) has been carried out along the alignment corridor. The Geological reference Model (GRM) has been prepared and presented in the L-section, and geological and geotechnical interpretation has been made based on these investigations and available data and presented as prefinal geotechnical interpretative report, which has been considered by the experts as reasonably sufficient to develop the preliminary design, construction methodology, type of TBMs to be deployed and other construction equipments required for the execution of work etc. (Refer volume III Pre-final GIR).

Further, Intrusive investigations in form of boreholes and laboratory/in-situ testing is being carried for confirmation of geological contacts, weak zones, fracture/shear zones, water table etc. This information will be crucial to be provided to the prospective bidders as for their information in addition to other data available for adjacent projects. The same will be completed in due course of time and will be included in bid document before closing final addendum and corrigendum for bidding process.

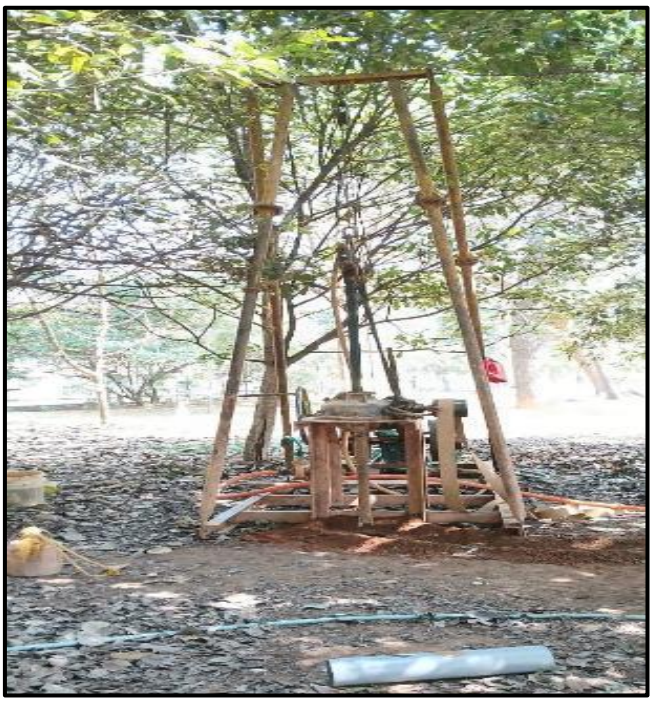


Figure 13: Geophysical and Intrusive Geotechnical investigation on Site

1.6.10 Traffic Surveys Analysis

Classified Vehicle Count, Origin and Destination and Turning Movement Count surveys were conducted at numerous locations. The locations were selected to get the real traffic trends that directly and indirectly impact the project. The traffic surveys were extended to a larger area outside of the project. The traffic survey were conducted on numerous locations to reflect the actual traffic conditions on the project road and project corridor and the project influence area.

Table 11: Traffic Survey Locations

S. No.	Survey Types	Unit	Quantity	Survey Date
1	Classified Traffic Volume Count	Locations	9	Aug-2024
2	Turning Moment Count at Intersections	Locations	7	Aug-2024
3	Passenger Origin-Destination Survey	Locations	11	Aug-2024
4	Speed and delay	KM	25	Aug-2024

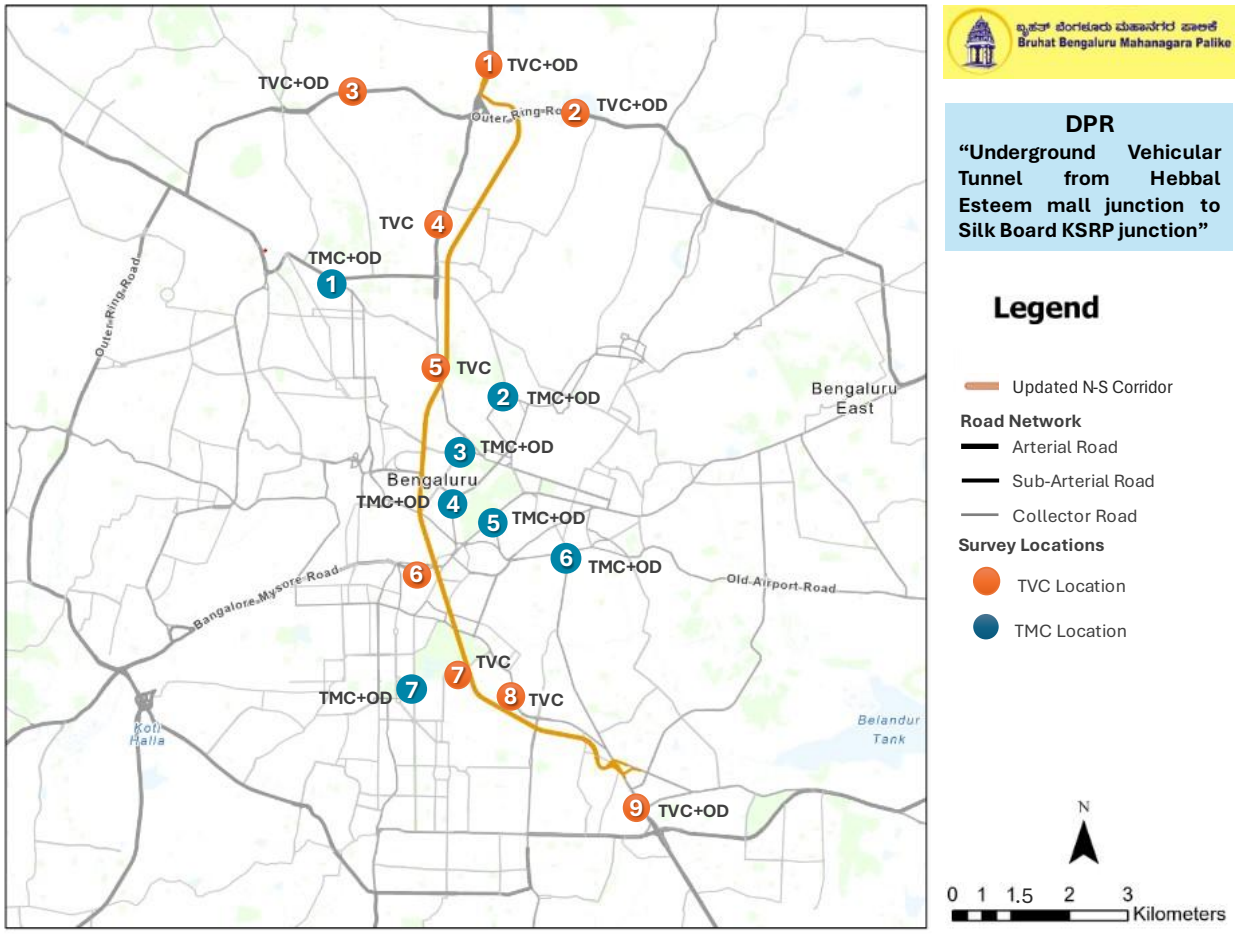


Figure 14: Map Showing Locations of Traffic Volume Count Surveys.

At the following locations, Traffic Surveys were conducted, and their detailed analysis is presented in chapter 6 of Main Report.

Table 12: Traffic Survey Locations (CVC and OD)

Sr. No.	Location	CVC	OD
1	NH-44 Bellary Road (Near-Sakar Nagar)	Done	Done
2	NH-75 Malur -Byranahalli Rd Outer Ring Road (Near-Nagavara park)	Done	Done
3	NH-75 Malur -Byranahalli Rd Outer Ring Road (Near-Devinagar BEL Circle)	Done	Done
4	AH-47 Malur Road (Near-Science Gallery)	Done	Done
5	Guttahalli Main Road (Near-Uniworth Plaza)	Done	Done
6	NR road (Near-Silver Jubilee Park)	Done	Done
7	Siddapura Road (Near-Maharaja Agrasena Bhavana)	Done	Done
8	Marigowda Road (Near-National Institute of Mental Health & Neuro Sciences)	Done	Done
9	NH-44 Bengaluru-Chennai Highway (Near-Madiwala footbridge)	Done	Done

The Turning Movement Count survey has been conducted at the following junctions in the project influence area.

Table 13: Traffic Survey Locations (Turning Moment Count)

Sr. No.	Turning Movement Count Locations
1	CN Rao underpass Junction
2	Bangalore Cantt Junction
3	Basaveshwara circle
4	KR Circle
5	Cubbon Park UB City signal
6	Shoolay Circle
7	Lalbagh Chowk

Speed and Delay survey was also conducted along the North-South corridor. Traffic flow diagrams are presented in the traffic chapter of Main Report along with the traffic demand analysis done via PTV Visum software, and their findings are discussed in the traffic chapter of the Main Report.

1.6.11 Current level of Service in the project Influence Area

The Level of service is defined as per the IRC: IRC:106-1990-Guidelines for Capacity of Urban Roads in Plain Areas and Highway Capacity Manual *(Indo-HCM)*-2012-17 published by the CRRI.

Table 14: LOS as per-IRC

LOS	Description
A	Represents a condition of free flow with average travel speeds usually about 90 % of the free-flow speed.
B	Represents a zone of stable flow, with the drivers still having reasonable freedom to select their desired speed and maneuver within the traffic stream
C	This also is a zone of stable flow but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream.
D	Represents the limit of stable flow, with conditions approaching close to unstable flow. Due to high density, the drivers are severely restricted in their freedom to select desired speed and maneuver within the traffic stream.
E	Represents operating conditions when traffic volumes are at or close to the capacity level. The speeds are reduced to a low, but relatively uniform value, the average value being one-third of the free flow speed.
F	Represents zone of forced or breakdown flow

As per the findings of traffic volume count the current Level of Service on the below mentioned stretches in the project influence area is mentioned below.

Table 15: LOS on the traffic cordon points on existing road

Sr. No.	Location	Direction	Peak Hour %	Level of Service	Peak Time
1	NH-44 Bellary Road (Near-Sakar Nagar)	Dir-I: Yelahanka to Hebbal (Towards Bengaluru)	6%	LOS F	09.00-10.00
		Dir I - Service Lane (Towards Bengaluru)		LOS E	
		Dir-II: Hebbal to Yelahanka (Towards Airport)		LOS F	
2	NH-75 Malur -Byranahalli Rd Outer Ring Road (Near-Nagavara park)	Dir-I: Bellary Road to Nagavara	6%	LOS C	09.30-10.30
		Dir I - Service Lane		LOS E	
		Dir-II: Nagavara to Bellary Road		LOS C	
		Dir II - Service Lane		LOS C	
3	NH-75 Malur -Byranahalli Rd Outer Ring Road (Near-Devinagar BEL Circle)	Dir-I: Hebbal to Yashwantpur	7%	LOS F	10.15-11.15
		Dir-II: Yashwantpur To		LOS E	

Sr. No.	Location	Direction	Peak Hour %	Level of Service	Peak Time
		Hebbal			
4	AH-47 Malur Road (Near-Science Gallery)	Dir-I: Mekhri circle to Airport	7%	**LOS E**	09.00-10.00
		Dir I - Service Lane		**LOS F**	
		Dir-II: Airport to Mekhri circle		**LOS F**	
		Dir II - Service Lane		**LOS D**	
5	Guttahalli Main Road (Near-Uniworth Plaza)	Dir-I: Mahalakshmi Gudi Circle to Bengaluru Golf Club	6.5%	**LOS F**	09.15-10.15
		Dir-II: Bengaluru Golf Club to Mahalakshmi Gudi Circle		**LOS F**	
6	NR road (Near-Silver Jubilee Park)	Dir-I: Kempegowda Tower to Chamrajpet	6.64%	**LOS D**	09.30-10.30
		Dir-II: Chamrajpet to Kempegowda Tower		**LOS F**	
7	Siddapura Road (Near-Maharaja Agrasena Bhavana)	Dir-I: Ashoka Piller to Mallinge Hospital	9%	**LOS F**	09.30-10.30
		Dir-II: Mallinge Hospital to Ashoka Piller		**LOS C**	
8	Marigowda Road (Near-National Institute of Mental Health & Neurosciences)	Dir-I: Dairy Circle to Wilson Garden	7%	**LOS F**	10.15-11.15
		Dir-II:Wilson Garden to Dairy Circle		**LOS F**	
9	NH-44 Bengaluru-Chennai Highway (Near-Madiwala footbridge)	Dir-I: Adugodi to Electronic City	7%	**LOS F**	09.30-10.30
		Dir-II: Electronic City to Adugodi		**LOS F**	

1.6.12 Traffic Volume Counts at Cordon Points

Nine cordon points were identified for an understanding of the traffic characteristics in the study area. The analysis of the classified volume count survey at the cordons is given in the sub-sections below. The total inbound and outbound traffic flow at each of the cordons is presented in Table below and daily traffic direction-wise on each cordon point is shown in Figure.

Table 16: Traffic Volume Counts at Cordon Locations

Sr. No.	Location	Direction	Daily Vehicles per Direction	Daily PCUs per Direction	Total Daily Vehicles	Total Daily PCUs
1	NH-44 Bellary Road (Near-Sakar Nagar)	Dir-I: Yelahanka to Hebbal	1,44,592	1,38,970	2,88,243	2,76,854
		Dir-II: Hebbal to Yelahanka	1,43,651	1,37,884		
2	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Nagavara park)	Dir-I: Bellary Road to Nagavara	1,17,553	1,13,677	2,22,323	2,12,544
		Dir-II: Nagavara to Bellary Road	1,04,770	98,867		
3	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Devinagar	Dir-I: Hebbal To Yashwantpur	74,262	74,124	1,39,793	1,40,205
		Dir-II: Yashwantpur To Hebbal	65,531	66,081		

Sr. No.	Location	Direction	Daily Vehicles per Direction	Daily PCUs per Direction	Total Daily Vehicles	Total Daily PCUs
	BEL Circle)					
4	AH-47 Malur Road (Near-Science Gallery)	Dir-I: Mekhri circle To Airport	1,28,808	1,22,070	2,46,077	2,32,456
		Dir-II: Airport To Mekhri circle	1,17,269	1,10,386		
5	Guttahalli Main Road (Near-Uniworth Plaza)	Dir-I: Mahalakshmi Gudi Circle To Bengaluru Golf Club	1,03,247	97,762	2,03,804	1,95,093
		Dir-II: Bengaluru Golf Club To Mahalakshmi Gudi Circle	1,00,557	97,332		
6	NR Road (Near-Silver Jubilee Park)	Dir-I: Kempegowda Tower To Chamrajpet	82,397	83,027	1,80,589	1,77,181
		Dir-II: Chamrajpet To Kempegowda Tower	98,192	94,154		
7	Siddapura Road (Near-Maharaja Agrasena Bhavana)	Dir-I: Ashoka Piller To Mallinge Hospital	31,705	28,716	65,075	58,422
		Dir-II: Mallinge Hospital To Ashoka Piller	33,370	29,706		
8	Marigowda Road (Near-National Institute of Mental Health & Neuro Sciences)	Dir-I: Dairy Circle To Wilson Garden	54,855	54,282	1,08,421	1,07,684
		Dir-II:Wilson Garden To Dairy Circle	53,566	53,402		
9	NH-44 Bengaluru-Chennai Highway (Near-Madiwala footbridge)	Dir-I: Adugodi To Electronic City	1,17,725	1,09,335	2,32,494	2,16,724
		Dir-II: Electronic City To Adugodi	1,14,769	1,07,389		

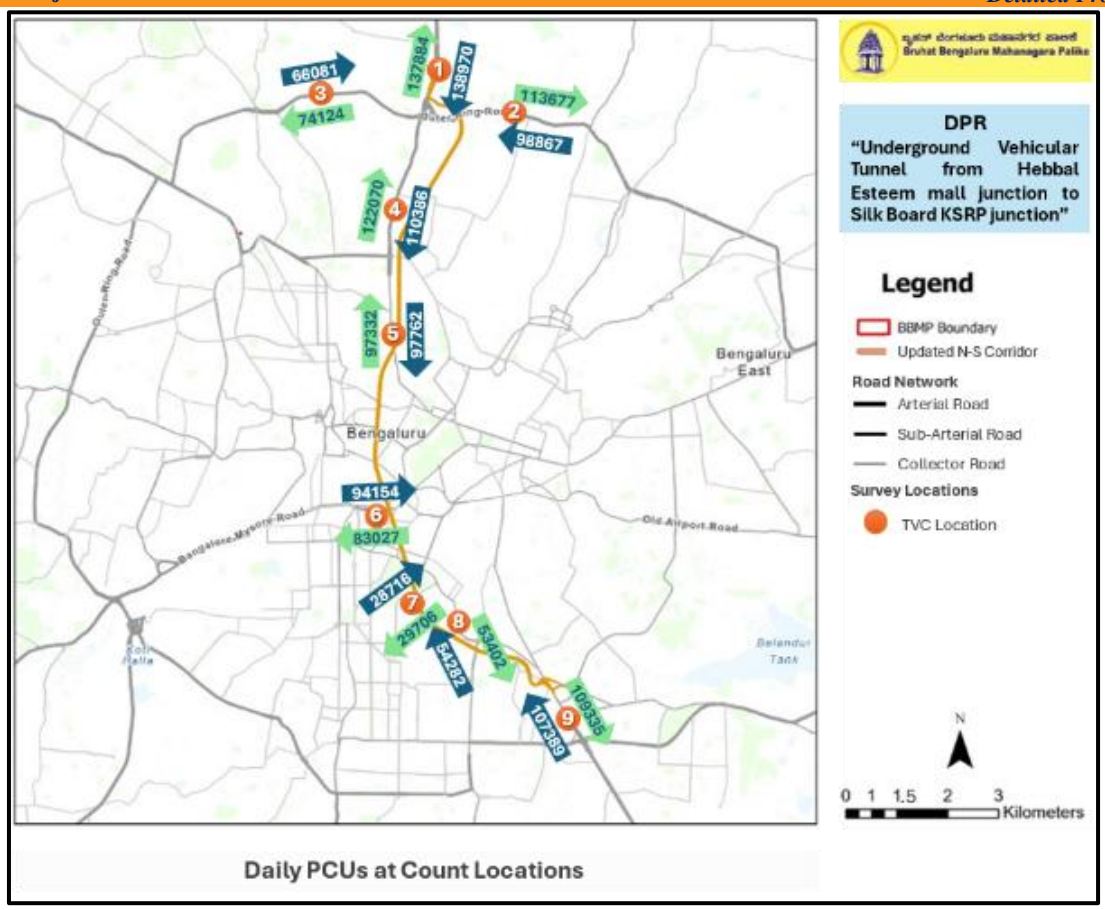


Figure 15: Existing Traffic Count at Survey Locations

1.6.13 Traffic Modelling and Level of Service on Project alignment

The North-South Corridor is proposed in Bengaluru to decongest the vehicular traffic congestion within the city. The diversion estimation for the proposed North-South Corridor is done considering the Modal Share prescribed in the Comprehensive Mobility Plan, 2020 to understand the amount of traffic that will be diverted to the proposed facility.

The diversion estimation was done on state-of-the-art software PTV Visum 2024 to model real-life scenario for realistic traffic evaluation through the input of the primary data as well as secondary data.

Error! Reference source not found. below shows the total mode-wise estimated trips for horizon year 2031 and 2041 for all three scenarios where Scenario 1 consists of the largest modal share of cars and Scenario 3 consists of the largest modal share of public transport due to which Scenario 1 has the highest number of car trips and Scenario 3 has the lowest number of car trips. All scenarios are referred to from CMP 2020.

Table 17: Estimated Total trips during morning peak hour.

	Year 2031			Year 2041		
Mode	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Auto Rickshaw	25111	23812	19859	29631	28098	23434
Two-Wheeler	153528	128708	100381	181163	151876	118449
Car	83005	72507	61168	97946	86211	72178

Further, all these three scenarios were evaluated considering toll and without toll conditions. In without toll condition, the Level of Service is compromised in the year 2031 for section 2 and 3 therefore it was not a viable option to be considered.

For with toll scenario, the average toll price considered for Car is Rs 19.42 /km. Considering this, for horizon year 2031 and 2041 all three scenarios were evaluated to understand the impact of the application

of toll in the proposed North-South Corridor. However, scenario 2 is considered as the reasonable scenario and it is considered for further evaluations.

The proposed corridor was divided into four sections based on the ramp locations. Table 18 shows section wise morning peak hour volume on the proposed corridor. It can be observed that all the sections of the corridor are having Level of Service B and C in horizon year 2031 and 2041. However, section 2 and 3 towards the Silkboard Junction has high volume in horizon year 2031.

Table 18: Assignment Results - Scenario 2 (Morning Peak Hour PCU) for 2031 and 2041 (with toll)

Assignment Results		Morning Peak Hour (PCU)			
		Year 2031 (With Toll)	LOS	Year 2041 (With Toll)	LOS
Section 1	Towards Airport	3038	LOS B	4015	LOS C
	Towards Bengaluru City	3067	LOS B	4242	LOS C
Section 2	Towards Airport	2053	LOS B	2679	LOS B
	Towards Bengaluru City	4914	LOS C	6294	LOS D
Section 3	Towards Airport	2823	LOS B	4049	LOS C
	Towards Bengaluru City	4343	LOS C	5552	LOS D
Section 4	Towards Airport	2479	LOS B	3215	LOS B
	Towards Bengaluru City	1758	LOS B	2263	LOS B

Table 19: The Level of Service on the Project Corridor during Morning Peak Hour

		2027-28	2031	2041	2051
	Location	LOS	LOS	LOS	LOS
Section 1	Towards Airport	LOS B	LOS B	LOS C	LOS C
	Towards Bengaluru City	LOS B	LOS B	LOS C	LOS D
	Ramp A (Main Exit)	LOS B	LOS B	LOS B	LOS B
	Ramp B (Main Entry)	LOS A	LOS A	LOS A	LOS A
	Ramp C (Service Exit)	LOS C	LOS C	LOS C	LOS D
	Ramp D (Service Entry)	LOS A	LOS A	LOS B	LOS B
	Ramp E	LOS A	LOS A	LOS B	LOS B
	Ramp F	LOS C	LOS C	LOS D	LOS F
	Ramp R	LOS C	LOS C	LOS C	LOS D
	Ramp S	LOS B	LOS B	LOS B	LOS C
	Ramp T	LOS B	LOS B	LOS C	LOS D
	Ramp U	LOS A	LOS A	LOS B	LOS C
Section 2	Towards Airport	LOS B	LOS B	LOS B	LOS B
	Towards Bengaluru City	LOS C	LOS C	LOS D	LOS F
	Ramp G	LOS A	LOS A	LOS A	LOS A
	Ramp H	LOS B	LOS B	LOS C	LOS C
	Ramp I	LOS B	LOS B	LOS B	LOS C
	Ramp J	LOS B	LOS B	LOS C	LOS D
	Ramp K	LOS C	LOS C	LOS D	LOS F
	Ramp V	LOS C	LOS C	LOS D	LOS E
Section 3	Towards Airport	LOS B	LOS B	LOS C	LOS D
	Towards Bengaluru City	LOS C	LOS C	LOS D	LOS E
	Ramp L	LOS A	LOS A	LOS A	LOS B
	Ramp M	LOS C	LOS C	LOS E	LOS F
Section 4	Towards Airport	LOS B	LOS B	LOS B	LOS C
	Towards Bengaluru City	LOS A	LOS B	LOS B	LOS B
	Ramp N	LOS A	LOS A	LOS A	LOS B
	Ramp O	LOS B	LOS B	LOS B	LOS C
	Ramp P	LOS B	LOS B	LOS B	LOS C

		2027-28	2031	2041	2051
	Location	**LOS**	**LOS**	**LOS**	**LOS**
	Ramp Q	LOS A	LOS A	LOS A	LOS A

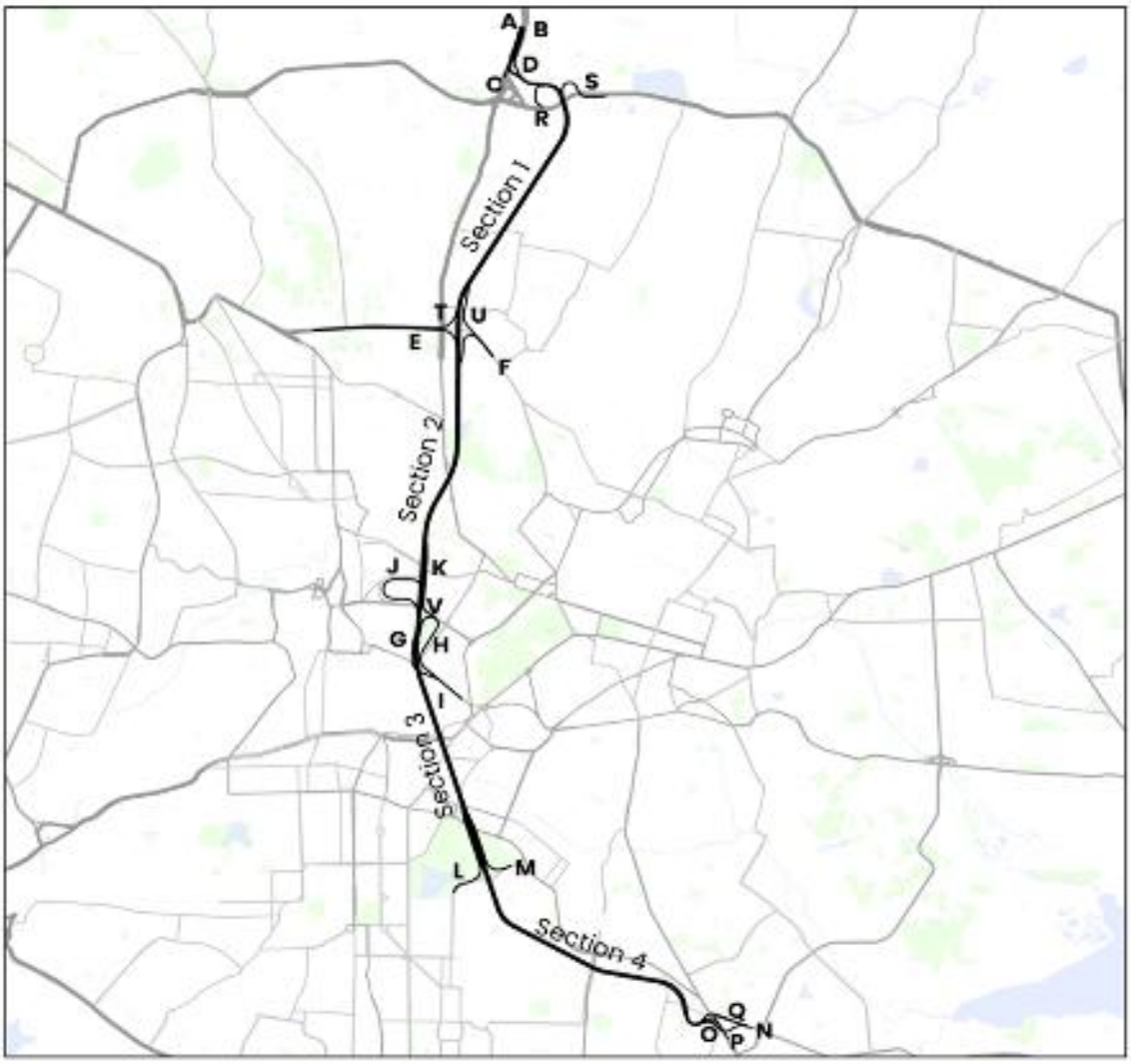


Figure 16: Sections for Level of Service Analysis

The detailed process of data collection, CMP-2020 incorporation in the project, Traffic analysis and traffic modelling through PTV Visum has been mentioned in detail in Traffic Chapter of Main Report.

1.6.14 Estimated Travel Time with Tunnel or Without Tunnel on Existing Road

Travel time analysis was conducted in the PTV Visum Model and a comparison of travel via the Existing route and the travel time via the Tunnel corridor is presented below.

Table 20: Estimated Travel Time Comparison - Without and With Corridor

Route	Length (in km) (without corridor)	Travel Time (without corridor)	Travel Time (with corridor)
Hebbal to Silkboard Junction	~18	~1 hr 12 min	~34 min
Silkboard Junction to Hebbal	~18	~1 hr 26 min	~34 min
Hebbal to Vidhan Soudha	~9	~30 min	~16 min

1.7 Development Proposals

These improvement proposals are based on the scope of the works, need to decongest the traffic between Hebbal to Sil Board aligned with findings of various engineering surveyed carried out on the project roads. The improvement proposals for proposed development include the following major items:

a) Main Tunnel (Twin tube Tunnel)

b) Cut & Cover Tunnel and Open Cut Ramps

c) Entry/ Exit ramps (NATM tunnel, Cut & Cover, Open Cut)

d) Cross Passage

e) Vertical Shaft

f) Traffic Control and Safety Measures

g) Drainage System

h) Lighting system

i) Ventilation system

j) Fire & safety system

k) Development of Intermodal Hubs

l) Proposal of Ev buses inside the tunnel

1.7.1 Design Standards

Geometric Design

Geometric design of a highway is the process whereby the layout of the road in specific terrain is designed to meet the needs of the road users keeping in view the road function, type and volume of traffic, potential traffic hazards and safety as well as convenience of the road users. The principal areas of control for fulfilment of this objective are- the horizontal alignment, vertical alignment and the road cross-section.

The Consultants have referred to the latest IRC publications and MORT&H circulars regarding design standards for National Highways in India. After careful review of all available data and requirements of the project road the proposed Design Standards for adoption on the project road have been recommended.

Design Speed

The project road passes through plain terrain. For geometric design of the highway, design speed is used as an index which links road function, traffic flow and terrain. An appropriate design speed should correspond to general topography and adjacent land use. The speed selected for design should also cater to travel needs and behaviour of the road users. For the design speed, Indian Highway Capacity Manual *(Indo-HCM)*-2012-17 published by the CRRI has been adopted. As the proposed tunnel corridor is for car and electrical buses, the proposed corridor has been considered as a Inter- urban expressway. The design speed of 80 KMPH for the main Tunnel and 50 KMPH for Ramps.

Levels of Service (LOS)

The Level of Service (LOS) characterizes the operating conditions on the roadway in terms of traffic performance measures related to speed and travel time, freedom to manoeuvre, traffic interruptions, and comfort and convenience. The levels of service range from level-of-service A (least congested) to level-of-service F (most congested). The Indian Highway Capacity Manual *(Indo-HCM)*-2012-17 Published by CRRI provides the following levels of service definitions: Considering the importance of the highway, whereas Level of Service (LOS) 'B' is desirable and level of service up to LOS- 'C' may be acceptable.

1.7.2 Main Tunnel

Main tunnel will be TBM tunnel which will be constructed by Tunnel boring machine. The launching and retrieval of TBM will be through shaft location. TBM section will be modified using NATM technique to accommodate additional lanes at entry/ exit intersections.

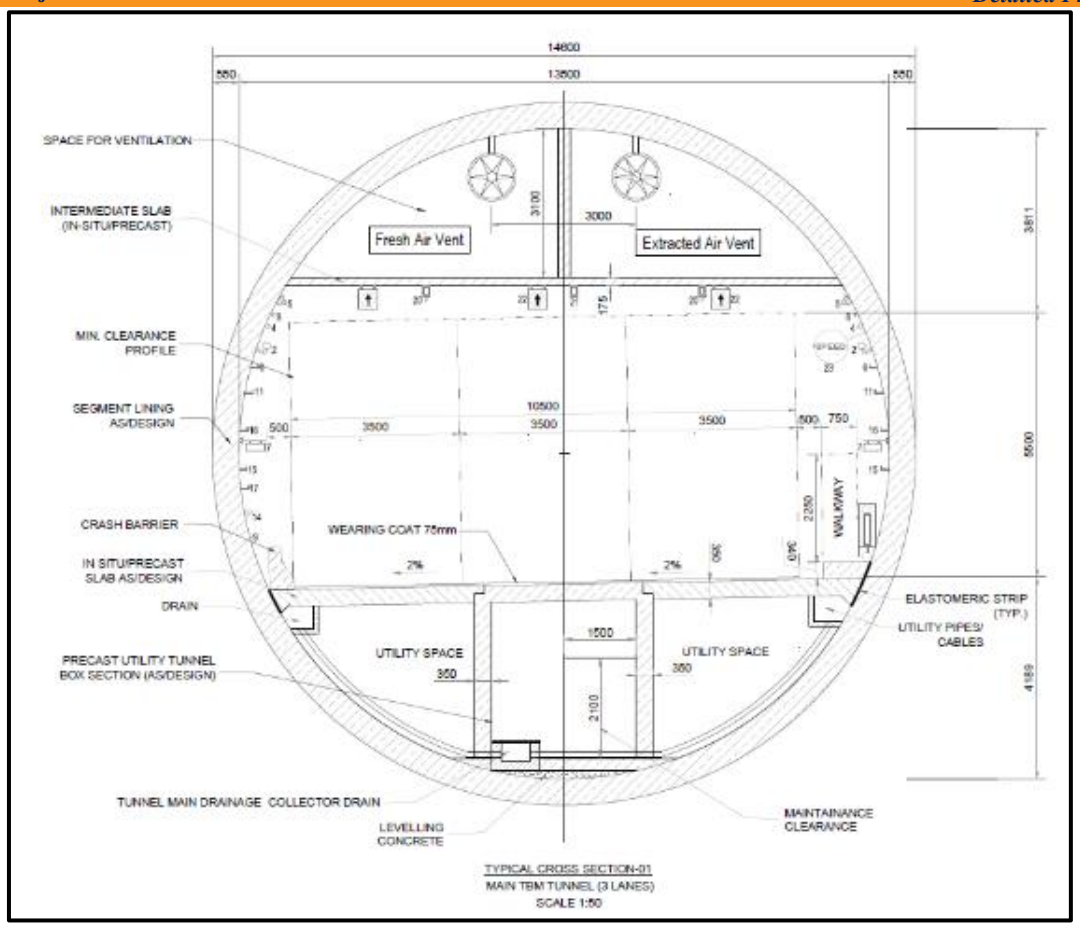


Figure 17: Typical Cross Section of TBM Tunnel

Lining Type and Geometry

The finished inner diameter for the Underground Vehicular Tunnel is 13.500m. Universal configuration of the segment is considered with 9+1 arrangement. The typical bored tunnel cross-section is shown in typical cross section given later in the chapter along with their TCS Schedule.

Design Considerations

The segments shall be designed to ensure that the full design life of 100 years. The design method for the analysis of the bored tunnel linings has been done considering the interaction between the lining and the ground, the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining, the variability and the compressibility of the ground, with this, the design shall take into account all additional loads, stresses and strains imposed by or on to adjacent Existing Building Structure (EBS).

The Loads acting on the lining include earth pressure, water pressure, dead load, reactions, surcharge & seismic forces. The lining shall also be checked to resist the various loads arising due to handling, stacking, temporary grout load pressure, TBM thrust, Load on Bolts & erector, gasket forces etc.,

The pre-cast concrete linings are designed in accordance with IS 456. However, other International Codes may be used in addition to the Indian Standard as and when required.

The Analysis methods, Material and design calculation is mentioned in Design Report which is submitted as Volume II-B

1.7.2.1 For NATM (new Austrian Tunneling Method) Tunnel

The NATM Tunnel has been proposed in the ramps location to make the project cost effective. There are two types of NATM sections proposed i.e., Regular Cross Section and Regular Cross Section (VCP) which are used for the project. The NATM Tunnel is details has been shown in typical cross section in details and their Schedules which are mentioned later in chapter.

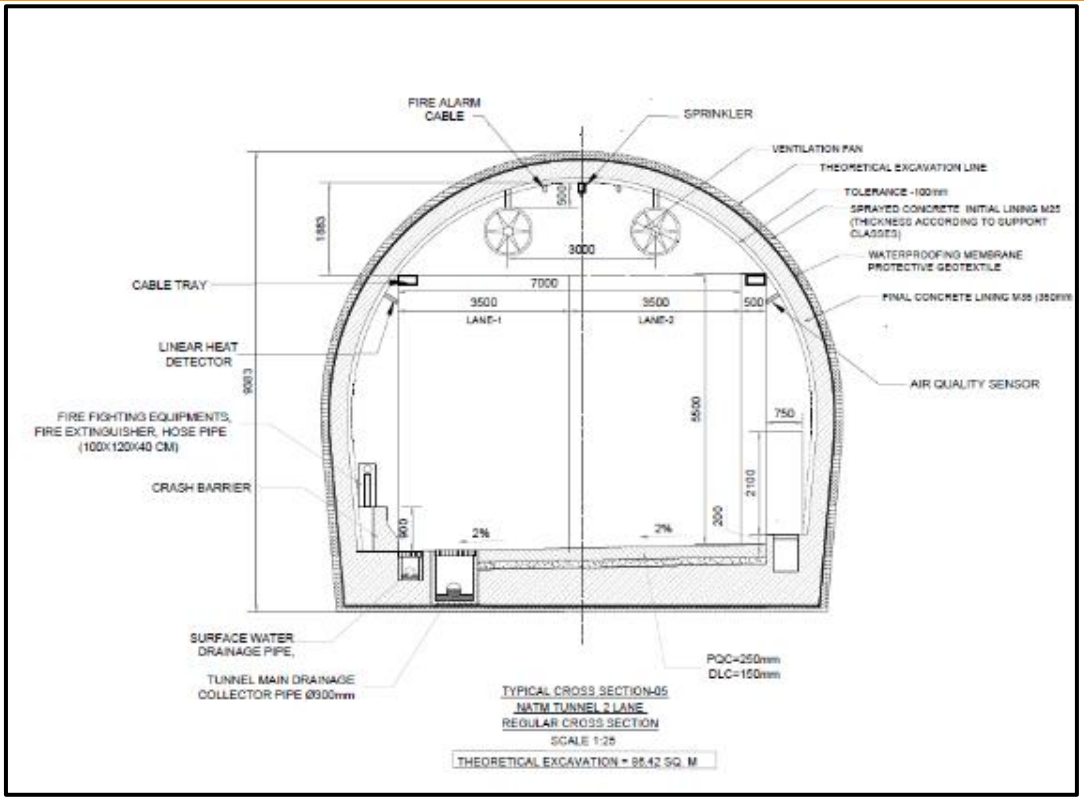


Figure 18: Typical Cross Section of NATM Tunnel

Design Considerations

The Tunnel tube is proposed to be constructed according to New Austrian Tunnelling Method (NATM) excavation in different weathering grade of rock mass. Ground excavations require the use of structural supports, to establish equilibrium and to limit the displacements around the excavation and at surface. The tunnel will be supported with primary support for temporary condition and a cast in-situ concrete as a permanent support. Primary support design has been done by considering site ground condition. The design has been performed for the combination of different load cases analyzed in Numerical Modelling Tools. The Analysis methods, Material and design calculation is mentioned in Design Report which is submitted as Volume II-B

1.7.2.2 Cut and Cover Section

The cut & cover tunnel has been proposed in approaches to the main tunnel and ramps. Different configuration (lane & height) of Cut & Cover Tunnel has been proposed as per the requirement. The Cut and cover can be reinstated after the construction.

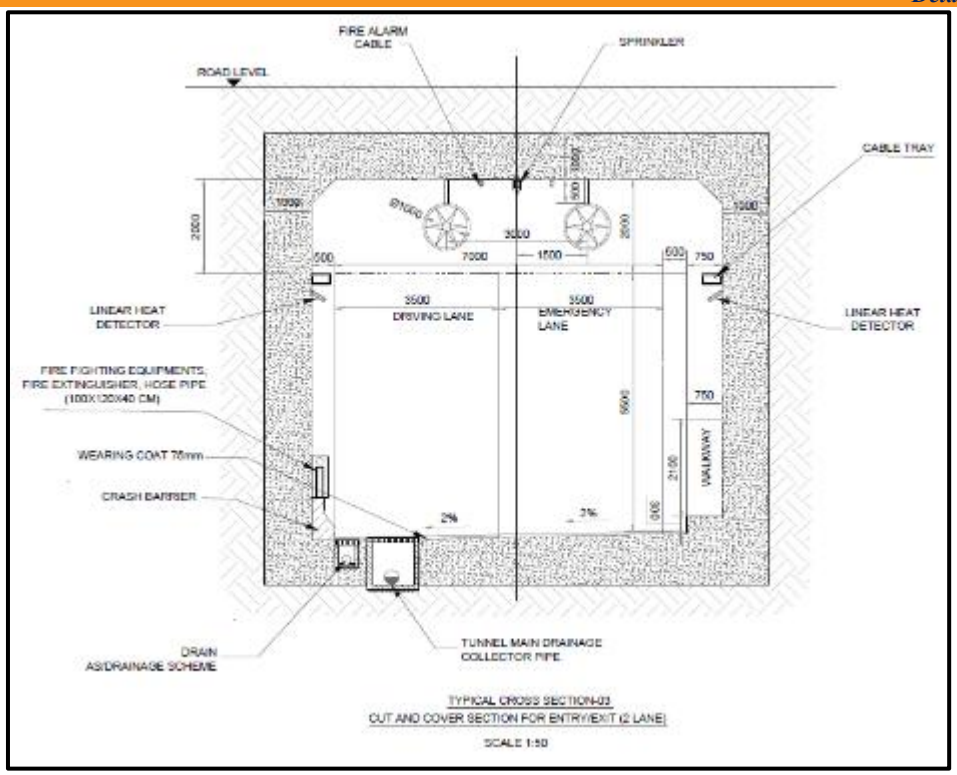


Figure 19: Typical Cross Section of Cut and Cover Section

The Analysis methods, Material and design calculation are mentioned in Design Report which is submitted as Volume II-B

1.7.2.3 Open Cut Section

The open Cut ramps have been provided in the approach of main tunnel and ramps.

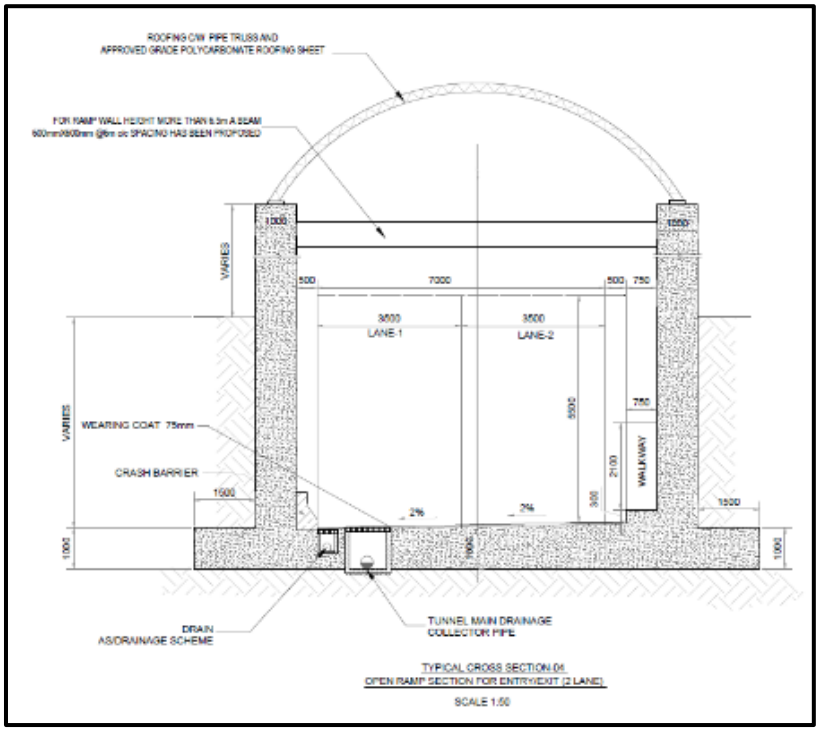


Figure 20: Typical Cross Section of Open Cut Section

The Analysis methods, Material and design calculation are mentioned in Design Report which is submitted as Volume II-B.

1.7.3 Typical Cross Section and TCS Schedule

The Typical Cross Section and Schedule has been prepared based on cross sectional width, type of tunnel (TBM Tunnel , NATM Tunnel and Cut & Cover Tunnel) and design requirements. The TCS Schedules have been provided separately for Package 1 and Package 2. The typical Cross Section are mentioned in Chapter 8 and Drawing volumes of the respective packages and its TCS Schedules are mentioned below.

1.7.3.1 Proposed Typical Cross Sections and TCS Schedule of Package 1

Typical cross section of the proposed section Main tunnel, Entry & Exit Ramps are as under:.

Table 21: TCS Schedule of Package 1

Main Tunnel with Entry and Exits						
At Hebbal Side						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
Portion Common at Hebbal Side to Tube-1 and Tube-2						
1	0+000	0+400	400	TCS-07	Open Cut	2+2 Lane
2	0+400	0+550	150	TCS-08	Cut and Cover	2+2 Lane
3	0+550	0+770	220	TCS-09	Cut and Cover	3+2 Lane
4	0+770	0+870	100	TCS-10	Open Cut	3+3 Lane
5	0+870	1+123	253	TCS-14	Cut and Cover	3+3 Lane
TBM Tunnel						
TBM Tunnel Tube 1 (Hebbal to Silk Borad)						
1	1+123	1+337	214	TCS-06	Cut and Cover	3 Lane
2	1+337	1+442	105	SHAFT	TBM SHAFT	
3	1+442	5+026	3584	TCS-1	TBM Tunnel	3 Lane
4	5+026	5+126	100	SHAFT	TBM SHAFT	
5	5+126	8+748	3622	TCS-1	TBM Tunnel	3 Lane
TBM Tunnel Tube 2 (Silk Borad to Hebbal)						
1	1+123	1+330	207	TCS-06	Cut and Cover	3 lanes
2	1+330	1+430	100	SHAFT	TBM SHAFT	
3	1+430	5+004	3574	TCS-1	TBM Tunnel	3 Lane
4	5+004	5+104	100	SHAFT	TBM SHAFT	
5	5+104	8+725	3621	TCS-1	TBM Tunnel	3 Lane
Intermediate Ramps						
Entry and Exit Ramps at Hebbal						
Entry Ramp 1 (Hebbal Service Road)						
1	0+000	0+100	100	TCS-4	Open Cut	2 Lane
2	0+100	0+341	241	TCS-4	Open Cut	2 Lane
1	0+000	0+150	150	TCS-3A	Cut and Cover	2 Lane
Entry Ramp 2 (From ORR To Main Tunnel Towards Silk Board/ Sarjapur road)						
1	0+000	0+140	140	TCS-4	Open Cut	2 Lane
2	0+140	0+200	60	TCS-3A	Cut and Cover	2 Lane
3	0+200	0+570	370	TCS-3	Cut and Cover	2 Lane
4	0+570	0+762	192	TCS-5	NATM Tunnel	2 Lane
5	0+762	0+814	52	-	In Shaft	2 Lane
Exit Ramp 7 (From Main Tunnel To ORR Towards ORR (Outer Ring Road))						
1	0+000	0+180	180	TCS-3	Cut and Cover	2 Lane
2	0+180	0+200	20	TCS-3A	Cut and Cover	2 Lane
3	0+200	0+415	215	TCS-4	Open Cut	2 Lane
Exit Ramp 8 (Hebbal Service Road)						
1	0+000	0+150	150	TCS-3A	Cut and Cover	2 Lane
2	0+150	0+548	398	TCS-4	Open Cut	2 Lane
Palace Ground						

Portion Common for Entry Ramps 3 and Exit Ramps 5						
1	0	170	170	TCS-11	Open Cut	2 x Intermediate Lane
2	170	290	120	TCS-12	Cut and Cover	2 x Intermediate Lane
Entry Ramp 03 (From Jaya Mahal Road)						
1	0+290	0+370	80	TCS-13	Cut and Cover	Intermediate Lane
2	0+370	0+871	501	TCS-15	NATM Tunnel	Intermediate Lane
Exit Ramp 5 (From Main Tunnel To Jaymahal Road Towards Jaymahal Road)						
1	0+290	0+370	80	TCS-13	Cut and Cover	Intermediate Lane
2	0+370	1+110	740	TCS-15	NATM Tunnel	Intermediate Lane
Portion Common to Entry 4 and Exit 6 (On CV Raman Road)						
1	0+000	0+260	260	TCS-11	Open Cut	2 x Intermediate Lane
2	0+260	0+310	50	TCS-12A	Cut and Cover	2 x Intermediate Lane
3	0+310	0+330	20	TCS-12	Cut and Cover	2 x Intermediate Lane
Entry Ramp 4 (From CV Raman Road to Main Tunnel Towards Hebbal)						
1	0+330	0+600	270	TCS-13	Cut and Cover	Intermediate Lane
2	0+600	1+945	1345	TCS-15	NATM	Intermediate Lane
Exit Ramp 06 (From Silk Board Towards C V Raman Road)						
1	0+330	0+600	270	TCS-13	Cut and Cover	Intermediate Lane
2	0+600	1+942	1342	TCS-15	NATM	Intermediate Lane

1.7.3.2 Proposed Typical Cross Sections and TCS Schedule of Package 2

Typical cross section of the proposed section Main tunnel, Entry & Exit Ramps are as under:

Table 22: TCS Schedule of Package 2

Main Tunnel with Entry and Exits						
TBM Tunnel						
TBM Tunnel Tube 1 (Hebbal to Silk Borad)						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
1	8+748	8+848	100	SHAFT	TBM SHAFT	
2	8+848	12+625	3777	TCS-1	TBM Tunnel	3 Lane
3	12+625	12+725	100	SHAFT	TBM SHAFT	
4	12+725	15+990	3265	TCS-1	TBM Tunnel	3 Lane
5	15+990	16+090	100	SHAFT	TBM SHAFT	
6	16+090	16+155	65	TCS-6	Cut and Cover	3 Lane
TBM Tunnel Tube 2 (Silk Borad to Hebbal)						
1	8+725	8+824	99	SHAFT	TBM SHAFT	
2	8+824	12+612	3788	TCS-1	TBM Tunnel	3 Lane
3	12+612	12+712	100	SHAFT	TBM SHAFT	
4	12+712	15+968	3256	TCS-1	TBM Tunnel	3 Lane
5	15+968	16+070	102	SHAFT	TBM SHAFT	
6	16+070	16+140	70	TCS-6	Cut and Cover	3 Lane
At Silk Board Side						
Portion Common to Tube-1 and Tube-2 At Silk Board Side						
1	**Tube-2 16+140** (Tube-1 16+155)	Tube-2 16+320 (Tube-1 16+315)	180	TCS-14	Cut and Cover	3+3 Lane
2	Tube-2 16+320 (Tube-1 16+315)	Tube-2 16+350 (Tube-1 16+345)	30	TCS-10	Open Cut	3+3 Lane
Tube 2 (Silk Board to Hebbal)						
1	16+350	16+571	221	TCS-4	Open Cut	2 Lane

Tube 1 (Hebbal to Silk Board)						
3	16+345	16+357	12	TCS-02	Open Cut	3 Lane
4	16+357	16+400	43	TCS-4	Open Cut	2 Lane
5	16+400	16+600	200	TCS-03A	Cut and Cover	2 Lane
6	16+600	16+745	145	TCS-4	Open Cut	2 Lane
Intermediate Ramps						
Exit and Entry Ramps at Silk Board.						
Entry Ramp 8 (From Sarjapur Road)						
1	0+000	0+190	190	TCS-4	Open Cut	2 Lane
2	0+190	0+390	200	TCS-03A	Cut and Cover	2 Lane
3	0+390	0+654	264	TCS-4	Open Cut	2 Lane
Exit Ramp 1 (Towards Sarjapur Road)						
1	0+000	0+050	50	TCS-4	Open Cut	2 Lane
2	0+050	0+250	200	TCS-03A	Cut and Cover	2 Lane
3	0+250	0+455	205	TCS-4	Open Cut	2 Lane
At Racecourse						
Freedom park / Seshadri Road (Exit 3& 4)						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
Common Ramp for Entry and Entry 6 from District Officer Road (CSI Hudson Memorial Church)						
1	0+000	0+130	130	TCS-02	Open Cut	3 Lane
2	0+130	0+162	32	TCS-06	Cut and Cover	3 Lane
Entry Ramp 5 (Towards Hebbal Junction)						
1	0+162	0+270	108	TCS-03	Cut and Cover	2 Lane
2	0+270	1+197	927	TCS-05	NATM Tunnel	2 Lane
Entry Ramp 6 (Towards Silk Board Junction)						
1	0+162	0+270	108	TCS-03	Cut and Cover	2 Lane
2	0+270	1+783	1513	TCS-05	NATM Tunnel	2 Lane
Portion Common to Exit Ramp-5 & Exit Ramp 6						
1	0+840	1+141	301	TCS-02	Open Cut	3 Lane
2	0+820	0+840	20	TCS-06A	Cut and Cover	3 Lane
3	0+790	0+820	30	TCS-06	Cut and Cover	3 Lane
Exit Ramp-4 (From Hebbal Towards KR Circle On Seshadri Road)						
1	0+000	0+610	610	TCS-05	NATM	2 Lane
2	0+610	0+790	180	TCS-03	Cut and Cover	2 Lane
Exit Ramp-3 (From Silk Board KR Circle On Seshadri Road)						
1	0+000	**0+575**	575	TCS-05	NATM	2 Lane
2	**0+575**	1+465	890	TCS-03	Cut and Cover	2 Lane
At Lalbagh						
Exit Ramp 2 (Towards Siddapura Road near Wilson Garden)						
1	0+000	0+900	900	TCS-05	NATM Tunnel	2 Lane
2	0+900	0+960	60	TCS-03	Cut and Cover	2 Lane
3	0+960	1+081	121	TCS-04	Open Cut	2 Lane
Entry Ramp 7 (From Siddapura Road near Ashok Pillar)						
1	0+000	0+130	130	TCS-04	Open Cut	2 Lane
2	0+130	0+160	30	TCS-03A	Cut and Cover	2 Lane
3	0+160	0+410	250	TCS-03	Cut and Cover	2 Lane
4	0+410	1+416	1006	TCS-05	NATM	2 Lane

Note: The TCS Schedule is to be read along with Drawing Volume.

Typical Cross Sections have been presented in Chapter 8 of this report and Drawing Volume of the DPR

1.7.4 Tunnel clear space

The clear distance between the twin tubes shall be kept depending upon the type of strata and structural

stability of the tunnel subject. However, the c/c spacing between the twin tubes shall not be less than two times the diameter of tunnel.

Clear distance between both tunnel: 15.4 m

C/C distance between both Tunnel: 30 m

1.7.5 Cross Passages

As per IRC:SP:91-2019 the twin tube tunnels shall be connected by a cross passage at every 500 m for emergency evacuation in the event of an incident/accident in one of the tubes. The cross passage shall have provision for one traffic lane, edge strip of 0.60 m, crash barriers and walkways on either side. In normal conditions the cross passage shall be closed.

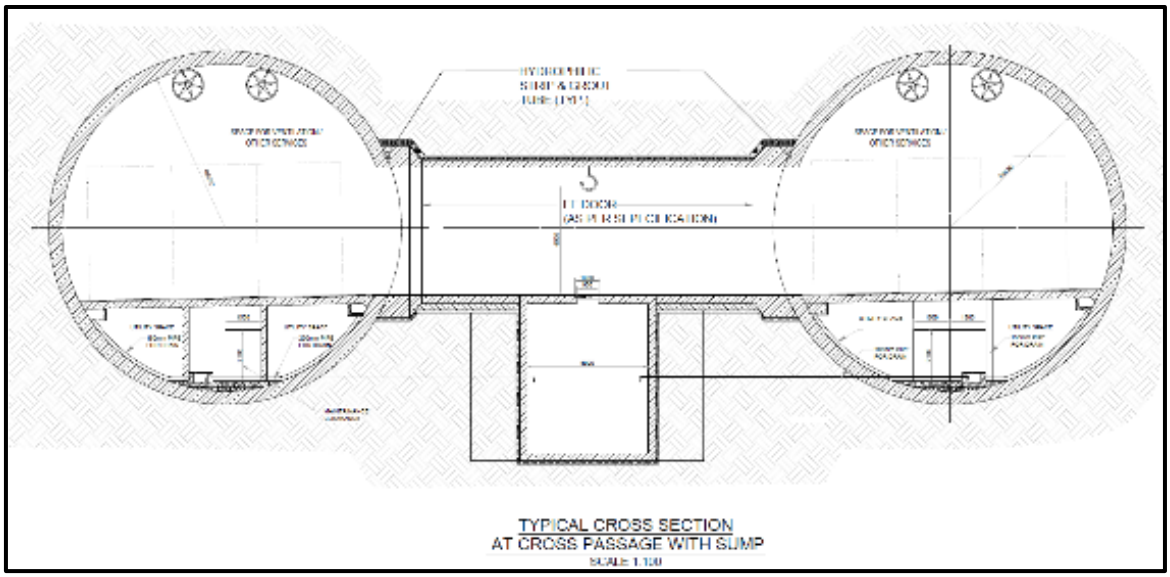


Figure 21: Typical Cross Section for Tunnel Cross Passage

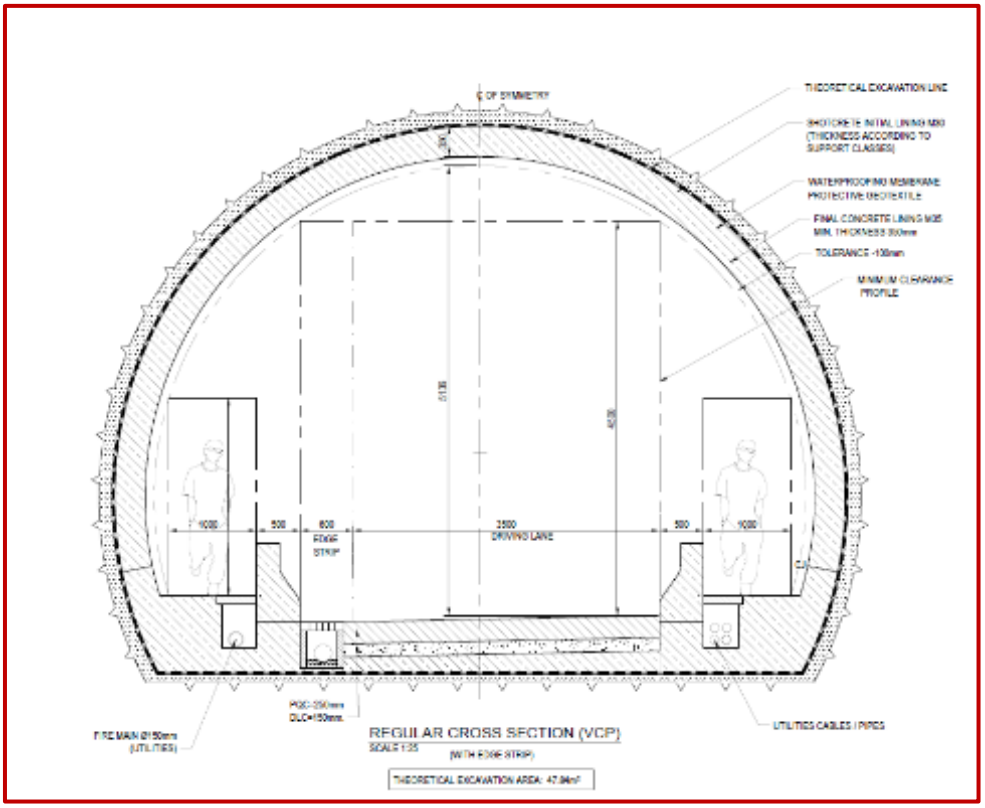


Figure 22: Typical Cross Section for Tunnel Cross Passage

1.7.6 Launching and Retrieval Shafts (TBM Shafts)

A vertical shaft for a tunnel is a critical infrastructure component that connects the surface to underground passageways, serving multiple essential functions. Primarily, it provides access for workers and equipment, enabling the efficient movement of personnel and materials to and from the tunnel. Additionally, these shafts play a vital role in ventilation, ensuring a continuous flow of fresh air to maintain safe working conditions below ground. The design of a vertical shaft typically considers factors such as depth, diameter, and structural integrity, often employing methods like drilling and blasting or cut-and-cover techniques for construction. Safety is paramount, with rigorous monitoring for ground stability and water ingress, as well as clear emergency egress routes for personnel. Overall, vertical shafts are indispensable in facilitating safe and efficient underground operations in tunneling projects.

A total of 5 TBMs shafts are proposed out of which 2 shafts are proposed in Package and 3 shafts in package 2 . Each of the shafts have an area of about 100 m x 50 m.

Table 23: TBM Shaft Locations

	Tube 1		Tube 2	
	Start	**End**	**Start**	**End**
Shafts in Package 1				
Shaft 1	1+337	1+442	1+330	1+430
Shaft 2	5+026	5+126	5+004	5+104
Shafts in Package 2				
Shaft 3	8+748	8+848	8+725	8+824
Shaft 4	12+625	12+725	12+612	12+712
Shaft 5	15+990	16+090	15+968	16+070

1.7.7 Inter Model Interchange Hubs:

Intermodal interchange hubs for buses in tunnels are specialized facilities designed to facilitate the efficient transfer of passengers between different modes of transportation, particularly in urban settings where space is limited. The Hubs are designed to accommodate bus services alongside other transport modes, such as metros and public transport. Interchange hubs have well-planned layouts to ensure smooth passenger movement, minimizing congestion and wait times. Features may include escalators, elevators, and clear signage. Intermodal interchange hubs for buses in tunnels are essential for enhancing urban transit efficiency, safety, and sustainability, ultimately improving the passenger experience and contributing to a more effective transportation network.

Following are the guiding principles for designing of intermodal interchange:

1. **Safety and Accessibility:** Ensure the station is safe and easily accessible for all passengers. This includes designing clear and simple navigation, providing adequate lighting and signage, and incorporating safety features such as emergency exits, fire alarms, and CCTV surveillance.
2. **Efficient Passenger Flow:** Design the station to facilitate efficient passenger flow and minimize congestion. This can be achieved by providing sufficient platform width, designing clear and intuitive routes for passengers, and incorporating features such as escalators, staircases, and elevators to facilitate easy movement between levels.
3. **Comfort and Amenities:** Create a comfortable and welcoming environment for passengers by incorporating amenities such as comfortable seating, clean and well-maintained facilities, and convenient services like Wi-Fi, charging stations, and retail outlets.
4. **Sustainability and Resilience:** Design the station with sustainability and resilience in mind. This includes incorporating energy-efficient systems, using durable and low-maintenance materials, and designing the station to withstand natural disasters and other potential disruptions.
5. **Aesthetic Appeal and Community Integration:** Create a visually appealing and unique design that reflects the local community and culture. This can be achieved by incorporating public art, using locally inspired materials and design elements, and designing the station to integrate seamlessly with the surrounding neighbourhood.

1.7.7.1 Need for the Intermediate Stations

The intermediate stations at Hebbal Junction and Mekhri Circle. These stations are strategically located near major urban and transit hubs to maximize connectivity and usage. They are designed to provide essential passenger amenities, including retail spaces, waiting areas, ticketing counters, and restrooms, ensuring a comfortable and user-friendly commuting experience. Parking facilities at these stations accommodate private vehicles, encouraging park-and-ride behaviour and reducing surface-level congestion, especially at high-traffic areas like Hebbal Junction and Central Silk Board.

In addition to passenger convenience, these stations support the operational requirements of the tunnel system. They house essential services and utilities such as power, ventilation, and drainage, while also acting as monitoring and maintenance hubs. The stations also facilitate traffic redistribution by offering an efficient alternative to road-based transport, alleviating notorious traffic bottlenecks at places like Mekhri Circle.

Moreover, these stations are designed to integrate seamlessly with Bengaluru's broader transportation network, enhancing multimodal connectivity. For instance, Hebbal Junction , being major transit nodes, will connect the tunnel system with buses, metro, and rail, supporting regional mobility. The inclusion of retail spaces and commercial activities promotes Transit-Oriented Development (TOD), transforming these stations into vibrant urban nodes while generating additional revenue through public-private partnerships. This revenue offsets project costs and boosts economic viability.

The intermediate stations not only ensure the functional success of the tunnel project but also contribute significantly to Bengaluru's urban development by improving mobility, reducing congestion, enhancing safety, and fostering sustainable transit practices. They exemplify a holistic approach to urban infrastructure that prioritizes both commuter convenience and the city's long-term development goals.

1.7.7.2 Details about the Facilities

a) **Podium-Level Features**

- **Bus Stands**: Dedicated bays for BMTC buses, ensuring smooth boarding and alighting processes.
- **Auto and Taxi Stands**: Organized areas to facilitate last-mile connectivity, reducing road clutter and enhancing commuter convenience.
- **Skywalk**: Connecting the Shaft at Mekhri circle and the Nearest metro station, which help in the movement of Pedestrian and also buggies.
- **Retail and Commercial Spaces**: Shops, kiosks, food courts, and essential service outlets to cater to daily commuter needs and generate economic activity.
- **Landscaped Plazas**: Open areas with green spaces, seating, and pedestrian pathways to create a relaxing urban environment.
- **Drop-Off Zones**: Designated zones for private vehicles and shared mobility options for quick and efficient passenger movement.

b) **Parking Infrastructure**

- **Car Parking**: Ample parking facilities for four-wheelers and two-wheelers (at podium level), with separate zones for short-term and long-term parking.
- **EV Charging Stations**: Dedicated spaces for electric vehicle charging to promote sustainable mobility.

c) **Safety and Accessibility Features**

- **Emergency Exits**: Strategically placed and clearly marked escape routes for quick evacuation during emergencies.
- **Surveillance Systems**: CCTV cameras and security personnel to ensure passenger safety.
- **Universal Accessibility**: Elevators, escalators, ramps, and tactile pathways for differently-abled

and elderly passengers.

1.7.7.3 Facilities Inside the Shaft

a) **Ventilation Systems**

- **Air Quality Management**: Advanced ventilation systems to maintain optimal air quality within the tunnel and shafts.
- **Exhaust Systems**: High-capacity exhaust systems to remove pollutants and ensure safe air circulation.

b) **Emergency Infrastructure**

- **Fire Suppression Systems**: Fire detection and suppression systems to handle emergencies effectively.
- **Emergency Lifts**: High-capacity lifts for evacuation and movement of personnel and equipment.

c) **Utility Services**

- **Power Supply Systems**: Backup power generators and uninterrupted power supply units.
- **Water Management**: Systems for drainage, potable water supply, and firefighting water reserves.
- **Communication Systems**: Intercoms and emergency communication systems for coordination during critical situations.

1.7.7.4 Conceptual Layout plan of intermediate stations (at Shaft Location):

Figure 23: Conceptual Layout at Hebbal

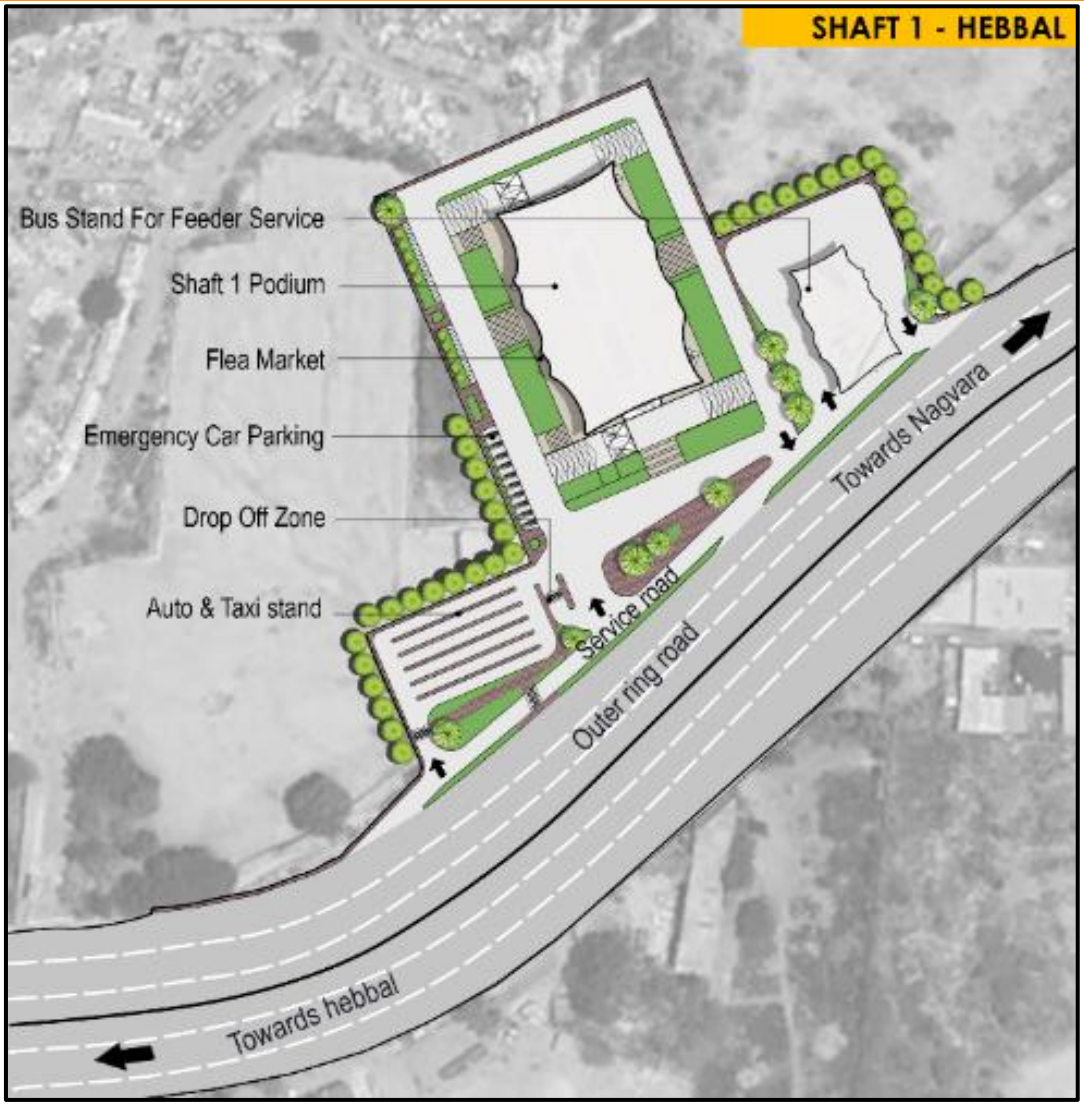


Figure 24: Shaft 1 at Hebbal

Figure 25: Conceptual Layout at Mekri Circle

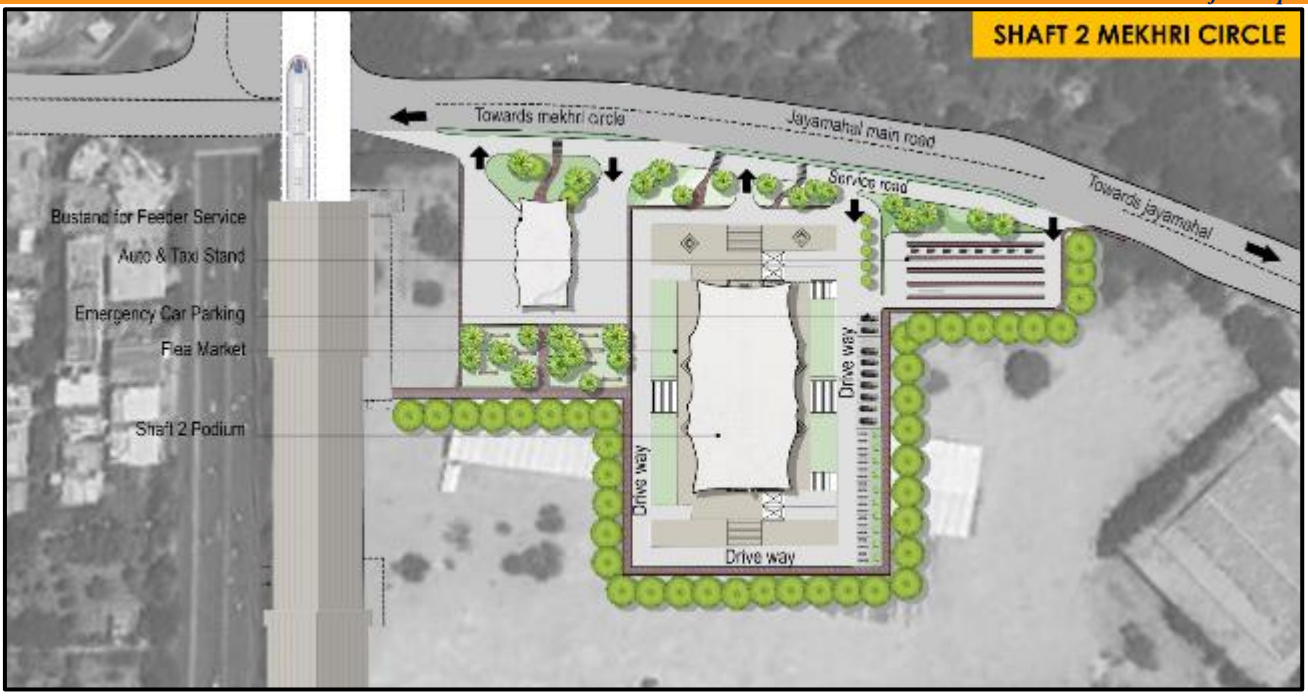


Figure 26: Shaft 2 at Mekri Circle

Figure 27: Conceptual Layout at Race-Course

Figure 28: Shaft 3 at Race-Course

Figure 29: Conceptual Layout at Lalbagh

Figure 30: Shaft 4 at Lalbagh

Figure 31: Conceptual Layout at Silk Board

Figure 32: Shaft 5 at Silk Board

1.7.7.5 EV Buses

The Ev buses have been planned to circulate inside the Tunnel with station at Hebbal and Mekri Circle. The passenger can enter and exit from the intermediate station planned at a shaft location. This will facilitate additional high speed public transport without any interruption to the surface traffic. These buses will have charging facilities at Hebbal & Silk Board shaft Location. The bushes will have amenities like WIFI, separate screen for each passenger etc.

1.7.7 Design Proposal

Table 24: Geometric Design Criteria adopted (IRC 86-2018)

SL	Description	Details
1	Design Speed (Main Tunnel) Design Speed (Ramps)	80 KMPH 50 KMPH
2	Lane Configuration on each tube (Main Tunnel)	3 lane
3	Single lane width	3.5 m
4	Kerb Syness	0.5m
5	Lane Configuration of ramps (entry & exit)	2 lane
6	Radius of Horizontal Curve	400 m min.
7	Max. Super elevation	5%
8	Intermediate Sight Distance	240m
10	Minimum length of Vertical curve	60m
11	Cross fall camber	2.0%
12	Vertical clearances	5.5m
13	Vertical Gradient	
13A	Transition Ramp and Cut & Cover (adopted)	3-6%
13B	Tunnel	3% max.
14	Tunnel Finished Dia.	13.500m
15	Cross Passage @ 500m interval Cross Passage for Electrical Sub Station Carriageway	26 Nos. 19 Nos. 3.5m

SL	Description	Details
	Edge Strip	0.6m
	Crash Barrier	2 x 0.5m
	Walkway	2 x 1.0m

1.7.8 Safety Measures

For the safety during fire in tunnel safety measures via ventilation system is being proposed. The proposals for Road and Tunnel Markings, Smart traffic signs (VMS- Variable Message Sign Boards), Solar lights, CCTV Surveillance, Road Studs, Lights, Cat's Eye etc. as per IRC.

1.7.9 Traffic Control and Safety Measures

Road Marking & Traffic Signs

Road markings will be made for centre and edge lines using reflective thermoplastic paints. Appropriate road markings will be provided at junctions and crossings. Road signs are to placed according to IRC: 67-2022. The signs will be placed on embankment so that extreme edge of sign would be 2.0 m away from the edge of the carriageway. The location of each sign is to be decided in accordance with the guidelines their in.

Illumination

Tunnel illumination/lighting shall be designed and provided as per MoRTH Guidelines for

Expressway, Chapter 13.5 for Tunnel Lighting.

Tunnel Furnishing

Provisions shall be made for installation of tunnel furnishing such as sign boards, firefighting arrangements, cable trays for telephone and power lines etc. in consultation with relevant local authorities.

Signages and Carriageway Markings

Variable messages signs inside the tunnel shall be provided for the information of traffic of lane blockage/closure due to incidents related to vehicles/non-vehicles, weather and human hazards etc. or maintenance operations as also to warn of possible hazard ahead due to any abnormal situation. Signage system shall be complemented by providing traffic lights above each lane at the entry portal end and inside. Signages indicating distance travelled, distance/ direction to an exit on evacuation route shall be provided inside the tunnel.

Tunnel carriageway markings consisting of a discontinuous line separating the traffic lanes and continuous line separating the lateral traffic lane from the paved shoulder, shall have good day/night visibility and conform to IRC:35. The markings shall be done by means of self-propelled machine which has a satisfactory cut-off capable of applying broken line automatically.

1.7.10 Ventilation

Tunnel ventilation systems of fully transverse type is provided in the main tunnel where fresh air will be injected through vent and polluted/ smoked air exhausted out through vent. Separately, the tunnel ventilation capacity requirements for emergency ventilation (typically for the control of smoke and hot gases during fire) must also be assessed and the system designed accordingly.

Detailed design of ventilation was carried out as per IRC: SP:91-2019, PIARC and others applicable European Standards, keeping in view the length, shape, size, tunnel environs and complexion of the likely traffic for which tunnel has been designed. The details of design of Tunnel Ventilation system is provided in Volume II-D.

The ventilation system is designed considering two aspects on the basis of IRC: SP:91-2019 guidelines:

- Dilution of pollutants such as CO, NOx, and PM in congestion scenarios under normal operating conditions.
- Effective suppression of fire, removal of smoke and safe evacuation of the people and vehicles during a fire scenario.

The emission rates are calculated for a combination of 100 % PCUs. Air flow rate through each section to dilute this emission is estimated by considering the maximum flow rate required. In the present case this is obtained for NOx. Then both the longitudinal and fully transverse systems were considered for design. Considering the length of the tunnels and requirement for immediate local extraction of the smoke during a fire, a fully transverse system with two ducts (one for fresh air and the other for exhaust air) is recommended for the current design in the main tubes between ventilation stations. While for the entry and exit ramp sections, the longitudinal system is recommended. The air flow rate, power and separation distance of the fans are calculated for the longest section (length ~ 3.82 km) with maximum possible air flow requirement and these are used for the whole system based on the conservative approach. Two ventilation blocks between the ventilation stations are taken to reduce the air flow rate and hence the power requirement. Provision for the fans in the cross-passages (every 500 m in the main tunnel) is also made.

1.7.11 Fire safety

The following facilities is provided in the tunnel which will be active during Operational phase as a fire Safety Considerations:

- **Smoke detection systems:** Early fire detection systems are essential to activate the ventilation system promptly in case of a fire and the same has been provided here.
- **Fire suppression systems:** Automatic sprinkler systems or other fire suppression methods to be installed to contain a fire in its early stages.
- **Emergency evacuation routes:** Clear and well-marked escape routes are crucial for safe evacuation during a fire. The cross passage has been provided for escape route.

1.7.12 SCADA System:

The SCADA (Supervisory Control and Data Acquisition) system is provided in this tunnel which will enable efficient monitoring and controls for various aspects of the tunnel's operations, including ventilation, lighting, traffic management, fire detection, and emergency systems, allowing operators to remotely manage the tunnel's functionality and respond to potential issues in real-time from a central control room located at shaft location. The key function of SCADA is as under-

Monitoring:

- Sensor data collection from throughout the tunnel, including air quality, temperature, humidity, CO levels, water leaks, and equipment status.
- Monitoring traffic flow and vehicle speeds.
- Surveillance camera feeds for visual observation

Control:

- Adjusting ventilation fan speeds based on air quality conditions.
- Regulating lighting levels depending on time of day and traffic conditions.
- Activating emergency systems like fire alarms, sprinklers, and evacuation procedures.
- Managing traffic control systems like variable message signs and lane closures.

Benefits of a tunnel SCADA system:

Enhanced safety:

Real-time monitoring and control of critical systems can help to prevent accidents and quickly respond to emergencies.

Operational efficiency:

Optimized ventilation and lighting based on traffic conditions can lead to energy savings.

Improved maintenance:

Early detection of potential issues allows for preventative maintenance and minimizes downtime

1.8 Preconstruction Activities

- Land Acquisition: The land acquisition will be required at tunnel approaches in cut & cover section and open cut section and multimodal hub including TBM launching Shaft Locations to be carried out by BBMP. DPR Consultant will provide LA Plan (on revenue map) and schedule (Titles of the land parcels) in due course of time for the land parcels indicated in Land Plan.
- The cost for Land acquisition and rehabilitation in cut & cover section has been considered in cost estimate on Lump Sum basis as per discussion held with all stakeholders.
- Utility Shifting: The utilities shifting (Electrical, Tele communication and PHED) at the approach of the main tunnel approaches in cut & cover section and open cut section and multimodal hub including TBM launching Shaft Locations. The cost for shifting utilities has been considered in cost estimate on Lump Sum basis.
- Trees relocation: The tree cutting or relocation number will be finalized after completion of land acquisition schedules and joint measurement survey of forest department and revenue department, compensation/CA will be as per state policy. The cost for tree relocation and felling has been considered in cost estimate on Lump Sum numbers of the trees.
- In addition to the available data from other projects along the alignment DPR consultant has carried out Geological survey, Geo physical investigations. The intrusive investigations are being carried out. All these information are indicative and will be included in bid document for information to the prospective bidders. However, the bidders are expected to carry out their own assessment on the basis of information available and investigations carried out by themselves.

1.9 Environmental Impact Assessment

As per EIA notification S.O-1533 Dt 14th September 2006 of Ministry of Environment and Climate Change and its subsequent amendments under the Environment (Protection) Act,1986. “Tunnel” is not covered under the Regulations of 2006. referred to Entry No. 7(f) i.e., ‘Highways’ – (both National Highways or State Highways). Therefore, the proposed Underground Tunnel is not required to secure environmental clearance in the form of an approved EIA from the Ministry of Environment, Forest and Climate Change (MOEFCC) per national policies and Regulations.

As per S.O-2559(E) of 22nd August 2013 (as amendment of 14th September 2006) whereas the Committee has submitted its report to the Ministry and on this ToR, the Committee has recommended exempting highway expansion projects from the requirement of scoping and that Environmental Impact Assessment or Environment Management Plan for highway expansion projects may be prepared on the basis of model ToRs to be posted on Ministry’s website and in respect of requirement of environmental clearance, the Committee has recommended that expansion of National Highway projects up to 100 kms involving additional right of way or land acquisition up to 40 mts on existing alignments and 60 mts on re-alignments or by-passes may be exempted from the preview of the notification” The Proposed tunnel alignment Start and End of NH-44 and Right of Way within 60 Mtr Except Interchange Ramps/Loops/Toll Plaza. Hence Environmental Clearance Exempted from preview of EIA notification 2006 and its amendment.

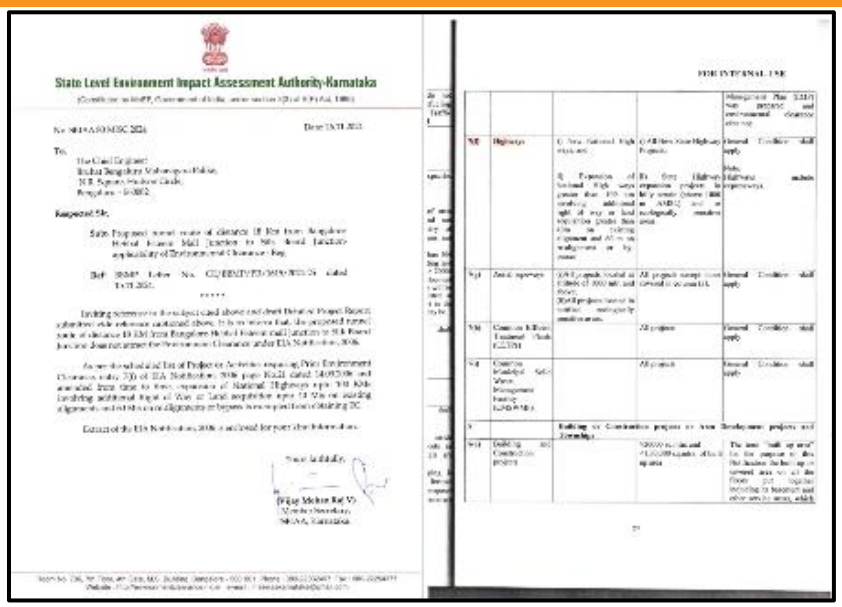

State Level Environment Impact Assessment Authority-Karnataka

Figure 33: State Authority Letter Reg. Environment Clearance

1.10 Construction Time and Phasing

The project is proposed to be completed in 50 months considering methodology of construction and the time required for procurement, transportation, mobilization and initial drive of Tunnel Boring Machines (TBM). It is presumed that 4 TBMs shall be driven for each package simultaneously.

The preliminary workplan has been attached as an Annexure.

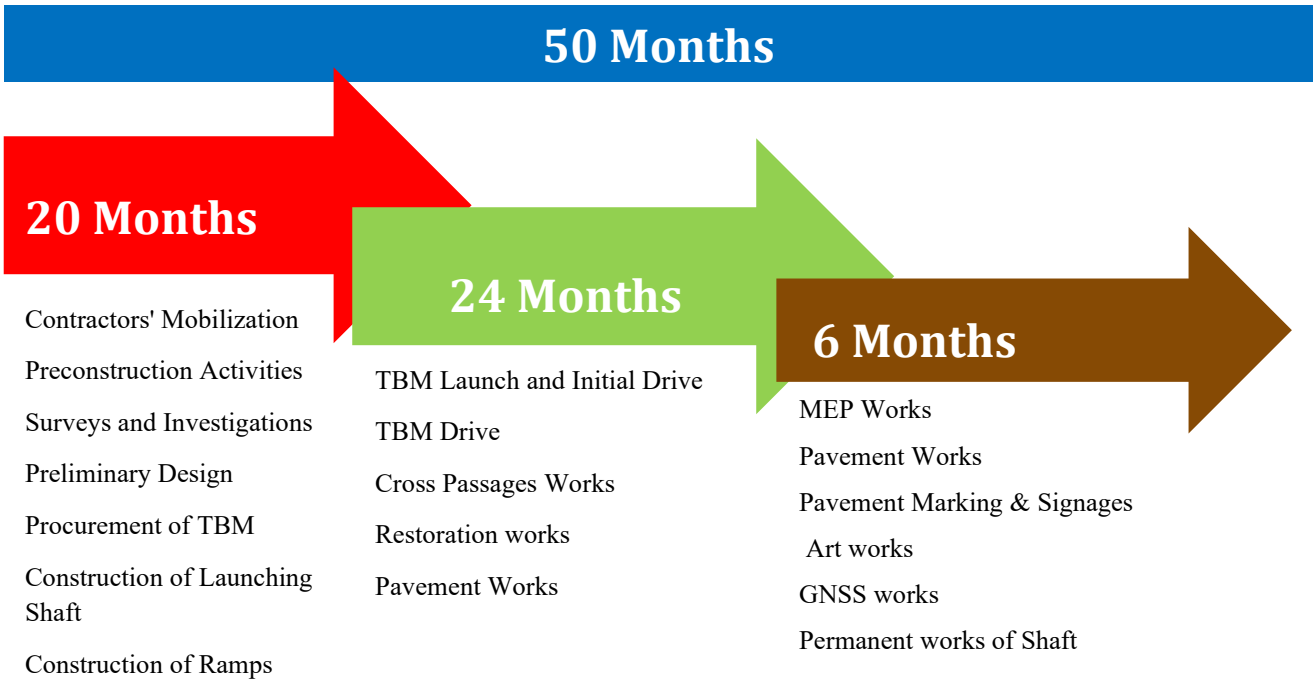


Figure 34: Phasing and Construction Time

1.11 Cost Estimate

1.11.1 General

Cost estimation is an important component of the study as it provides vital input & financial evaluation and insights for proper planning of project execution. Over and above construction costs, provision has been made for land acquisition social and environmental mitigation measures. Cost Estimates are done based on the detailed engineering designs and detailed drawings presented in drawing volume.

1.11.2 Methodology

The cost of the tunnel, cut & cover and open cover sections has been worked out based on the cross-sections and the plan and other drawings for the project.

Tentative locations for TBM lowering shaft have been identified and suitably quantified for the cost estimation. The quantification of various items of work related to tunnels have been detailed out from the structural drawings.

Quantities of traffic signs, marking and other road appurtenances and various project facilities are worked out in the plan drawing and costing has been accordingly.

1.11.3 Unit Rates of Materials

The Rates of materials for different components of project is referred from the government issued data and prevailing market rates.

- SOR 2023-24 Karnataka for Zone 1
- Some rates have been taken from similar referral projects and market rates.
- Rate of special components such as TBM, Tunnel Ventilation and firefighting systems, Lighting and electrical components are taken from market.

1.11.4 Summary of Cost Estimate

Table 25: Summary of Cost for Package 1

Item No.	Description	Total Amount (Rs.)
BILL NO. 1	Site Clearance	60,10,749
BILL NO. 2	**Tunnel Work**	
A	**Main Tunnel**	
a.	Tunnelling By TBM	45,89,80,77,332
b.	Cross Passages	26,73,67,124
c.	Cut And Cover Tunnel	3,06,19,00,476
d.	Open Cut (Ramps)	53,69,34,960
e.	Shafts (2 No's)	93,43,11,771
B	**Intermediate Entry/Exit**	
a.	NATM Tunnel	3,13,89,84,309
b.	Open Cut (Ramps)	1,21,87,99,719
c.	Cut And Cover Tunnel (2-lane,3-lane & Intermediate Lane)	2,82,44,08,299
C	**Sub Total Cost of Tunnel Works(A+B)**	**57,88,07,83,989**
D	Electro- Mechanical Works	3,96,70,10,106
E	I&M cost @1% of C	57,88,07,840
F	Tunnel Ventilation & Fire Fighting	1,02,85,60,940
G	Cement concrete wearing coat	30,45,37,265
H	Inter Modal Building -2 Nos	3,27,60,63,038
BILL NO. 3	Traffic Signs, Markings, Appurtenances etc.	8,89,02,666
BILL NO. 4	Reconstruction/New Construction of Structures	
a.	Aqueduct at Km 0+288, Entry Ramp-02(ORR)	52,21,373
b.	Nala Diversion at Hebbal	17,45,78,795
BILL NO. 5	**Road Restoration and Development**	
a.	Reclamation Of Existing Road in Shaft, Approach Area & Ramps (Road, Footpath, Lighting etc.)	9,24,40,759
b.	Junction Development	3,94,94,324
BILL NO. 6	**High-Capacity & High-Speed Busses with Driving and Trailing Coaches (Neo-Bus System)**	
a.	Telecommunication & Passenger Information System	5,00,00,000
b.	Fare Collection System	5,00,00,000

Item No.	Description	Total Amount (Rs.)
c.	EV Coach of Minimum 12 M Length	20,00,00,000
BILL NO. 7	Miscellaneous (Trees, Artwork in Tunnel etc.)	2,85,02,940
BILL NO. 8	GPS/GNSS-Based Tolling	3,22,00,000
B) Estimated Construction Cost Without GST		**67,80,31,14,783**
Labour Cess @ 1% Of (B)		67,80,31,148
GST @ 18% Payable on Construction Cost Only (On B)		12,20,45,60,661
C) Construction Cost Including Labour cess & GST		**80,68,57,06,592**
Contingencies @ 1% Of (B)		67,80,31,148
Planning & Designing Charges @ 1% Of (B)		67,80,31,148
Construction Supervision Charges @ 2% Of (B)		1,35,60,62,296
Maintenance For 20 Years I.E. @ 0.25% for the first 5 years, 0.35% for the next five years, 0.45% for next five years, 0.5% for the next five years (On C)		-
Escalation @ 5% Per Annum For 2nd, 3rd,4th, Year During Construction Payable to Contractor Of (C)		-
D) Total Cost Including Centages		**83,39,78,31,183**
Land Acquisition, Resettlement, Rehabilitation Cost		4,00,00,00,000
Utility Shifting Cost		75,00,00,000
E) Total Project Cost (Sum of All the Above)		**88,14,78,31,183**

Table 26: Summary of Cost for Package 2

Item No.	Description	Total Amount in Rs.
BILL NO. 1	Site Clearance	32,37,906.40
BILL NO. 2	**Tunnel Work**	
A	Main Tunnel	
a.	Tunnelling By TBM	45,46,51,66,550.23
b.	Cross Passages	24,59,05,906.74
c.	Cut And Cover Tunnel	1,32,60,10,638.63
d.	Open Cut (Ramps)	33,66,24,192.27
e.	Shafts (3 No's)	1,39,59,54,884.37
B	Intermediate Entry/Exit	
a.	NATM Tunnel	5,41,72,08,181.92
b.	Open Cut (Ramps)	1,16,02,05,284.92
c.	Cut And Cover Tunnel (2-lane,3-lane & Intermediate Lane)	3,49,56,27,989.84
C	**Sub Total Cost of Tunnel Works(A+B)**	**58,84,27,03,628.93**
D	Electro- Mechanical Works	3,13,94,74,157.47
E	I&M cost @ 1% of C	58,84,27,036.29
F	Tunnel Ventilation & Fire Fighting	1,18,65,82,932.00
G	Cement concrete wearing coat	35,44,20,402.17
H	Inter Modal Logistic Building -3 Nos	4,36,11,83,192.90
BILL NO. 3	Traffic Signs, Markings, Appurtenances etc.	9,29,45,319.73
BILL NO. 4	Reclamation Of Existing Road In Shaft, Approach Area & Ramps (Road, Footpath, Lighting etc.)	6,00,55,959.00
a.	Junction Development	3,74,62,651.45
BILL NO.5	High-Capacity & Highspeed EV Busses	
a.	Telecommunication & Passenger Information System	5,00,00,000.00
b.	Fare Collection System	5,00,00,000.00
c.	EV Coach of Minimum 12 M Length	20,00,00,000.00
BILL NO. 6	Miscellaneous (Trees, Artwork in Tunnel etc.)	2,85,17,460.00
BILL NO. 7	GPS/GNSS-Based Tolling	3,22,00,000.00
B) Estimated Construction Cost Without GST		**69,02,72,10,646.35**
Labour Cess @ 1% Of (B)		69,02,72,106.46

Item No.	Description	Total Amount in Rs.
GST @ 18% Payable on Construction Cost Only (On B)		12,42,48,97,916.34
C) Construction Cost Including Labour cess & GST		**82,14,23,80,669.16**
Contingencies @ 1% Of (B)		69,02,72,106.46
Planning & Designing Charges @ 1% Of (B)		69,02,72,106
Construction Supervision Charges @ 2% Of (B)		1,38,05,44,212.93
Maintenance For 20 Years I.E. @ 0.25% for the first 5 years, 0.35% for the next five years, 0.45% for next five years, 0.5% for the next five years (On C)		-
Escalation @ 5% Per Annum For 2nd, 3rd,4th, & 5th Year During Construction Payable to Contractor Of (C)		-
D) Total Cost Including Centages		**84,90,34,69,095.01**
Land Acquisition, Resettlement, Rehabilitation Cost		4,00,00,00,000.00
Utility Shifting Cost		75,00,00,000.00
E) Total Project Cost (Sum of All the Above)		**89,65,34,69,095.01**

1.12 Financial Analysis

Financial viability is carried out for concession period of 25/30 years excluding the construction period of 50 months for the present project corridor of length with two options with the following parameters with varying the max grant of 40%. The basic methodology followed for estimating the financial viability of the project is to calculate the FIRR (Financial Internal Rate of Return) on the investment for the project.

The following assumptions are taken into consideration for the financial analysis: -

- Debt – Equity ratio: - 70:30
- Escalation – 5%.
- Principal Moratorium: six months

Based on the traffic study and toll rate analysis, the financial viability analysis has been carried out as per the methodology outlined in the financial chapter. In association with toll revenue, the development of project would generate revenue from other source, which are generated from commercial space, Advertisements, Naming Rights and leasing out space for OFC and other utilities lines in the tunnel area.

The objective of the viability analysis is to ascertain the existence of sustainable project returns, which shall successfully meet the expectations of its financial investors. The Returns on Investment and Returns on Equity for 25 and 30 years concession period with maximum grant up to 40% has been estimated and the summary of results for each scenario is given in Table below

Table 27: Results in BOT Mode for following Concession period – Package 1

Concession period	4+ Years (50 Months) + 25 years	4+ Years (50 Months) + 30 Years
Deciding factor	**With 40% Grant**	**With 40% Grant**
Project IRR	15.27%	15.64%
Equity IRR	17.79%	18.24%
DSCR	2.26	2.26
ENPV	928.00	1142.52
Remark	Viable	viable

Table 28: Results in BOT Mode for following Concession period – Package 2

Concession period	4+ Years (50 Months) + 25 years	4+ Years (50 Months) + 30 Years
Deciding factor	**With 40% Grant**	**With 40% Grant**
Project IRR	14.36%	14.78%
Equity IRR	16.13%	16.68%
DSCR	2.09	2.09
EIRR -NPV	663.79	862.50
Remark	Viable	Viable

1.13 Economic Analysis

The project will have direct and indirect benefits for the project influence areas and commuters.

Economic benefits

- Saving in Vehicle operating cost, with reduction in wear and tear of vehicle components.
- Improved connectivity by providing congestion-free traffic over the project.
- Fuel savings due to reduced congestion.
- Employment Generation: Increased employment opportunities for the local population during the construction and maintenance period.

Environmental Benefits

- Reduced Emission of air pollutants and lower damage to environment due to pollution.
- Lower impact on environment by reducing greenhouse gas emissions increasing the health benefits for the city population.
- Minimum effect on the need of land acquisition and Rehabilitation and relocation activities.

As the proposed tunnel is developed to ease the transportation to the North South corridor. Summary of economic benefits are given in table below. All the costs are discounted at a rate of 12% as per planning commission.

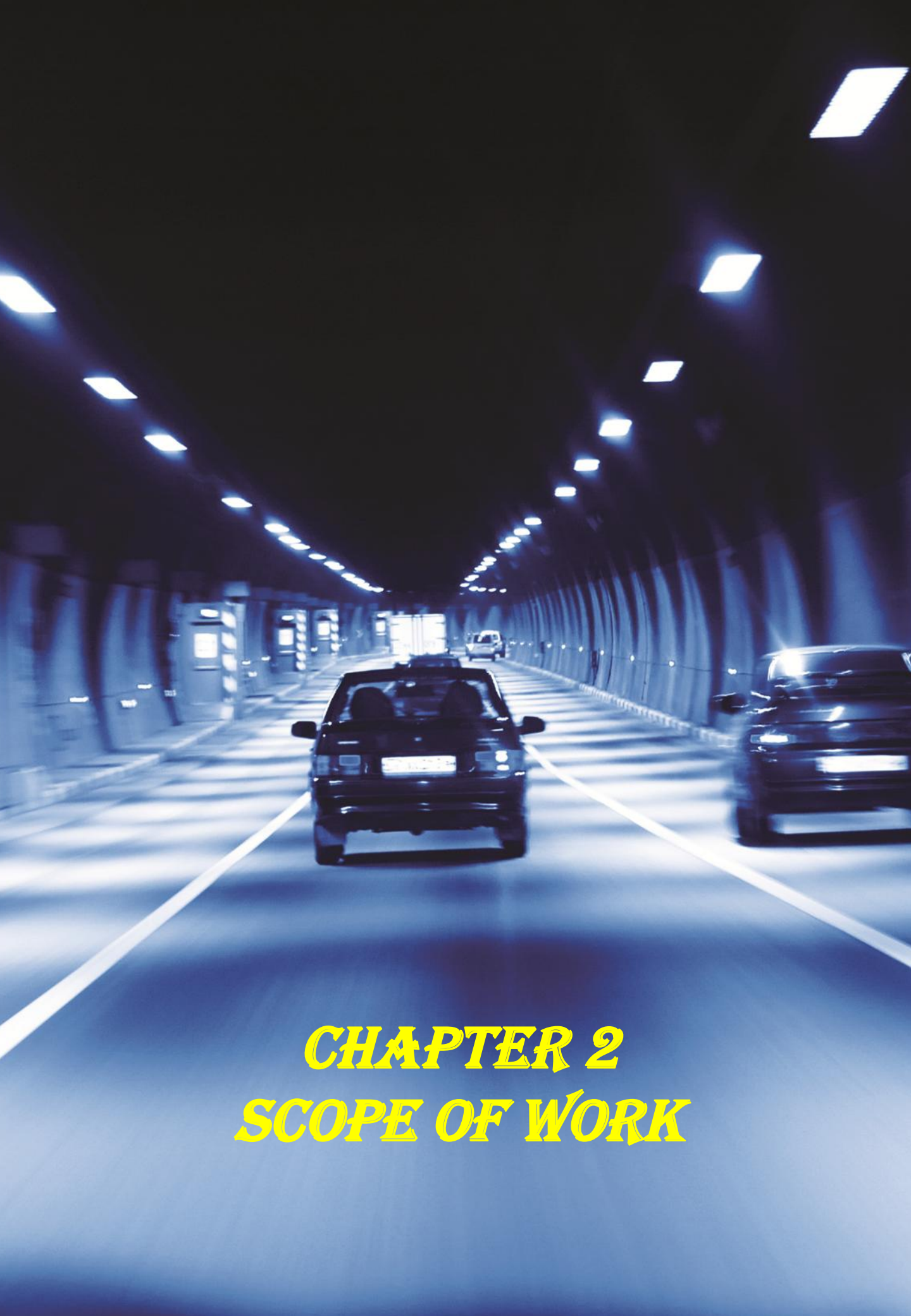
Table 29: Economic Benefits

S. No.	Description	Details
1	Total Economic benefits @ 12% rate (amount in cr.)	18703
2	Net Economic Costs @ 12% rate (amount in cr.)	9710
3	Internal rate of Return	19.07%
4	Economic NPV @ 12% (amount in cr.)	8993
5	Benefit / Cost Ratio	1.926

From the above analysis the results show that the EIRR of the project road is more than the discount rate of 12%. Hence, this project shall be taken up for implementation.

1.14 Conclusion and Recommendation

The project may be executed through BOT mode of construction as it is viable for 30 years concession period (4 Years 2 Months+25 years) with 40% of VGF.



CHAPTER 2
SCOPE OF WORK

CHAPTER 2: SCOPE OF WORK

The project underlines the scope of work of the consultant and the delivery planned at different stages of the project. A brief description of the Terms and reference (TOR) and deliverables are presented in the report. However, for the detailed Scope of work, TOR can be referred from the Contract Agreement.

2.1. Objective and Broad Scope of Work.

Detailed scope of work is presented below,

a. Traffic surveys and demand assessment

b. Engineering surveys and investigations

c. Location, layout and type of toll collection and toll plazas

d. Concept plan, detailed plan, virtual drive through, 3D Model with detachable segment to view a realistic Tunnel alignment etc.

e. Location and layout of approach ramps, loops ramps, interchanges and lay byes,

f. Vertical shafts, escape shafts etc.

g. Location and layout of bus bays and bus shelters at the interchange.

h. Social impact assessment.

i. Environment impact assessment.

j. Preliminary Typical designs of road, bridges, structures, etc.

k. Preparation of Land Plan Schedules.

l. Preparation of state-of-the-art Utility Relocation Plans.

m. Preparation of detailed BOQ and detailed Cost Estimates.

n. Preparation of RFP Document for main component work tender i.e., DPR.

o. Preparation of conceptual plans for road-side amenities and Land Acquisition drawings.

p. Physical facilities necessary for Advanced Traffic Management System (ATMS).

q. Survey of existing borewells, water bodies, building structures, pile foundations of major and multi storied structures along the alignment

r. Precautionary measures for construction of tunnel road.

s. Detailed design and drawings for fire safety and all other safety measures to be incorporated.

The above-mentioned work has been bifurcated in various stages of deliverables.

2.2. Stages of Deliverables

As per the TOR of the Contract Agreement following stages of deliverables are to be submitted.

Stage 1. Inception Report

On commencement of the Consultancy, the Inception Report. The Inception Report shall be submitted which will include (i) understanding the RFP and the Work Plan, (ii) Consultants team mobilization, (iii) survey and investigation plana and (iv) overall approach towards the assignment and deliverables

Stage 2. Final Project Report

- Report on Available Data and Plans
- Report on Traffic Survey
- Development Proposal

Stage 3. Final Project Report

- Including the comments on Final report.

Stage 4. Final Comprehensive Road Infrastructure Plan

- A Final Project Report- Including Investigation report, Preliminary Designs, Set of General Arrangements of Drawings, Preliminary Costing
- Land Plan Schedules
- Utility Relocation Plans
- Report on Environment and Social Impact Assessment and
- Report on Indicative GAD's

Stage 5. Final Comprehensive Road Infrastructure Plan

- Final Report on the above-mentioned reports.

2.3. Final Detailed Project Report

This project report consists of deliverables as per the Terms of Reference of Contract Agreement.

Table 30: Description of data and reference locations

Description	Reference
Drawings	Chapter 8 of Main Report, Volume-V: Drawings.
Traffic and Details	Chapter 7 of Main Report
Investigation Reports	Chapter 6 of Main Report, Volume-III: Geotechnical Interpretive Report
Preliminary Design and GADs	Chapter 8 of Main Report, Volume-II B: Structural Design Report, Volume-II C: Electrical Design Report, Volume-II D: Ventilation Design Report and Volume V Drawings.
Preliminary Costing	Chapter 9 of Main Report, Volume IV: Preliminary Cost Estimate.
Implementation Schedule	Provided in Main Report
Financial Analysis	Chapter 10 of Main Report
Land Plans Schedules	Submitted Separately
Utility Relocation Plans	Submitted Separately

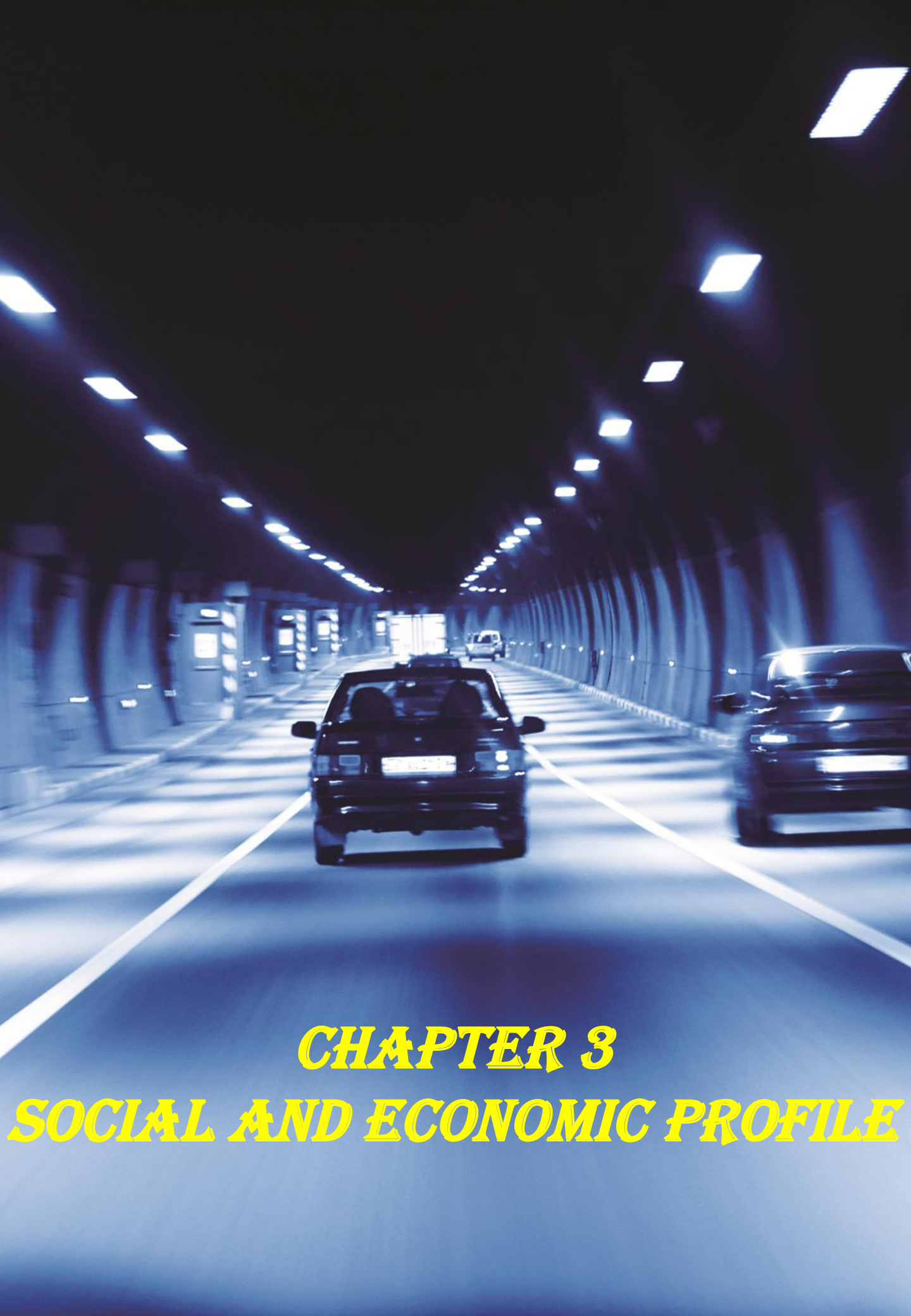
This stage is the Final project report stage. And the deliverables have been divided into volumes. The submission has the following volumes along with this Project Main Report.

- Volume-I: Main Report with Annexure
- Volume-II A: Geotech Design Report
- Volume-II B: Structural Design Report
- Volume-II C: Electrical Design Report
- Volume-II D: Ventilation Design Report
- Volume-III: Pre-final Geotechnical Interpretive Report
- Volume-IV: Preliminary Cost
- Volume-V: Drawings

This Main Volume consists of 13 chapters which focus on each aspect of project varying from investigations, design standards, cost and conclusion and recommendation. The chapters are as follows.

- Chapter 1: Executive Summary
- Chapter 2: Scope of Work
- Chapter 3: Social and Economic Profile

- Chapter 4: Available Data Plans
- Chapter 5: Alignment Study
- Chapter 6: Engineering Survey and Investigation
- Chapter 7: Traffic Study and Analysis
- Chapter 8: Improvement Proposals
- Chapter 9: Project Implementation and Scheduling
- Chapter 10: Preliminary Cost Estimation
- Chapter 11: Financial Analysis
- Chapter 12: Economic Analysis
- Chapter 13: Operation and Maintenance
- Chapter 14: Codes and References



CHAPTER 3
SOCIAL AND ECONOMIC PROFILE

CHAPTER 3: SOCIAL AND ECONOMIC PROFILE

3.1 Introduction

The project influence areas of the proposed project are located in the Bengaluru City of Bangalore Urban district in the state of Karnataka.

3.1.1 General

The description of socio-economic features of the state and districts through which the project road traverses comprise the demographic, social and economic aspect of the population, it includes the features of population distribution, density of population, workforce and share of workers in major economic categories, and the vulnerable groups.

The physical and socio-economic profile of the state and districts concerned are illustrated separately in the following sections.

3.2 Karnataka State

Karnataka is a state in the southwestern region of India. It was formed as Mysore State on 1st November 1956, with the passage of the States Reorganisation Act, and renamed Karnataka in 1973. The state is bordered by the Lakshadweep Sea to the west, Goa to the northwest, Maharashtra to the north, Telangana to the northeast, Andhra Pradesh to the east, Tamil Nadu to the southeast, and Kerala to the southwest. With 61,130,704 inhabitants at the 2011 census, Karnataka is the eighth-largest state by population, comprising 31 districts. With 15,257,000 residents, the state capital Bangalore is the largest city of Karnataka.

The economy of Karnataka is one of the most productive in comparison to other states in the country, with ₹20.5 trillion (US$260 billion) in gross domestic product and a per capita GDP of ₹305,000 (US$3,800). The state of Karnataka has one of the highest economic growth rates comparatively to other states in the country, with a GSDP (Gross State Domestic Product) growth of 9.5% in the 2021–22 fiscal year. After Bangalore Urban, Dakshina Kannada, Hubli-Dharwad, and Belagavi districts contribute the highest revenue to the state respectively. The capital of the state, Bangalore, is known as the Silicon Valley of India, for its immense contributions to the country's information technology sector. A total of 1,973 companies in the state were found to have been involved in the IT sector as of 2007.

Karnataka is the only southern state to have land borders with all of the other four southern Indian sister states. The state covers an area of 191,791 km2 (74,051 sq mi), or 5.83 per cent of the total geographical area of India. It is the sixth-largest Indian state by area. Kannada, one of the classical languages of India, is the most widely spoken and official language of the state. Other minority languages spoken include Urdu, Konkani, Marathi, Tulu, Tamil, Telugu, Malayalam, Kodava and Beary. Karnataka also contains some of the only villages in India where Sanskrit is primarily spoken.

3.2.1 Geography

The Indian State of Karnataka is located between 11°30' North and 18°30' North latitudes and between 74° East and 78°30' East longitude. It is situated on a tableland where the Western Ghats and Eastern Ghats converge into the complex, in the western part of the Deccan Peninsular region of India. The State is bounded by Maharashtra and Goa States in the north and northwest; by the Lakshadweep Sea in the west; by Kerala in the south-west and Tamil Nadu in the south and south-east, Andhra Pradesh in the south-east and east and Telangana in the north-east. Karnataka extends to about 850 km (530 mi) from north to south and about 450 km (280 mi) from east to west.

Karnataka is situated in the Deccan Plateau and is bordered by the Arabian Sea to the west, Goa to the northwest, Maharashtra to the north, Andhra Pradesh to the southeast and east, Telangana to the east, Tamil Nadu to the south and southeast, and Kerala to the southwest. It is situated at the angle where the Western Ghats and Eastern Ghats of South India converge into the Nilgiri hills. The highest point in Karnataka is the Mullayanagiri hill in Chikkamagaluru district which has an altitude of 1,929 metres (6,329 ft) above sea level.

Karnataka consists of four main types of geological formations – the Archean complex made up of Dharwad schists and granitic gneisses, the Proterozoic non-fossiliferous sedimentary formations of the Kaladgi and Bhima series, the Deccan trappean and intertrappean deposits and the tertiary and recent laterites and

alluvial deposits. Laterite cappings that are found in many districts over the Deccan Traps were formed after the cessation of volcanic activity in the early tertiary period. Eleven groups of soil orders are found in Karnataka, viz. Entisols, Inceptisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, Aridisols, Vertisols, Andisols and Histosols. Depending on the agricultural capability of the soil, the soil types are divided into six types, viz. red, lateritic, black, alluvio-colluvial, forest and coastal soils.

About 38,284 km2 (14,782 sq mi) of Karnataka (i.e. 16% of the state's geographic area) is covered by forests. The forests are classified as reserved, protected, unclosed, village and private forests. The percentage of forested area is slightly less than the all-India average of about 23%, and significantly less than the 33% prescribed in the National Forest Policy.

3.2.2 Rainfall

The southwest monsoon accounts for almost 80% of the rainfall that the state receives. The annual rainfall across the state ranges from low 50 cm (20 in) to copious 350 cm (140 in). The districts of Vijapura, Raichuru, Ballari, Yadagiri and Southern half of Kalaburagi experience the lowest rainfall ranging from 50 to 60 cm (24 in) while the west coastal region and Malenadu enjoy the highest rainfall.

3.2.3 Climate

Karnataka experiences four seasons. The winter in January and February is followed by summer between March and May, the monsoon season between June and September and the post-monsoon season from October till December. Meteorologically, Karnataka is divided into three zones – coastal, north interior and south interior. Of these, the coastal zone receives the heaviest rainfall with an average rainfall of about 3,638.5 mm (143 in) per annum, far in excess of the state average of 1,139 mm (45 in). Amagaon in Khanapura taluka of Belgaum district received 10,068 mm (396 in) of rainfall in 2010. In 2014 Kokalli in Sirsi taluka of Uttara Kannada district received 8,746 mm (344 in) of rainfall. Agumbe in Thirthahalli taluka and Hulikal of Hosanagara taluka in Shimoga district were the rainiest cities in Karnataka, situated in one of the wettest regions in the world.

The state is projected to warm about 2.0 °C (4 °F) by 2030. The monsoon is set to provide less rainfall. Agriculture in Karnataka is mostly rainfed as opposed to irrigated, making it highly vulnerable to expected changes in the monsoon. The highest recorded temperature was 45.6 °C (114 °F) in Raichuru district. The lowest recorded temperature was 2.8 °C (37 °F) at Bidar district.

3.2.4 Flora and fauna

Karnataka is home to a variety of wildlife. It has a recorded forest area of 38,720 km2 (14,950 sq mi) which constitutes 12.3% of the total geographical area of the state. These forests support 25% of the elephant and 10% of the tiger population of India. Many regions of Karnataka are as yet unexplored, so new species of flora and fauna are found periodically. The Western Ghats, a biodiversity hotspot, includes the western region of Karnataka. The Bandipur and Nagarahole National Parks were included in the Nilgiri Biosphere Reserve in 1986, a UNESCO designation. The Indian roller and the Indian elephant are recognised as the state bird and animal while sandalwood and the lotus are recognised as the state tree and flower respectively. Karnataka has five national parks: Anshi, Bandipur, Bannerghatta, Kudremukh and Nagarhole. It also has 27 wildlife sanctuaries of which seven are bird sanctuaries.

Wild animals that are found in Karnataka include the elephant, the tiger, the leopard, the gaur, the sambar deer, the chital or spotted deer, the muntjac, the bonnet macaque, the slender loris, the common palm civet, the small Indian civet, the sloth bear, the dhole, the striped hyena, the Bengal fox and the golden jackal. Some of the birds found here are the great hornbill, the Malabar pied hornbill, the Ceylon frogmouth, herons, ducks, kites, eagles, falcons, quails, partridges, lapwings, sandpipers, pigeons, doves, parakeets, cuckoos, owls, nightjars, swifts, kingfishers, bee-eaters and munias. Some species of trees found in Karnataka are Calophyllum tomentosum, Calophyllum apetalum, Garcinia cambogia, Garcinia morella, Alstonia scholaris, Flacourtia montana, Artocarpus hirsutus, Artocarpus lacucha, Cinnamomum zeylanicum, Grewia tiliifolia, Santalum album, Shorea talura, Emblica officinalis, Vitex altissima and Wrightia tinctoria. Wildlife in Karnataka is threatened by poaching, habitat destruction, human-wildlife conflict and pollution.

3.2.5 Forests

About 38724 km² (or 20% of Karnataka's geographic) are covered by forests. The forests are classified as reserved (28,611 km²) protected (3,932 km²), unclosed (5,748 km²), village (124 km²) and private (309 km²) forests. The percentage of forests area to Geographical area in the State is less than the all-India average of about 23%, and 33% prescribed in the National Forest Policy. The area under protected forests in the neighboring States is as follows: Andhra Pradesh 62,000 km² (9% of the total area of the country), Maharashtra 54,000 km² (8%), Tamil Nadu 22,000 km² (3%) and Kerala 11,000 km² (2%).

Karnataka is known for its valuable timbers from the evergreen forests in the Western Ghat region, notably Teak and Rosewood, the richly ornate panels of which adorn the beautiful chambers of the Two Houses of Karnataka Legislature.

3.2.6 Demographic Profile

Karnataka, with a total population of 61,100,000, is one of the major states in South India. Kannada is the official state language, while other linguistic minorities in the state include Kodava, Konkani, Tulu and Urdu. Karnataka is also at the forefront of population control measures, with the first two birth control clinics in history opening in 1930 in the Mandya district.

3.2.6.1 Population

At the time of the 2011 Census of India, the total population in Karnataka was 6.25 crores (an amount equating to 10 million), with 50.9% being males and 49.1% females. There was a decadal population increase of 17.3% between 1991 and 2001. As per the 2011 census, the population density is 319 per km², the sex ratio is 973 females to 1,000 males, and 38.67% of the people in Karnataka live in urban areas.

The literacy rate in Karnataka was 75.4% at the time of the 2001 census; the eight most-populous cities of the state, in-order from highest to lowest total population, were Bengaluru, Hubballi-Dharwad, Mysuru, Belagavi, Kalburgi, Mangaluru, Davanagere and Ballari. Bengaluru Urban and Belagavi are the most populous Districts, each of them having a population of more than three million. Gadaga, Chamarajanagara and Kodagu districts have a population of less than one million. Karnataka has one of the largest populations of Anglo-Indians in India. Seen below is a composite table of languages and religions of the state at the census of 2001.

Table 31: Languages and Religions of the State at the Census

Description	2011	2001
Approximate Population	6.11 Crores	5.29 Crore
Actual Population	61,095,297	52,850,562
Male	30,966,657	26,898,918
Female	30,128,640	25,951,644
Population Growth	15.60%	17.25%
Percentage of total Population	5.05%	5.14%
Sex Ratio	973	965
Child Sex Ratio	948	946
Density/km2	319	276
Area(Km 2)	191,791	191,791
Total Child Population (0-6 Age)	7,161,033	7,182,100
Literacy	75.36 %	66.64 %
Male Literacy	82.47 %	76.10 %
Female Literacy	68.08 %	56.87 %

3.2.6.2 Religion

At the time of the 2011 Census of India, 84.0% of the population were Hindu, 13.00% Muslim, 1.80% Christian, 0.7% Jain, 0.2% Buddhist, <0.1% Sikhs, with the remaining percentage belonging to other religions. Karnataka is also the location of some tribes, such as the Nayaka, Soliga, and Yerava. The joint family system is prevalent in the rural areas of Karnataka; there are extreme cases, like the Narasinganavars,

who reside in the Dharwad district, and are recognised as one of the largest undivided families in the world.

Table 32: Details of Religion

Description	Percentage
Hindu	84.00 %
Muslim	12.92 %
Christian	1.87 %
Jain	0.72 %

3.2.6.3 Languages

Government Census (2001) Kannada 68.5 %, Urdu 10.5 %, Telugu 6.2 %, Tamil 3.2 %, Tulu 2.1 %, Hindi 2.6%, Konkani 1.0 %, Beary 1.3 %, other 4.1 %.

3.2.7 Districts of Karnataka

Table 33: List of Karnataka Districts

District	Total area (sq km)	Total Population (2011)
Bidar	5448	17,03,300
Kalaburagi	10,951	25,66,326
Belagavi	13,415	47,79,661
Vijayapura	10,494	21,77,331
Yadagiri	5,273	11,74,271
Bagalkot	6,575	18,89,752
Raichur	8,440	19,28,812
Uttara Kannada	10,291	14,37,169
Dharwad	4,260	19,54,802
Gadag	4,656	10,64,570
Koppal	7,189	13,89,920
Ballari	4252	14,00,970
Vijayanagara	5644	13,53,628
Haveri	4,823	15,97,668
Shivamogga	8,477	17,52,753
Davanagere	5,924	19,45,497
Udupi	3,880	11,77,361
Chikkamagaluru	7,201	11,37,961
Chitradurga	8,440	16,59,456
Dakshina Kannada	4,560	20,89,649
Hassan	6,814	17,76,421
Tumakuru	10,597	26,78,980
Chikkaballapura	4,524	12,55,104
Kodagu	4,102	5,54,519
Mysuru	6,854	30,01,127
Mandya	4,961	18,05,769
Chamarajanagar	10,494	10,20,791
Ramanagara	6,827	10,82,636
Kolar	3,969	15,36,401
Bengaluru Rural	2,259	9,90,923
Bengaluru Urban	2,190	96,21,551

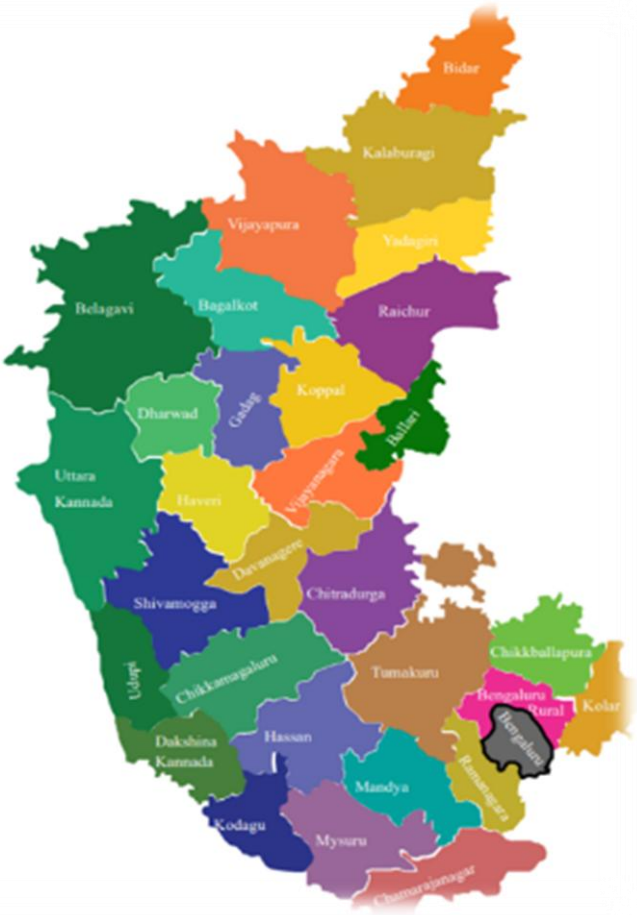


Figure 35: Districts of Karnataka

3.3 Bangalore Urban District

Bangalore, officially known as Bengaluru, is the Capital of the Indian State of Karnataka. It has a population of over ten million, making it a megacity and the Third populous City and 5th most populous urban agglomeration in India. It is located in Southern India on the Deccan Pleteau . Its elevation is over 900 m (3,000 ft) above sea level, the highest of India's major cities.

Bengaluru Urban District has the distinction of being the Karnataka State Capital. State Legislature and High Court are in its jurisdiction. It is the nerve center of Karnataka State's Legislative, Judicial and Executive Administration. Bengaluru Urban District comprises five Taluks, namely

Bengaluru North, Bengaluru North (Addl.), Bengaluru South, Bengaluru East and Anekal

The district is the Principal Administrative unit below the state level. The Deputy Commissioner, being the head of the District Administration, is perhaps the only officer vested with powers under the largest number of both Central and State Laws. The D.C. office comes in direct contact with the people and people's representatives at various levels. The office of the Deputy Commissioner apart from having many original works enumerated under different Acts and Rules has got the supervisory and coordinating roles at the district level. Apart from regulatory functions, the Deputy Commissioner guides and coordinates the developmental activities of the district.

Bangalore is sometimes referred to as the "Silicon Valley of India" (or "IT capital of India") because of its role as the nation's leading information technology (IT) exporter. Indian technological organisations ISRO, Infosys, Wipro and HAL are headquartered in the city. A demographically diverse city, Bangalore is the second fastest-growing major metropolis in India. It is home to many educational and research institutions in India, such as Indian Institute of Science (IISc), Indian Institute of Management (Bangalore)(IIMB), National Institute of Fashion Technology, Bangalore, National Institute of Design, Bangalore (NID R&D Campus), National Law School of India University (NLSIU) and National Institute of Mental Health and

Neurosciences (NIMHANS). Numerous state-owned aerospace and defence organisations, such as Bharat Electronics, Hindustan Aeronautics and National Aerospace Laboratories are located in the city. The city also houses the Kannada film industry.

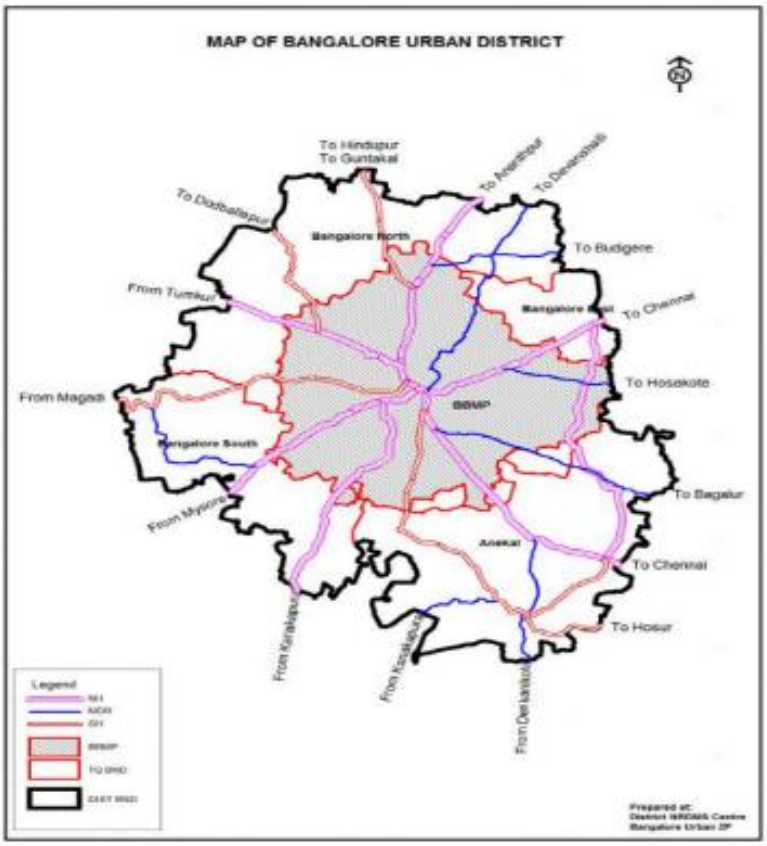


Figure 36: Bangalore Districts Map

3.3.1 Geography of Bangalore Region

Bangalore lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Precambrian Deccan Plateau) at an average elevation of 920 m (3,020 ft). It is positioned at 12.97°N 77.56°E and covers an area of 1741 km2 (673 mi2). The majority of the city of Bangalore lies in the Bangalore Urban district of Karnataka and the surrounding rural areas are a part of the Bangalore Rural district.

In the 16th century, Kempe Gowda I constructed many lakes to meet Bangalore's water requirements. The Kempambudhi Kere, since overrun by modern development, was prominent among those lakes. In the earlier half of 20th century, the Nandi Hills waterworks was commissioned by Sir Mirza Ismail (Diwan of Mysore, 1926–41 CE) to provide water supply to the city. Currently, the river Kaveri provides around 80% of the total water supply to the city with the remaining 20% being obtained from the Thippagondanahalli and Hesaraghatta reservoirs of the Arkavathi river. Bangalore receives 800 million liters (211 million US gallons) of water a day, more than any other Indian city. However, Bangalore sometimes does face water shortages, especially during the summer season — more so in the years of low rainfall. A random sampling study of the air quality index (AQI) of twenty stations within the city indicated scores that ranged from 76 to 314, suggesting heavy to severe air pollution around areas of traffic concentration.

Bangalore has a handful of freshwater lakes and water tanks, the largest of which are Madivala tank, Hebbal Lake, Ulsoor Lake and Sankey Tank. Groundwater occurs in silty to sandy layers of the alluvial sediments. The Peninsular Gneissic Complex (PGC) is the most dominant rock unit in the area and includes granites, gneisses and migmatites, while the soils of Bangalore consist of red laterite and red, fine loamy to clayey soils.

Vegetation in the city is primarily in the form of large deciduous canopy and minority coconut trees.

3.3.2 Geology

The city of Bangalore is located in central part of the Dharwar Craton. As its base, the Basement Gneiss, a polyphase migmatite (Tonalite- trondhjemite-granodiorite-TTG) originated over a period of 3400Ma. Over it the volcano- sedimentary Sargur Supracrustal (green stone belt) rocks were deposited and metamorphosed, and what was subsequently intruded by another phase of TTG about 3000Ma which is referred to as the Peninsular Granite Suite-1 groups of rocks.

Subsequent tectonic deformations created linear belts of basins for the deposition of the younger volcano-sedimentary deposits and their metamorphism, also referred to as the rocks of the younger Dharwar/ Kolar type Super Group around 2700Ma. These belts comprised of rocks which metamorphosed included grits/arenites, pelites, Bimodal mafic- felsic volcanics, pyro clasts, agglomerates, layers of BIF, local komatiites, Quartzites (locally cross bedded), manganese marble, stromatolitic carbonate, calc- silicate, cordierite bearing pelites, amphibolite etc. This was followed by the next phase of granitic- granodiorite intrusion rich in potassium and mafic constituents about 2350-2600My. The resultant rocks occurring to the East of the Closepet Granite is referred to as Peninsular Gneiss II (Bangalore Supersuite)/ Dharwar Batholith.

The Dharwar Batholith which is characterized by rocks of granites, granodirites, monzonites, diorites and their high strained gneissic equivalents. These rocks are understood to have been uplifted as diapiric structures following a process of anatexis. The melts that intruded the overlying rock, normally had a wedge or elongated dome shapes trending approximately N-S to NW-SE. Swarms of mafic dykes have cut across these granitic plutons during more recent ages.

The exposed rocks have been undergoing weathering processes, and the residual patches are exposed as laterites locally and are identified with the Neogene period and the transported soils of the Quaternary period.

The superimposed folding patterns in the rocks suggest that the entire sequence of the rock groups appears to have deformed in a ductile manner. Throughout the gneissic terrain, small enclaves of reworked older rocks are observed to be signatures of even older deformational, metamorphic and magmatic history in the area.

The Diapiric uplift of the granitic melts was followed up by a prominent transcurrent sinistral Shear. Multiple generations of folding are interpreted in the rock groups at all scales. However, the NNW -SSE trend is the most prominent in the area and appears to represent the strike of the axial plane of a particular generation.

The project alignment is approximately N-S oriented between Esteem Mall Junction to Silk Board Junction. The project alignment takes off from close North of the Hebbal Lake near Esteem Mall. Proceeding southwards, the alignment passes through a topographic depression, thorough which a nalla/drain flows connecting the Hebbal and Nagavara Lakes. The area is suspected have a significant fill material and deeper weathered zone. The bedrock in the area is identified with Grey Granite equivalent to Closepet Granite Formation of Paleo-Proterozoic age.

Further south, near to the Palace Ground, where the proposed link Tunnels are proposed to connect the main tunnel and having the Sankey Tank towards the west of the Main Tunnel Alignment and the Palace Lake over the alignment, a substantial outcropping and thickening of laterite rocks is observed.

Advancing further south, immediately after the Racecourse, the next set of intersections are also set in the same Grey Granite as bedrock. Further south, in the Lal Bagh area, the Bed rock is in a transition zone. The alignment is set to cross a prominent lineament, which the Lal bagh lake in the vicinity and the Grey Granite bedrock in contact with Hornblende Granite. The alignment curves eastward and is set to negotiate through the Hornblende Granite for about 1.5-2Km before crossing into the Hornblede-Biotie Gneiss of Precambrian Geiessic Complex-II.

3.3.3 Topography

Bangalore has two unique Topography terrains—North Bangalore taluk and the South Bangalore taluk. The North Bangalore taluk is a relatively more level plateau and lies between an average of 839 to 962 meters above sea level. The middle of the taluk has a prominent ridge running NNE-SSW. The highest point in the

city, Doddabettahalli, (962m) is on this ridge. There are gentle slopes and valleys on either side of this ridge. The low-lying area is marked by a series of water tanks varying in size from a small pond to those of considerable extent, but all fairly shallow.

The topography of Bangalore is undulating with a central ridge running NNE-SSW. The highest point is Doddabettahalli, which is 962 m (3,156 ft) and lies on this ridge. No major rivers run through the city, though the Arkavathi and (Dakshin Pinakini river) cross paths at the Nandi Hills, 60 km (37 mi.) to the north. River Vrishabhavathi, a minor tributary of the Arkavathi, arises within the city at Basavanagudi and flows through the city. The rivers Arkavathi and Vrishabhavathi together carry much of Bangalore's sewage. A sewerage system, constructed in 1922, covers 215 km2 (133 mi2) of the city and connects with five sewage treatment centers located in the periphery of Bangalore. Outflow from Bellandur lake and Varthur lake valleys go to Ponnaiyar river that flows towards Hosur.

The South Bangalore taluk has an uneven landscape with intermingling hills and valleys. The southern and western portions of the city consist of a topology of granite and gneissic masses. The eastern portion is a plane, with rare minor undulations.

There are no major rivers flowing through the city. However, rivers Arkavathi and Kaveri merge within the proximity of Mekedatu, which lie 60 km south of Bangalore. River Vrishabhavati, a tributary of Arkavathi, flows for a small stretch in the Bangalore North taluk and carries a bulk of the city's sewerage. The age old South Pennar river, also known as Dakshina Pinakini, used to run through the eastern side of the city. Now it is being considered for renewal and rejuvenation by the government. The city has a handful of freshwater lakes and water tanks such as Madivala tank, Hebbal tank, Ulsoor lake and Sankey Tank. Groundwater occurs in silty to sandy layers of alluvial sediments and jointed quartzite.

The rock types prevalent in the district belong to the Saugar, Charnokite and Peninsular Gneissic Complex (PGC) groups. The PGC is the dominant group of rocks and covers two-thirds of the area and includes granites, gneisses and migmatites. The soils in Bangalore vary from red laterite to clayey soils.

3.3.4 Climate

Due to its elevation, Bangalore enjoys a pleasant and equable climate throughout the year with occasional extreme weather events like heatwaves, coldwaves, floods and droughts. The highest temperature ever recorded in Bengaluru is 41.8°c in April 30, 2024 in Kengeri at Bengaluru. Winter temperatures rarely drop below 13 °C (52 °F) and summer temperatures seldom exceed 37 °C (97 °F).

The hottest summer day on average has a maximum temperature of about 37°c , and the coldest winter day has a temperature of about 13°c. Occasionally, heat waves can cause temperatures of up to 38-40°c. Occasional coldwaves will be leading to the temperatures as low as below 9-10°c . Bangalore receives about 970 mm of rain annually, with the wettest months being August, September and October. The heaviest rainfall recorded in a 24-hour period was 18 cm recorded on 1988.

Most of the rainfall occurs during late afternoon, evening or night and rain before noon is infrequent. November 2015 (290.4 mm) was recorded as one of the wettest months in Bangalore with heavy rains causing severe flooding in some areas, and closure of a number of organisations for over a couple of days.

3.3.5 Seismicity

Because it lies in the seismically stable region, Zone II (encompassing parts of Karnataka, Maharashtra, Kerala, Tamil Nadu and Andhra Pradesh), Bangalore has been untouched by major seismic events. The highest earthquake that has hit Bangalore is reported to have occurred on 7th January 1916, This earthquake had the intensity of VI.

3.3.6 Land use

According to data contained in the Bangalore Mahanagara Palike Master Plan, 40.4% of the land in the city is used for residential purposes. Transport uses 24.3% of the land, while land used for industrial, and commercial purposes comprise 6.9% and 2.7% respectively. As the city of Bangalore expands, the BMP expects the percentage of land used for industrial purposes to decrease, while it expects the percentages of land used for residential, commercial and public and semi-public purposes to increase.

3.3.7 Demographic Profile of the District

According to the 2011 census Bangalore Urban district has a population of 9,621,551, roughly equal to the nation of Belarus. This gives it a ranking of third in India (out of a total of 640). The district has a population density of 4,378 inhabitants per square kilometre (11,340/sq mi). Its population growth rate over the decade 2001-2011 was 46.68%. Bangalore has a sex ratio of 908 females for every 1000 males, and a literacy rate of 88.48%. 90.94% of the population lives in urban areas. Scheduled Castes and Scheduled Tribes make up 12.46% and 1.98% of the population respectively.

Languages of Bangalore Urban district (2011)

- Kannada (44.47%)
- Tamil (15.99%)
- Telugu (13.99%)
- Urdu (12.11%)
- Hindi (4.55%)
- Malayalam (2.94%)
- Marathi (1.92%)
- Others (4.82%)

At the time of the 2011 census, 44.47% of the population spoke Kannada, 15.20% Tamil, 13.99% Telugu, 12.11% Urdu, 4.55% Hindi, 2.94% Malayalam and 1.92% Marathi as their first language.

Table 34: Demographic profile of Bangalore urban Districts

Category	Absolute Figures
Area	2196 Sq. kms
Population- Total	9621551
Male	5022661
Female	4518890
Rural	871607
Urban	8749944
Decadal Population Growth	47.18%
Literacy-Total	87.67%
SC Population – Total	1198385
ST Population – Total	190239
Sex Ratio (females per 1000 males)	916
Child Sex Ratio (0 to 6 years)	944
Occupational pattern of Population Total Workers	3998286

3.3.8 Economy

Bangalore is one of the fastest-growing metropolises in India. Bangalore contributes 38% of India's total IT exports. Its economy is primarily service oriented and industrial, dominated by information technology, telecommunication, biotechnology, and manufacturing of electronics, machinery, automobiles, food, etc. Major industrial areas around Bangalore are Adugodi, Bidadi, Bommanahalli, Bommasandra, Domlur, Hoodi, Whitefield, Doddaballapura, Hoskote, Bashettihalli, Yelahanka, Electronic City, Peenya, Krishnarajapuram, Bellandur, Narasapura, Rajajinagar, Mahadevapura etc. It is the fifth Indian city to host maximum numbers of Fortune Companies, after Mumbai, Delhi, Kolkata and Chennai.

The growth of IT has presented the city with unique challenges. Ideological clashes sometimes occur between the city's IT moguls, who demand an improvement in the city's infrastructure, and the state government, whose electorate is primarily from rural Karnataka. The encouragement of high-tech industry in Bangalore, for example, has not favoured local employment development, but instead increased land values and forced out small enterprises. The state has also resisted the massive investments required to reverse the rapid decline in city transport, driving new and expanding businesses elsewhere in India.

Bangalore is a hub for Indian biotechnology-related industry and in 2005 was home to around 47% of the 265 biotechnology companies in India, including Biocon, India's largest biotechnology company, giving Bangalore the nickname of the "Biotech Capital of India". Bangalore is also the country's fourth largest fast-moving consumer goods (FMCG) market. Forbes considers Bangalore one of "The Next Decade's Fastest-Growing Cities". The city is the third largest hub for high-net-worth individuals. There were a large number of high-net-worth individuals with a ₹4.5 crore investment surplus in 2007. In the Ease of Living Index 2020, it was ranked the most livable Indian city with a population of over a million.

The city is widely regarded as the "Silicon Valley of India", as the largest IT hub of the country. Infosys, Wipro, Mindtree, Mphasis, Flipkart, and Myntra are headquartered in Bangalore. IT companies located in the city contributed 33% of India's ₹1,442 billion (US$20 billion) IT exports in 2006–07. Bangalore's IT industry is divided into three main clusters: Software Technology Parks of India (STPI); International Tech Park, Bangalore (ITPB); and Electronic City. Most of the IT companies are located in Bommanahalli, Domlur, Whitefield, Electronic City, Krishnarajapuram, Bellandur, and Mahadevapura.

3.3.9 Economic sectors

The earliest startups that were launched in the city in the 1990s include Infosys, Wipro Technologies, and Mindtree being popular ones and smaller ones include Tejas Networks. Flipkart, having originated in Bangalore, acquired several other e-commerce companies in Bangalore like Myntra, and was eventually acquired by Walmart in 2018 for close to $20 Billion. Startup companies such as Swiggy, Ola Cabs, InMobi, Quikr, and RedBus are also based in the city.

Bangalore is a favorable destination for industrial development. United Breweries Group is headquartered in Bangalore. The city is an automobile production hub. Tata Hitachi Construction Machinery, Mahindra Electric, Bharat Earth Movers, Toyota Kirloskar Motor, Tesla India, and Ather Energy are headquartered in Bangalore within their operations. Robert Bosch GmbH, Mercedes-Benz, Volvo, General Motors, Royal Enfield, Honda Motorcycle and Scooter India, Scania AB, Larsen & Toubro have their plants and research & development (R&D) centers around Bangalore. ABB, General Electric, and Tyco International have their research and development centers in Bangalore. Aerospace industries are also popular around Bangalore, which made it as Aviation Monopoly capital of India. Airbus, Boeing, Tata Advanced Systems, Indian Space Research Organisation, and Liebherr Aerospace have their units in Bangalore. Bangalore has also emerged as an electronics and hardware manufacturing hub in India. It houses Dell, Nokia, Philips, and Wistron manufacturing and R&D units. Public sector undertakings (PSUs) such as Bharat Electronics Limited (BEL), Hindustan Aeronautics Limited (HAL), National Aerospace Laboratories (NAL), Bharat Earth Movers Limited (BEML), Central Manufacturing Technology Institute (CMTI), HMT (formerly Hindustan Machine Tools) and Rail Wheel Factory (RWF). SKF also has a plant in the city.

Information Technology

Bangalore is known for its IT industry, housing companies like Infosys, Mphasis, Wipro, Tata Consultancy Services, Nasdaq, Facebook, Google, and Microsoft etc. India's two largest IT companies – Infosys and Wipro to name a few have their headquarters here in Bangalore. Electronic City is a place in Bangalore, which houses IT companies in Bangalore along with Infosys headquarters. Whitefield is another major suburb housing many IT companies. It is called as "The Silicon Valley of India' and "IT Capital of India".

Aerospace and aviation

Bangalore is also called the aviation monopoly capital of India. It accounts for more than 65% of India's aerospace business. World Aerospace giants such as Boeing, Airbus, Goodrich Archived 6 June 2013 at the Wayback Machine, Dynamatics, Honeywell, GE Aviation, UTL, others have their Research & Development and Engineering centres in Bangalore.

Before Bangalore was called the Silicon Valley of India, the city made its name as headquarters to some of the largest public sector companies of India such as NGEF, BEML, BEL, BHEL etc. The Hindustan Aeronautics Limited (HAL) headquarters is in Bangalore, and is dedicated to research and development activities for indigenous fighter aircraft for the Indian Air Force. With over 9,500 employees, it is one of the largest public sector employers in Bangalore.

Today, HAL manufactures, under license, various fighter aircraft for the Indian Air Force (IAF) including Sukhoi 30 Flankers and Jaguars. HAL also develops indigenous products for the IAF such as HAL Tejas,

Aeronautical Development Agency, HAL Dhruv and HAL HF-24 Marut. Aeronautical Development Agency is also headquartered in Bangalore.

The National Aerospace Laboratories (NAL) is also headquartered in Bangalore and is dedicated to the development of civil aviation technologies. Incorporated in 1960, NAL often works in conjunction with the HAL and has a staff strength of over 1,300 employees. NAL also investigates aircraft malfeasance.

A 1,000-acre (4.0 km2) special economic zone for the aerospace industry is being set up near the Kempegowda International Airport. Bangalore was also home to large domestic airlines – now defunct Simplifly Deccan and Kingfisher Airlines.

Biotechnology

Biotechnology is a rapidly expanding field in the city. Bangalore accounts for at least 97 of the approximately 240 biotechnology companies in India. Interest in Bangalore as a base for biotechnology companies stems from Karnataka's comprehensive biotechnology policy, described by the Karnataka Vision Group on Biotechnology. In 2003–2004, Karnataka attracted the maximum venture capital funding for biotechnology in the country – $8 million. Biocon, headquartered in Bangalore, is the nation's leading biotechnology company and ranks 16th in the world in revenues.

Institute of Bioinformatics and Applied Biotechnology (IBAB), initiated by Biotechnology vision group, ICICI and Biocon (located at ITPL) is trying to shape revolutionary scientists in the field.

Like the software industry which initially drew most of its workforce from the local public sector engineering industries, the biotechnology industry had access to talent from the National Center of Biological Sciences (NCBS) and the Indian Institute of Science (IISc).

Manufacturing

Other heavy industries in Bangalore include Bharat Electronics Limited, Bharat Heavy Electricals Limited (BHEL), Indian Telephone Industries (ITI), Bharat Earth Movers Limited (BEML), HMT (formerly Hindustan Machine Tools), Hindustan Motors (HM) and ABB Group.

Bangalore is also becoming a destination for the automotive industry. Volvo and many other auto suppliers have manufacturing plants in Bangalore.

Bangalore houses many small and medium scale industries in its Peenya industrial area that claimed to be one of the biggest in Asia 30-years ago; newly including Apple's India manufacturing plant – the only active plant in the world outside of China.

Other sectors

The city has several types of entrepreneurial pursuits that have shaped it along the way from the early '90s. The city is known for several restaurateurs who innovated on fast service models commonly called Darshini restaurants that served hot breakfast and beverages. Orkla Foods, the Norwegian foods company bought MTR Foods, traditional ready-to-eat consumer goods brand in 2007 for approximately $60m. A recent $100m brand is ID foods, fast becoming popular in retail. Swiggy an on-demand food delivery Unicorn is popular along with Zomato, a restaurant review, listing and food delivery business, that initially started in Bangalore. FreshMenu is a near-unicorn cloud kitchen business that only delivers via mobile apps and other on-demand food apps. Cafe Coffee Day, a listed entity is a coffee store chain with stores in Prague, Bratislava, Riga and Warsaw. Chai Point is a chain of tea stores founded in Bangalore in 2010.

Several Venture Capital funded startups like housing.com, nestaway, nobroker, commonfloor.com (acquired by the Unicorn, Quikr) are disrupting the rental marketplace in India. Several listed real estate brands have their origins in the city like Prestige Group, Brigade Enterprises, Total Environment and Sobha Developers.

India's largest indigenous OEM, Hindustan Aeronautics Limited (HAL) had its headquarters in India. Several smaller tier 1 and tier 2 suppliers had their base in the city to serve the OEM need. The National Aerospace Laboratories (NAL) is also headquartered in Bangalore and is dedicated to the development of civil aviation technologies. Bangalore also housed now-defunct full-service airline brand Kingfisher Airlines, which acquired another airline startup, Air Deccan, a budget airline.

The Indian Space Research Organization (ISRO), one of the top national space agencies in the world is headquartered in the city. ISRO is recognized world over for its indigenous capabilities in launching low cost satellites using its own launch vehicles, the PSLV and the GSLVs. ISRO has a record of deploying 104 satellites in orbits successfully in a single launch, which is a world record. ISRO has also launched a Mars mission, Mars Orbital Mission Archived 5 February 2019 at the Wayback Machine, which was the lowest cost inter-planetary orbital mission. Startups have made attempts to launch lunar rovers and are analysing satellite images to uses in agriculture and climate.

Bangalore is the home of India's first electric car brand, Reva was acquired by a large domestic car company, Mahindra & Mahindra. Several startups in automotive services, marketplaces are situated in the city. On-demand taxi service, Ola Cabs, a Unicorn, originated in the city and acquired its early competition and peer, taxiforsure. Bounce is an on-demand motorbike startup that originated in the city. Car rental companies operating in the city includes Avis, Carzonrent, Hype Luxury Mobility, Mylescars, Revvcar and Zoomcar. Zoomcar is on demand inter city car transportation startup running out of the city. RedBus is an intercity bus aggregator that was bought by Naspers group.

BigBasket.com, Zopnow.com and Zopper.com, started in on-demand grocery and compete with Amazon's Prime Now platform. Offline, formal retail format grocers originating from the city include FoodWorld supermarkets that started in 1996 and several other local brands.

Urban Ladder is a leading omnichannel commerce furniture retailer founded by entrepreneurs from the city. Lifestyle, now part of Dubai-based Landmark group originated as a brand in Bangalore in 1999. Tanishq is a jewellery retail store brand and is owned by the Tata Group. Printo is a chain of stationery and printing services stores.

Several fintech's have their origins in the city. The revolutionary low-cost brokerage firm Zerodha, several cryptocurrency exchanges. Pine Labs is a recent unicorn that builds POS systems. Capillary Technologies is a loyalty, analytics provider built over POS systems. QwikCilver, a gifting and loyalty platform founded in Bangalore was acquired by Amazon.

The city is known for its craft breweries, popular ones being Toit, Arbor Brewing Company and others. Kingfisher is one of the world's largest beer brands that originated in Bangalore. Amrut is India's first Single Malt Whisky brand that is sold all over the world and was named as the number three whisky in the world in 2010. United Breweries Group has its headquarters in Bangalore. It produces Kingfisher (beer).

Biocon is one of India's largest pharmaceutical companies which also owns a majority stake in India's largest Clinical Research Outsourcing (CRO) company Syngene International that works with global pharmaceutical majors. Strides Arcolab manufactures pharma products for emerging markets and is a listed entity in the Indian Stock Markets. The Himalaya Drug company makes several pharma and beauty care products and is headquartered in Bangalore.

Wildcraft, a fast-growing outdoor adventure goods company was founded in the city. Zivame is an online commerce lingerie company fast growing into the number 1 brand in India.

Narayana Hrudayalaya, a listed business, is a popular hospital chain that was built by renowned Bangalore cardiac surgeon. Portea Medical and Practo are some of the fast-growing startups in the space. Cloud Nine is a chain of fast-growing maternity and childcare brands founded in the city in 2007.

DTDC is an asset light logistics company built by first generation entrepreneurs in the city.

Lucia is a Kannada movie that is renowned as India's first crowdsourced movie. The movie was extensively shot in Bangalore.

There are many sports facility aggregators where consumers can book indoor courts or swimming pool slots like Playo. Many entrepreneurs are setting up sports facilities due to higher interest in fitness. There is a fitness chain called CureFit, invested in by early entrepreneurs and restaurants attached like EatFit.

Many wine yards are springing up around the city due to interest among a globally aware community of people residing in the city. Bangalore is also India's largest export of roses, about 70% of all rose exports come from the city.

Samsung Electronics in 2018, opened Largest Mobile Experience Centre in the World at Bengaluru's Iconic Opera House. Samsung Opera House will be a must-do destination for the city's millennials looking for exciting tech-enabled experiences and entertainment. One will be able to enjoy VR experiences such as the 4D Sway Chair or the Whiplash Pulsar 4D chair that makes 360 degrees three-dimensional movements. One can slip into the role of a fighter pilot doing extreme aircraft stunts, or experience a space battle, or a roller coaster ride. The 33,000 sq ft standalone property, which during the British era hosted plays and Operas, has been restored over two years and its facade continues to don its magnificent original look and feel. On the inside, a modern experiential space has been developed with extensive use of modern technology.

Economic Zones in the City

There are several economic clusters, as in many cities in the world, in the city.

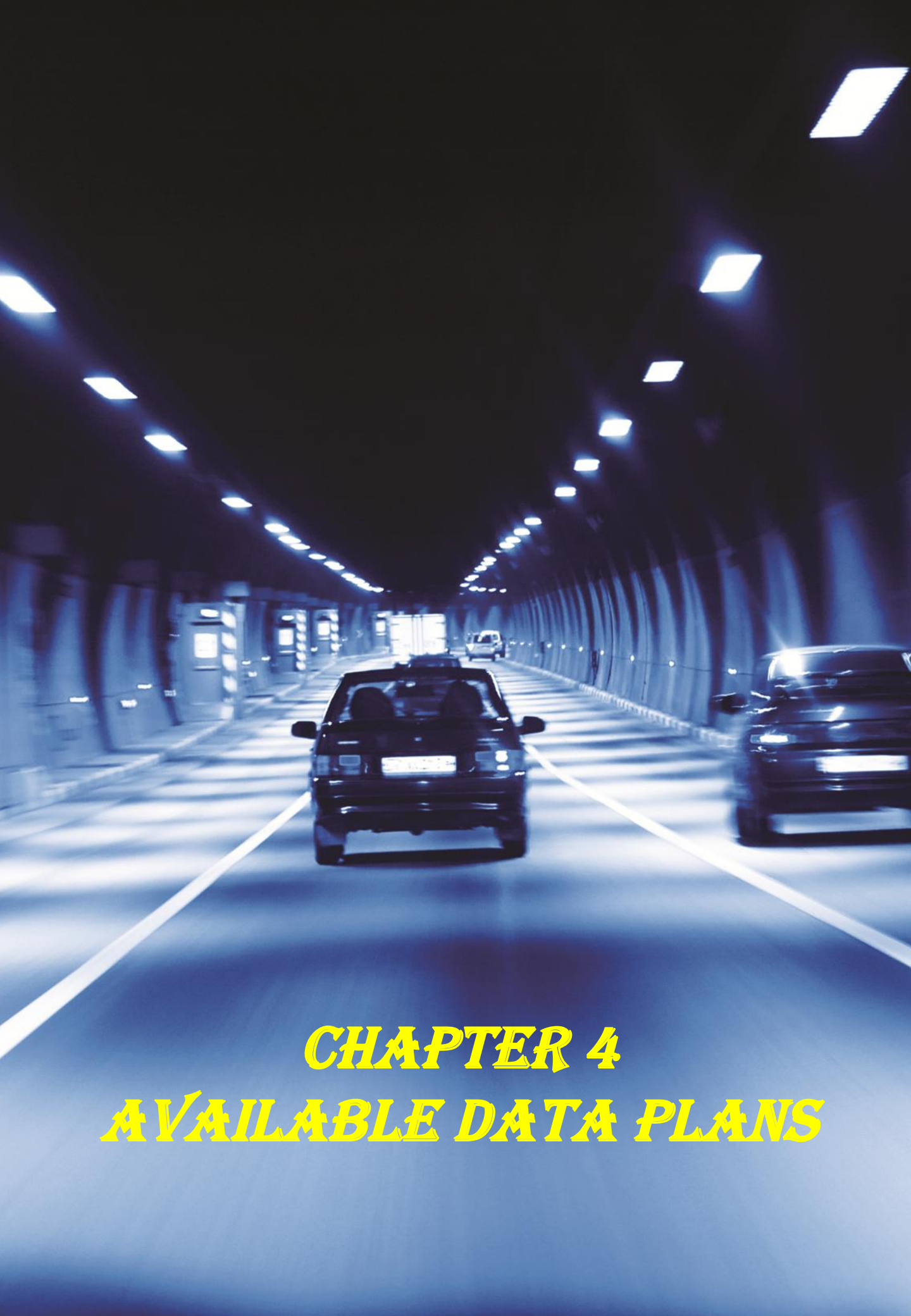
- Chickpete area is known for textile trades and early entrepreneurs in the city
- Shivajinagar area houses auto spares and services clusters
- Whitefield was a neighbouring town to Bangalore, but over time has been assimilated into the city. Whitefield houses several Information Technology Parks and many global firms have their India headquarters located in the area.
- Koramangala and JP Nagar have traditionally been the area where tech startups take birth
- Electronics City houses all the major IT service providers of India

3.3.10 Education

Bangalore has a literacy rate of around 88%, according to the 2011 national census. Primary, middle school and secondary education in Bangalore is offered by various schools which are affiliated to one of the government or government recognised private boards of education, such as the Secondary School Leaving Certificate (SSLC), Central Board of Secondary Education (CBSE), Council for the Indian School Certificate Examinations (CISCE), International Baccalaureate (IB), International General Certificate of Secondary Education (IGCSE) and National Institute of Open Schooling (NIOS). Schools in Bangalore are either government run or are private (both aided and un-aided by the government). Bangalore has a significant number of international schools due to large number of expats and people employed in the IT sector. After completing their secondary education, students either attend a pre-university course or continue an equivalent high school course in one of three streams – arts, commerce or science – in various combinations. Alternatively, students may enrol in diploma courses. Upon completing the required coursework, students enrol in general or professional degrees in universities through lateral entry.

The Bangalore University, established in 1886, provides affiliation to over 500 colleges, with a total student enrolment exceeding 300,000. The university has two campuses within Bangalore – Jnanabharathi and Central College. University Visvesvaraya College of Engineering was established in the year 1917, by Bharat Ratna Sir M. Visvesvaraya, At present, the UVCE is the only engineering college under the Bangalore University. Bangalore also has many private Engineering Colleges affiliated to Visvesvaraya Technological University.

Indian Institute of Science, which was established in 1909 in Bangalore, National Centre for Biological Sciences, National Institute of Mental Health and Neuro-Sciences, Jawaharlal Nehru Centre for Advanced Scientific Research and the Raman Research Institute are the premier institutes for scientific research and study in India. Nationally renowned universities and institutes such as the, National Institute of Design, National Institute of Fashion Technology, National Law School of India University, the Indian Institute of Management, International Institute of Information Technology, Christ University, Brindavan College of Engineering, RV Educational Institutions, University of Agricultural Sciences, Bangalore, the ICAR-National Institute of Animal Nutrition and Physiology, the Indian Statistical Institute are located in Bangalore. Bangalore also has some of the best medical colleges in the country, like St. John's Medical College and Bangalore Medical College and Research Institute. The M. P. Birla Institute of Fundamental Research has a branch located in Bangalore. Mount Carmel College, a premier institution for women's education in India is located in Bangalore. It is affiliated to Bangalore University, as is Acharya Bangalore Business School, established in 2008.



CHAPTER 4
AVAILABLE DATA PLANS

CHAPTER 4: AVAILABLE DATA PLANS

Bangalore city has undergone rapid development in the last decade and in order to meet the demand of growing population development proposals have been planned and some of the projects are under execution.

The authority has aimed to mitigate the congestion of the city and in order to find conclusion steps have been taken to find both short-term and long-term traffic mitigation plans. Few of the past studies have been analyzed to plan the North South Vehicular Tunnel connecting Hebbal to Silkboard Junction. Some major construction projects are under execution, and some are in pipelines in near coming future.

The past traffic studies, under construction projects and planned projects are mentioned below.

4.1 Comprehensive Mobility Plan-2020 prepared by Infrastructure Development Corporation (Karnataka) Limited

This is a detailed report which gives us detailed account of traffic, possible scenarios of developments by integration of Public Transport, Multimodal connectivity and other scenarios.

- Strategy 1: Expand reach and augment capacity of public transport system.
- Strategy 2: Improve operational efficiency of public transport systems.
- Strategy 3: Promote multimodal operations
- Strategy 4: Promote Transit Oriented Development.
- Strategy 5: Improve efficiency of road infrastructure.
- Strategy 6: Augment capacity of road infrastructure.
- Strategy 7: Make commuters bear full cost of externalities of mobility modes.
- Strategy 8: Influence mobility choice through regulatory, fiscal and pricing.
- Strategy 9: Promoting use of electric and cleaner fuel vehicles.
- Strategy 10: Establish mechanism for planning, capacity building and accountability.

The outputs and guidelines of the CMP has been incorporated in our project traffic analysis and project planning for future forecasting and assuming the intermodal split of traffic.

4.2 Feasibility Study Report (North-South Corridor) prepared by Altinok Consulting Engineering Inc. in JV with Lion Group.

A comprehensive road Infrastructure plan has been prepared in this report which propose the 190 Kms of the congested sections of Bangaluru City. Out of which North- South Corridor proposed to be taken up as Underground Vehicular Tunnel was one of the critical sections.

The report focuses on how the proposal for a tunnel is better over the elevated proposal or widening of the existing road. The benefits of tunnel such as uninterrupted flow, lower land acquisition, minimal disruption to existing traffic and lower environmental impact.

The feasibility gives us information about the current Level of Serviceability (LOS) in Peak Hour, which varies in LOS of E and LOS F.

The Feasibility paved the way for the further preparation of Detailed Project Report for Underground Vehicular Tunnel connecting Hebbal junction to Silk board junction while also connecting ramps at Palace Ground, Racecourse/Vidhan Soudha and Lalbagh Botanical Garden.

4.3 Existing Project in Bangalore

Currently there are three road projects that are sanctioned in Bengaluru, which are Satellite Town Ring Road, Intermediate Ring Road and Peripheral Ring Road as shown in Figure below.

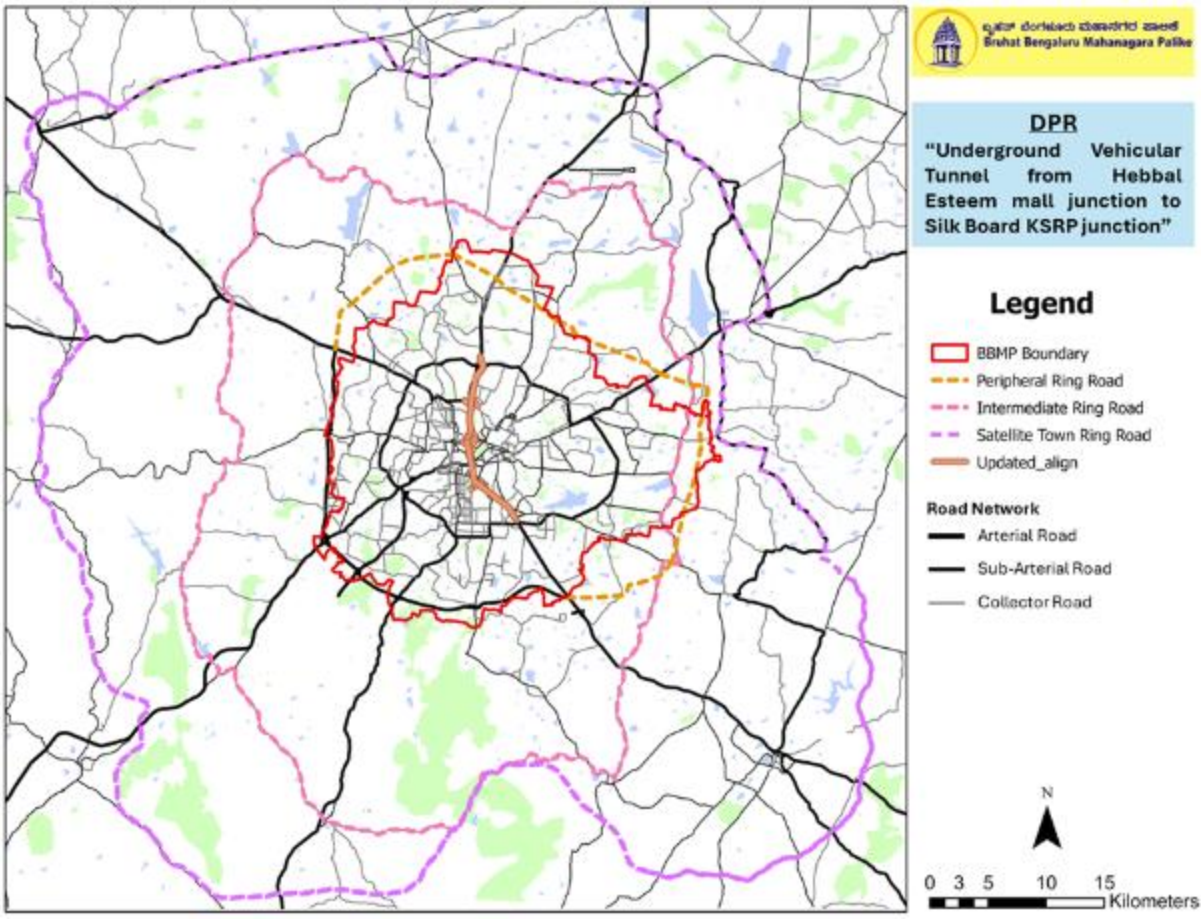


Figure 37: Three Road Projects that are Sanctioned in Bengaluru

4.3.1 Satellite Town Ring Road:

In order to ensure a safe, smooth, efficient, and high-speed transport corridor to Bangalore city, it is impetus that the infrastructure of the city and adjoining towns anticipated the development. National Highways NH 648 (NH 207), NH 48 (NH 4), NH 275, NH 948, NH 209 & NH 75 (Hassan Road), and the majority of State Highways SH 3, SH 85, & SH 35 pass through Bangalore city comprising heavy commercial traffic movement. Most of this traffic is not intended to pass through Bangalore city. This traffic further aggravates the scenario in the city roads and results in huge traffic jams. The Satellite Town Ring Road will prevent the inclusion of non-intended traffic into city traffic, traffic would be mitigated through the Satellite Town Ring Road project.

4.3.2 Peripheral Ring Road:

The proposed "Peripheral Ring Road" is 65 km long and connects 10 major Highways namely Tumkur Road (NH-4), Hesaraghatta Road(SH-39), Doddaballapura Road(SH-09), Bellary Road (NH-7), Hennur - Baglur Road (SH-104), OMR (NH-4), Whitefield road, Channasandra Main Road, Hoskote-Anekal Road(SH-35), Sarjapur Road and Hosur Road(NH-7). Overall, it intersects 4 National Highways and 6 state Highways. The proposed PRR length from the start point on Tumkur Road up to the end point on Hosur Road is 64.201 Km. Since the alignment is getting integrated with NICE road on Tumkur Road (~ 368m) and Hosur road (~ 546m), the total length of the project road is considered to be 65.115 Km.

4.3.3 Inner Ring Road:

Inner Peripheral Ring Road, which is a newly identified ring in between ORR and PRR. The alignment is a combination of existing and new roads. It connects suburbs such as Yelahanka, Jakkur, RK Hegde Nagar, Horamavu, Kithaganur, Sonnenahalli, Kadugodi, Varthur, ChikkaBegur, Hulimavu, Kengeri, Ullal, Nagasandra and Chikbanavara.

4.3.4 Namma Metro

Transport Demand Forecast Study and Identification of Phase III Corridors of Bengaluru Metro was undertaken by Bengaluru Metro Rail Corporation Limited (BMRCL) to extend the metro system in Phase III for the areas not covered by Phase-I & II and interconnect the metro system network as shown in Figure below. All metro routes of Phase-I are operational, some routes of Phase-II are operational, and the rest are ongoing projects and all routes in Phase-III are upcoming projects as given in the metro DPRs.

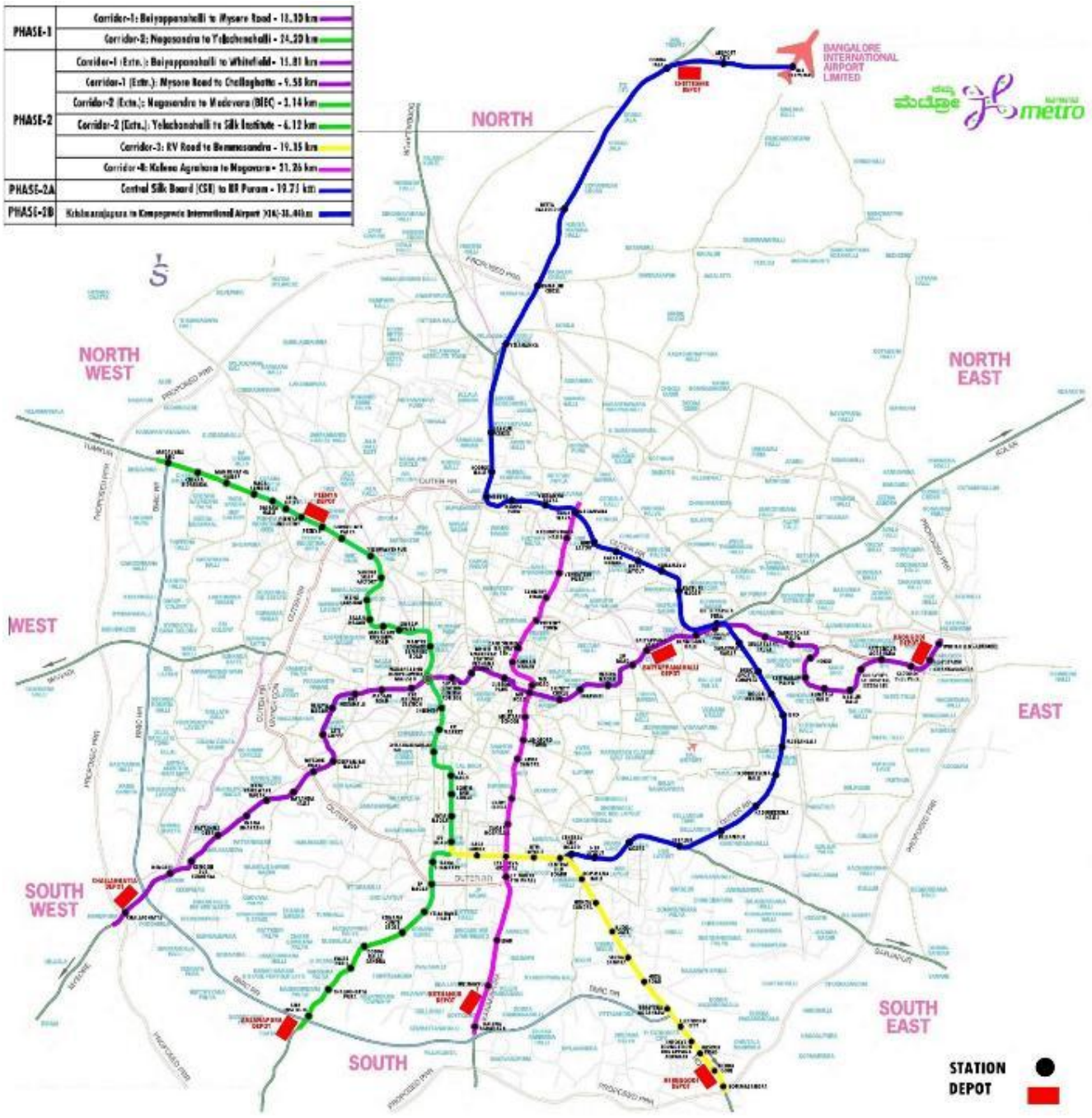
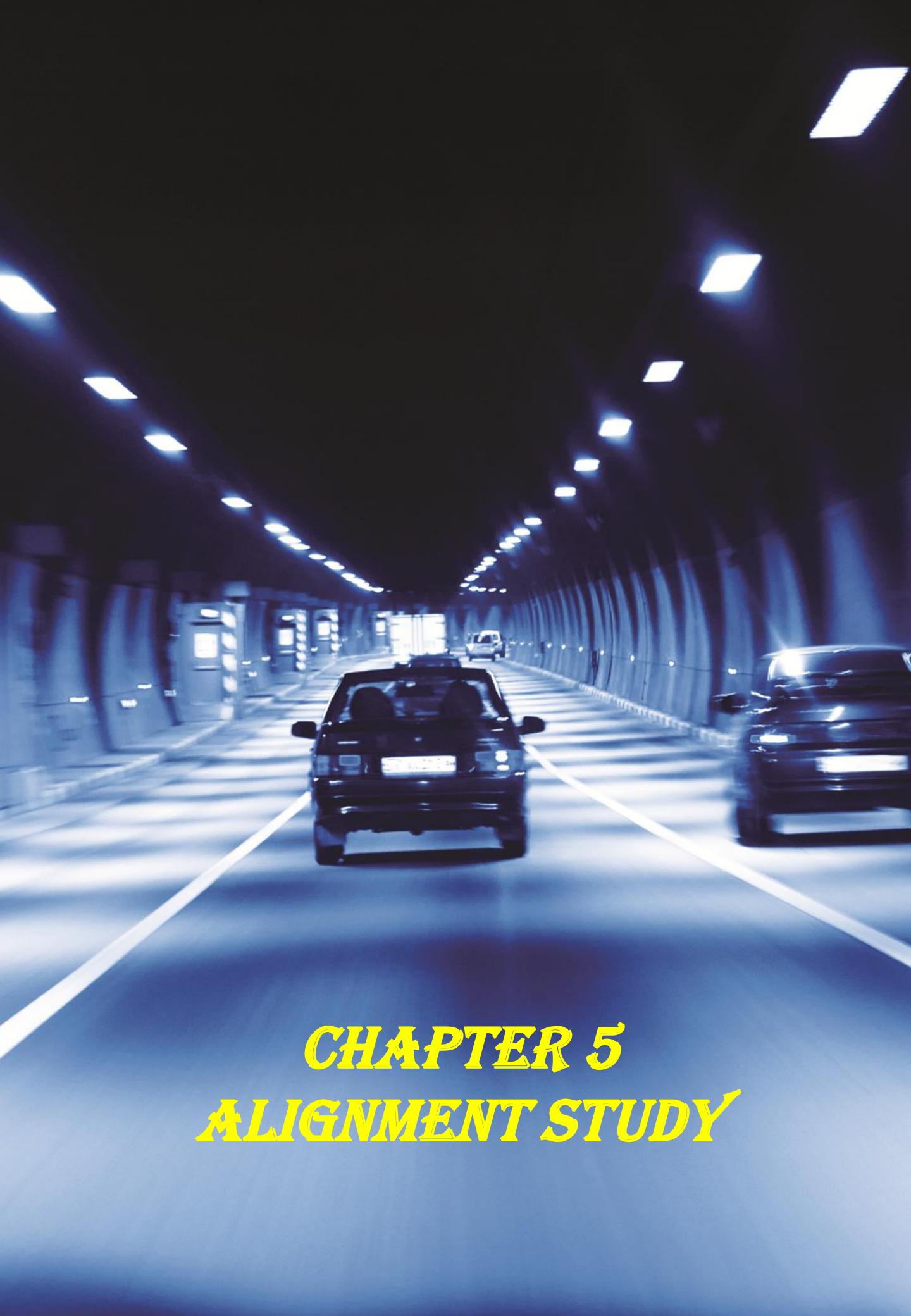


Figure 38: Existing Metro Connectivity



CHAPTER 5
ALIGNMENT STUDY

CHAPTER 5: ALIGNMENT STUDY

5.1 General

The alignment developed were analysed for the merits and demerits on basis of a matrix developed with robust criteria, which shall involve and consider all aspects pertaining to providing connectivity, Ease of Construction, Land Acquisition, Environment, and Social Impact, traffic movement, nodal point and direct connection between two nodes.

The entire project lies in the Bengaluru city and connects the northern part of Bangalore to the southern part of the city.

The North – South Corridor starts from Hebbal Esteem Mall junction and goes to Silk Board KSRP Junction. The road sections are going to connect the electronic city (Southern part) to Hebbal Junction (Northern Part) of the project.

At present the commuter to Silk Board from Hebbal has to travel via the busiest nodes of city and follows the route of Hebbal Flyover- Mekri circle-Chalyuka circle-Lalbagh Botanical Garden-Silk Board Jn. The existing corridor width varies from four lanes to six lane. And it takes approximately 90 minutes to cover a mere distance of 18 Km by road.

The project is going to develop as Underground Vehicular tunnel with twin tube configuration. To provide seamless connectivity to important intermediate nodes entry exit ramps have been provided at three intermediate locations. After the completion of the project commuters will be able to cut the travel time of 90 minutes to about 35 minutes.

The alignment was presented to the Authority at the inception stage. The alignment was presented in a series of meetings at Bangalore, suggestions and observations were recorded and incorporated in the alignment submitted in Draft DPR Stage.

The alignment was formally finalized on Approved and intimated vide BBMP Office letter BBMP/EIC/PR/2024-25 Dated 22-01-2025.

The alignment has the following proposal

- Entry Point at Hebbal: with 2 entry and 2 exits
- 3 Intermediate locations to provide connectivity in the city. The locations are ,
  - Near Palace Ground
  - Near Racecourse/Vidhan Saudha
  - Near Lalbagh Botanical Garden.
- Exit point at Silk Board Junction with 2 entries and 2 exits.

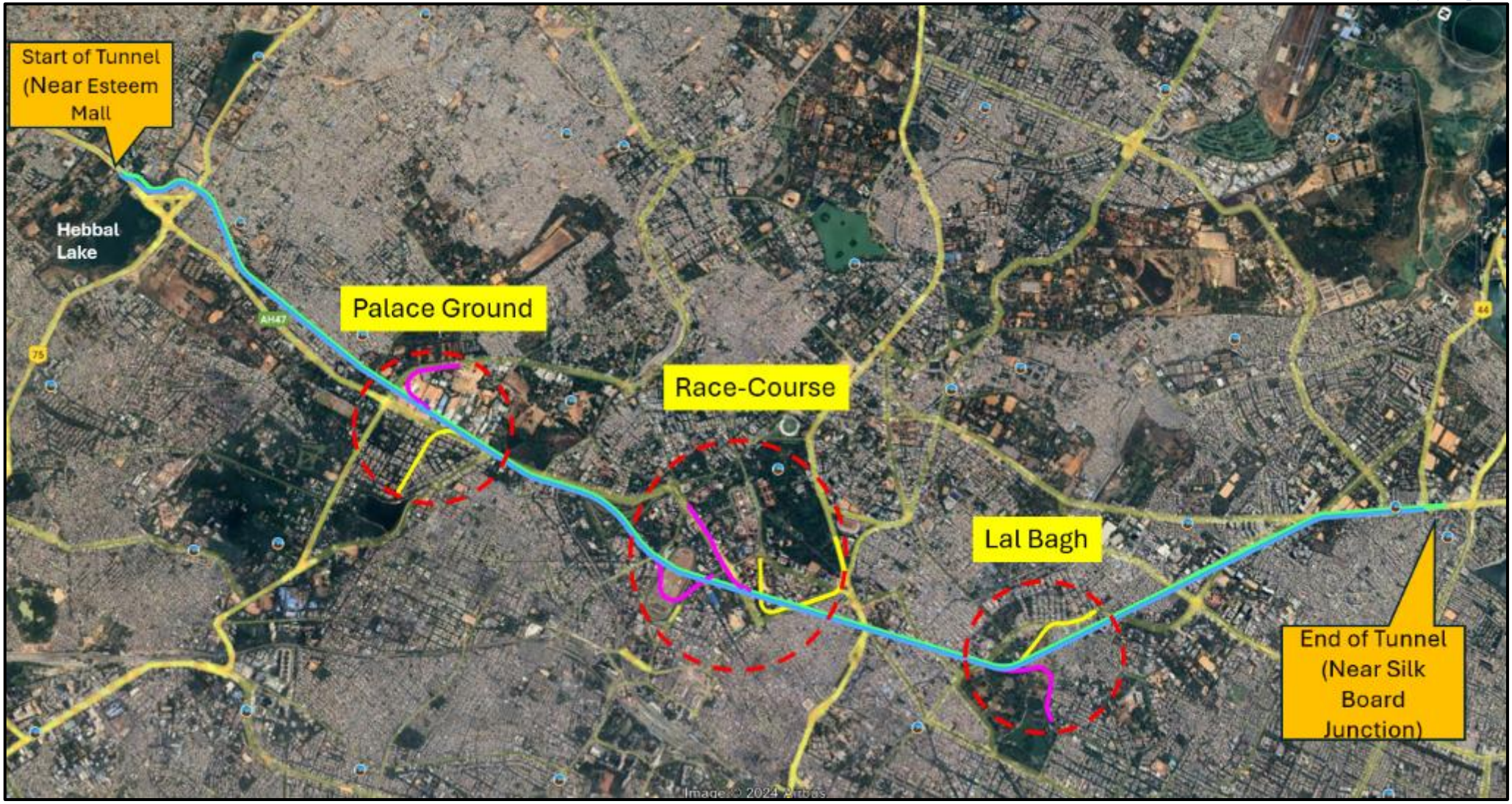


Figure 39: Project Alignment (At Inception Stage)

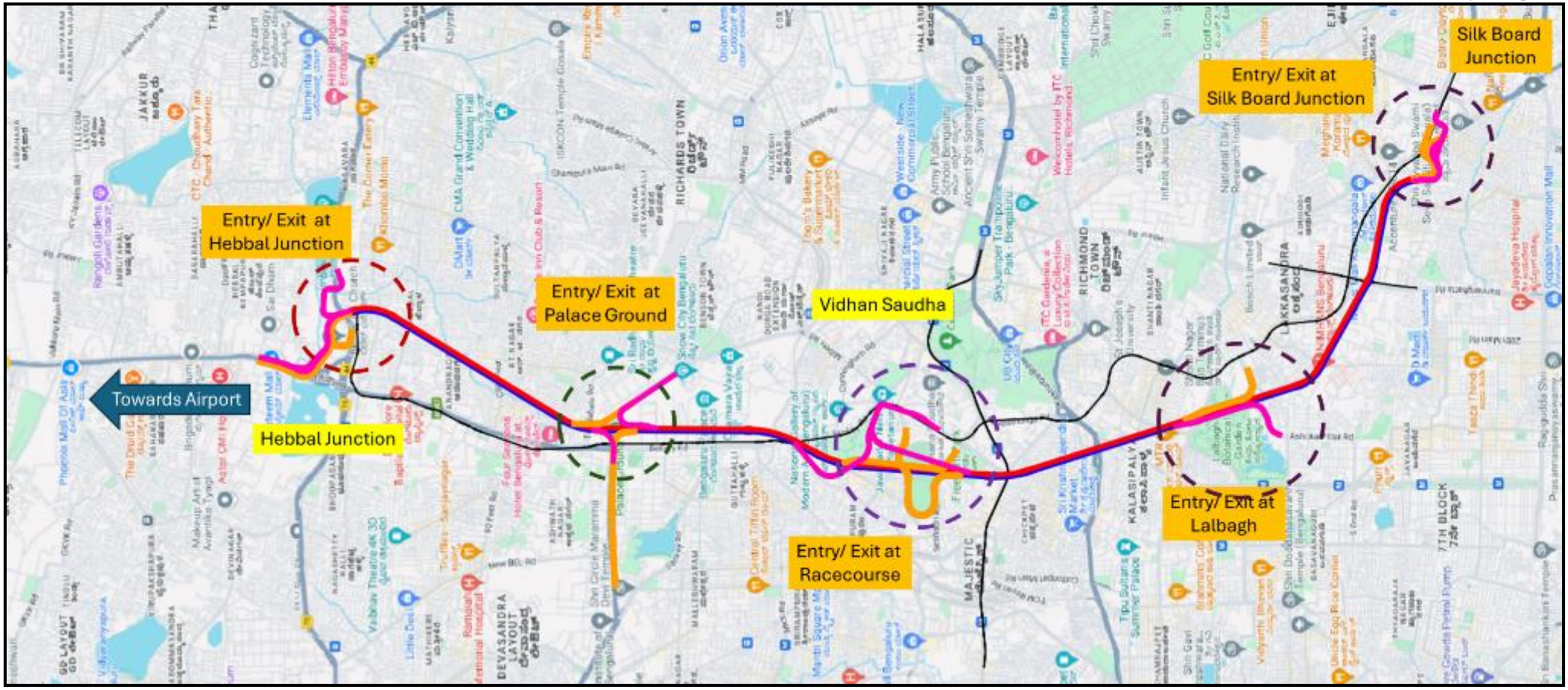


Figure 40: Project Alignment (At Draft DPR Stage)

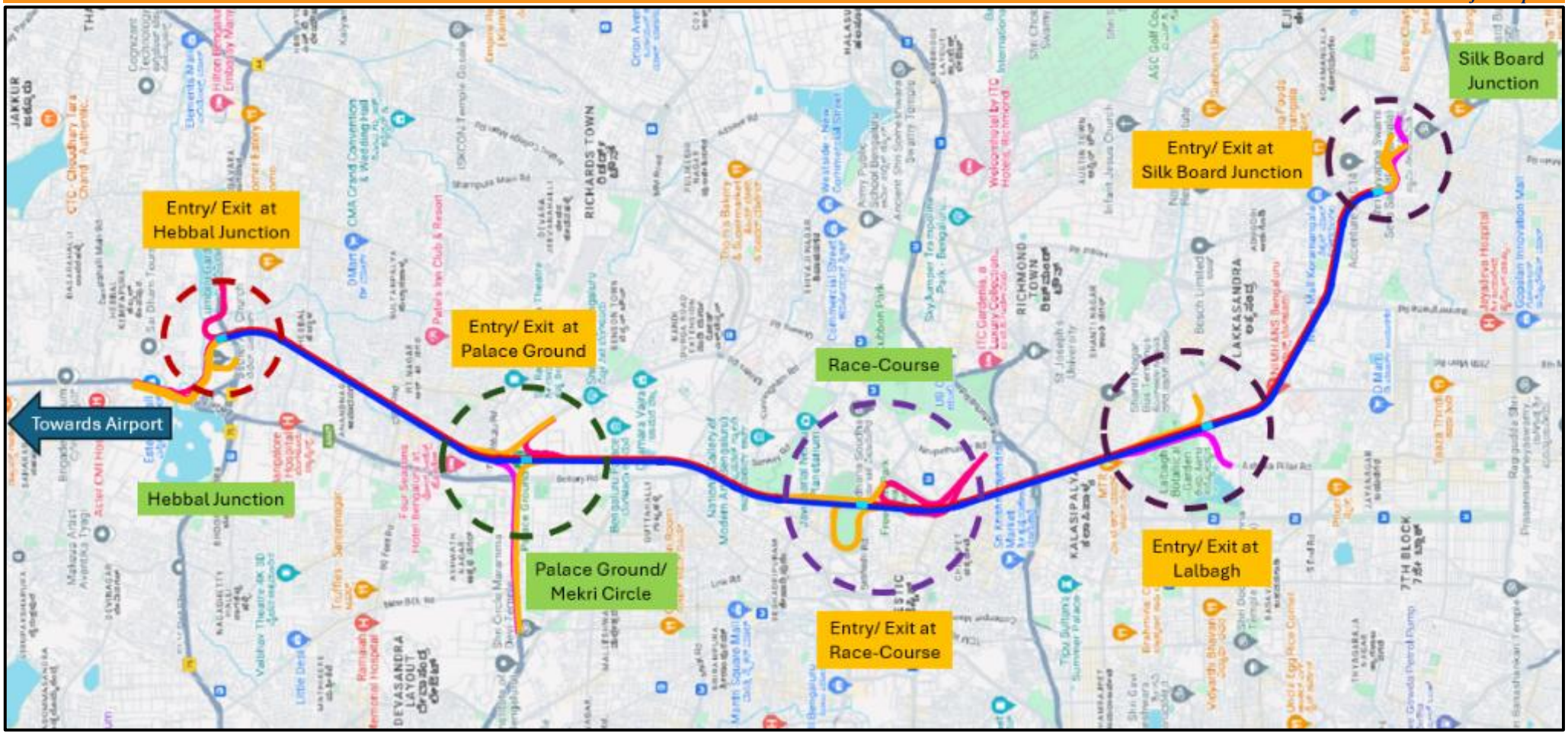


Figure 41: Final Approved Project Alignment

5.2 Design Consideration

The horizontal and the vertical alignments of the roads will have a significant impact on the design of the tunnel which will need to account for aspects such as stoppage distances, lines of sight in narrow curves, speed limits, number of lanes, gradients, etc. In addition, the design must consider all applicable Codes and Standards. In this case, the options were based on the design criteria of having 6 total lanes, three in each direction.

Table 35: Geometric Design Criteria adopted (IRC 86-2018)

SL	Description	Details
1	Design Speed	100-80 KMPH (Urban Expressway) for Tunnel 50 KMPH for Ramps
2	Lane Configuration on each tube (Mian Tunnel)	3 lane
3	Single lane width	3.5 m
4	Kerb Syness	0.5m
5	Lane Configuration of ramps (entry & exit)	2 lane
6	Radius of Horizontal Curve	400 m min.
7	Max. Super elevation	5%
8	ISD	240m
10	Minimum length of Vertical curve	60 m
11	Cross fall camber	2.0%
12	Vertical clearances	5.5m
13	Vertical Gradient	
13A	Transition Ramp and Cut & Cover (adopted)	3-6%
13B	Tunnel	3% max.

5.3 The start Point of Project

The project Stretch Start from Hebbal near Esteem Mall and end near silk board junction, where existing road is a 6-lane divided carriageway road.

The Entry at the start location has been planned near esteem mall for connecting traffic from Airport flyover and another entry has been provided from service road for the traffic coming from Sahakarnagar & Yelahanka to the main tunnel for conflict free movement at junction another entry ramps have been proposed at the Ring Road. Similarly, two exits have been proposed, one towards the Ring road and another on service road.

The starting point has two entry ramps into the tunnel and two exits. Each entry and exit have 2 lane configurations.

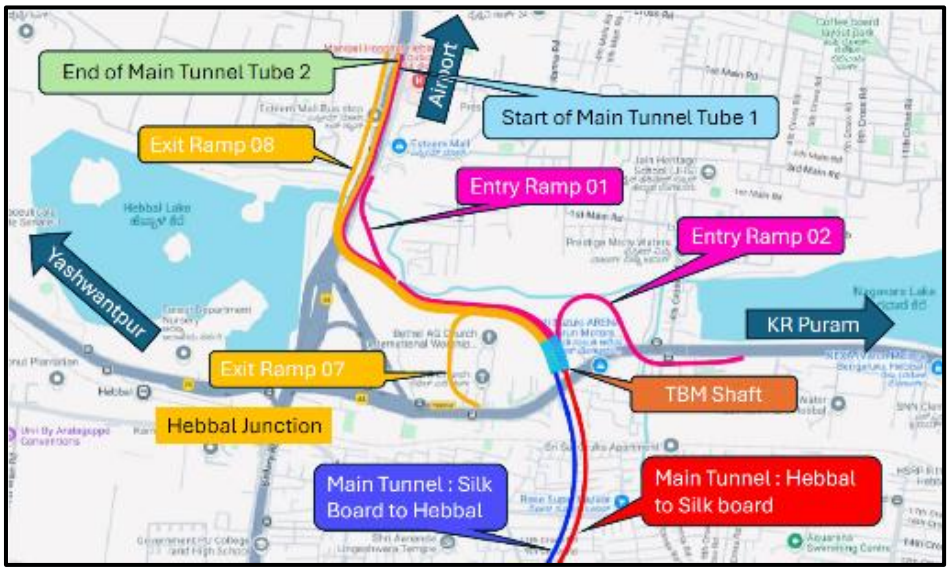


Figure 42: Entry and Exit at Hebbal Junction

5.4 First Intermediate Ramps

The first intermediate location has been planned near Mehkri circle. There are a total of 4 Entry Exit Ramps at this location.

- Two ramps have been proposed on Jayamahal Road: One exit ramp for the traffic coming from Hebbal Side, and one entry ramp for traffic going to Silk Board side from Jayamahal Road.
- Two Ramps have been proposed on CV Raman Road: One exit Ramp on CV Raman Road for the traffic coming from Silk board side and one entry ramp for the traffic going to Hebbal side from CV Raman Road.

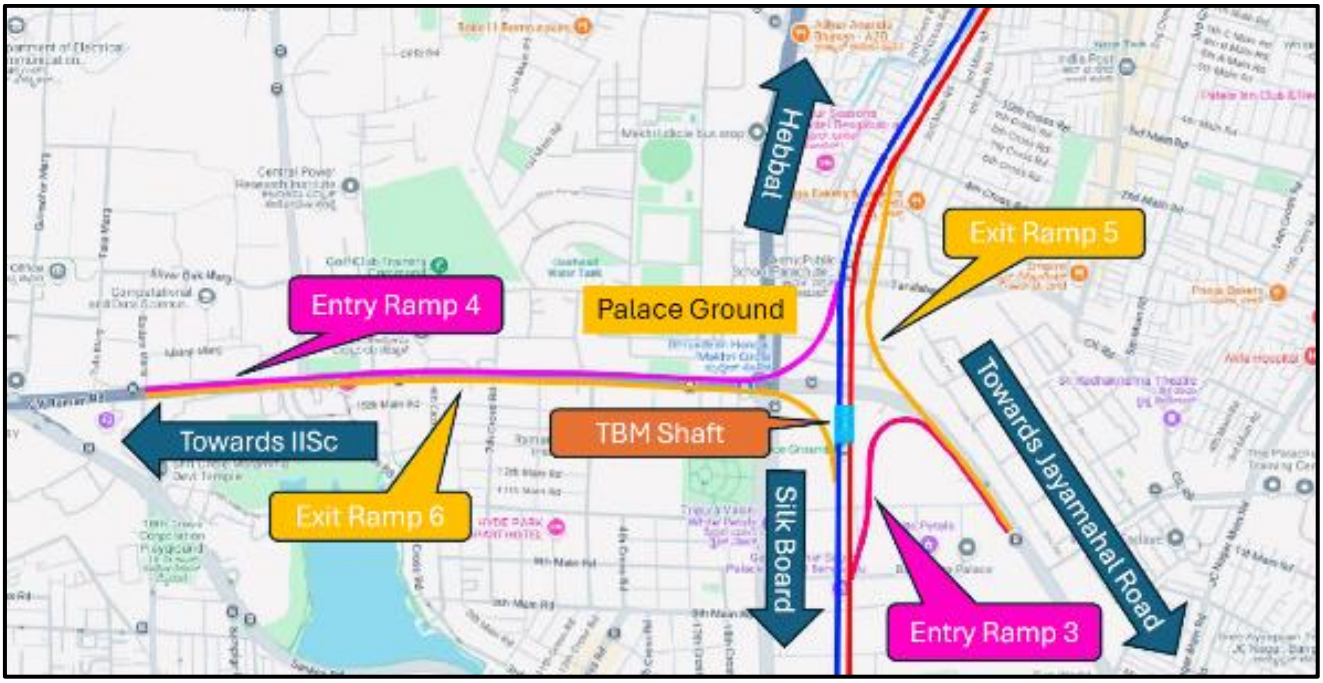


Figure 43: Entry and Exit Ramps at Palace Ground

5.5 Second Intermediate Ramps

There are a total of 4 exit and entry ramps at racecourse.

- Two Exit Ramps have been proposed on Seshadri Road for Traffic coming from Hebbal Side and as well as for the traffic coming from Silk board side.
- Two Entry Ramps have been proposed from District Officer Road (CSI Hudson Memoria Church) for traffic going to Hebbal side as well as Silk Board side.

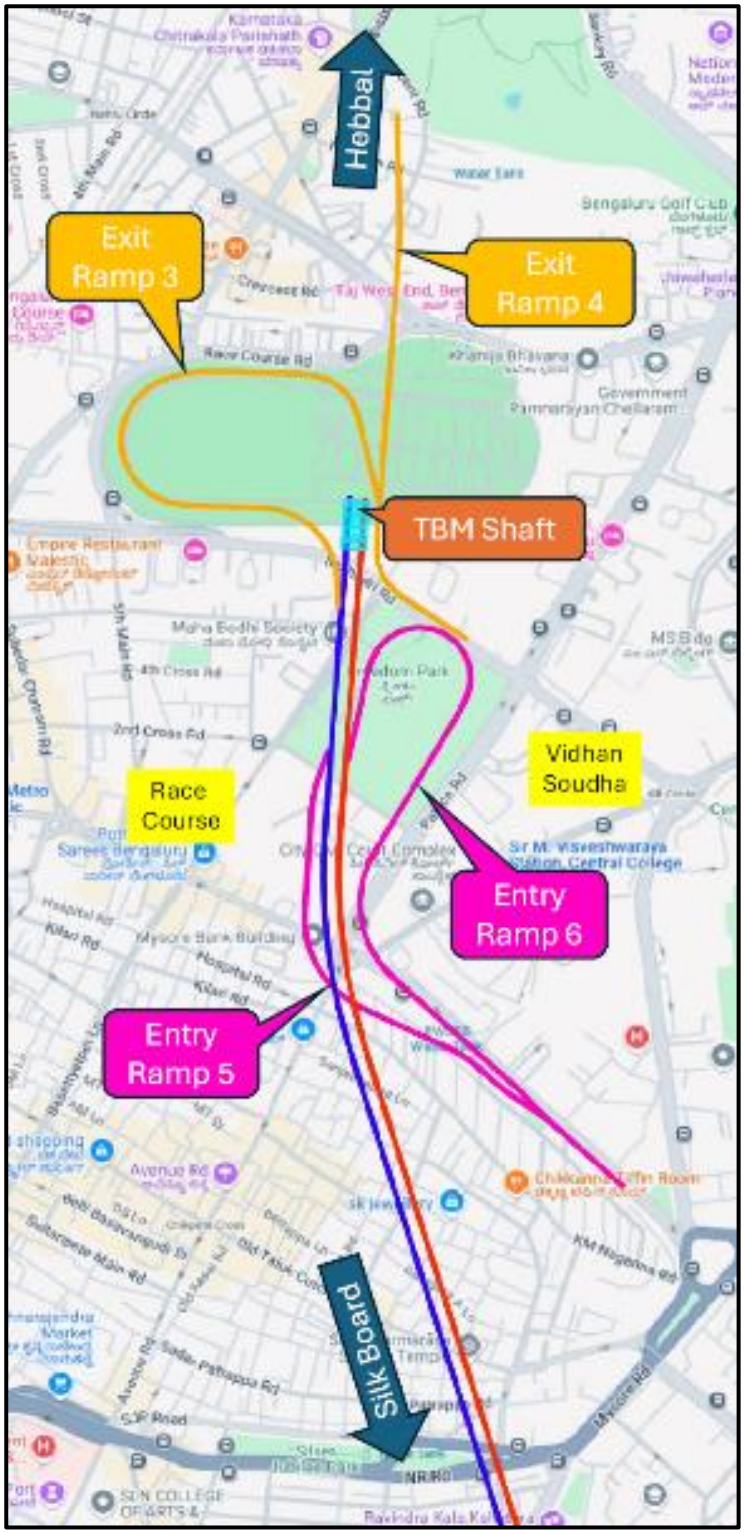


Figure 44: Entry and Exit Ramps at Race Course and Vidhan Soudha

5.6 Third Intermediate Ramps

The 3rd intermediate location is planned near Lalbagh. There is a total of 2 entry and exit ramps at this location.

- One exit ramp on Marigowda road towards Dairy circle at Wilson Garden have been proposed.
- One entry ramp from Ashoka Pillar on Siddapura road for traffic going to Hebbal junction has been proposed.

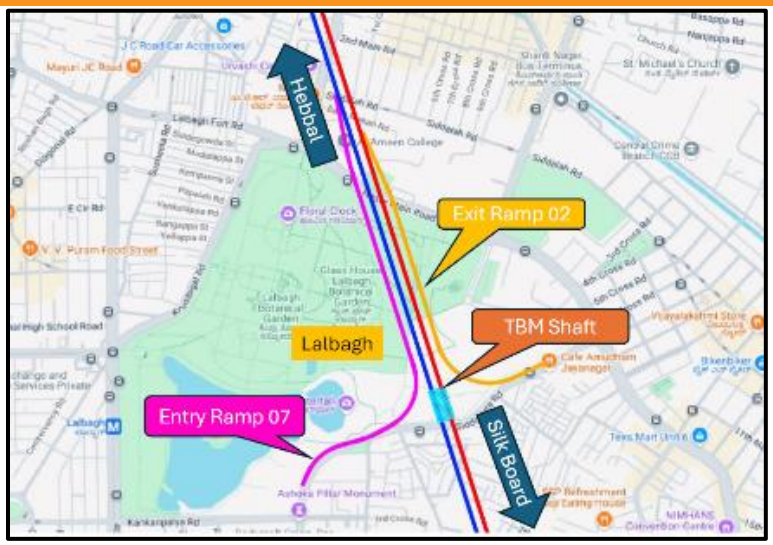


Figure 45: Entry and Exit Lalbagh Botanical Garden

5.7 The End point of Project

The Tunnel ends before silk board junction on Hosur road. Both entry and exit ramps has been planned on Hosur Road for the traffic going to electronic city. However, additional, entry & exit ramp has been planned to connect the traffic going to Ring Road/ HSR layout area on Sarjapur road near St. John Hospital.

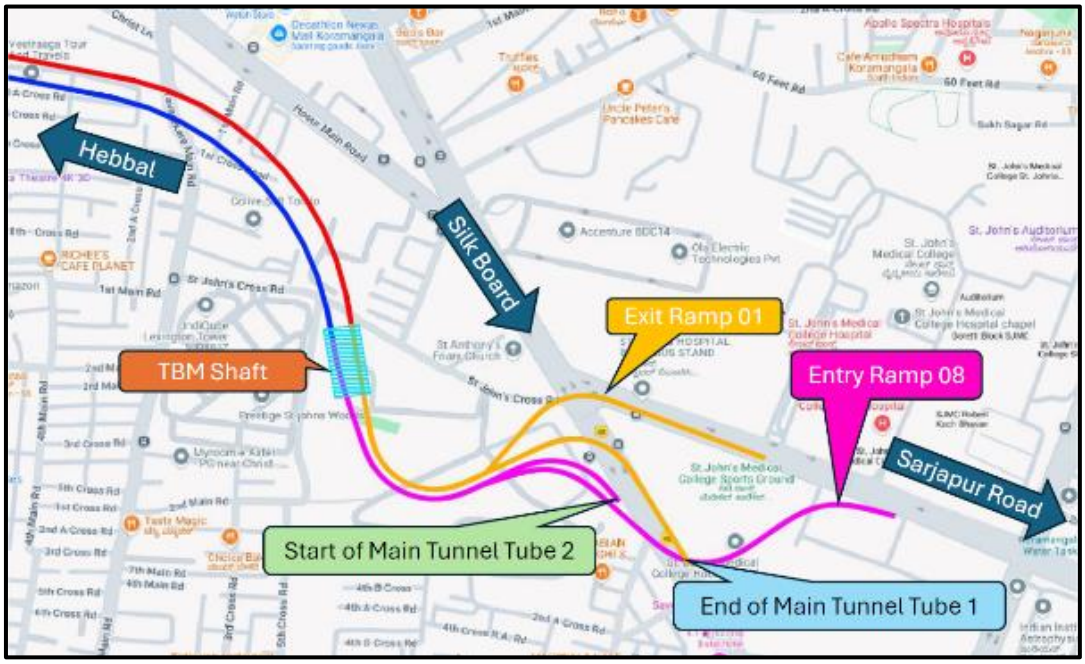


Figure 46: End Point of Project Alignment

5.8 Packaging of Project

The project have been bifurcated in two number of packages based on discussion with competent authority. The packages have been designed by considering the following aspects of the project.

- For the ease and timely construction of the tunnel project.
- Factors such as bid capacity of the leading tunnel construction firms in India and Across Globe.
- The per day boring capacity of a TBM.
- Civil construction cost of the project
- Geography of the project.

The package has been divided into North and South Portions from Km 8+748. The upper half has been considered as package 1 and lower half has been considered as Package 2 .

The detail of the project is as mentioned below,

- **Package 1:** Design and Construction of 3 lane Underground Twin Tunnel Road from Hebbal (Esteem Mall junction) (Km. 0+000) and Silk Board (KSRP Junction) along with 3lane/2-lane entry & exit ramps on Enhanced BOT (Toll) Mode including operation and maintenance in Bangalore City (North South Corridor).Package 1- Hebbal Near Esteem Mall Junction to Seshadri Road, Freedom Park (8.748 Km
- **Package 2:** Design and Construction of 3 lane Underground Twin Tunnel Road from Hebbal (Esteem Mall junction) (Km. 0+000) and Silk Board (KSRP Junction) along with 3lane/2-lane entry & exit ramps on Enhanced BOT (Toll) Mode including operation and maintenance in Bangalore City (North South Corridor). Package-2: **F**rom Seshadri Road, Freedom Park (Km 8.748) to Silk Board (Km 16.745).

5.8.1 Details of Package 1

Package 1 starts at the Km 0+000 at Hebbal Junction and Ends at Km 8+748 Kms. This package consists of upper half (North portion) of the North-South corridor of our projects. Package consists of twin tube tunnel (Tube 1 and Tube 2), Two TBM Launching and retrieval shafts , Connecting Ramps at Outer Ring Road (ORR) and Intermediate ramps at Place Ground for traffic travelling to CV Raman Road and Jayamahal Road.

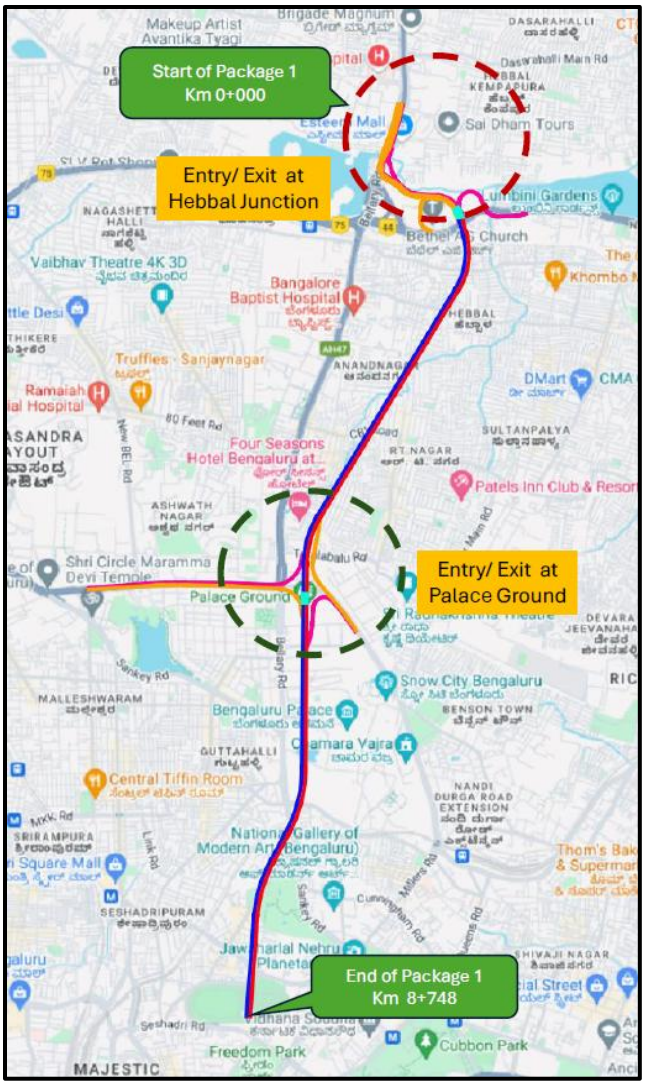


Figure 47: Entry and Exit at Hebbal Junction

5.8.2 Details of Package 2

Package 2 starts at the Km 8+748 Near Racecourse and Ends at Km 16+745 Kms. This package consists of the lower half (South portion) of the North-South corridor of our project. Package consists of twin tube tunnels (Tube 1 and Tube 2), Three TBM Launching and retrieval shafts, and Intermediate ramps at Racecourse, Lal Bagh and Silk Board Junction.

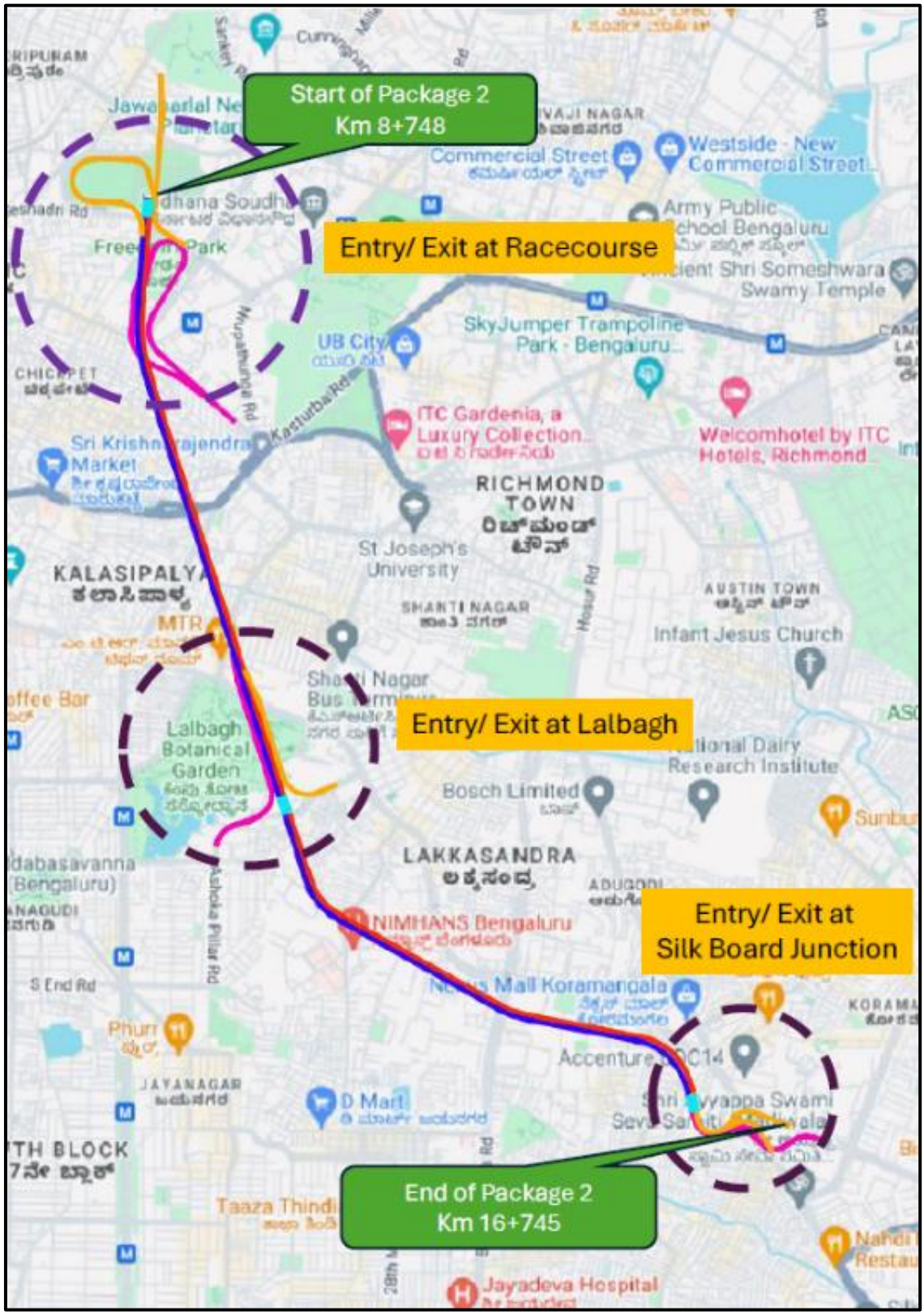
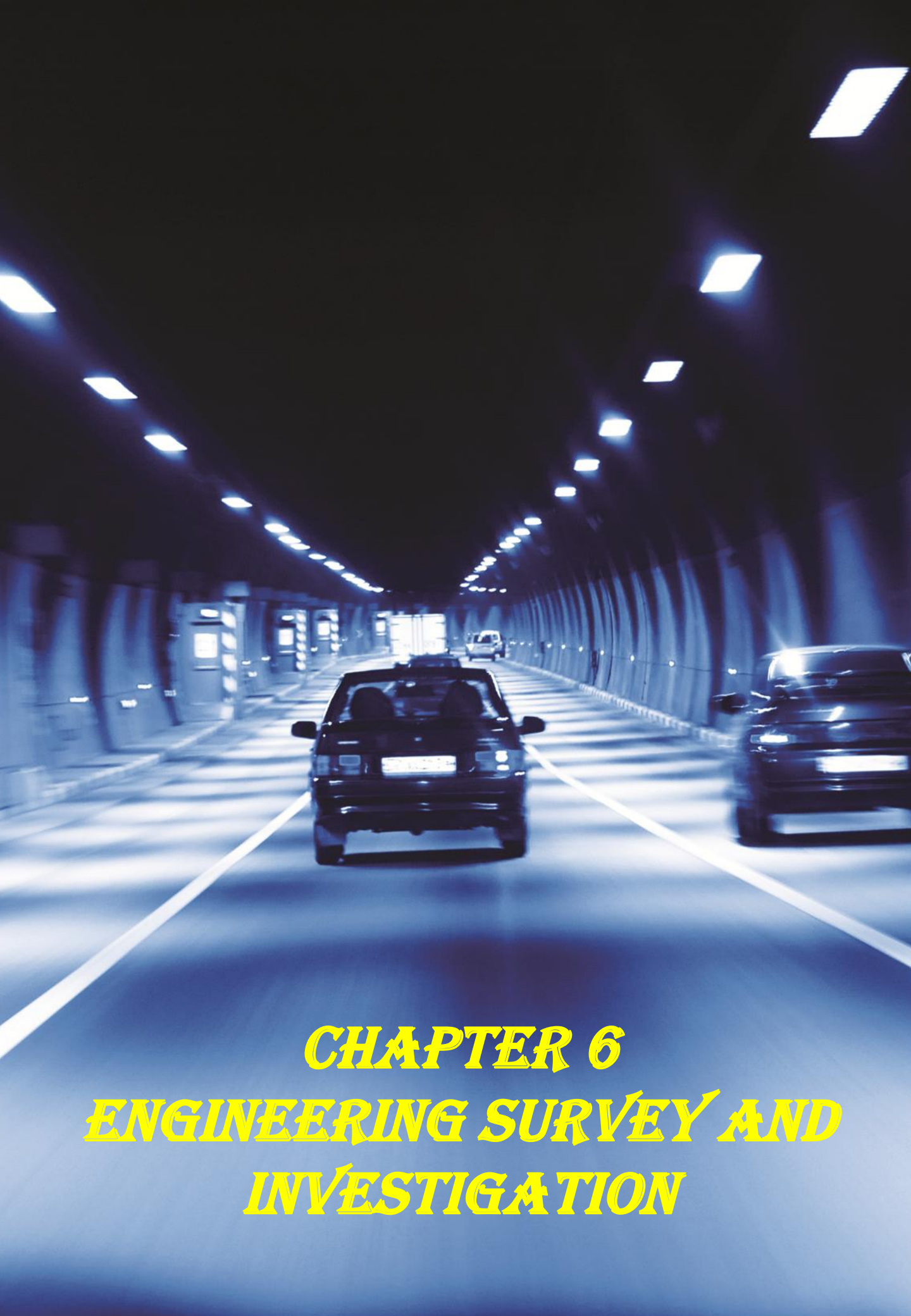


Figure 48: Alignment of Package 2



CHAPTER 6
ENGINEERING SURVEY AND INVESTIGATION

CHAPTER 6: ENGINEERING SURVEYS AND INVESTIGATION

6.1 General

Based upon the objectives of the project. With careful planning and efficient use of resources different tasks were performed simultaneously. An appropriate methodology was developed by the consultants to address the other requirements also, especially regarding various intermediate targets and completion period, manning schedule, and TOR.

A work plan was prepared based on the methodology developed. A competent team of suitably qualified key professionals as per the requirements and other supporting staff were selected to carry out the services fieldwork and office work.

Field Surveys Conducted

- Reconnaissance Survey
- Field Surveys
- Desktop Study
- Traffic Survey
- Topographic Survey
- Geological, Geotechnical & Geophysical Investigation

6.2 Existing Features of Project

The project starts near Esteem Mall Hebbal Junction and Ends at Silk board Junction. The alignment passes through nodal points/ stretch of the Bengaluru city.

First stretch is Hebbal to Golf course whose existing roadway width is 6 lane divided carriageway, then further there is connectivity to Chalukya circle via 4 lane existing divided carriageway road. After that Calukya circle is connected to Lalbagh and finally Lalbagh to Silkboard junction all the stretches are 4 lane divided carriageway.

The location of the entry and exit ramps were analyzed.

- At the Start End, the road is 6 lanes with divided carriageway. There is presence of Minor bridges near Esteem mall which channelizes the stream of Hebbal lake. The construction of metro (name of metro line and its links) is underway, which affects our project start point.
- At the End Point the road is 4 lanes with divided carriageway. The road has a under construction double decker flyover at Silk Board junction and metro is also under construction at the project end location.

The alignment passes through some of the prominent stretches of the Bengaluru city which caters the heavy traffic throughout the day.

6.3 Reconnaissance Survey

A preliminary survey was conducted to gather general information about the project area. The purpose of the reconnaissance survey is to get a broad understanding of the terrain, conditions, Environmental and Social Considerations, Safety and Risk Assessment of the project area.

6.4 Field Surveys

6.4.1 Road Inventory

Road inventory was carried out in the first week of August 2024 over the possible locations of the project alignment. The road conditions are found to be good, some of the roads have undergone strengthening of bitumen surface through the provision of White Topping. Metro is being constructed at the starting point of our project alignment. However, the project influence area the volume of traffic is quite high.

6.4.2 Existing Carriageway

The existing road infrastructure includes lane configurations of 4 lanes, and 6 lanes in various segments.

Furthermore, it is observed that several metro routes intersect with these corridors. The road stretches and lane details are as follows:

Table 36: Existing Carriageway

Stretch	Lane Configuration
1. Hebbal to Golf course	6 lanes
2. Golf course to Chalukya	4 lanes
3. Chalukya to Lalbagh botanical garden	4 lanes
4. Lalbagh botanical garden to silk board	4 lanes

6.4.3 Alignment and Geometry

An current average travel speed is 15-20 km/hr in the project stretch because of traffic congestion.

6.4.4 Terrain and Land Use

Project area lies in plain terrain in entire length. The land-use pattern for the project area is densely populated builtup of Bengaluru City.

6.5 Traffic Survey

For the evaluation of the traffic demand estimation on the proposed North – South corridor in Bengaluru and impact on the road network in study area, traffic model was developed in PTV Visum 2024 software. Macro simulation analysis was conducted to understand the overall travel patterns in the study area. PTV Visum 2024 helped us to understand the existing traffic and travel patterns and bottlenecks in the transportation system. Further it is used for scenario testing according to the changes in demand and infrastructure. Comprehensive data collection was done to understand the existing traffic and travel pattern and for development of the base year model. Further updating the demand and network in the model the diversion to the corridor is estimated.

The traffic survey was conducted along the proposed corridor, The location of traffic survey mainly for classified Volume count, O-D Survey and Turning movement survey has been studied and detailed analysis has been described in Chapter 7 of this report.

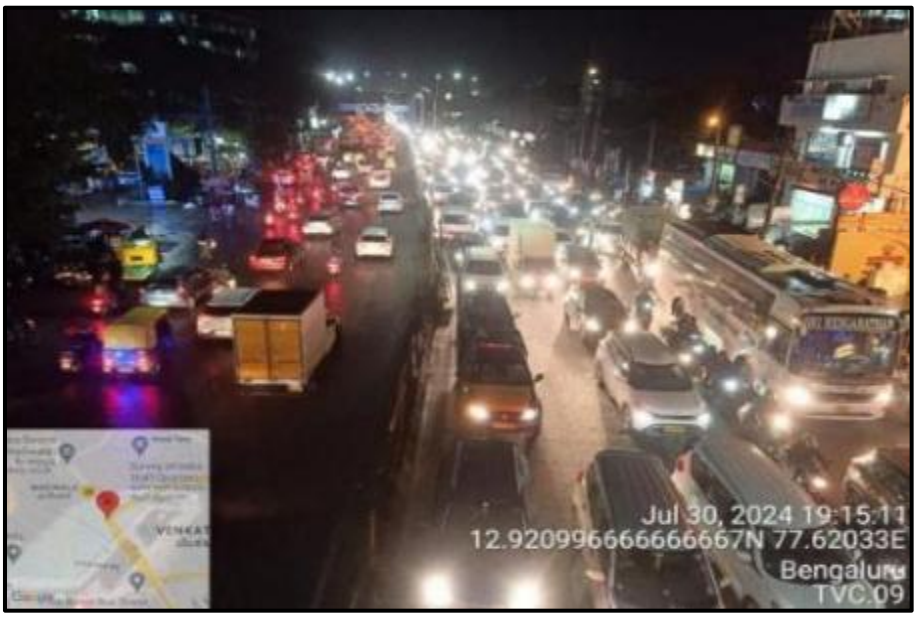


Figure 49: Traffic Surveys conducted at Project Location

6.6 Topography Survey:

The topography survey was carried out using DGPS (Differential Global Positioning System) for all the entry, exit and intermediate ramps locations.

Figure 50: Topography Survey on Site

6.7 Geotechnical & Geophysical Investigation:

The geological setup of the project corridor was studied through extensive literature survey of the existing geological literatures and maps of the project area published by GSI and other geo-scientists, and existing geotechnical investigation information carried out by other agencies in the vicinity of proposed route alignment, followed by detailed geological foot survey of the alignment corridor. After the detailed geological analysis of the project corridor, the geological reference model (GRM) of the project component was prepared.

The GRM is further validated by the Geophysical survey carried out along the road tunnel alignment in form of Seismic Refraction test (SRT) and Multichannel Analysis of Surface Wave (MASW) and accordingly the GRM was also updated. Based on the outcome of the updated GRM, the project alignment is further refined and optimized. The Geological reference Model (GRM) has been prepared and presented as the Geological L-section, and geological and geotechnical interpretation has been made based on these investigations and available data and presented as prefinal geotechnical interpretative report. (Refer volume III Pre-final GIR).

Further, Intrusive investigations in form of boreholes and laboratory/in-situ testing is being carried for confirmation of geological contacts, weak zones, fracture/shear zones, water table etc. This information will be crucial to be provided to the prospective bidders as for their information in addition to other data available for adjacent projects. The same will be completed in due course of time and will be included in bid document before closing final addendum and corrigendum for bidding process.

Figure 51: Geophysical Survey on Site

The list of Geophysical Survey carried out along the project alignment is given in table below.

Table 37: Location of Seismic Refraction test

Sr. No.	SRT	Start		End		Length (m)
		Easting (m)	Northing (m)	Easting (m)	Northing (m)	
1	SRT -1	E-781859	N-1443184	E-781742	N-1443167	118
2	SRT-1A	E-781748	N-1443435	E-781737	N-1443320	116
3	SRT-1B	E-781841	N-1443527	E-781953	N-1443553	115
4	SRT-1C	E-781492	N-1443485	E-781427	N-1443388	117
5	SRT-2	E-780927	N-1439791	E-780861	N-1439886	116
6	SRT-3	E-780084	N-1437422	E-780197	N-1437256	201
7	SRT-4	E-780090	N-1436704	E-780071	N-1436471	234
8	SRT-5	E-779628	N-1436707	E-779604	N-1436478	230
9	SRT-6	E-780016	N-1435891	E-779945	N-1435802	114
10	SRT-7	E-780772	N-1433141	E-780808	N-1433031	116
11	SRT-7A	E-780973	N-1432707	E-780859	N-1432722	115
12	SRT-9	E-781398	N-1431824	E-781509	N-1431863	118
13	SRT-10	E-782775	N-1431247	E-782721	N-1431146	115
14	SRT-11A	E-783417	N-1430840	E-783424	N-1430722	118
15	SRT-11B	E-783501	N-1430676	E-783606	N-1430723	115
16	SRT-12A	E-783860	N-1430688	E-783925	N-1430593	115
17	SRT-12B	E-783934	N-1430577	E784045	N-1430610	116
18	SRT-13	E-784019	N-1430500	E-784120	N-1430444	115

Table 38: Location of Multichannel Analysis of Surface Wave (MASW)

Sr. No.	MASW	Start		End		Length (m)
		Easting (m)	northing (m)	easting (m)	northing (m)	
1	MASW-2	E-781806	N-1442978	E-781875	N-1442987	70
2	MASW-3	E-781710	N-1442598	E-781777	N-1442583	69
3	MASW-4	E-781429	N-1442348	E-781529	N-1442313	106
4	MASW-5	E-781206	N-1441835	E-781137	N-1441842	69
5	MASW-6	E-781082	N-1441533	E-781013	N-1441533	69
6	MASW-7	E-780879	N-1441281	E-780872	N-1441212	69
7	MASW-8	E-780727	N-1441006	E-780698	N-1440943	69
8	MASW-9	E-779172	N-1440172	E-779103	N-1440167	69
9	MASW-9A	E-779480	N-1440187	E-779411	N-1440187	69
10	MASW-10	E-780013	N-1435517	E-779980	N-1435457	68
11	MASW-11	E-780167	N-1435096	E-780141	N-1435031	70
12	MASW-12	E-780345	N-1434468	E-780351	N-1434400	68
13	MASW-13	E-780573	N-1433822	E-780558	N-1433754	70
14	MASW-14	E-783216	N-1431059	E-783281	N-1431035	69

The detailed report of geophysical survey has been attached as Annexure of Volume-III (Pre-final GIR).

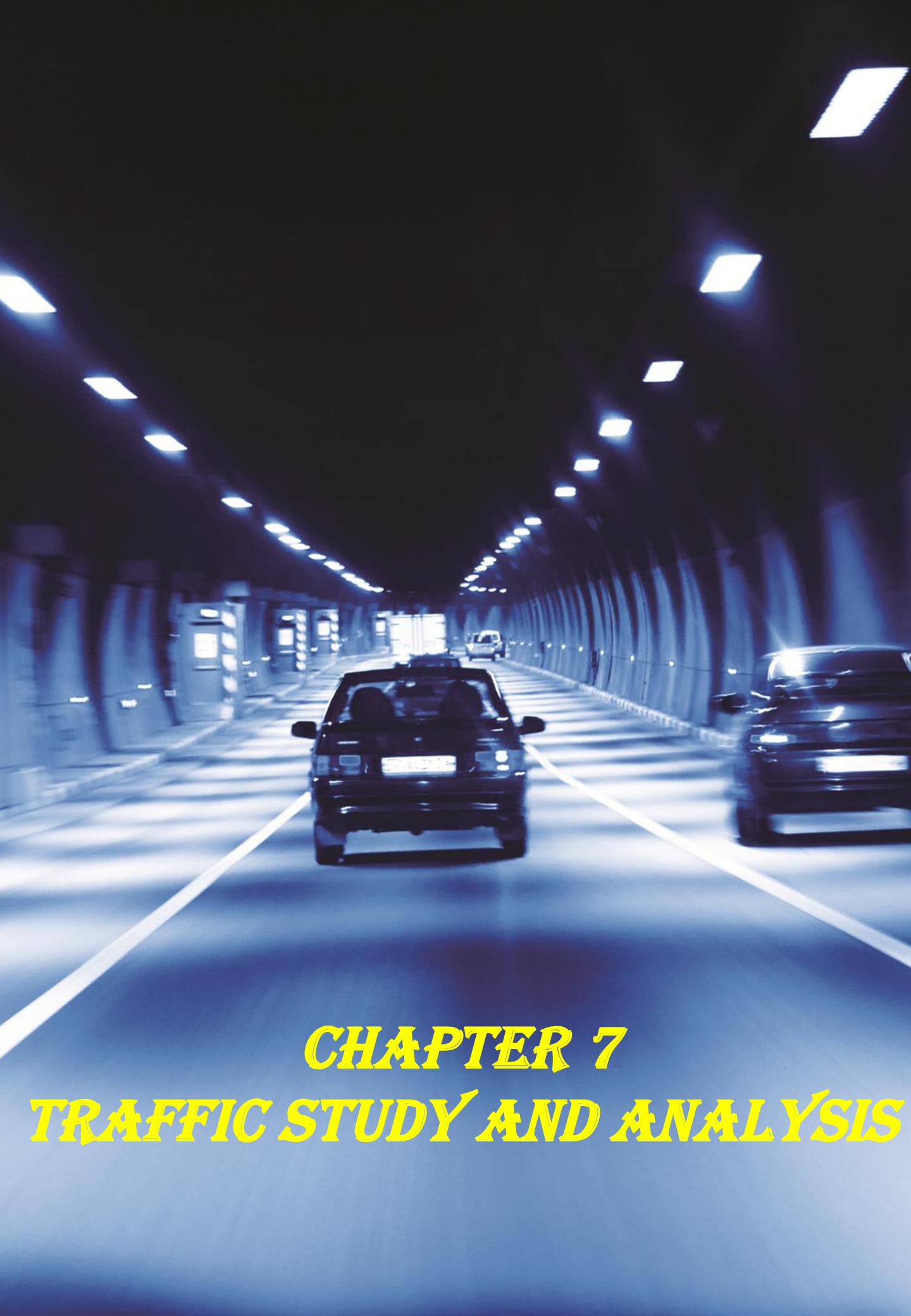
The details of proposed intrusive investigation (borehole) location is given in the table below.

Table 39: Bore Hole List

Sr. No.	BH. No.	Chainage	Co-ordinate		Proposed Depth (m)
			Easting (m)	Northing (m)	
1	BH-1	1+330	781713.384	1443449.247	43
2	BH-2	1+430	781752.481	1443360.348	32
3	BH-3	7+700	780122.621	1437522.04	57
4	BH-4	8+800	780039.119	1436422.875	43
5	BH-5	1+375	780240.929	1436187.314	32
6	BH-6	9+350	780019.095	1435873.311	62
7	BH-7	0+210	780421.946	1435233.735	22
8	BH-8	10+700	780311.207	1434564.678	53
9	BH-9	12+050	780725.643	1433278.783	42
10	BH-10	12+700	780923.86	1432660.916	42
11	BH-11	12+820	780959.135	1432551.46	39
12	BH-12	13+410	781221.228	1432028.551	12
13	BH-13	13+720	781490.312	1431872.322	75
14	BH-14	14+450	782127.304	1431516.247	70
15	BH-15	14+950	782592.586	1431335.927	60
16	BH-16	15+980	783433.917	1430910.445	36
17	BH-17	16+380	783651.014	1430692.502	15
18	BH-18	1+650	781810.5636	1443147.744	45
19	BH-19	2+250	781516.1849	1442366.03	55
20	BH-20	3+135	781205.417	1441829.916	50
21	BH-21	4+380	780577.9906	1440755.216	40
22	BH-22	5+010	780483.2649	1440137.459	43
23	BH-23	1+060	779721.1191	1440175	46
24	BH-24	6+835	780451.8492	1438320.226	53
25	BH-25	9+820	780043.1579	1435409.75	75
26	BH-26	10+500	780247.733	1434757.803	60
27	BH-27	11+425	780531.1742	1433874.615	44

Figure 52: Ongoing Borehole along proposed tunnel alignment

The intrusive investigation is in process and expected to be completed shortly. Upon completion of the intrusive boreholes the final GIR will be prepared on the basis of the information gathered from these boreholes and submitted in due course of time.



CHAPTER 7
TRAFFIC STUDY AND ANALYSIS

CHAPTER 7: TRAFFIC STUDY AND ANALYSIS

7.1 Approach & Methodology

7.1.1 Approach

For the evaluation of the traffic demand estimation on the proposed North – South corridor in Bengaluru and impact on the road network in the study area, a traffic model was developed in PTV Visum 2024. Macro simulation analysis was conducted to understand the overall travel pattern in the study area. PTV Visum 2024 helps to understand the existing traffic, travel patterns and bottlenecks in the transportation system. Further it was used for scenario testing according to the changes in the demand and infrastructure. Comprehensive data collection was done to understand the existing traffic and travel patterns and for the development of the base year model. Further, the demand and network in the model were updated for horizon years to estimate the diversion on the corridor.

7.1.2 About Software

For the development of the simulation model State of the art simulation software PTV Visum 2024 was used.

PTV Visum 2024 is a comprehensive, flexible software system for strategic traffic and transport planning. Around the globe, the software is used for metropolitan, regional and state-wide infrastructure planning. PTV Visum 2024 is one of the world's leading software for traffic analyses, forecasts and GIS-based data management. It consistently models all road users and their interactions and has become a recognized standard in the field of transport planning. Transportation experts use PTV Visum 2024 to model transport networks and travel demand, analyse expected traffic flows, to plan public transport services and to develop advanced transport strategies and solutions.

7.1.3 Methodology

The overall methodology included various steps starting from data collection and analysis, deriving inputs from primary and secondary data, base-year model preparation, model validation in PTV Visum 2024, Updating demand along with network and estimation of diversion on the proposed corridor. The figure mentioned below provides the complete methodology for the travel demand estimation.

The process was divided into seven distinct stages, each with specific objectives and tasks. Stage 1 focused on data collection, encompassing both primary and secondary sources. Primary data was collected through classified traffic volume surveys, classified turning movement surveys, origin-destination surveys, and speed and delay studies. Secondary data was sourced from previous studies such as the Comprehensive Mobility Plan 2020, feasibility reports, sustainable mobility reports, and Metro DPRs. This data was utilized to extract valuable information like zone boundaries, link shape files, demand matrices, and other relevant planning data.

In Stage 2, the collected data was analyzed to derive inferences and identify potential transport and infrastructure proposals and projections. Stage 3 involved developing a base-year macro simulation model using PTV Visum 2024 software, incorporating both primary and secondary survey data. In Stage 4, Model calibration and validation was done using the primary survey's count data. Stage 5 focused on deriving projections for traffic, mode share, and modal shift based on past studies. Stage 6 updated the model's demand and network considering future proposals, while Stage 7 estimated diversion for the corridor using the PTV Visum 2024 model. This comprehensive approach ensured a thorough understanding of the existing traffic conditions and facilitates informed decision-making for future transportation planning and development.

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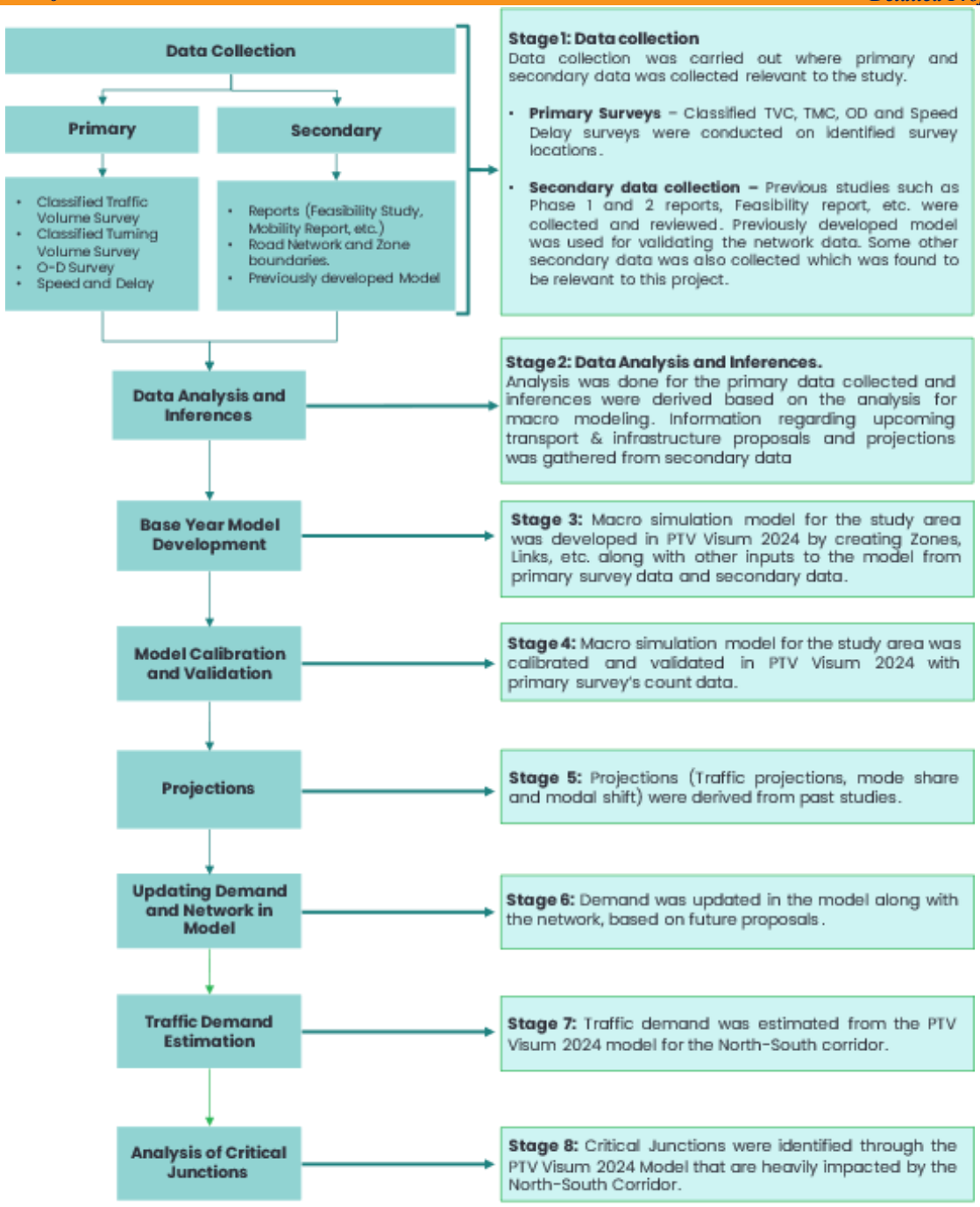


Figure 53: Overall Methodology

7.1.4 Stage 1 - Data Collection

This stage focused on data collection, including data from both primary and secondary sources. Primary data was gathered through classified traffic volume surveys, classified turning movement surveys, origin-destination surveys, and speed and delay studies. Secondary data was sourced from previous studies such as the Comprehensive Mobility Plan 2020, feasibility reports, sustainable mobility reports, and Metro DPRs. This data was utilized to extract valuable information like zone boundaries, link shape files, demand matrices, and other relevant planning data.

Primary Data collection

To comprehensively understand the traffic and travel dynamics within the study area, a series of surveys were conducted. These surveys included:

- **Classified Traffic Volume Count at Mid-blocks:** This survey involved recording the volume of vehicles passing through designated mid-block sections along the corridor. By categorizing vehicles based on type (e.g., cars, trucks) and direction (e.g., northbound, southbound), patterns of traffic flow can be analyzed.
- **Classified Turning Movement Count at Intersections:** At key intersections within the study area, turning movement counts were conducted. This involved observing and categorizing vehicles based on their turning movements (e.g., left turn, right turn, through movement). This data provided insights into the distribution of traffic movements at critical junctions.
- **Origin and Destination Survey**: This survey aimed to identify the starting points (origins) and destinations of vehicles traveling along the corridor. By understanding where vehicles begin and end their journeys, planners can assess travel patterns and needs, which is crucial for future transportation planning and infrastructure development.
- **Speed-Delay Surveys**: Speed and delay measurements were recorded at various points along the corridor. This survey captured data on vehicle speeds and any delays encountered due to congestion, traffic signals, and other factors. Analyzing speed and delay data helps in evaluating the efficiency of the roadway network and identifying potential areas for improvement.

These surveys were essential for gathering accurate and detailed information about the traffic flow, travel patterns, and operational characteristics within the study area. The data collected formed the basis for informed decision-making in transportation planning and management, aiming to enhance overall traffic efficiency and commuter experience along the corridor.

Secondary Data collection

Various reports and secondary data including Comprehensive Mobility Plan Bengaluru 2020, Feasibility report (North – South corridor), sustainable mobility report, metro DPRs, Metro routes, bus routes, vehicular registration data, CMP Model, road network, zone boundaries and other relevant data will be collected in this stage.

7.1.5 Stage 2 - Data Analysis and Inferences

In this stage, analysis was done for the primary data collected and inferences were derived based on the analysis such as the peak hour traffic and PCU counts and travel pattern for each mode. Information regarding upcoming proposals of transport and infrastructure projects, proposed modal share and modal shift, metro DPRs, feasibility report and sustainable mobility report. Data from the CMP model was also extracted to get planning data.

7.1.6 Stage 3 - Base year model development

The development of the base year model in PTV Visum 2024 involved a structured process aimed at accurately representing the current transportation network and travel patterns within the study area. The immediate study area (influence area) was considered approximately 2.5 km buffer from the proposed North-South Corridor which consisted of internal zones for the model. The base year model consisted of the existing road network (Links and Nodes) which was imported from OSM Maps and Open Data of Bengaluru, and the carriageway widths were validated from the reconnaissance survey. Further the data was imported into the model regarding inventory information, traffic analysis zones, OD matrices and base year volume counts based on the primary survey. The methodology for model development is given below.

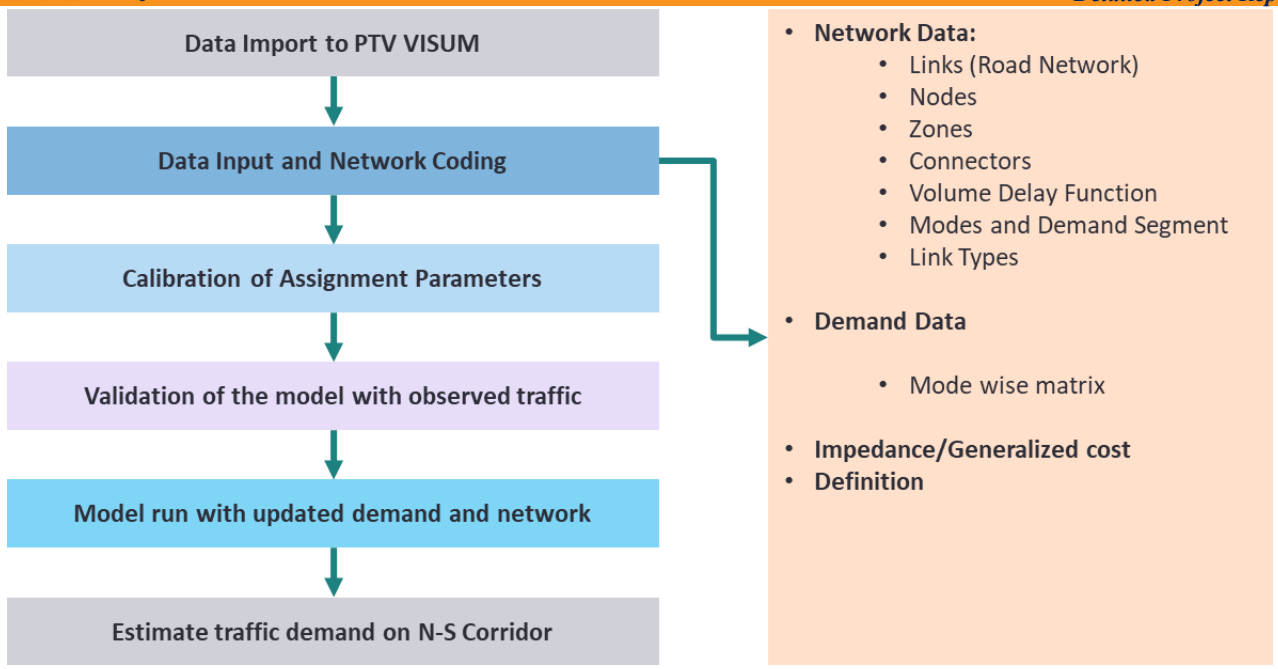


Figure 54: Model Development

7.1.7 Stage 4 - Model calibration and validation

In this stage, the vehicle data count from the primary survey and the model outputs from PTV Visum 2024 were compared for accuracy. Based on statistical measures such as GEH the model counts were validated. In case of deviation from the standards, the OD matrices for each needed to be updated based on the matrix correction procedure T-Flow fuzzy procedure. T-Flow-Fuzzy is meant to adjust a demand matrix, so that its assignment results for the supply match the real supply observed. In relation to traffic assignments, it is used for the following purposes:

- Calibration of the generated demand matrix from the network model using the traffic counts data from the primary survey.
- A matrix generated from incomplete or unreliable data is improved by more comprehensive/reliable volume count data simultaneously.

For the update, the specified count values were compared with the volumes, which resulted from a pre-calculated assignment of the previous demand matrix. Differences between primary count volume and modelled volumes were balanced by adjustment of the demand matrix for the assigned demand segment. The methodology of Fuzzy procedure is shown as below.

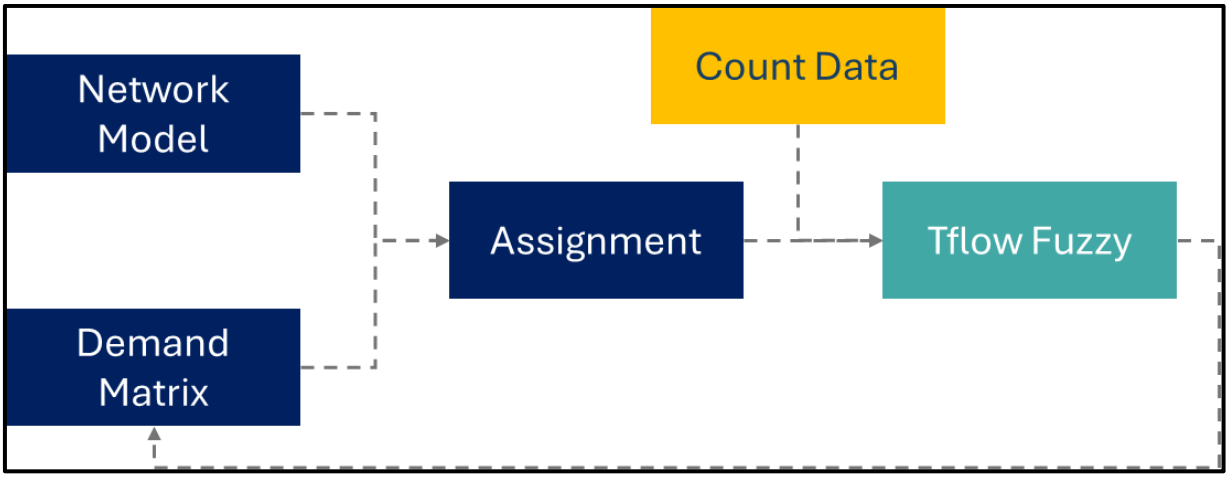


Figure 55: Fuzzy Procedure

7.1.8 Stage 5 - Projections

In this stage, the projections were derived from the secondary data. The future traffic growth, and modal shift were referred from the CMP 2020 report for the horizon period of 25 years. Other information such as Vehicular Registration data, and proposals regarding the road upgradation, new road construction, proposed metro routes and other infrastructure projects were referred to estimate the projection factors for each mode.

7.1.9 Stage 6 - Updating demand and network in model

In this stage, the model was updated with the projected demand and the road network was also updated based on the proposals from the reports regarding upgradation and new construction. The proposed North – South corridor was added to the model at this stage.

7.1.10 Stage 7 – Traffic Demand Estimation

In this stage, traffic assignment was done in the calibrated model to estimate the traffic demand on the proposed North – South corridor. The model then provided the traffic to be expected on the corridor and its impact on the road network in the study area.

7.2 Study area

For estimation of traffic on the proposed North-South corridor, the study area considered was the entire BBMP area + BDA Area. The primary study area (influence area) is taken as a buffer of approximately 2.5 km from the corridor as shown in the figure below. The zones within the study area (Approximately 2-3 km) are considered as primary internal zones, zones within the remaining BBMP and BDA area were considered as secondary zones. Beyond the primary zones, the access to the corridor will be via the major road network only.

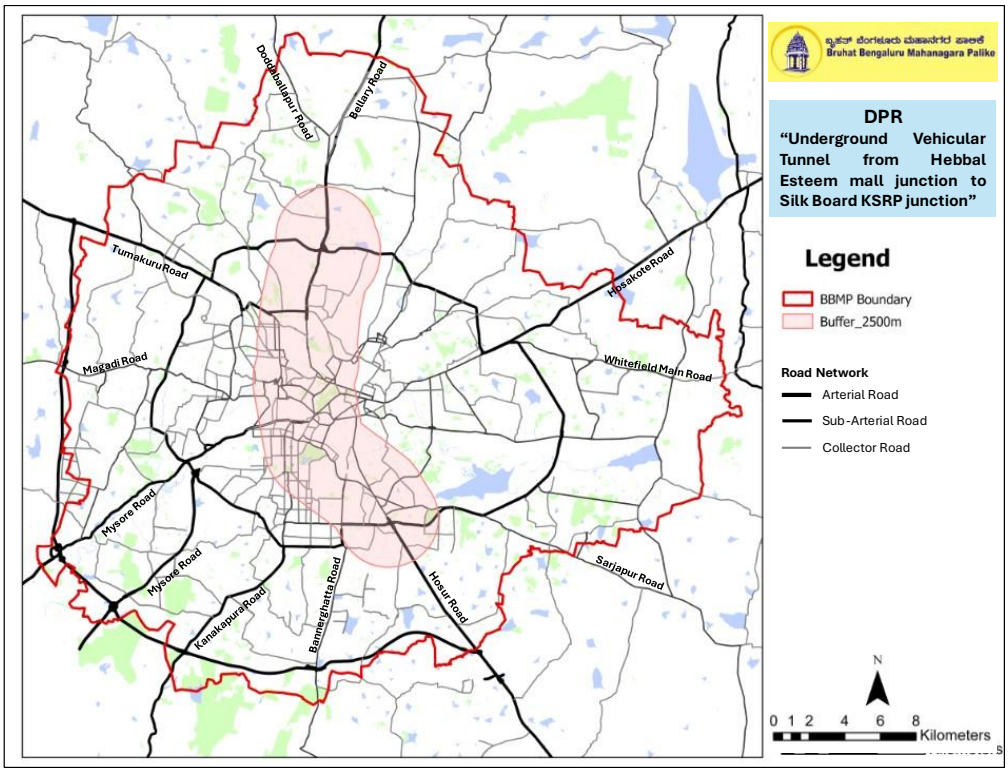


Figure 56: Study Area

7.2.1 Zoning

Traffic Analysis Zones (TAZs) are geographically defined areas that are used to model traffic flow and demand within a transportation network. These zones typically represent neighbourhoods, commercial districts, industrial areas, or other distinct land-use zones. By dividing a study area into TAZs, transportation planners analyze traffic patterns, forecast future demand, and evaluate the effectiveness of various transportation improvement projects.

In CMP 2020 ward boundaries were taken as TAZs. As this study is related to the estimation of traffic on proposed North-South Corridor, therefore the wards along the proposed corridor were sub-divided into smaller zones within the primary study area (influence area) (Zone 1 to 74) and these zones were considered as internal zones for this study. The Wards outside the influence area were combined into larger zones (Zone 201 to 307) and these are the immediate external zones. The area outside the BBMP was divided into 4 Zones i.e. Zone no. 501, 502, 503 and 504 based on direction of incoming traffic from outside the BBMP Area (North, West, South and East respectively). TAZs of study area is shown in the figure below.

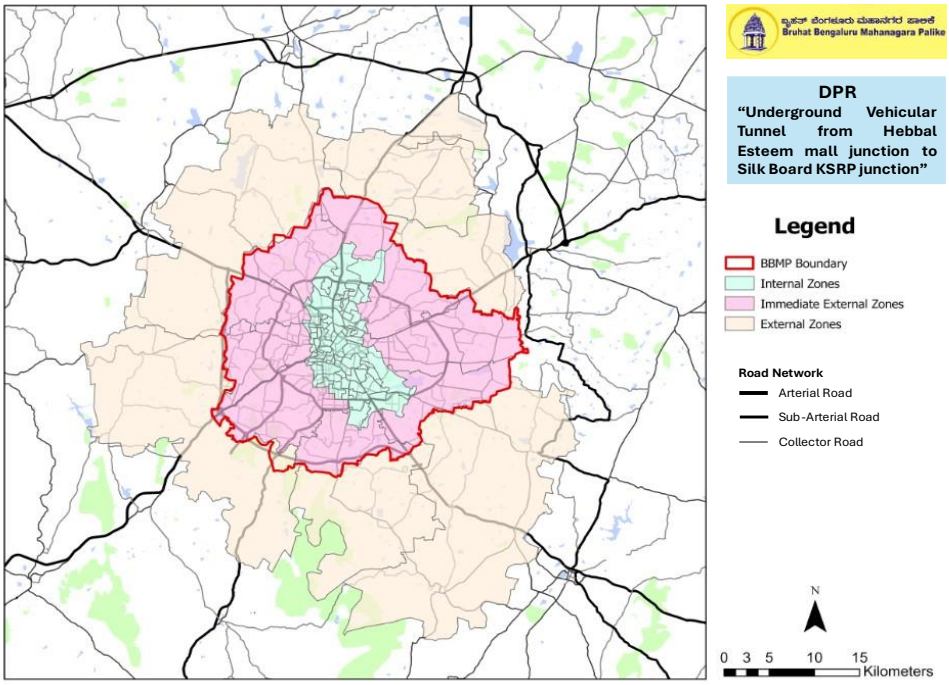


Figure 57: Zoning of Study Area

7.2.2 Road Network

Bengaluru's road network is a testament to the city's rapid growth and development, boasting a vast expanse of arterial roads, sub-arterial roads, and collector roads as shown in figure below.

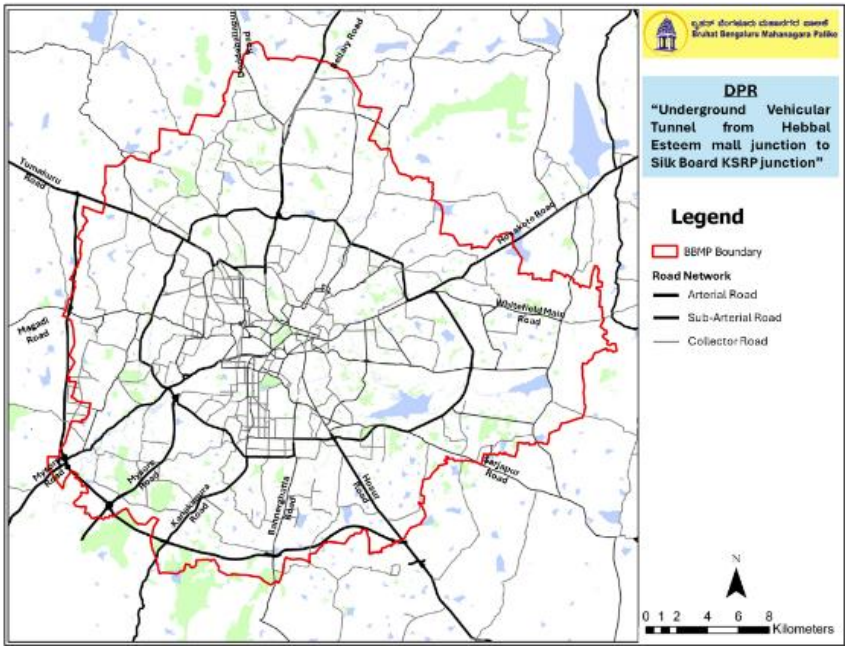


Figure 58: Bengaluru Road Network

For this study the road network in the primary zones network was considered for developing the transport demand model. The road network was developed based on the data extracted from the Open Street Maps, Bengaluru Open Data Portal and site reconnaissance surveys.

7.3 Review of City Urban Transport Scenario and Secondary Data Information

7.3.1 City Profile

Bengaluru, the capital of Karnataka, is a bustling metropolis renowned as India's "Silicon Valley," largely due to its influential technology sector. Despite its economic vitality, Bengaluru faces significant challenges related to traffic and transportation. The city's rapid urbanization has led to severe traffic congestion, exacerbated by an influx of vehicles and inadequate road infrastructure. Although Bengaluru boasts an expanding metro system and a well-developed road network, these developments have struggled to keep pace with the growing demand. Addressing these traffic and infrastructure issues remains crucial for maintaining the city's economic and liveability standards.

7.3.2 Population

The population of the Bengaluru Metropolitan Area had been growing since independence as shown in figure below. The BMA area, which had a population of about 17 Lakh in 1971, reached 85 lakhs in 2011. Bengaluru was one of the fastest-growing Indian metropolises for the decade 1991–2011. It has an average density of about 148 people / hectare. In CMP 2020, the estimated population is 122.98 Lakh for 2018.

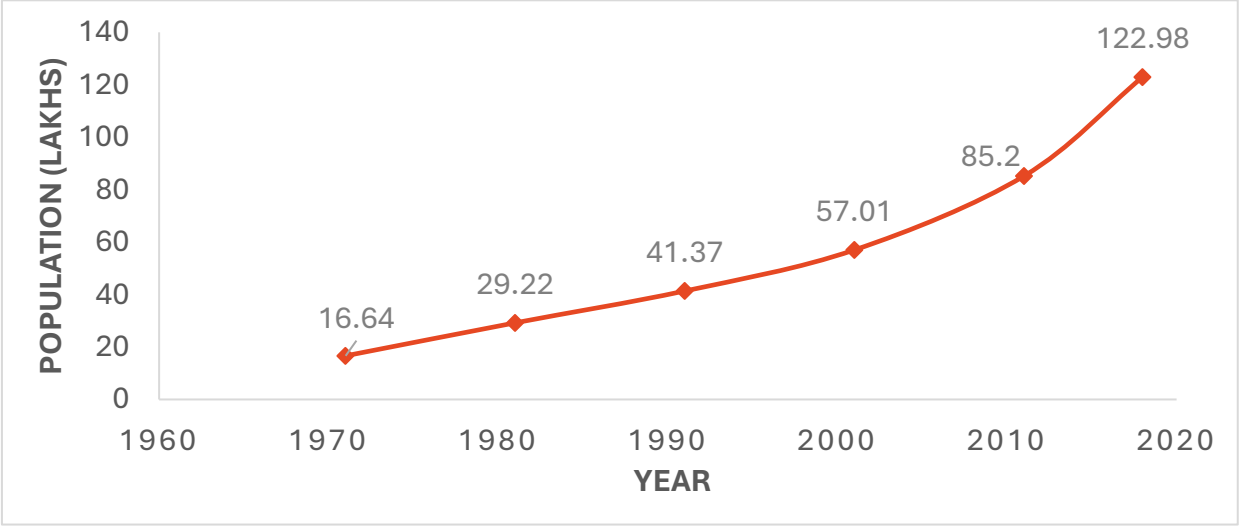


Figure 59: Growth of Population in BMA

Source: Census; CMP 2020

7.3.3 Road Network

Bengaluru is endowed with a ring-radial pattern of road network in the core area of the city. Bengaluru's road network, spanning 14,000 km of the road network consists of ring roads, major roads (arterial roads, sub-arterial roads and other mobility corridors) and residential streets. However, there is no clear hierarchy of roads, and this situation has resulted in low speeds, increased traffic conflicts, etc. Though there is a large network of roads in the city, the major arterial road network comprises less than 20% of the total road network in the city. The major roads in the study area are shown in figure below.

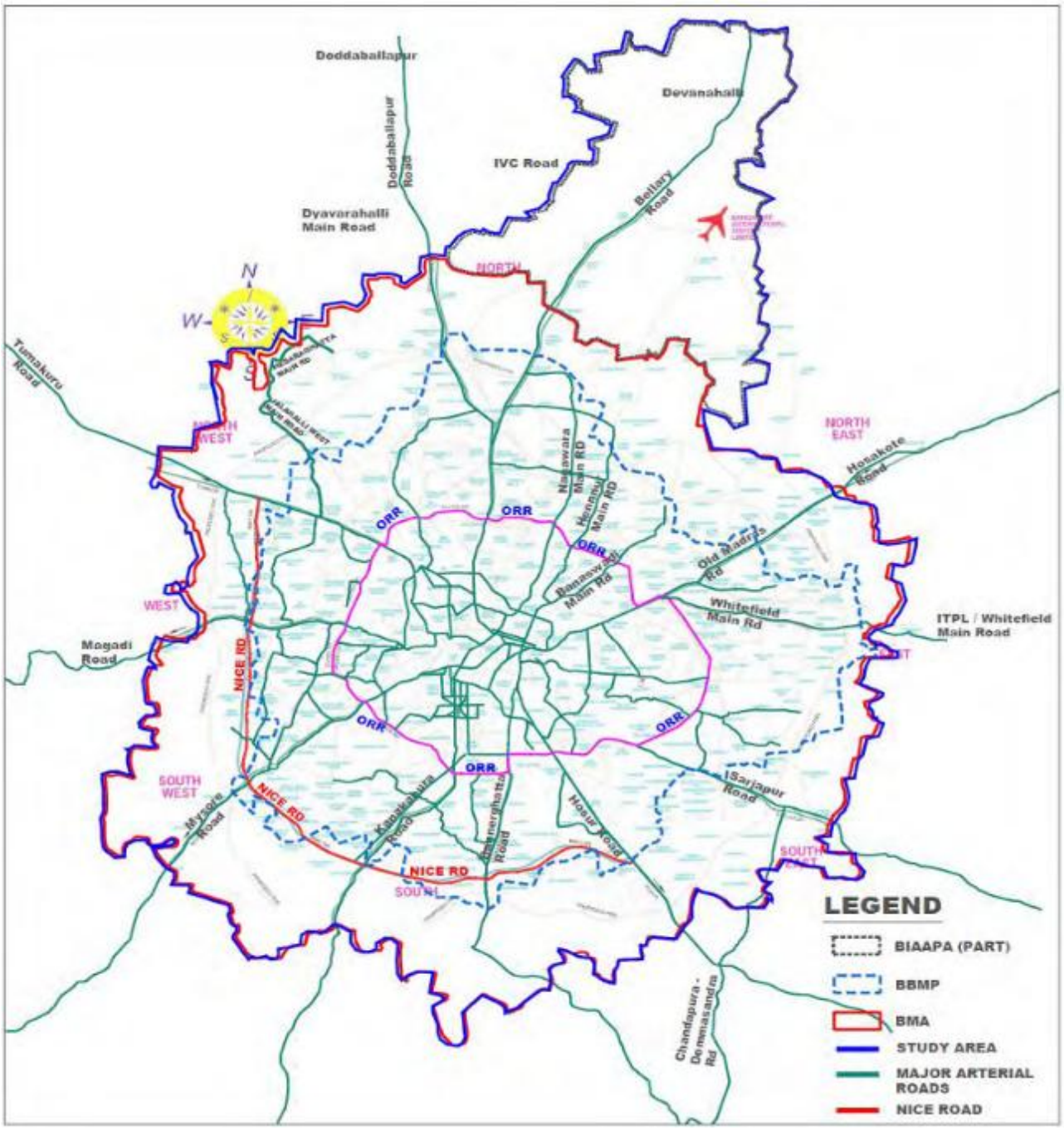


Figure 60: Road Network of Bengaluru City

Source: CMP 2020

7.4 Overview of Public Transport

7.4.1 Bus

The bus system operated by BMTC has been the primary public transport system in Bengaluru City. BMTC has established 45 depots for providing services in the city. BMTC is operating 6143 schedules (as of Aug 2018) every day. The Physical performance of BMTC is presented in Table below.

Table 40: Bus Performance in Bengaluru

Parameter	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Depots	39	39	40	40	43	44	45
Fleet Operated	6139	6473	6244	6216	6219	6143	6143
Effective Km. Per day (Lakh)	12.71	13.14	12.9	12.21	11.52	11.42	11.38

Parameter	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Total Service km (Lakh km)	4638.38	4795.9	4708.6	4469.8	4205.2	4164.5	-
Veh. Utilization (Km)	221.1	218.2	214.5	208.5	206.5	203.8	202
Passengers carried per day (Lakh)	48.46	50.25	51.3	50.74	45.34	44.37	-
Passenger load factor (%)	68.5	67.2	75.8	74.2	68.8	66.8	-

Source: BMTC Bengaluru

7.4.2 Metro

Two corridors of Metro Rail are in operation in Bengaluru. One is the East-West corridor, and the other is the North-South corridor. The East-West Corridor starts at Baiyappanahalli (R1) and ends at Mysore Road (R2). The North-South Corridor starts at Nagasandra (R3) and ends at Puttenahalli (R4). The total length of the Metro Rail network under operation is 42.30 Km. Below mentioned table presents the operational metro in Bengaluru.

Table 41: Metro Corridors along with Stretches and their Status

S.No	Corridor	Length (Km)	Status
Phase 1			
1	Baiyappanahalli to Mysore Road (East - West Corridor- Purple Line) (R1 & R2)	18.1	Operational
2	Nagasandra to Yelachenahalli (North- South Corridor- Green Line) (R3 & R4)	24.2	Operational

Source: BMRC

7.4.3 Sub-Urban Rail

Bengaluru city has a good rail network of about 62 km within the city. There are a few diesels operated passenger trains that connect Bengaluru City with Tumkur, Mysore and Kuppam (Andhra Pradesh). The trains run in the morning and return in the evening catering to commuters from suburban areas, satellite towns and neighboring cities. They are well patronized and in the recent past patronage has shown a good growth rate. But their frequency and availability are not adequate to make this as primary / preferred mode of transportation. The utilization of existing railway network in the city for running robust sub-urban rail services connecting the peripheral areas and settlements around Bengaluru is being explored and a detailed study has been made by Indian Railways to introduce a commuter rail service including identifying the improvement requirement to the railway network.

7.5 Vehicle Growth in the City

Bengaluru City has a total registered vehicle count of approximately 1 crore vehicles in 2023, vehicles have grown at an average growth rate of 8% over the past 10 years. The vehicle registration trend is shown in figure below.

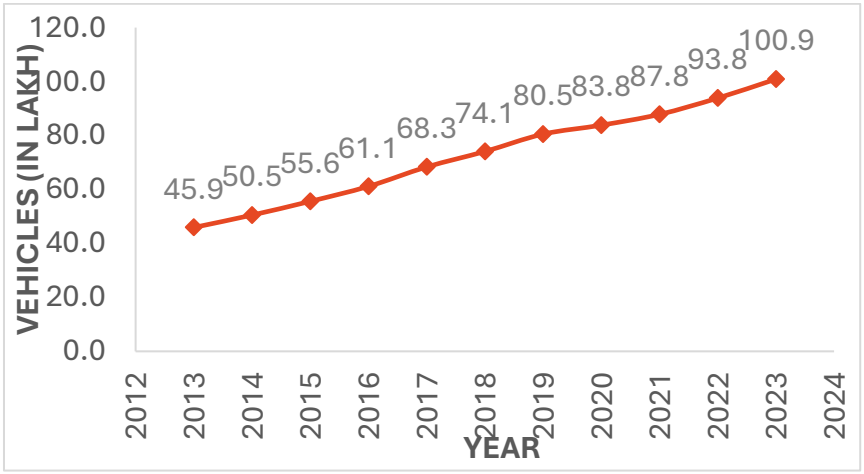


Figure 61: Vehicular growth in Bengaluru

(Source: Annual report – Karnataka Transport Department)

7.6 Transport and Infrastructure Proposals

7.6.1 Road

As per current information available there are three major road projects that are sanctioned in Bengaluru, which are Satellite Town Ring Road, Intermediate Ring Road and Peripheral Ring Road as shown in figure.

a) **Satellite Town Ring Road:** To ensure safe, smooth, efficient, and high-speed transport corridor to Bangalore city, it is impetus that the infrastructure of city and adjoining towns anticipated the development. National Highways NH 648 (NH 207), NH 48 (NH 4), NH 275, NH 948, NH 209 & NH 75 (Hassan Road), and majority of State Highways SH 3, SH 85, & SH 35 pass through Bangalore city comprising heavy commercial traffic movement. Most of this traffic are not intended to pass through the Bangalore city. This traffic further aggravates the scenario in the city roads and resulting huge traffic jams.

b) **Peripheral Ring Road:** The proposed "Peripheral Ring Road" is 65 km long and connects 10 major Highways namely Tumkur Road(NH-4), Hesaraghatta Road(SH-39), Doddaballapura Road(SH-09), Bellary Road (NH-7), Hennur- Baglur Road (SH-104), OMR (NH-4), Whitefield road, Channasandra Main Road, Hoskote-Anekal Road(SH-35), Sarjapur Road and Hosur Road(NH-7). Overall, it intersects 4 National Highways and 6 state Highways. The proposed PRR length from start point on Tumkur Road up to end point on Hosur road is 64.201 Km. Since the alignment is getting integrated with NICE road on Tumkur Road (~ 368m) and Hosur road (~ 546m), the total length of the project road is considered to be 65.11 Km.

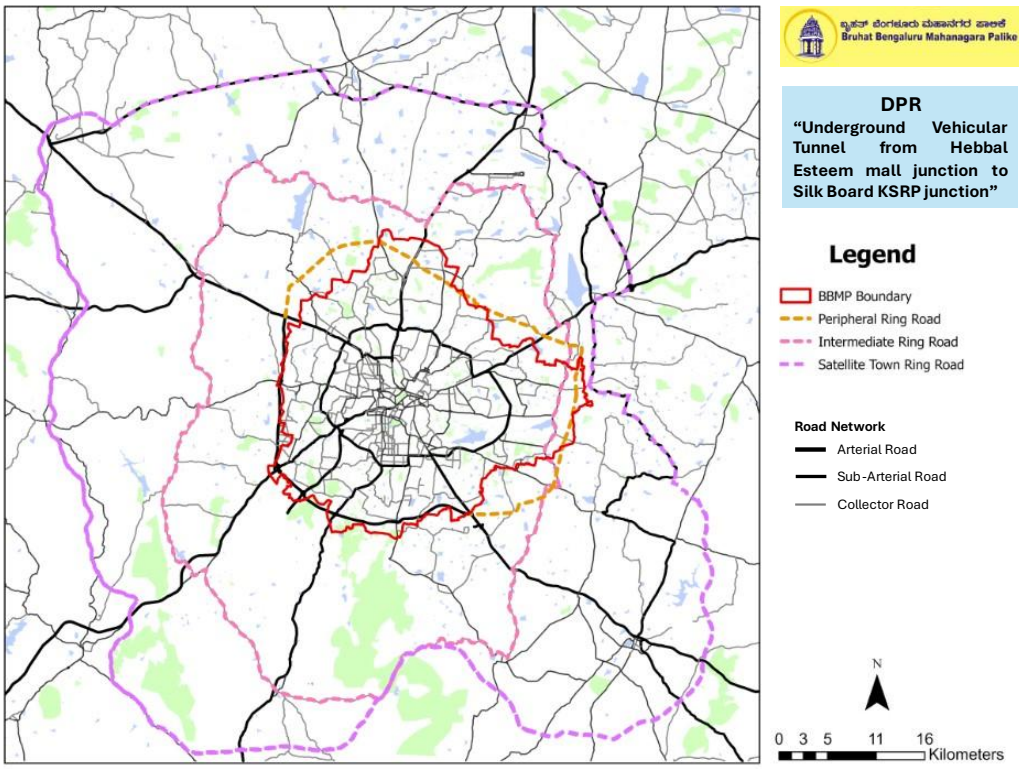


Figure 62: Proposed Roads in Bengaluru

Source: Feasibility reports and DPR

7.6.2 Metro

Transport Demand Forecast Study and Identification of Phase III Corridors of Bengaluru Metro was undertaken by Bengaluru Metro Rail Corporation Limited (BMRCL) to extend the metro system in Phase-III for the areas not covered by Phase-I & II and interconnect the metro system network as shown in figure below this section. All metro routes of Phase-I are operational, some routes of Phase-II are operational, and the rest are ongoing projects and all routes in Phase-III are the upcoming projects as given in the metro DPRs. The details of Phase-I, Phase-II and Phase-III are shown in tables mentioned below.

Table 42: Metro Operational Projects

S. No	Phase	Detail	Length in KM			No of Stations		
			UG	Elevated	Total	UG	Elevated	Total
1	Phase 1	Mysore Road To Kempegowda Metro Station, Majestic, Kempe Gowda Metro Station Majestic to Baiyappanahalli, Nagasandra to Yeshwantpur, Yeshwantpur to Kempegowda Metro Station Majestic, Kempegowda Metro Station Majestic To Yelachenahalli	8.79	33.51	42.3	9	34	43
2	Phase 2	Baiyappanahalli to Krishnaraja Pura, Kengeri to Challaghatta, Krishnarajapura to Whitefield, Yelachenahalli To Silk Institute, Kengeri to Mysore Road	-	31.51	31.51	-	27	27

Source: Metro DPR

Table 43: Metro Ongoing Projects

S. No	Phase	Detail	Length in KM			No of Stations		
			UG	Elevated	Total	UG	Elevated	Total
1	Phase 2	Nagasandra to Madavara (BIEC),Bommasandra to Beratena Agrahara, Beratena Agrahara to Bommanahalli, Bommanahalli to R.V. Road,Kalena Agrahara To Tavarekere, Tavarekere to Rashtriya Military School, Rashtriya Military School to Shivajinagar, Shivajinagar Station to Tannery Road, Tannery Road To Nagawara	13.88	29.66	43.54	12	25	37
2	Phase 2A	Central Silk Board To Kadubeesanahalli, Kodibeesanahalli To K.R. Puram	-	19.75	19.75	-	13	13
3	Phase 2B	Kasturi Nagar to Kempapura, Hebbal to Bagalur Cross, Bettahalasuru To KIA Terminal	-	38.44	38.44	-	17	17

Source: Metro DPR

Table 44: Metro Upcoming Projects

S. No	Phase	Section		Length in KM			No of Stations		
		From	To	UG	Elevated	Total	UG	Elevated	Total
1	Phase-3	1. Hebbal	1. J.P. Nagar 4th Phase	-	31	43		40	40
		2. Hosahalli	2. Kadabagere		12				
2	Phase-3A	1. Sarjapur	1. Hebbal	17	19	36	14	15	29

Source: Metro DPR

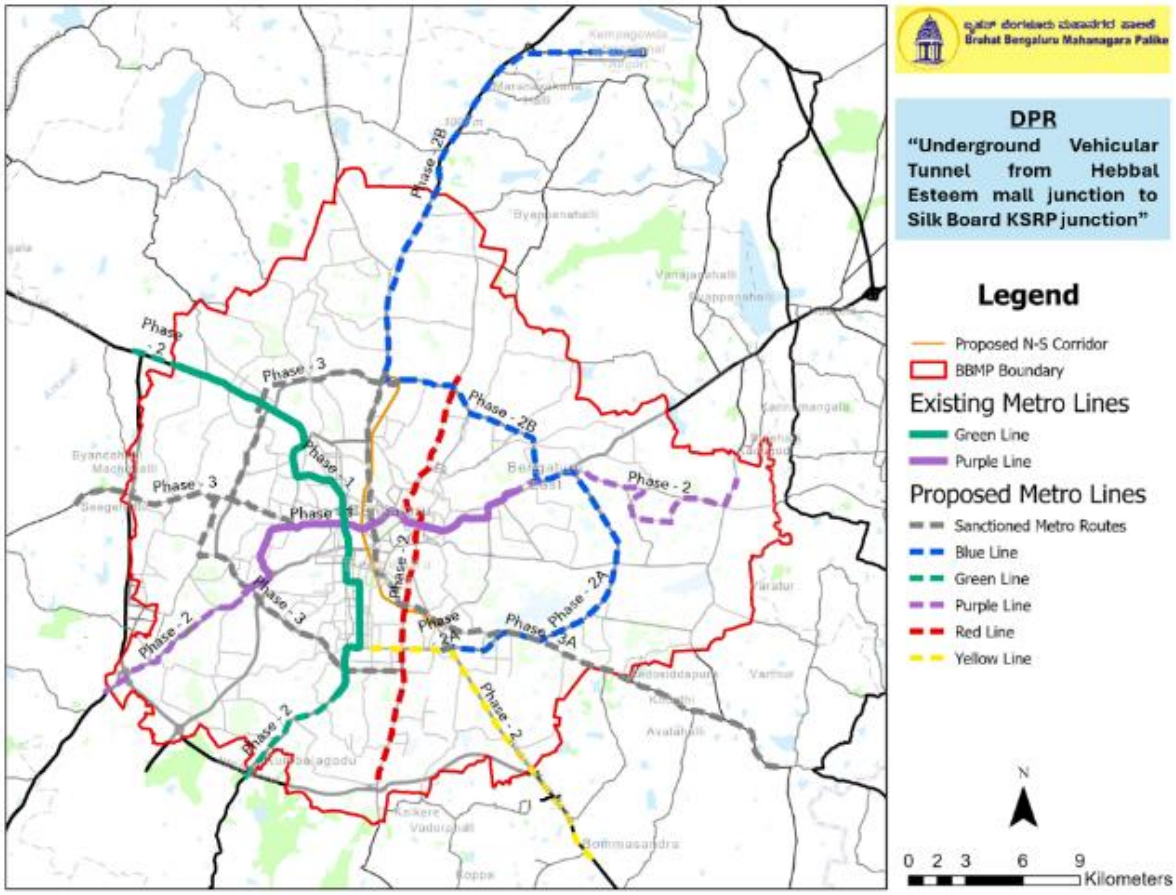


Figure 63: Bengaluru metro network (Existing and Proposed)

Source: BMRC

7.7 Travel Characteristics

This section discussed the trip characteristics based on the CMP 2020 report. These trip characteristics were used the validate the outputs from this study.

7.7.1 Mode Share Motorized trips

The modal share of motorized trips referred from CMP 2020 is shown in table below.

Table 45: Modal Share (Motorized Trips)

S. No.	Mode	Trips
1	Car/Taxi	21.0%
2	2-Wheeler	23.5%
3	Auto Rikshaw	7.7%
4	Public Transport	47.8%
Total		**100%**

Source: CMP 2020

7.7.2 Mode-wise Distribution of Average Trip Length

The average trip length as per CMP 2020 by mode of travel is presented in the table below. The average trip length for Walk is 1.0 Km, for 2-wheeler is 8.0 km, for car and taxi are 12.8 km and 13.1 km respectively and for Bus it is about 10.7 km.

Table 46: Mode Wise Average Trip Length

S. No.	Mode	Average Trip Length (Km)
1	Car	12.8

S. No.	Mode	Average Trip Length (Km)
2	Taxi	13.1
3	Shared Taxi	15.4
4	2- Wheelers	8
5	Auto	3.7
6	Bus	10.7
7	Minibus	10.7
8	School Bus	5.1
9	Chartered Bus	15.1
10	Cycle	2.6
11	Walk	1

Source: CMP 2020

7.8 Travel Demand Assessment

The travel demand assessment was carried out in CMP 2020 with the focus to develop a long-term transportation strategy for Bengaluru with the help of an urban transport planning model. The output from the CMP was used for trips forecasting for the current study. This section summarizes the main outputs.

7.8.1 Population Forecasting

The population in CMP 2020 was forecasted up to Year 2051 shown in table below. The population of BMA Area and Extended Area has been forecasted separately.

Table 47: Forecasted population in CMP Study Area

Area	2015	2031	2041	2051
BMA	1,12,27,977	2,03,13,499	2,57,09,017	3,16,36,758
Extended Area	2,55,449	5,50,000	8,95,892	16,04,406
Total	**1,14,83,426**	**2,08,63,499**	**2,66,04,909**	**3,32,41,164**

Source: CMP 2020

7.8.2 Scenarios

For horizon year mode share and average trip lengths, CMP 2020 was referred to where the projections have been done in various scenarios. The scenarios are given below:

a) Scenario 1: Business as Usual scenario

The mode share and average trip length estimated in Scenario 1 are shown below.

Table 48: Comparison of Travel Characteristics between Base Year and Horizon Year

Modes	Peak Hour Trips	Base Year (2015)	BAU (2031)	
		Mode Share	Peak Hour Trips	Mode Share
Car + Taxi	2,64,649	21%	6,89,673	30%
Two-Wheeler	2,96,468	23%	6,66,685	29%
Auto Rickshaw	96,655	8%	1,14,946	5%
Public Transport	6,01,861	48%	8,27,608	36%
Total	**12,59,633**		**22,98,912**	

Source: CMP 2020

b) Scenario 2: Public Transport Augmentation and Efficiency Improvement, and Multimodal Transport.

The mode share estimated in Scenario 2 are shown in table below.

Table 49: Forecast Mode Share – Scenario 2

Modes	BAU (2031)		Scenario 2	
	Peak Hour Trips	Mode Share	Peak Hour Trips	Mode Share
Car + Taxi	6,89,673	30%	5,72,638	25%
Two-Wheeler	6,66,685	29%	3,04,780	13%
Auto Rickshaw	1,14,946	5%	71,406	3%
Public Transport	8,27,608	36%	13,50,088	59%
Total	**22,98,912**		**22,98,912**	

Source: CMP 2020

c) Scenario 3 – Public Transport Augmentation Plus Enhances capacity and Efficiency of Road Infrastructure.

The mode share estimated in the Scenario 3 are shown in table below.

Table 50: Forecast Mode Share – Scenario 3

Modes	BAU (2031)		Scenario 3	
	Peak Hour Trips	Mode Share	Peak Hour Trips	Mode Share
Car + Taxi	6,89,673	30%	5,32,581	23%
Two-Wheeler	6,66,685	29%	2,61,240	11%
Auto Rickshaw	1,14,946	5%	67,922	3%
Public Transport	8,27,608	36%	14,37,168	63%
Total	**22,98,912**		**22,98,912**	

Source: CMP 2020

d) Scenario 4 – Comprehensive Mobility Strategy: Transit Oriented Development, Factoring-in full cost of externalities, Regulations on private vehicles, besides Public Transport Augmentation Plus Enhances Capacity and efficiency of Road Infrastructure, and cleaner technology Vehicles.

The mode share estimated in the Scenario 4 are shown in table below.

Table 51: Forecast Mode Share – Scenario 4

Modes	BAU (2031)		Scenario 4	
	Peak Hour Trips	Mode Share	Peak Hour Trips	Mode Share
Car + Taxi	6,89,673	30%	3,94,472	17%
Two-Wheeler	6,66,685	29%	1,81,126	8%
Auto Rickshaw	1,14,946	5%	42,669	2%
Public Transport	8,27,608	36%	1,680,644	73%
Total	**22,98,912**		**22,98,912**	

Source: CMP 2020

7.9 Primary Data Collection and analysis

In any transport planning exercise, data collection is the cornerstone and the very foundation on which rests the superstructure. The data, so collected, is used to analyze the existing transport and traffic situation in the study area and to develop an urban transport demand model for the study area. This activity is undertaken to understand traffic and travel characteristics and highlight city-specific problems. The first and foremost step to initiate in the development of a transport demand model is the collection of relevant data to understand travel pattern and the factors that influence them. These travel pattern shall be the guiding principles in determining the traffic on the north-south corridor. The following surveys were carried out as shown in table mentioned below to meet the above objectives.

Table 52: Survey Details

S. No.	Survey Types	Unit	Quantity	Survey Date
1	Classified Traffic Volume Count	Locations	9	Aug-2024
2	Turning Moment Count at Intersections	Locations	7	Aug-2024

S. No.	Survey Types	Unit	Quantity	Survey Date
3	Passenger Origin-Destination Survey	Locations	11	Aug-2024
4	Speed and delay	KM	25	Aug-2024

Map showing the survey locations is presented below.

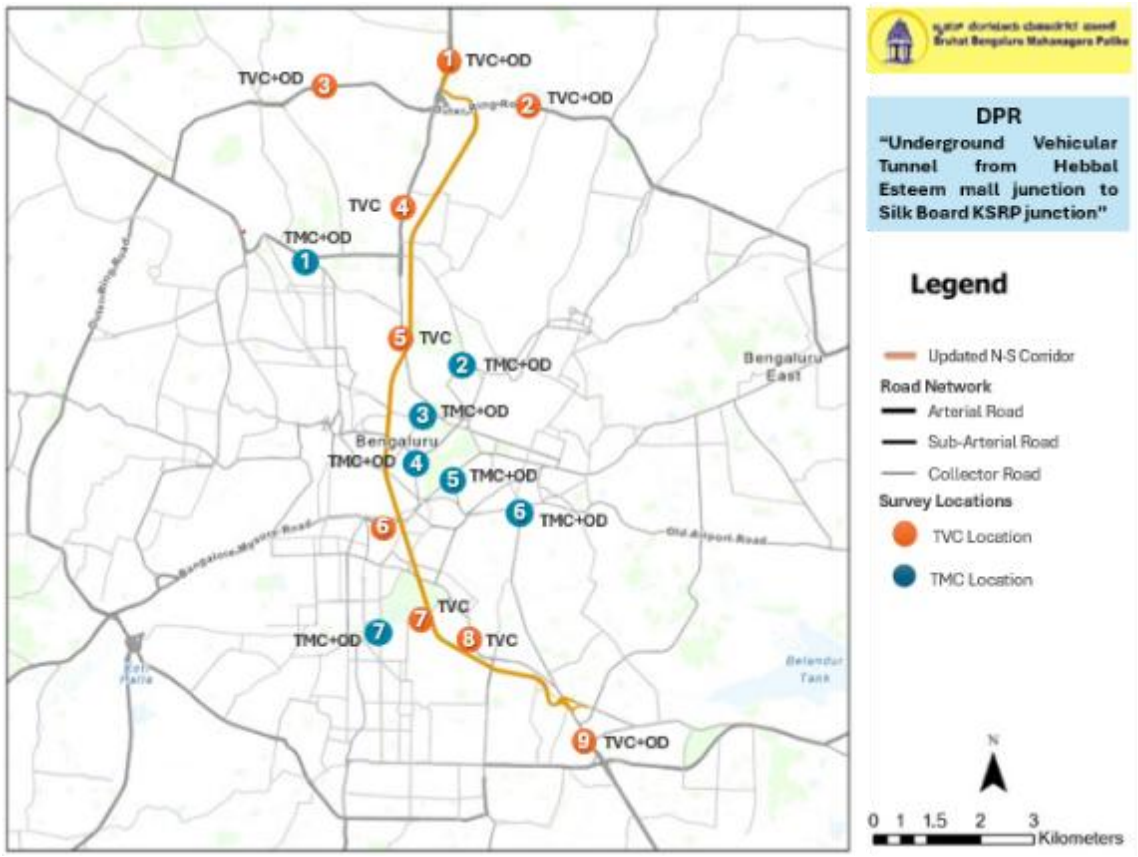


Figure 64: Survey Locations

7.9.1 Classified Traffic Volume Count

Scope of Survey: Counting of vehicles, classified by the type of vehicle, at selected locations, covering all turning movements, midblock & screen line.

Conduct: Videographic traffic counts were carried out at all the listed locations. At each identified station, both directional counts were done by vehicle type, i.e., fast-moving passenger vehicles, goods vehicles and slow-moving non-motorized vehicles. The vehicles counted were converted to Passenger Car Units (PCU) by adopting equivalent PCUs. The PCUs corresponding to urban roads as per IRC: 106-1990 is used and the values adopted are given in **table** below.

Table 53: PCU Values for Different Categories of Vehicles

Vehicle Type	PCU Values	
	Urban	
	UP TO 5%	> 5%
Bus	2.2	3.7
Car/Jeep/Van/Taxi	1	1
Two-Wheeler	0.5	0.75
E-Rickshaw	1.2	2
Auto-Rickshaw	1.2	2
Truck	2.2	3.7
MAV	4	5
LCV	1.4	2
Cycle	0.4	0.5

Vehicle Type	PCU Values	
	Urban	
	UP TO 5%	> 5%
Tractor	4	5
Cart	2	3
Cycle Rickshaw	1.5	2

Source: IRC:106-1990

7.9.2 Traffic Volume Counts at Cordon Points

A total of 9 cordon points were identified for understanding of the traffic characteristics in the study area. The analysis of the classified volume count survey at the cordons is given in the sub-sections below. The total inbound and outbound traffic flow at each of the cordons is presented in Table below and daily traffic on each cordon point direction-wise is shown in figure mentioned in this section.

Table 54: Daily Traffic Volume Counts at Cordon Locations (24 hours)

Location		Direction	Daily Vehicles per Direction	Daily PCUs per Direction	Total Daily Vehicles	Total Daily PCUs
1	NH-44 Bellary Road (Near-Sakar Nagar)	Dir-I: Yelahankat to Hebbal	1,44,592	1,38,970	2,88,243	2,76,854
		Dir-II: Hebbal to Yelahanka	1,43,651	1,37,884		
2	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Nagavara park)	Dir-I: Bellary Road to Nagavara	1,17,553	1,13,677	2,22,323	2,12,544
		Dir-II: Nagavara to Bellary Road	1,04,770	98,867		
3	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Devinagar BEL Circle)	Dir-I: Hebbal to Yashwantpur	74,262	74,124	1,39,793	1,40,205
		Dir-II: Yashwantpur to Hebbal	65,531	66,081		
4	AH-47 Malur Road (Near-Science Gallery)	Dir-I: Mekhri circle to Airport	1,28,808	1,22,070	2,46,077	2,32,456
		Dir-II: Airport to Mekhri circle	1,17,269	1,10,386		
5	Guttahalli Main Road (Near-Uniworth Plaza)	Dir-I: Mahalakshmi Gudi Circle to Bengaluru Golf Club	1,03,247	97,762	2,03,804	1,95,093
		Dir-II: Bengaluru Golf Club to Mahalakshmi Gudi Circle	1,00,557	97,332		
6	NR road (Near-Silver Jubilee Park)	Dir-I: Kempegowda Tower to Chamrajpet	82,397	83,027	1,80,589	1,77,181
		Dir-II: Chamrajpet to Kempegowda Tower	98,192	94,154		
7	Siddapura Road (Near-Maharaja Agrasena Bhavana)	Dir-I: Ashoka Piller to Mallinge Hospital	31,705	28,716	65,075	58,422
		Dir-II: Mallinge Hospital to Ashoka Piller	33,370	29,706		
8	Marigowda Road (Near-National Institute of Mental Health & Neuro Sciences)	Dir-I: Dairy Circle to Wilson Garden	54,855	54,282	1,08,421	1,07,684
		Dir-II: Wilson Garden to Dairy Circle	53,566	53,402		

	Location	Direction	Daily Vehicles per Direction	Daily PCUs per Direction	Total Daily Vehicles	Total Daily PCUs
9	NH-44 Bengaluru-Chennai Highway (Near-Madiwala footbridge)	Dir-I: Adugodi to Electronic City	1,17,725	1,09,335	2,32,494	2,16,724
		Dir-II: Electronic City to Adugodi	1,14,769	1,07,389		

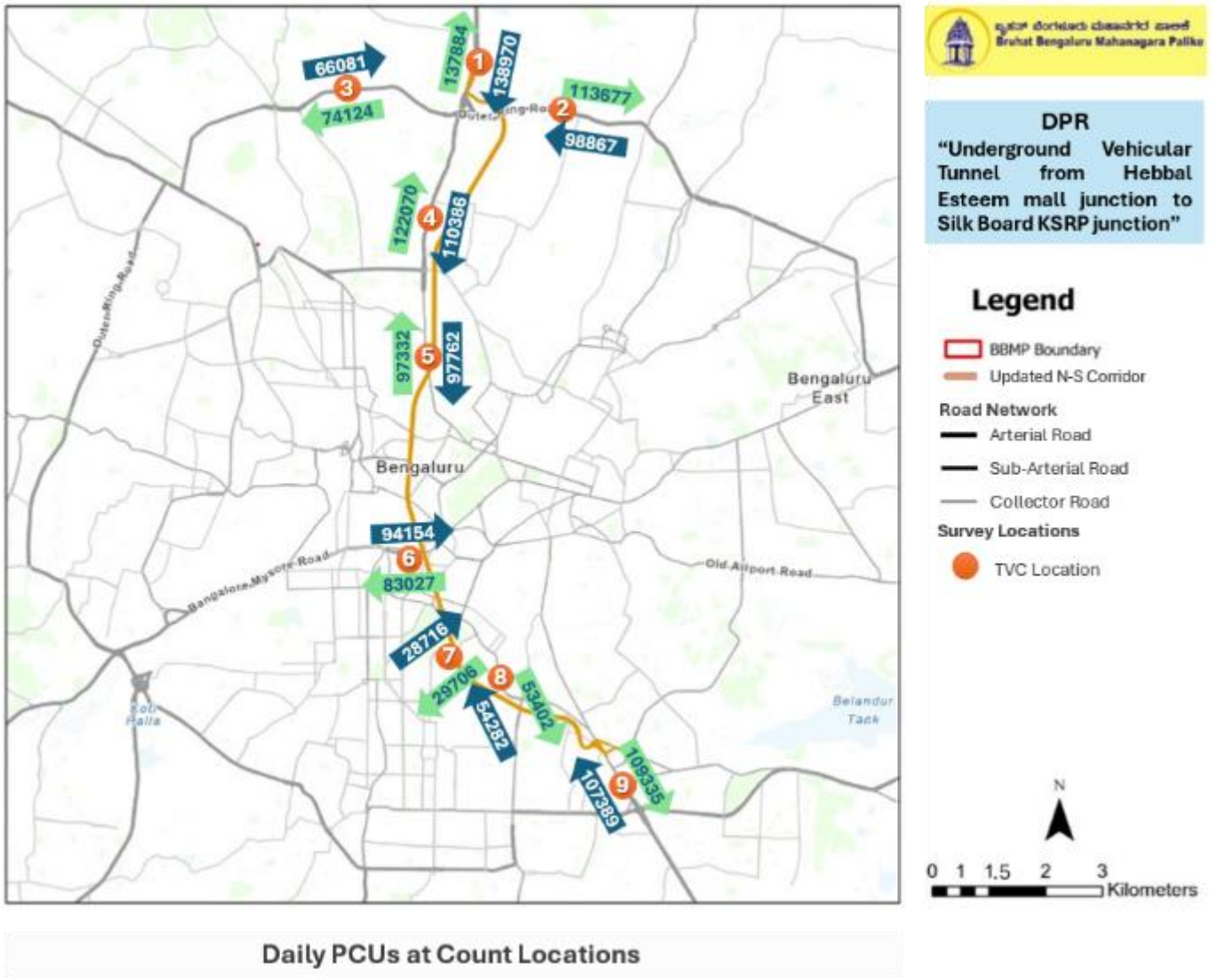


Figure 65: Map Showing Daily Traffic Volume at Count Locations.

Figure below presents the overall vehicle composition of the traffic. The highest share observed was of private vehicles, at 80%, of which two wheelers constituted 42% and four-wheelers 38%. This is followed by IPT vehicles, which contributed to about 9% of the total traffic.

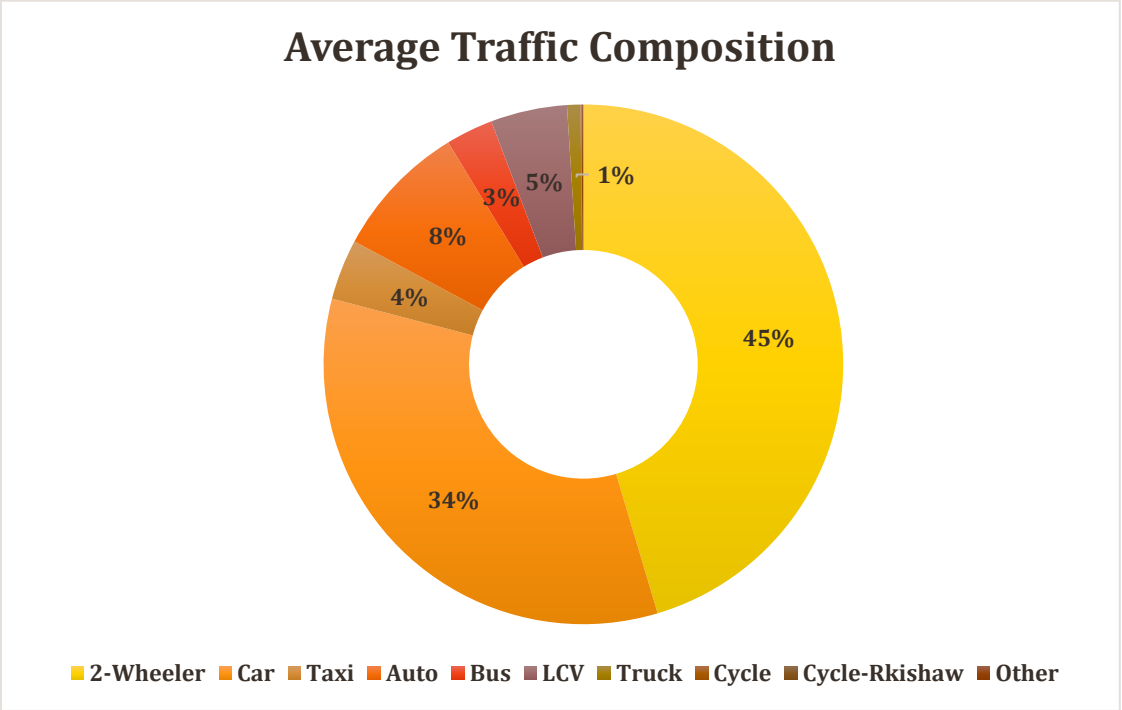


Figure 66: Overall Average traffic composition

The temporal variation of the traffic flow at each cordon is given in table below. Based on primary data for all the cordons, the morning peak period can be considered from 09:00 to 12:00 hours and the evening peak period can be considered from 17:00 to 20:00 hours.

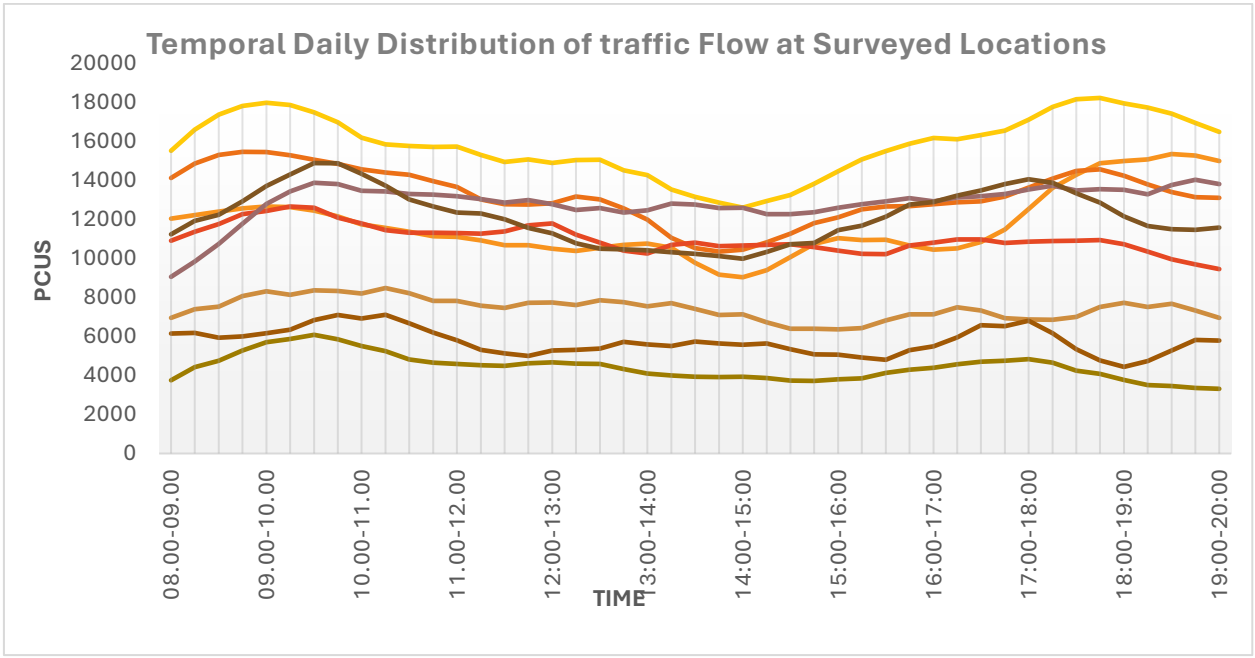


Figure 67: Temporal Daily Traffic at Surveyed cordon points

The peak volume and peak period at each cordon location are given in tables below. The volume in the peak hour varies in the range of 7-8% of the total volume.

Table 55: Morning Peak hour Volume at Surveyed Locations

	Location	Direction	Both Direction Vehicles	Peak Vehicles	Segregated Peak Vehicles	Both Direction PCUs	Peak PCUs	Segregated Peak PCUs	Peak Hour %	Level of Service	Peak Time
1	NH-44 Bellary Road (Near-Sakar Nagar)	Dir-I: Yelahanka To Hebbal (Towards Bengaluru)	19755	9794	6335	17967	8962	5718	6%	**LOS F**	09.00-10.00
		Dir I - Service Lane (Towards Bengaluru)			3459			3244		**LOS E**	
		Dir-II: Hebbal To Yelahanka (Towards Airport)		9961	9634		9005	8627		**LOS F**	
2	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Nagavara park)	Dir-I: Bellary Road To Nagavara	13865	7728	4945	12441	7011	3797	6%	**LOS C**	09.30-10.30
		Dir I - Service Lane			2785			2321		**LOS E**	
		Dir-II:Nagavara To Bellary Road		6137	4440		5430	3377		**LOS C**	
		Dir II - Service Lane			1697			1242		**LOS C**	
3	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Devinagar BEL Circle)	Dir-I: Hebbal To Yashwantpur	10563	5567	5567	9663	5171	5171	7%	**LOS F**	10.15-11.15
		Dir-II: Yashwantpur To Hebbal		4996	4996		4493	4493		**LOS E**	
4	AH-47 Malur Road (Near-Science Gallery)	Dir-I: Mekhri circle To Airport	17156	8914	5568	15443	7988	4996	7%	**LOS E**	09.00-10.00
		Dir I - Service Lane			3346			2991		**LOS F**	
		Dir-II: Airport To Mekhri circle		8242	5743		7455	5362		**LOS F**	
		Dir II - Service Lane			2499			2093		**LOS D**	
5	Guttahalli Main Road (Near-Uniworth Plaza)	Dir-I: Mahalakshmi Gudi Circle To Bengaluru Golf Club	13777	8129	8129	12651	7318	7318	6.5%	**LOS F**	09.15-10.15
		Dir-II: Bengaluru		5648	5648		5333	5333		**LOS F**	

Location		Direction	Both Direction Vehicles	Peak Vehicles	Segregated Peak Vehicles	Both Direction PCUs	Peak PCUs	Segregated Peak PCUs	Peak Hour %	Level of Service	Peak Time
		Golf Club To Mahalakshmi Gudi Circle									
6	NR road (Near-Silver Jubilee Park)	Dir-I: Kempegowda Tower To Chamrajpet	12753	4814	4814	11773	4534	4534	6.64%	**LOS D**	09.30-10.30
		Dir-II: Chamrajpet To Kempegowda Tower		7938	7938		7240	7240		**LOS F**	
7	Siddapura Road (Near-Maharaja Agrasena Bhavana)	Dir-I: Ashoka Piller To Mallinge Hospital	5897	3750	3750	5133	3307	3307	9%	**LOS F**	09.30-10.30
		Dir-II: Mallinge Hospital To Ashoka Piller		2147	2147		1826	1826		**LOS C**	
8	Marigowda Road (Near-National Institute Of Mental Health & Neuro Sciences)	Dir-I: Dairy Circle To Wilson Garden	7510	3845	3845	7105	3702	3702	7%	**LOS F**	10.15-11.15
		Dir-II:Wilson Garden To Dairy Circle		3665	3665		3404	3404		**LOS F**	
9	NH-44 Bengaluru-Chennai Highway (Near-Madiwala footbridge)	Dir-I: Adugodi To Electronic City	16872	7056	7056	14875	6186	6186	7%	**LOS F**	09.30-10.30
		Dir-II: Electronic City To Adugodi		9816	9816		8690	8690		**LOS F**	

Table 56: Evening Peak hour Volume at Surveyed Locations

Location		Direction	Both Direction Vehicles	Peak Vehicles	Segregated Peak Vehicles	Both Direction PCUs	Peak PCUs	Segregated Peak PCUs	Peak Hour %	Peak Time	LOS
1	NH-44 Bellary Road (Near-Sakar Nagar)	Dir-I: Yelahanka To Hebbal (Towards Bengaluru)	19609	10256	5507	18214	9483	5201	7%	17:45-18:45	**LOS F**
		Dir I - Service Lane (Towards Bengaluru)			4749			4282			**LOS F**
		Dir-II: Hebbal To Yelahanka (Towards Airport)		9353	8746		8731	8100			**LOS F**
		Dir II - Service Lane (Towards Airport)			607			632			**LOS B**
2	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Nagavara park)	Dir-I: Bellary Road To Nagavara	17381	9904	6337	15341	8673	5549	7%	18:30-19:30	**LOS F**
		Dir I - Service Lane			3569			3125			**LOS F**
		Dir-II:Nagavara To Bellary Road		7477	5409		6668	4824			**LOS E**
		Dir II - Service Lane			2068			1844			**LOS C**
3	NH-75 Malur - Byranahalli Rd Outer Ring Road (Near-Devinagar BEL Circle)	Dir-I: Hebbal To Yashwantpur	9271	5140	5140	8673	4839	4839	6%	18:00-19:00	**LOS E**
		Dir-II: Yashwantpur To Hebbal		4131	4131		3833	3833			**LOS C**
4	AH-47 Malur Road (Near-Science Gallery)	Dir-I: Mekhri circle To Airport	15816	8358	5404	14555	7715	4998	6%	17:45-18:45	**LOS E**
		Dir I - Service Lane			2954			2717			**LOS F**
		Dir-II: Airport To Mekhri circle		7458	6240		6840	5769			**LOS F**
		Dir II - Service Lane			1218			1072			**LOS B**
5	Guttahalli Main Road (Near-Uniworth Plaza)	Dir-I: Mahalakshmi Gudi Circle To Bengaluru Golf Club	11487	5341	5341	10964	5083	5083	6%	16:15-17:15	**LOS E**
		Dir-II: Bengaluru Golf Club To		6146	6146		5882	5882			**LOS F**

Location		Direction	Both Direction Vehicles	Peak Vehicles	Segregated Peak Vehicles	Both Direction PCUs	Peak PCUs	Segregated Peak PCUs	Peak Hour %	Peak Time	LOS
		Mahalakshmi Gudi Circle									
6	NR road (Near-Silver Jubilee Park)	Dir-I: Kempegowda Tower To Chamrajpet	11519	6087	6087	11022	5897	5897	6%	18:45-19:45	**LOS F**
		Dir-II: Chamrajpet To Kempegowda Tower		5432	5432		5125	5125			**LOS E**
7	Siddapura Road (Near-Maharaja Agrasena Bhavana)	Dir-I: Ashoka Piller To Mallinge Hospital	4844	1971	1971	4336	1823	1823	7%	17:00-18:00	**LOS C**
		Dir-II: Mallinge Hospital To Ashoka Piller		2873	2873		2514	2514			**LOS E**
8	Marigowda Road (Near-National Institute Of Mental Health & Neuro Sciences)	Dir-I: Dairy Circle To Wilson Garden	6994	3469	3469	6806	3358	3358	6%	17:00-18:00	**LOS F**
		Dir-II:Wilson Garden To Dairy Circle		3525	3525		3448	3448			**LOS F**
9	NH-44 Bengaluru-Chennai Highway (Near-Madiwala footbridge)	Dir-I: Adugodi To Electronic City	15427	9198	9198	14048	8267	8267	6%	17:00-18:00	**LOS F**
		Dir-II: Electronic City To Adugodi		6229	6229		5781	5781			**LOS F**

The cordon-wise traffic composition during the peak hour is given in the Figure below. Private modes (cars and two-wheelers) occupy the major share, at 83.4%, followed by Auto rickshaw which is 9%.

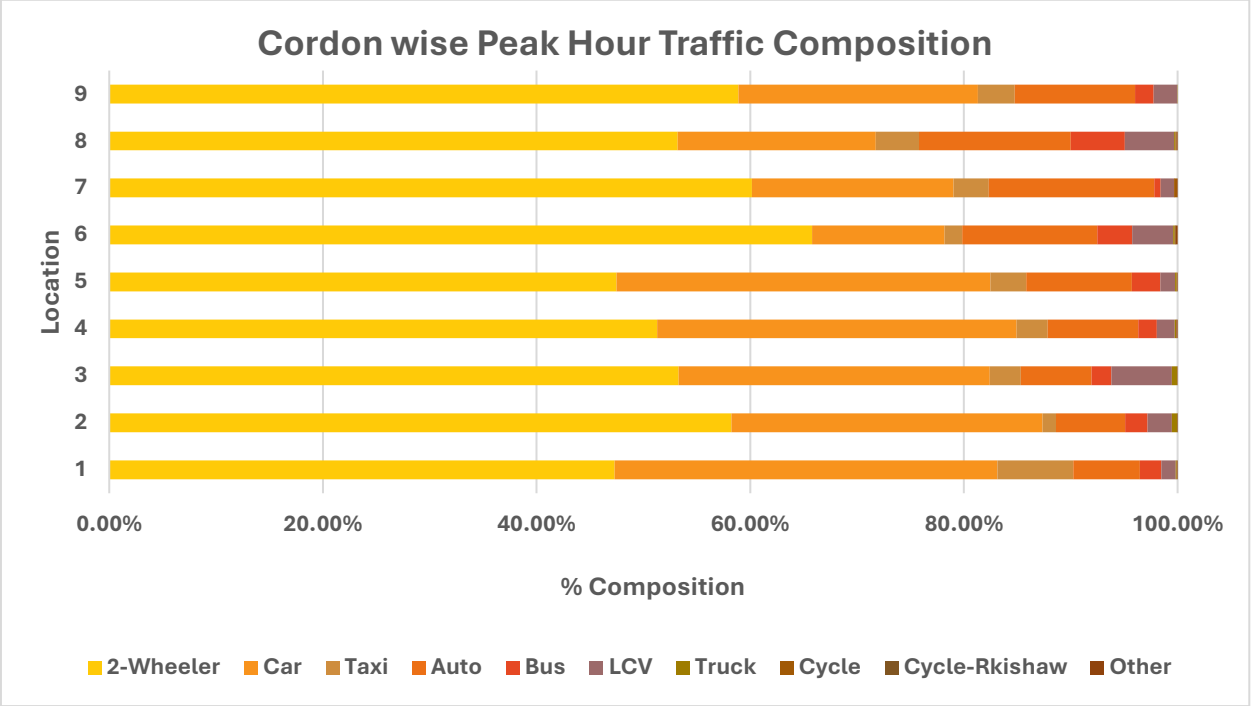


Figure 68: Cordon wise Peak hour Traffic Composition

7.9.3 Turning Movement Counts at Intersections

A total of 7 critical intersections were identified where the volume of vehicles in all turning directions were considered. The analysis of the turning movement volume count survey at the intersections is given in sub-sections below. Amongst the identified locations above, it was observed that, on average, the total traffic was observed to be more than 1,50,000 vehicles per day on most locations, with the highest per day vehicular volume observed at Basaveshwara circle, where 2,38,685 vehicles had accumulated, followed by Shoolay circle, Banglore Cantt Jn, Cn Rao Underpass Jn, respectively. The lowest per-day traffic volume was observed at Lalbagh Chowk with 1,19,980 vehicles in one day.

Table presented below shows the total volumes recorded at the intersections. Annexure consists of illustrations to represent the turning movement at intersections.

Table 57: Traffic Volume at Intersections

Location	Name of Junction	Daily Veh	Daily PCU	Morning			Evening			Direction of maximum Flow
				Peak Hour	Peak Hour Vehicles	Peak Hour PCUs	Peak Hour	Peak Hour Vehicles	Peak Hour PCUs	
1	CN Rao underpass Junction	172303	158783	10.45-11.45	13658	12244	18:45-19:45	12599	11237	Mekhri circle
2	Bangalore Cantt Junction	170379	155088	09.30-10.30	12797	11267	18:45-19:45	12589	11161	Vasant Nagar
3	Basaveshwara circle	238685	218271	09.00-10.00	15026	13347	18:00-19:00	16817	15053	Vasanth Nagar
4	KR Circle	163363	148977	10.15-11.15	13119	11432	16:00-17:00	10901	9686	Anand Rao Junction
5	Cubbon Park UB City signal	155057	142475	09.30-10.30	9681	8351	19:15-20:15	10617	9453	Kempegowda Tower
6	Shoolay Circle	187462	175475	09.30-10.30	12574	11160	18:45-19:45	11619	10335	Military Area
7	Lalbagh Chowk	119980	108159	10.45-11.45	7451	6581	16:30-17:30	7925	7034	South End Circle

Figure below shows the Temporal distribution of traffic at the Intersections.

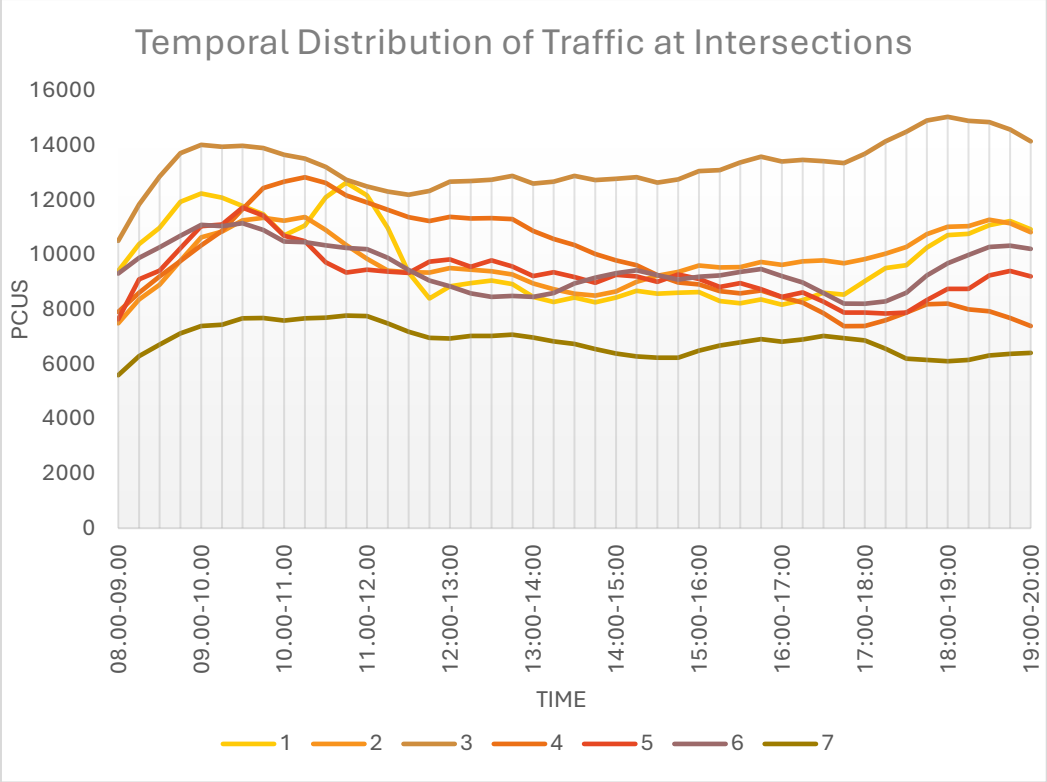


Figure 69: Temporal Distribution of traffic at Intersections

Figure below shows the turning moment count survey locations spatially with the daily volume at each intersection.

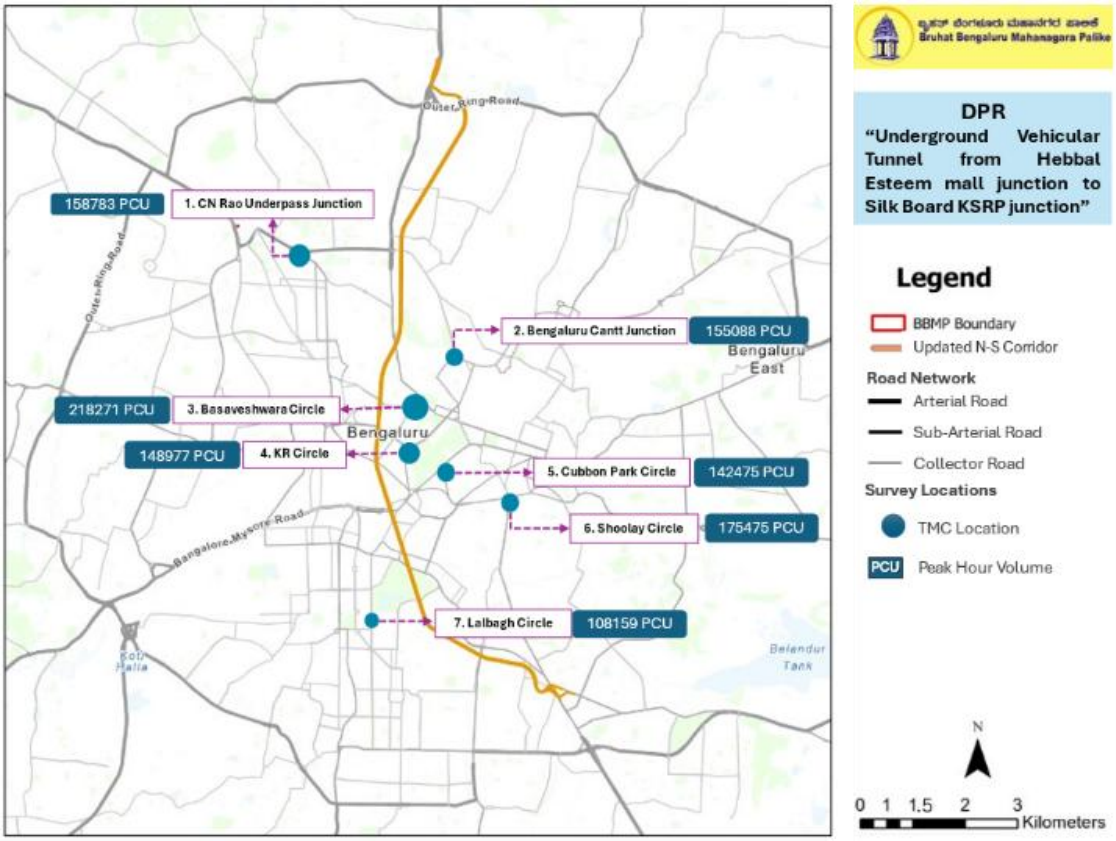


Figure 70: Map Showing Total Daily Traffic at Junctions in PCU

7.9.4 Speed and Delay

Speed and Delay study is done along the road connecting from Hebbal to Silk Board Junction (Upto Ring Road). As Shown in Figure below the route is congested at most of the locations, especially near the core area

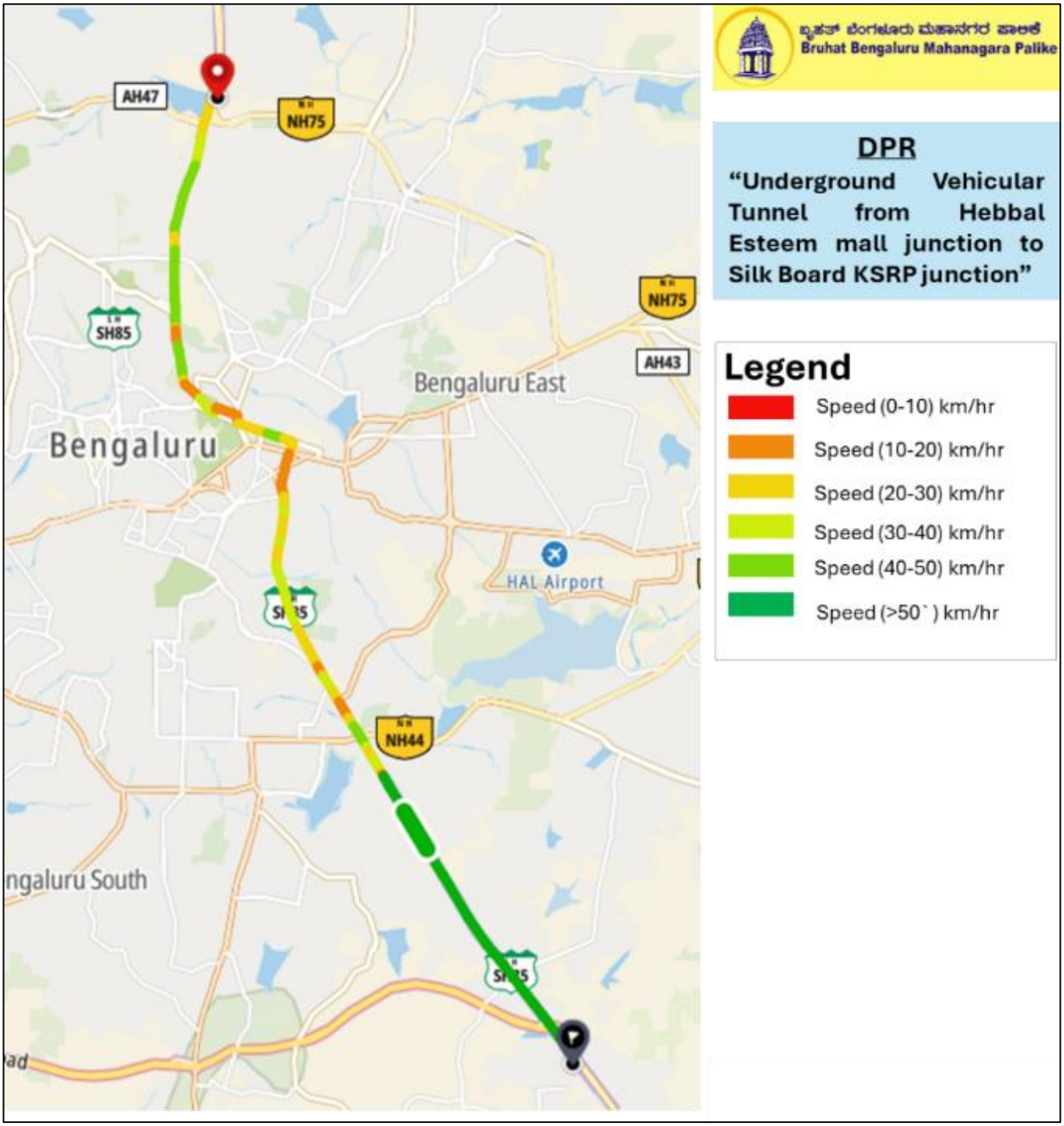


Figure 71: Speed and Delay

7.10 Travel Behavior

7.10.1 Origin-Destination Survey at Cordon Points

Roadside interviews were carried out on a sample basis to understand the characteristics of the ongoing trips. They captured details like purpose, modes, origin-destination, etc.

OBJECTIVE	• To derive the travel pattern of road users • These surveys were aimed at analysing the movement between the study area and external zones.
METHOD	• Interviews were carried out on a sample basis by stopping the vehicles
OUTPUT	• Information's like origin and destination of trip, occupancy, trip purpose and in the case of goods vehicles their type and tonnage.

7.10.2 Average Trip lengths

Based on the analysis of OD data the average trip lengths (ATL) for each mode were calculated as shown in table mentioned, for internal-to-internal movement the ATL of Car is 8 km followed by two-wheeler having 7.6 km ATL and 6.6 km for Auto.

Table 58: Average Trip Lengths (in km)

Mode	Internal - Internal (I-I)	Internal – External (I-E)	External – External (E-E)	External – Internal (E-I)
2-Wheeler	7.6	15.8	19	14.7
Car	8.0	16.2	24.5	18.4
Autorickshaw	6.6	13.5	16.2	12.7
LCV	7.1	18.3	24	20
HCV	5.8	13.6	14.1	18

7.10.3 Trip Purpose

The purpose wise distribution of trips is shown in Figure . The work trips were observed to have the highest share of 69% followed by Business trips 16% out of the total trips.

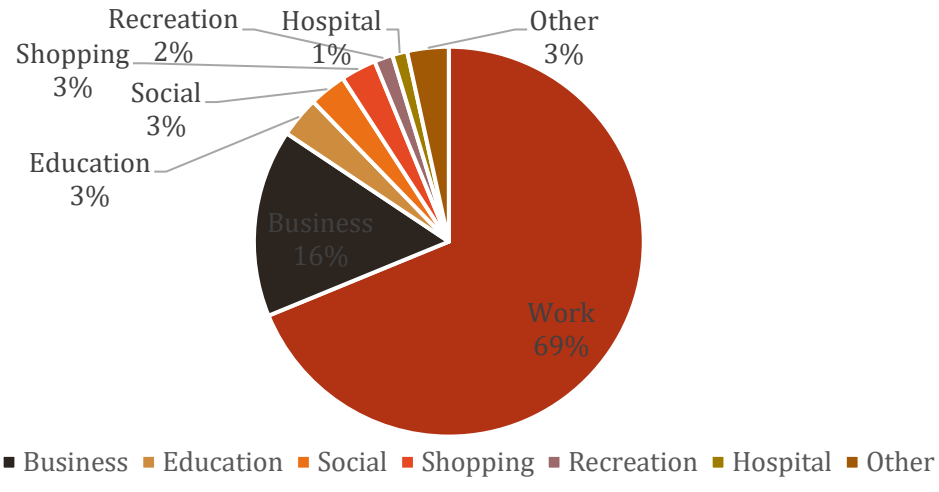


Figure 72: Purpose wise Distribution of Trips during peak hour

7.11 Base Year Travel Demand Model

7.11.1 Introduction

The base year model is developed for the year 2024 to understand and validate the travel patterns. A validated base year model acts as a check of the network credibility and is used to further evaluate future scenarios. For the current demand base model, PTV VISUM 2024 was used. The model was developed for

private transport passenger modes only. The Bus PCU's and freight traffic on the road network are taken as preload based on the count data.

PTV Visum 2024 is a comprehensive, flexible software system for strategic traffic and transport planning. Around the globe, the software is used for metropolitan, regional and state-wide infrastructure planning. PTV Visum is the world's leading software for traffic analyses, forecasts and GIS-based data management. It consistently models all road users and their interactions and has become a recognized standard in the field of transport planning. Transportation experts use PTV Visum to model transport networks and travel demand, to analyze expected traffic flows in the future, to plan public transport services and to develop advanced transport strategies and solutions.

7.11.2 Methodology for Base year model development

The base year model is developed for the critical peak hour i.e., 09:30 am to 10:30 am. The base year model is developed to establish calibrated matrices for different modes and the model is validated using the traffic count data at various locations.

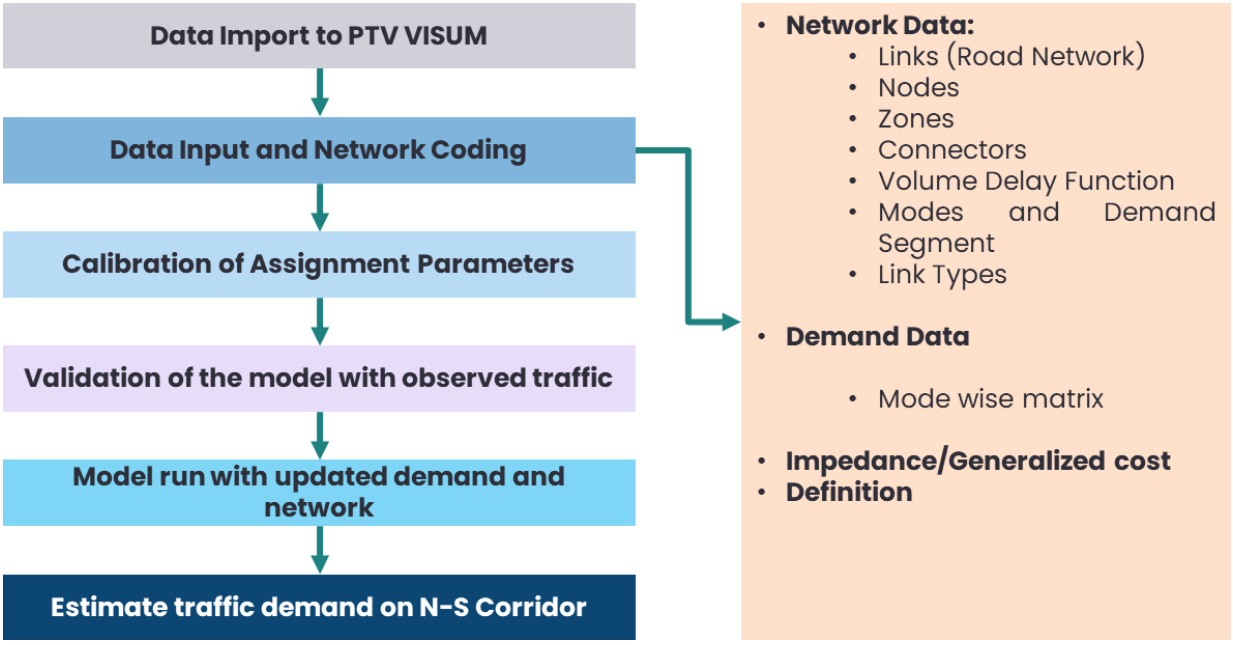


Figure 73: Methodology for base year development

Above mentioned figure provides the overall methodology for model development. The base year modelling involved data input to PTV Visum in the form of Traffic Volume Counts Data, Origin-Destination Matrices for each mode, etc. Network coding through formation of links, nodes, zones and connectors and input of Volume Delay Function. The parameters were modified to represent the travel pattern as observed. After which, the assignment procedure was executed. A user-equilibrium multi-modal assignment procedure based on generalized cost is used for loading matrices in PCU values.

Next step was calibration and validation of the model with observed traffic through volume counts data collected through primary survey data collection. The model was checked to ensure that it adequately performs the functions for which it was intended. This was done by process called validation which included assigning the developed matrices on the network and checking the assigned flows across the screen line/cordon against the observed count.

7.11.3 Network Development

7.11.3.1 Road (Links/Nodes)

The transport network in the study area includes road network presented below shows the base year road network in the study area. All the characteristics of road links were collected by network inventory. Link characteristics collected include length, carriageway type (divided/ undivided), type of operation (one-way/ two-way), number of lanes, average speed etc.

The road network had been imported from Open Street Maps and carriageway widths were validated with Bengaluru's Open Data and Network Inventory Primary Survey. (https://www.openstreetmap.org)

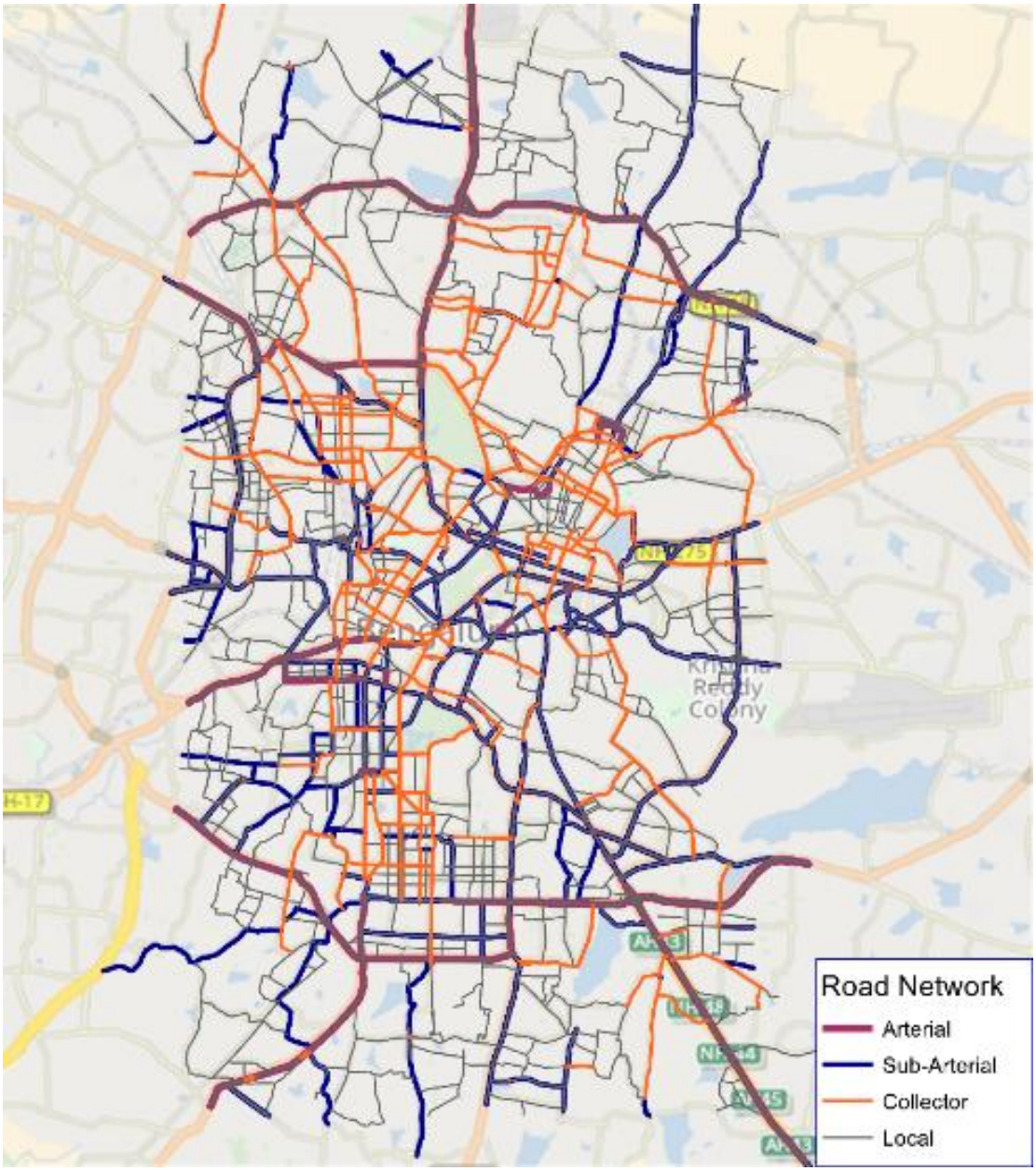


Figure 74: Road network developed in PTV Visum

7.11.3.2 Link Types

The traffic related properties of links were described via Link Types and following were the important parameters of a link type:

- List of permitted transport systems on a link
- Capacity
- Number of lanes

Volume Delay functions or capacity restrain functions define correlation between current volume of traffic and roadway capacity of a link. The result of the V-D function is the travel times in the loaded network for the Private vehicles. Thus, a V-D function defines the travel time of traversing a link in loaded state. The values for the different calibrated volume delay functions were estimated based on the capacity values for IRC 106, Indo HCM and other secondary data sources.

7.11.4 Base Year Travel Demand Analysis

The base year travel demand was estimated by importing the origin-destination matrices and executing the mode-wise matrix correction procedure through T-flow fuzzy method. T-flow fuzzy method also considers the volume count data of survey locations.

The assignment procedure was executed iteratively after the matrix correction procedure. The assignment results can be viewed in the form of bars where the large width bars represent more traffic on the links.

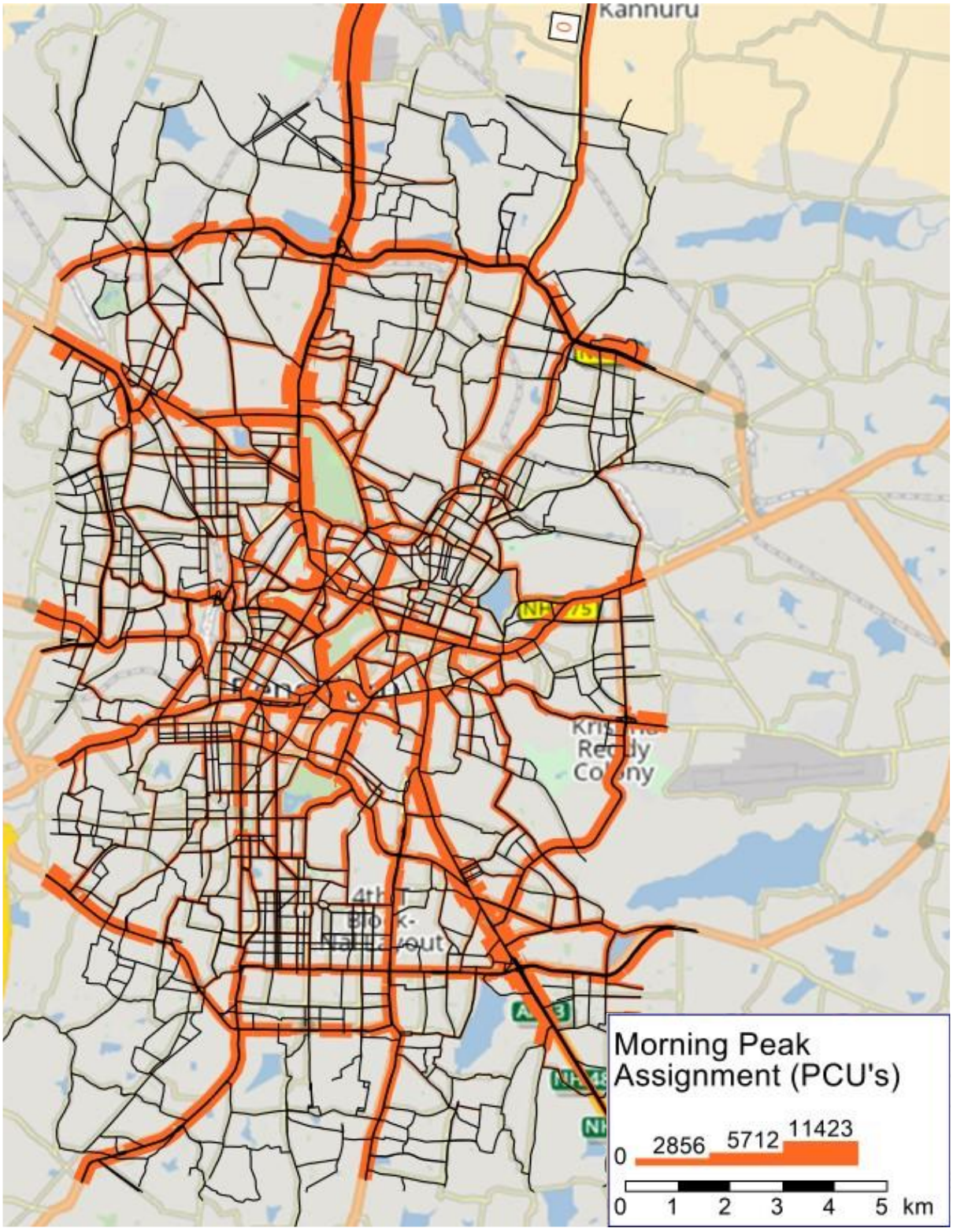


Figure 75: Traffic assignment, Study Areas (Base Year)

Below three figures demonstrate the count locations used to validate the assignment results with survey data.

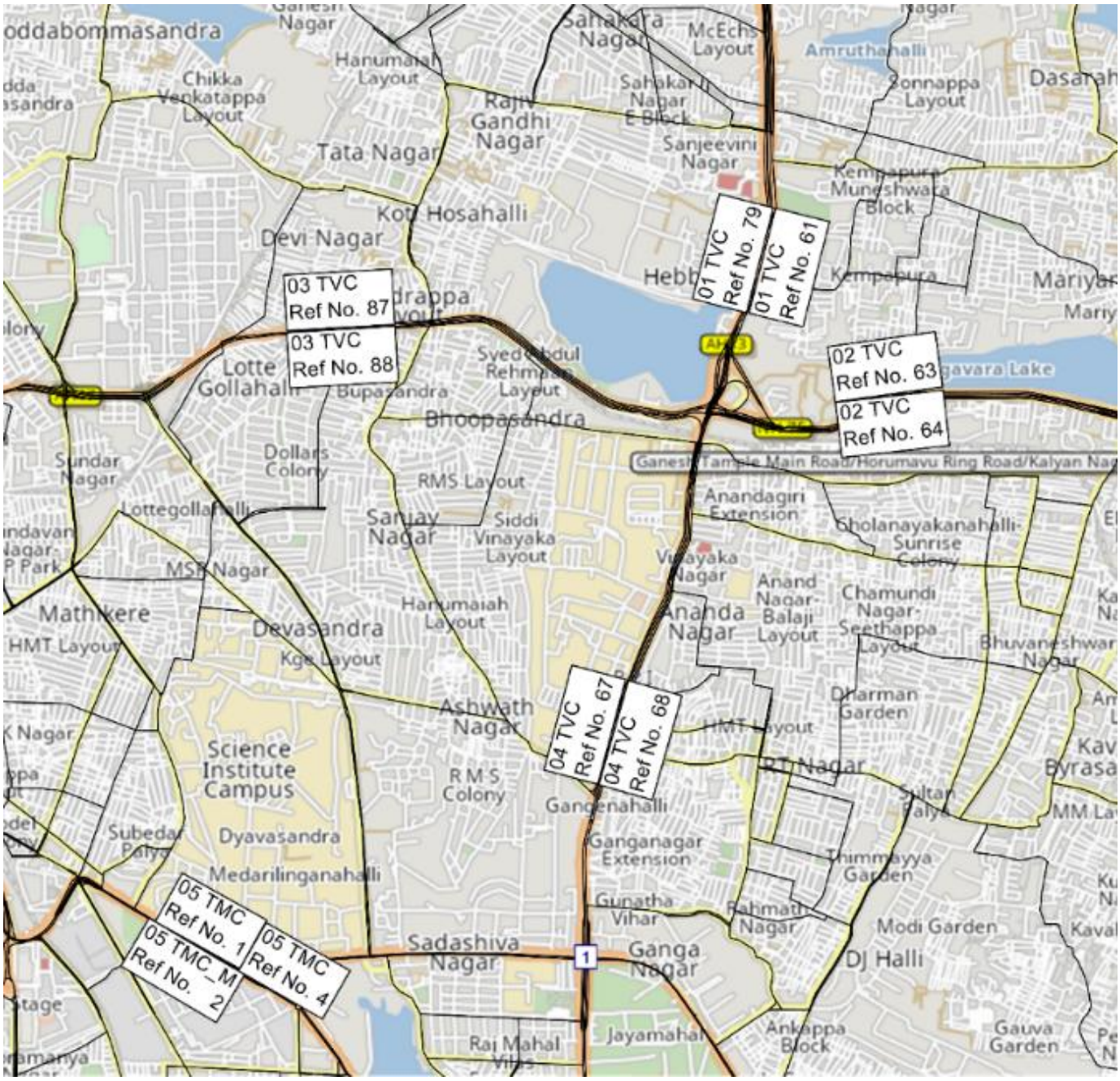


Figure 76: Count Locations for validation of base year assignment (a)

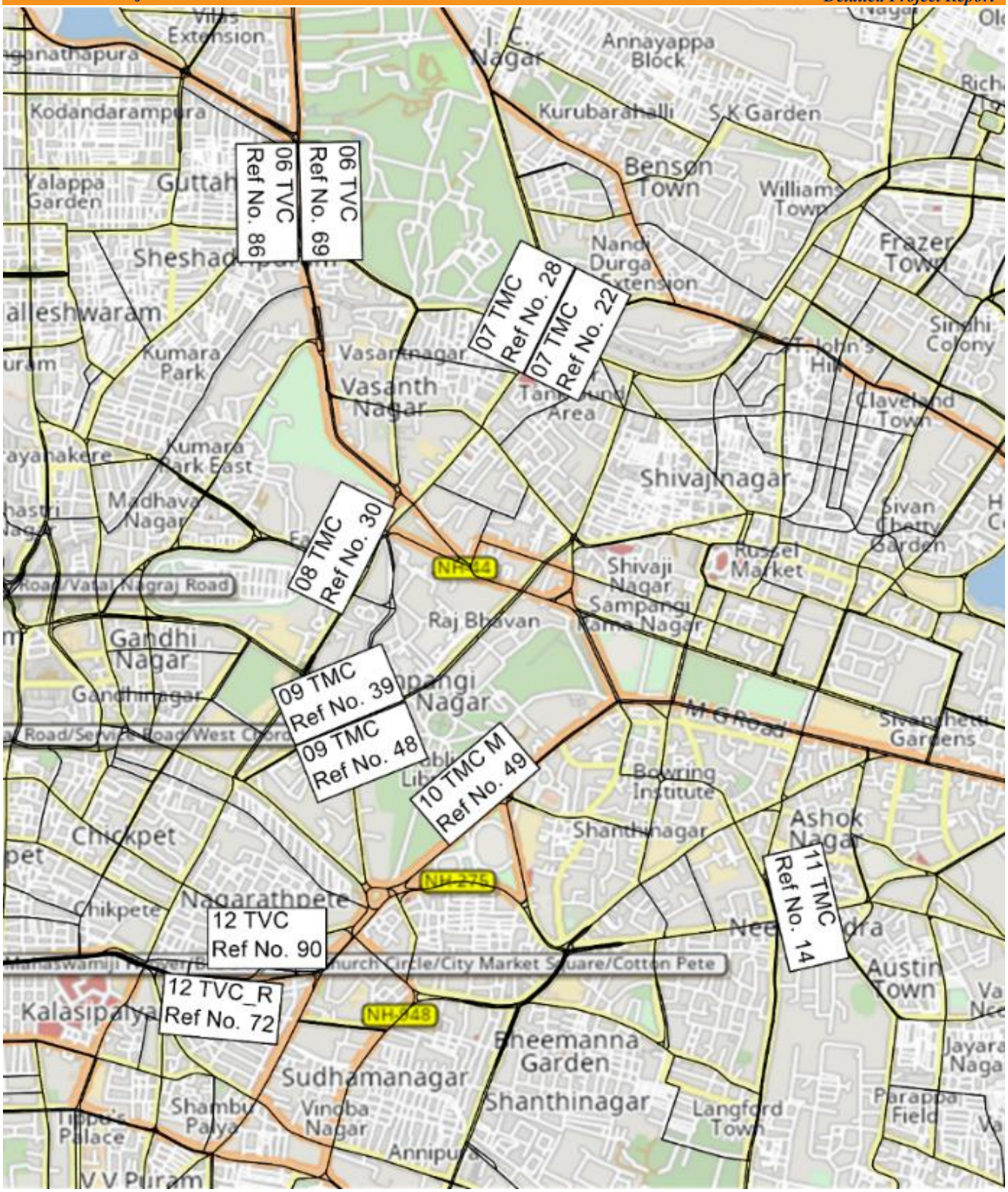


Figure 77: Count Locations for validation of base year assignment (b)

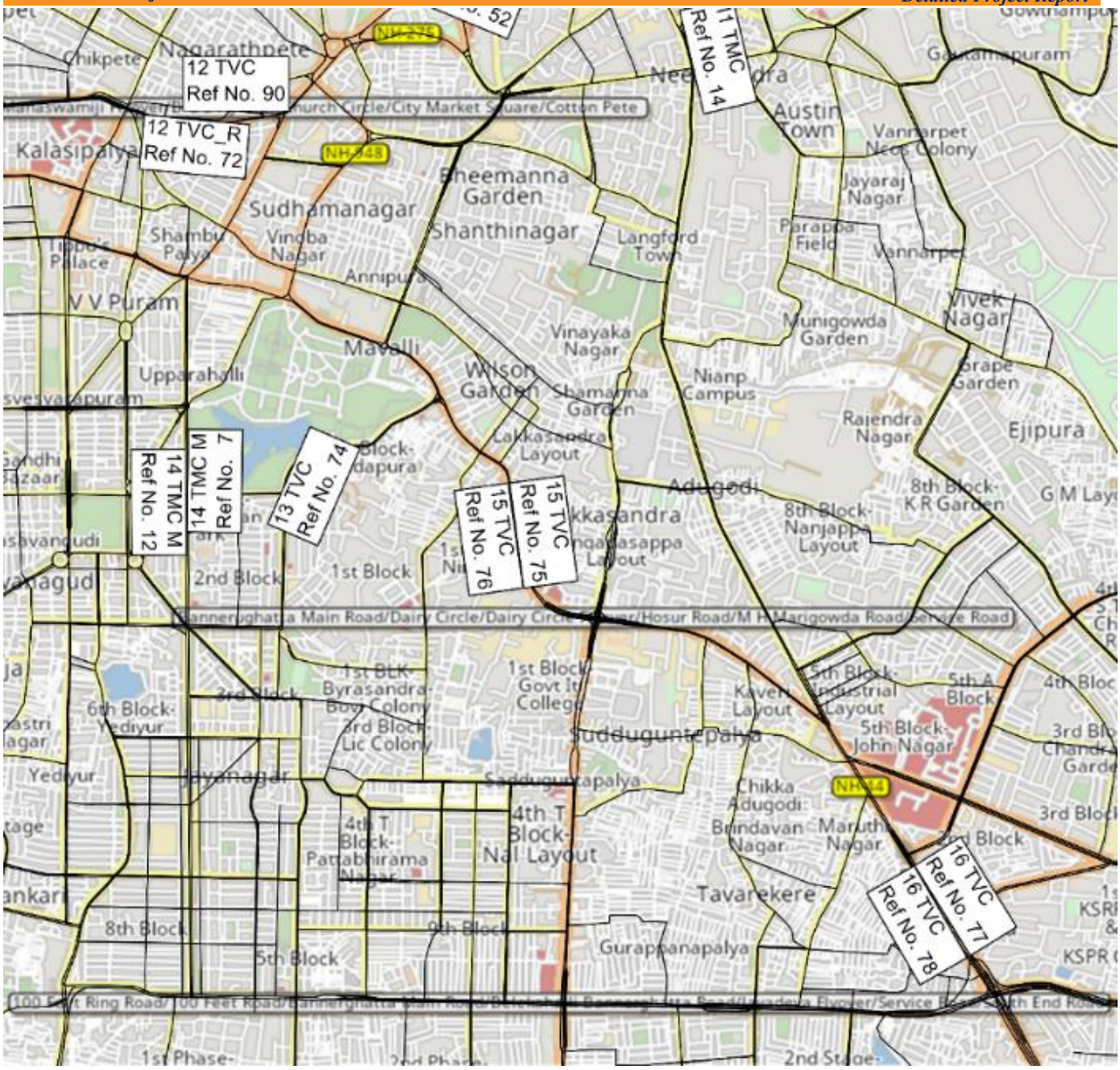


Figure 78: Count Locations for validation of base year assignment (c)

The assignment results were validated through GEH value which suggests that 90% of the assignment results should have GEH value of less than 10. This was considered as a validation measure to validate the model's accuracy. The GEH Values of the model results are shown in table below .

Table 59: Model Results

TVC	Car Observed Volume	Car Modelled Volume	GEH _CAR	TW Observed Volume	TW Modelled Volume	GEH_TW	Auto Peak Hour Observed Volume	Auto Peak Hour Modelled Volume	GEH _AUTO
01	3638	3805	3	2850	2625	4	320	320	0
01	3194	3314	2	2580	2348	5	295	229	4
01	1348	1209	4	1571	1787	5	245	253	1
02	1812	1671	3	2643	2552	2	492	392	5
02	1839	1558	7	2397	2268	3	311	327	1
02	799	806	0	1606	1684	2	0	129	16
02	130	291	11	1212	1281	2	101	105	0
03	1455	1334	3	3040	2889	3	324	314	1
03	1883	1883	0	2949	3235	5	396	382	1
04	2366	2059	7	2573	2263	6	295	385	5
04	2748	2826	1	2349	2253	2	427	415	1
06	2736	3107	7	4141	4346	3	526	621	4
06	1991	2133	3	2393	2459	1	751	740	0
12	1538	1509	1	2324	2458	3	1001	930	2
12	538	653	5	2550	1829	15	751	800	2
13	405	380	1	2600	2921	6	473	420	3
13	340	312	2	1434	1259	5	402	332	4
15	753	776	1	2005	1978	1	308	329	1
15	1097	885	7	2189	1677	12	584	489	4
16	1563	1531	1	4412	4564	2	956	751	7
16	2714	2834	2	5525	5823	4	926	1150	7

Table 60: Synthetics Validation of Base Year Network – Peak Hour

GEH Range	Car	Two-Wheeler	Auto-Rickshaw
<10	95%	90%	96%
>10	5%	10%	5%

7.11.5 Base Year Outputs

The outputs from the model are in the form of Trip Length Frequency Distribution to calculate mode-wise Average Trip Lengths along with the Total number of Trips generated and attracted in the modelled peak hour.

7.11.5.1 Trip Length Frequency Distribution

Trip Length Frequency Distribution provides insights into travel patterns, to understand the average distances traveled by commuters and identify areas with high concentrations of short or long trips. Through analyzing Trip Length Frequency Distribution (TLFD), Average Trip Lengths mode-wise were obtained to understand travel patterns within the study area. The Trip Length Frequency Distribution for Car, Two-Wheeler and Auto Rickshaw are shown in the three figures mentioned below.

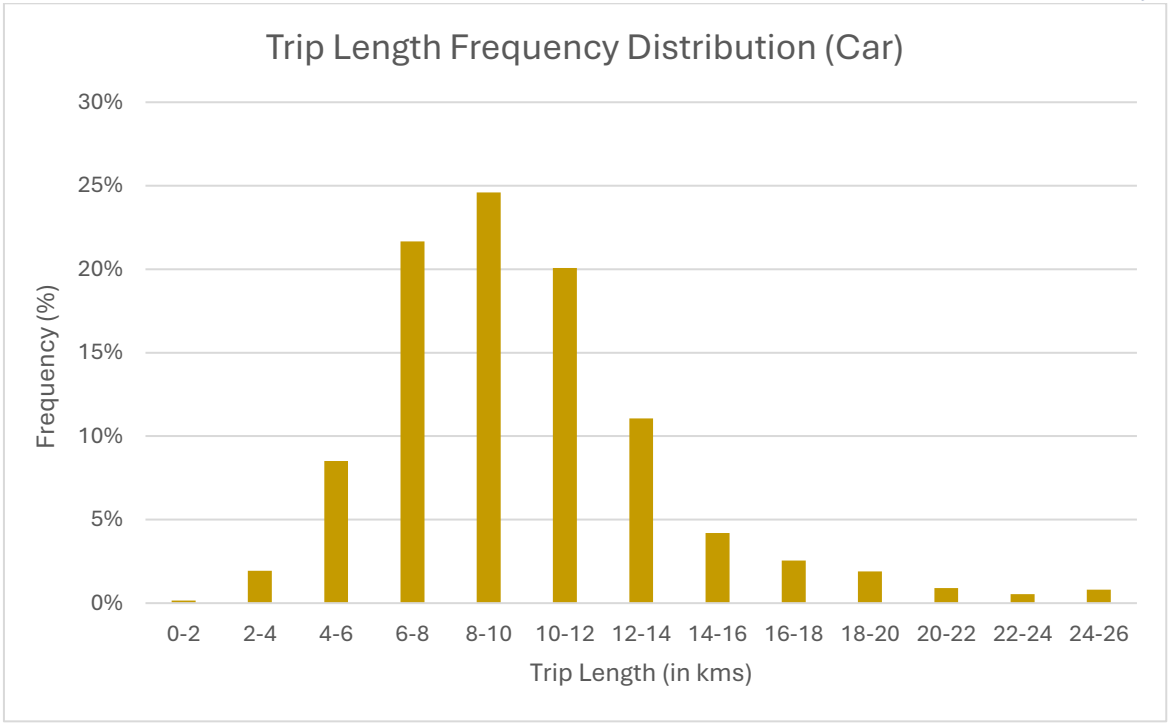


Figure 79: TLFD for Car Trips

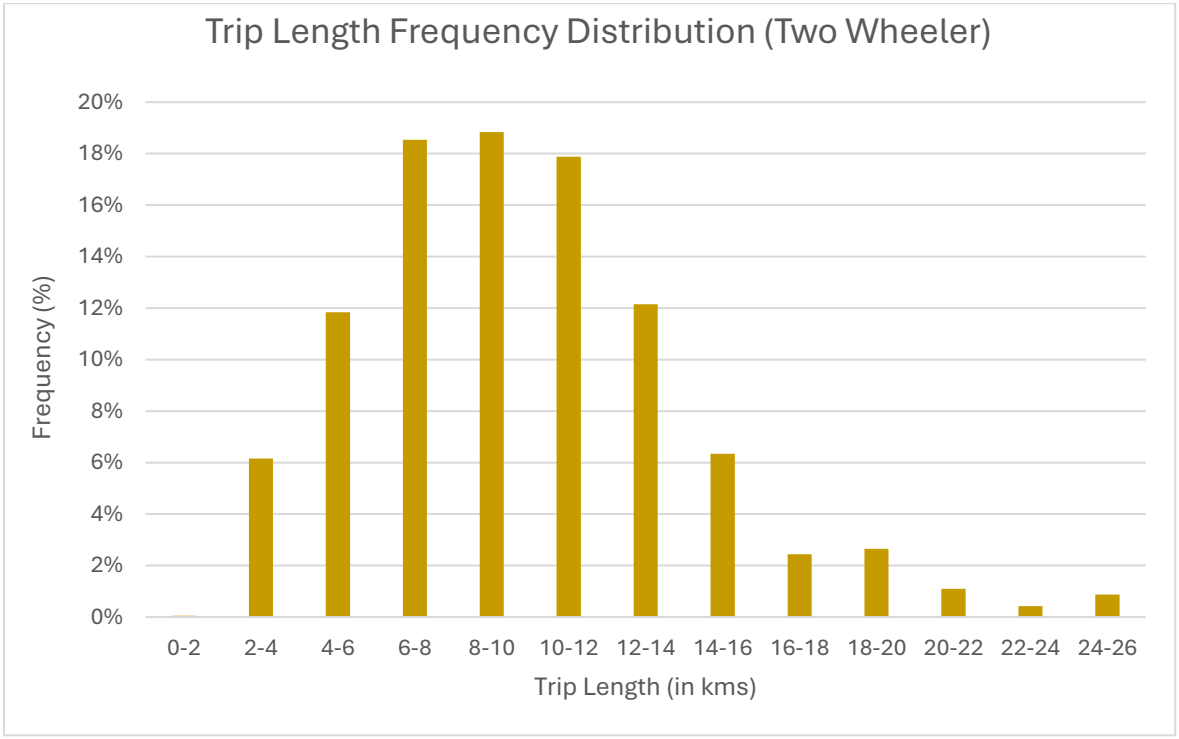


Figure 80: TLFD for Two-Wheeler Trips

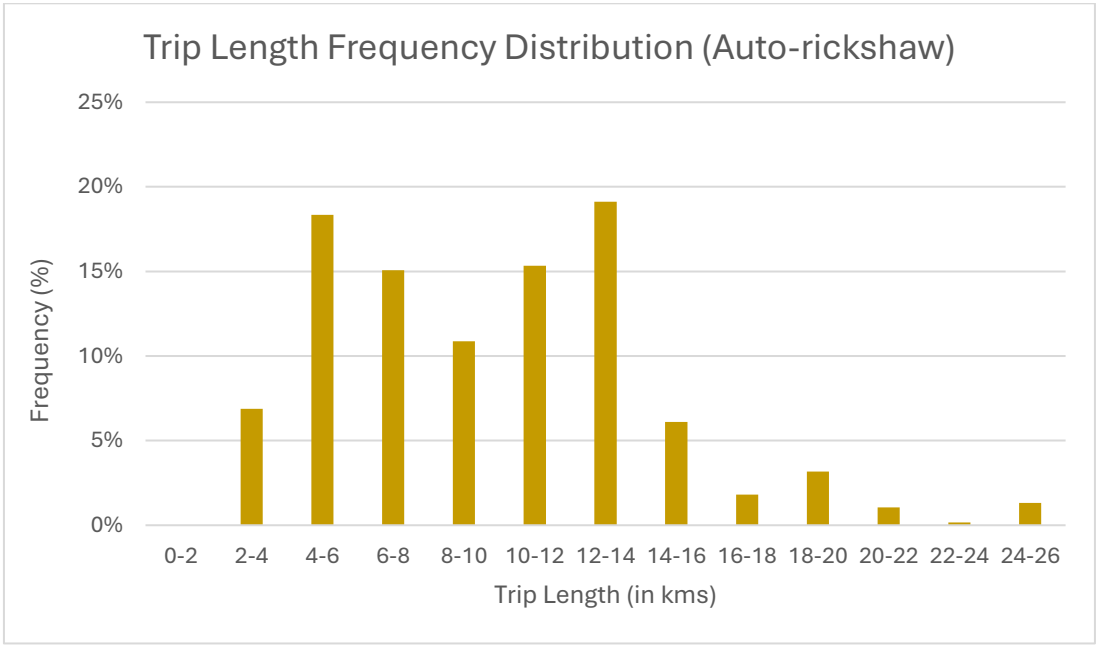


Figure 81: TLFD for Autorickshaw Trips

7.11.5.2 Estimated Trips

Table mentioned below shows the total no. of estimated trips produced by each mode for the study area. The maximum no. of trips produced was observed for Two-wheeler i.e., 1,20,288 trips followed by Car i.e., 59,322 and 25,603 by Autorickshaw among passenger vehicle in the modelled peak hour. A total of 3,854 trips are produced by freight vehicles in the modelled peak hour.

Table 61: Total no. of Trips (Mode-wise) - Morning Peak

Mode	No. of Trips
Car	59,322
Two-Wheeler	1,20,288
Autorickshaw	25,603

7.11.6 Summary

After running multiple iterations of base year assignment, the base year model had been calibrated, and the model was fit for the calculation of future travel demand of horizon year.

7.12 Traffic Projections and Horizon year model Assessment

7.12.1 Planning Period

The demand to be calculated for the future was estimated for 10 years, 15 years, 20 years and 25 years from the base year i.e., 2024. For future growth estimation, three scenarios were developed to estimate the number of trips diverted on the North-South corridor for Horizon Year. The model runs were done for the years 2031 and 2041, and other results were extracted from the result of these 2 years.

7.12.2 Planning Parameters

Population data was referred from CMP 2020 and the zone wise population distribution had been carried out for base year and zonal distribution of population had been done for horizon year considering similar distribution.

The horizon year population is given below.

Table 62: BBMP Population Projections

Year	Population
2021	1,28,62,825
2024	1,32,62,233

Year	Population
2031	1,68,56,904
2041	1,98,67,161

Source: CMP 2020

7.12.3 Scenario Building

The scenario building was done considering the scenarios formulated in Comprehensive Mobility Plan, 2020 for Bengaluru to guide the development of the city in line with the Comprehensive Mobility Plan 2020. In the Comprehensive Mobility Plan 2020, BAU scenario was considered to have the highest number of Cars, and the Scenario 4 was considered to have the highest share of Public Transport as compared to other scenarios, as discussed in Section 7.8.2. Table below provides a summary of the estimated modal shares as per the CMP 2020 report for different scenarios.

For the present study, 3 scenarios were considered Scenario 1 (S1) with highest modal share of Car which is BAU Scenario 2031 of CMP 2020, Scenario 3 (S3) with lowest modal share of Car which is Scenario 4 of CMP 2020 and an intermediate scenario between Scenario 1 and Scenario 3 i.e., Scenario 2 (S2) which is Scenario 3 of CMP 2020.

Table 63: Forecasted Modal Share for 2031

Mode	Year 2015	Year 2031			
	Base Year	BAU - S1	S2	S3	S4
Car + Taxi	21%	30%	25%	23%	17%
Two-Wheeler	24%	29%	13%	11%	8%
Auto Rickshaw	8%	5%	3%	3%	2%
Public Transport	48%	36%	59%	63%	73%

Source: CMP 2020

7.12.3.1 Scenario 1 (S1)

This scenario considers the mode share estimates as per the BAU scenario of CMP. In scenario 1, the existing road network with committed development projects are considered such as the construction of Peripheral Ring Road, Elevated Corridors, Construction of Metro Phase 2 and augmentation of BMTC buses to double the fleet. In this scenario, the high modal share of private vehicles doesn't align with the transport proposal as the city is focused on improving public transport.

7.12.3.2 Scenario 2 (S2)

This was considered as an intermediate scenario which is Scenario 3 of CMP 2020. This scenario focuses on improving efficiency of existing road infrastructure and augmenting the road capacity through junction improvements and smoothening bottlenecks, at-grade road widening and elevated roads while earmarking a part of the new capacity for bus-based public transport besides more ambitious expansion of the public transport. Also, investment in areas that promote NMT networks, rail-based infrastructure, etc. is also aimed at and lastly, need has been identified for augmenting the capacity of arterial roads in the CBD areas, as well as that of the ORR.

7.12.3.3 Scenario 3 (S3)

This scenario is also considered from CMP 2020 wherein it is referred to as Scenario 4. This scenario considered all future developments and redevelopments guided by Transit Oriented Development facilitating compact development coupled with efficient public transport corridors reducing the demand for large trip lengths. The use of private vehicles was discouraged significantly and leveraging road infrastructure for public transport. This scenario focused on expanding public transport systems and multi-modal integration.

The modal share for all scenarios is shown in table mentioned above "Forecast Modal Share" which is referred from CMP 2020.

The outcomes of Scenario 4 of CMP 2020 estimates 73% modal share of Public Transport, with 60% of city's population living in intense TOD Zone along with achieving gross density of 250 to 400 pph (persons

per hectare) along the mass transit corridors by 2031. It further envisages setting up 317 km metro rail network along with 4 corridors of suburban rail with a length of 149 km within the city and their 165 km extension to suburban areas. Under the road based public transport 11 high priority corridors with exclusive bus lanes and bus fleet proposed to be expanded to 16,582 by 2031. As per the current pattern of infrastructure development these targets seem very challenging to achieve by the year 2031.

Therefore, while calculations and diversion estimations were assessed for all scenarios, the intermediate scenario 2, with a modal share of 63% for public transport, is considered for further evaluation and assessment of diversion and planning for the proposed North South corridor.

The horizon year of CMP 2020 was 2031 therefore to forecast vehicular trips for 2041 the population projections given in the CMP are used. The total trips are assumed to be growing in align with population growth as per the trip generation estimates in the CMP.

7.13 Projections

7.13.1 Key Assumptions

- It is assumed that the city growth pattern will align with the vision of CMP 2020.
- Mode share has been referred from CMP 2020 for different scenarios of horizon year.
- For projection of trips for external zones, DPRs of sanctioned projects (Satellite Town Ring Road and Peripheral Ring Road) are referred and growth rates are derived from these documents.

7.13.2 Demand Projections

7.13.2.1 Zones within BBMP Area

To project the trips for horizon year, the percentage of base year production and attraction totals of each zone has been calculated from the zone-wise population for each mode to get the mode-wise proportion of population in each zone. Further, the modal shift (derived from CMP 2020) has been added to this mode-wise population proportion to get the horizon year proportion of population for each mode and horizon year trips have been calculated by multiplying the horizon year population with this proportion.

With this process, for the trip generation process, the production and attraction trip totals mode-wise for each scenario has been obtained. Table below provides the estimated total passenger trips.

Table 64: Estimated Total Vehicle trips during morning peak hour for study area

Mode	Base Year	Year 2031			Year 2041		
	2024	S1	S2	S3	S1	S2	S3
Auto Rickshaw	25,603	25,111	23,812	19,859	29,631	28,098	23,434
Two-Wheeler	1,20,288	153,528	128,708	100,381	181,163	151,876	118,449
Car	59,322	83,005	72,507	61,168	97,946	86,210	72,178

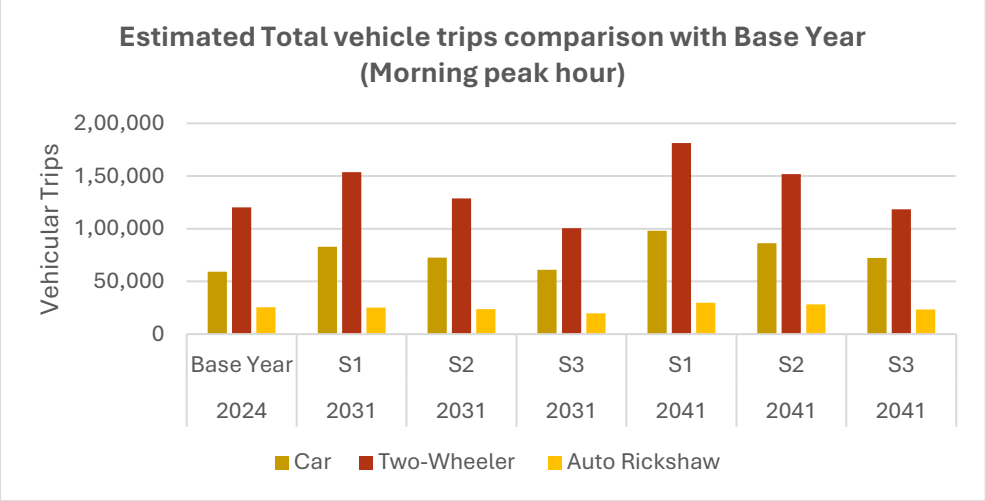


Figure 82: Estimated Total Vehicular Trips Comparison with Base Year (Morning Peak Hour)

The growth rates of Cars compared to Base scenario for 2031 for S1, S2 and S3 are 40%, 22% and 3% respectively. The growth rate of Autorickshaw for Scenario 2 when compared for 2031 with base case scenario showed a negative growth rate of 7% and Two-wheeler showed a positive growth rate of 7% for 2031.

7.13.2.2 Zones outside the BBMP Area

To forecast the trips in the zones which fall outside the BBMP area, growth rates were referred from the Peripheral Ring Road project which showed an average annual growth rate of 7%. The trips in the external zones outside BBMP area are projected to grow annually at a growth rate of 7%. (Final DPR – Peripheral Ring Road, 2020)

7.13.2.3 Freight Vehicles

For projecting trips for freight vehicles, the DPR documents for satellite town ring road and peripheral ring road were referred. Also, the SGDP and vehicle registration data were referred to derive growth rates for freight vehicles. Up to 2031 growth rate of 7% was taken and after 2031 growth rate of 5 % was considered for these vehicles.

7.13.3 Estimating Horizon year OD Matrices

Based on the estimated trip ends as discussed above, for the trip distribution procedure, to obtain the inter-zonal trip interchanges for each scenario of horizon year, fratar method of trip distribution was used.

The Fratar method, a widely used technique in urban planning and transportation engineering, is designed to model and distribute trips across various zones in a region. This iterative procedure starts with an initial set of trip distributions. It then adjusts these distributions to align with observed trip generation and attraction data for each zone. The process involves iteratively updating the trip matrix until the calculated trip ends match the known totals for each zone, ensuring a balanced distribution. This method is valued for its ability to reconcile initial estimates with actual data, providing a more accurate reflection of travel patterns and improving the reliability of transportation planning and infrastructure development.

$$T_{i-j} = t_{i-j} \times \frac{P_i}{p_i} \times \frac{A_j}{a_j} \times \frac{\sum^{k} t_{i-k}}{\sum^{k} \left[A_k / a_k \right] \times t_{i-k}}$$

Ti-j = Future Trips from Zone I to Zone j

ti-j = Present Trips from Zone I to Zone j

Pi = Future trips produced at Zone i

pi = Present trips produced at Zone i

Aj = Future trips attracted at Zone j

aj = Present trips attracted at Zone j

k = Total Number of Zones

The horizon year matrices for each scenario were obtained after applying this procedure.

7.13.4 Model Results

In this section the projected traffic on the corridor is discussed. Initially for the horizon years the model assignment was carried out considering all passenger private transport vehicles for the proposed North-South Corridor which resulted in a V/C ratio of 0.75 and more for all sections.

Considering this, only Cars were considered as the mode for the North-South Corridor. This was also in line with the allowed vehicles in similar facilities around the country. Further, it also reduces vulnerability of road crashes, especially with two wheelers and auto rickshaws (Source: Indo HCM). The assignment procedure was executed for the year 2031 and 2041 to keep in line with the modal share assumed in Comprehensive Mobility Plan 2020. The traffic assignment results were then interpolated/extrapolated for

the years 2037, 2047, 2051 and 2057. The output results were evaluated for various alignment options as discussed below, and the Level of Service is calculated considering the capacities mentioned in INDO-HCM, considering the capacity for Mid-Block Sections as 2300 PCU per lane, and reduced capacity for the ramps as per the Indo HCM.

7.13.4.1 Horizon Year Model Outputs – Without Tolls – Alignment Option 1

In this section we discuss the model outputs for the diversion on the proposed corridor for the alignment option 1 as given in the Figure below.

For the scenario with toll, the average toll price considered for Cars was Rs 19.42/km. Considering this, for 2031 and 2041 all the three scenarios were calculated with toll and without toll to understand the impact of the application of toll in the proposed North South Corridor.

For facilitating ease of analysis, the corridor is subdivided into 4 sections, Section1 starting from Hebbal and Section 4 ending at Silk Board Junction. Further, the entry and exit ramps are coded alphabetically to identify the entry and exit volumes at ramps in the figure below.

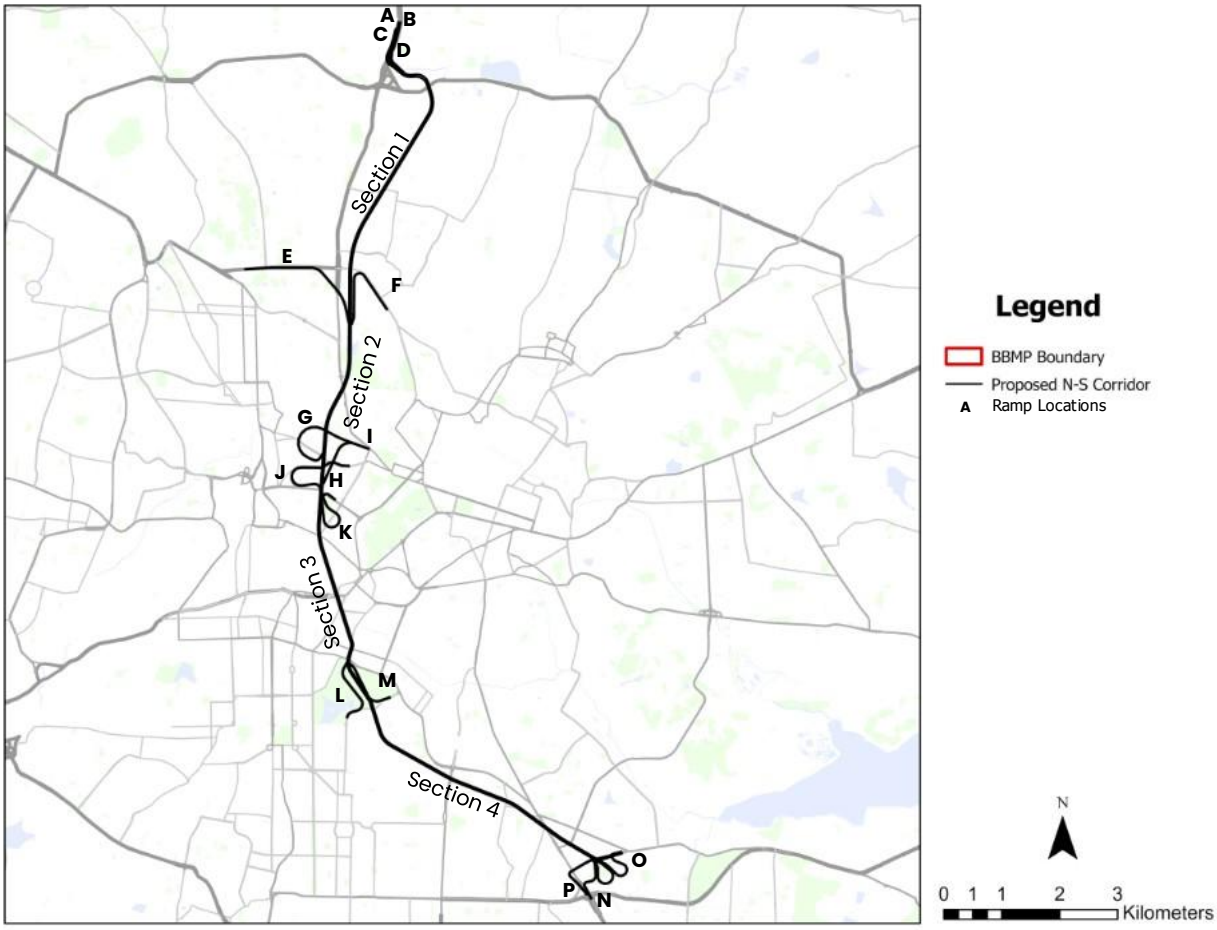


Figure 83: North-South Corridor: Entry/Exit Ramps Coding – Alignment Option 1

Alignment Option 1 consisted of 16 Ramps named alphabetically located among 4 sections of the North-South Corridor.

The assignment results for selected scenario 2 are shown in the table below. The highest volume in all the three scenarios for 2031 and 2041 was observed in the case of Section 2, particularly the traffic movement towards Silk Board Junction for the morning peak hour.

Table 65: Assignment Results (Morning Peak Hour PCU) for 2031 and 2041 (S2 without toll)

Average Traffic on each Section	Ramp/Section	S2 Year 2031 (Without Toll)	S2 Year 2041 (Without Toll)
Section 1	**Towards Airport**	1139	1665
	Towards Bengaluru City	1343	1621
	Ramp A (Main Exit)	797	1165
	Ramp B (Main Entry)	470	567
	Ramp C (Service Exit)	342	499
	Ramp D (Service Entry)	873	1054
	Ramp E	787	1057
	Ramp F	3065	3543
Section 2	**Towards Airport**	1696	2244
	Towards Bengaluru City	6151	7041
	Ramp G	459	955
	Ramp H	3486	3755
	Ramp I	3946	4709
	Ramp J	1998	2693
	Ramp K	2507	2895
Section 3	**Towards Airport**	3464	4460
	Towards Bengaluru City	5388	6023
	Ramp L	1134	1436
	Ramp M	3656	4018
Section 4	**Towards Airport**	2330	3024
	Towards Bengaluru City	1732	2005
	Ramp N	2330	3024
	Ramp O	2368	2627
	Ramp P	1096	1383

As shown in above table, for the year 2031 (no toll scenario), for section 2 and section 3 high volume of vehicles were estimated which led to poor level of service on the proposed corridor in the initial years itself, making no toll scenario infeasible. Also, it was observed that accessibility from Hebbal and Mekhri Circle needs further improvement. Hence, this alignment option was not considered for further evaluation.

7.13.4.2 Horizon Year Model Outputs with Tolls – Alignment Option 2

In this section we discuss the outputs from the alignment option 2 given in the figure below for with toll scenario. In this Alignment option, the ramp locations in Section 2 have changed for Ramp G and Ramp K.

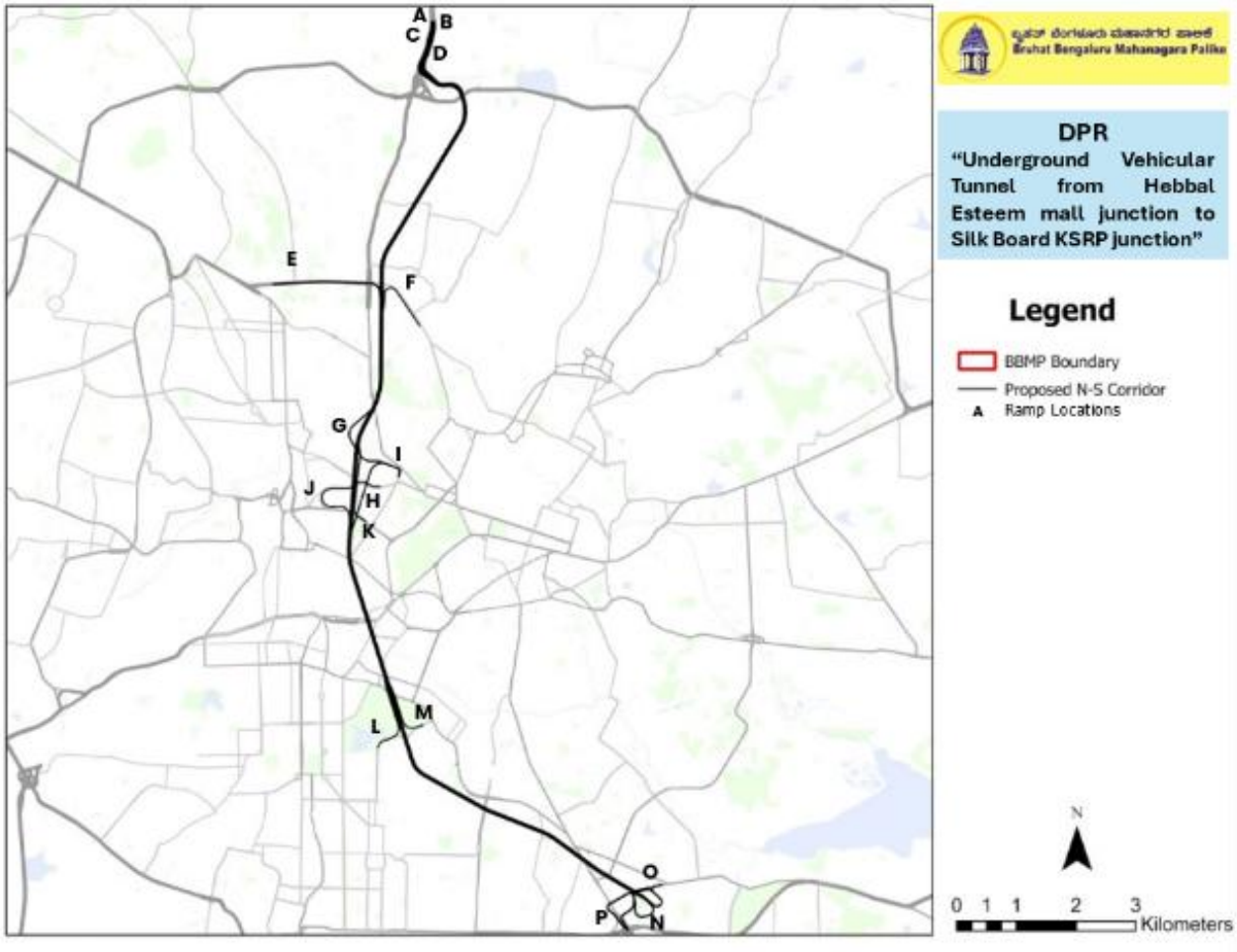


Figure 84: North-South Corridor: Entry/Exit Ramps Coding – Alignment Option 2

Table below provides the estimated traffic for the years 2031 and 2041 on the proposed corridors. The level of service has been calculated using the V/C ratio classification of INDO-HCM, the LOS for each section has improved compared to the non-toll scenario. Level of Service D was observed in the case of Section 3 with traffic movement towards Bengaluru (Silk Board Junction) for the year 2041.

Table 66: Assignment Results - Scenario 2: Morning Peak Hour PCU for 2031 and 2041 (with toll) (Alignment Option 2)

Assignment Results		Morning Peak Hour (PCU)			
		Year 2031 (With Toll)	LOS	Year 2041 (With Toll)	LOS
Section 1	Towards Airport	2522	LOS B	3156	LOS B
	Towards Bengaluru City	2645	LOS B	3770	LOS C
Section 2	Towards Airport	1834	LOS B	2333	LOS B
	Towards Bengaluru City	4030	LOS C	5161	LOS C
Section 3	Towards Airport	2653	LOS B	3742	LOS C
	Towards Bengaluru City	4705	LOS C	5559	LOS D
Section 4	Towards Airport	2005	LOS B	2951	LOS B
	Towards Bengaluru City	1551	LOS A	1811	LOS B

The average cross-sectional traffic for each section for the morning peak hour with tolls is presented in table below. The maximum cross-sectional volumes were observed for Section 3 followed by Section 2.

Table 67: Average Cross section traffic on Each Section (Peak Hour) – With Toll (Alignment Option 2)

Section	Average Cross section traffic on Each Section (Peak hour) (PCU) – S2 Toll Scenario	
	2031	**2041**
Section 1	5167	6926
Section 2	5864	7524
Section 3	7358	9431
Section 4	3556	4929

7.13.4.3 Horizon Year Model Outputs with Tolls – Alignment Option 3

After infrastructure consideration and evaluation, another Alignment Option 3 consisting of 22 Ramps located among 4 sections is evaluated. The alignment is shown in Figure below. In this option two additional ramps for entry/exit are added near to the Mekhri Circle (Ramp T and Ramp U) and at the ring road (Ramp S and ramp R), and the location of ramps near Silk Board are updated.

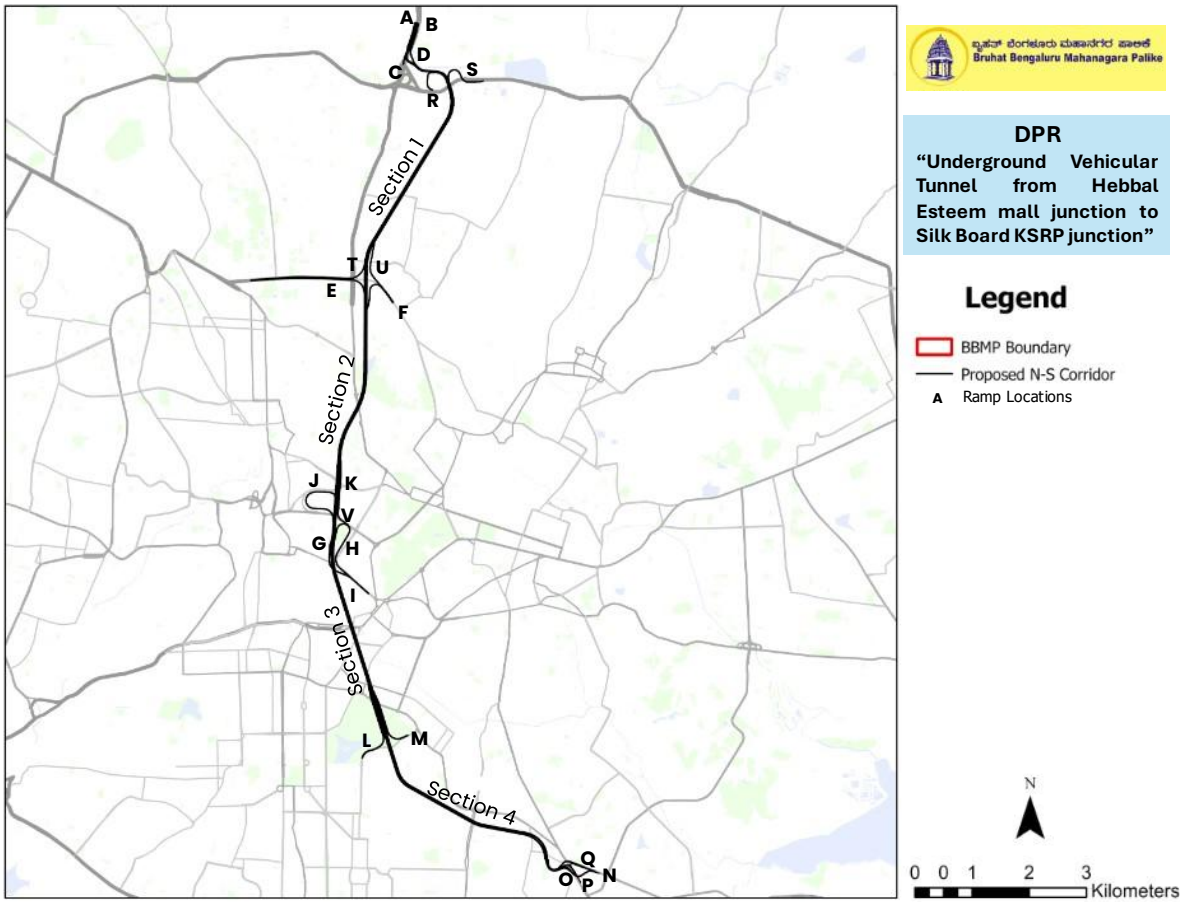


Figure 85: North-South Corridor: Entry/Exit Ramps Coding – Alignment Option 3

Similarly for Alignment Option 3, Scenario 2 with toll was considered for further evaluations. The assignment results for scenario 2 morning peak hour for the years 2031 and 2041 are shown in Table below. Overall traffic is increased from the previous alignment options due to better connected from the ring road and at the Mehkri Circle.

Table 68: Assignment Results - Scenario 2 (Morning Peak Hour PCU) for 2031 and 2041 (with toll) (Alignment Option 3)

Assignment Results		Morning Peak Hour (PCU)			
		Year 2031 (With Toll)	**LOS**	**Year 2041 (With Toll)**	**LOS**
Section 1	**Towards Airport**	3038	LOS B	4015	LOS C

Assignment Results		Morning Peak Hour (PCU)			
		Year 2031 (With Toll)	LOS	Year 2041 (With Toll)	LOS
	Towards Bengaluru City	3067	LOS B	4242	LOS C
Section 2	**Towards Airport**	2053	LOS B	2679	LOS B
	Towards Bengaluru City	4914	LOS C	6294	LOS D
Section 3	**Towards Airport**	2823	LOS B	4049	LOS C
	Towards Bengaluru City	4343	LOS C	5552	LOS D
Section 4	**Towards Airport**	2479	LOS B	3215	LOS B
	Towards Bengaluru City	1758	LOS B	2263	LOS B

The average cross-sectional traffic for each section for the morning peak hour with tolls is presented in table below. The maximum cross-sectional volumes are observed for Section 3 followed by Section 2.

Table 69: Average Cross section traffic on Each Section (Peak Hour) Scenario 2 – With Toll (Alignment Option 3)

Section	Average Cross section traffic on Each Section (Peak hour) (PCU) – Scenario 2 With Toll	
	2031	**2041**
Section 1	6105	8257
Section 2	6967	8973
Section 3	7166	9601
Section 4	4237	5478

For Alignment Option 3, vehicles using the corridor were estimated through model assignment for the scenarios with toll for 2031 and 2041. Table below illustrates the diversion of Car trips to the proposed North-South Corridor, a total of 17% and 19% trips are diverted in the years 2031 and 2041 respectively considering tolls.

Table 70: Vehicles using the corridor during morning peak hour in Scenario 2 (Alignment Option 3)

Vehicles using the corridor during peak hour		
Total Car Trips using Corridor	**2031 (Toll)**	**2041 (Toll)**
	12,477 (17% Diverted Trips)	16,609 (19% Diverted Trips)

7.14 Inferences and Summary

Various alignment options were evaluated to estimate the traffic diversion on the proposed corridor. The proposed corridor is expected to divert more than 17% of car traffic from the existing road network, thus improving the level of service on the network. The results for each horizon year and each OD pairwise are given in Annexure 0 and 7.19.

Without corridor assignment runs were also done for Scenario 2 and scenario 3 demand numbers to estimate the level of service on the road network in the study area, assuming no other road network augmentation proposal. Inference and Level of Service Maps are shown in Annexure 7.16.

Two figures mentioned below shows estimated traffic speeds on the corridor for the years 2031 and 2041. In 2031, among Mid-block sections, section 1 and section 4 are estimated to be operating at more than 60 km/hr and section 2 and 3 towards Bengaluru are expected to operate between 40-60 km/hr.

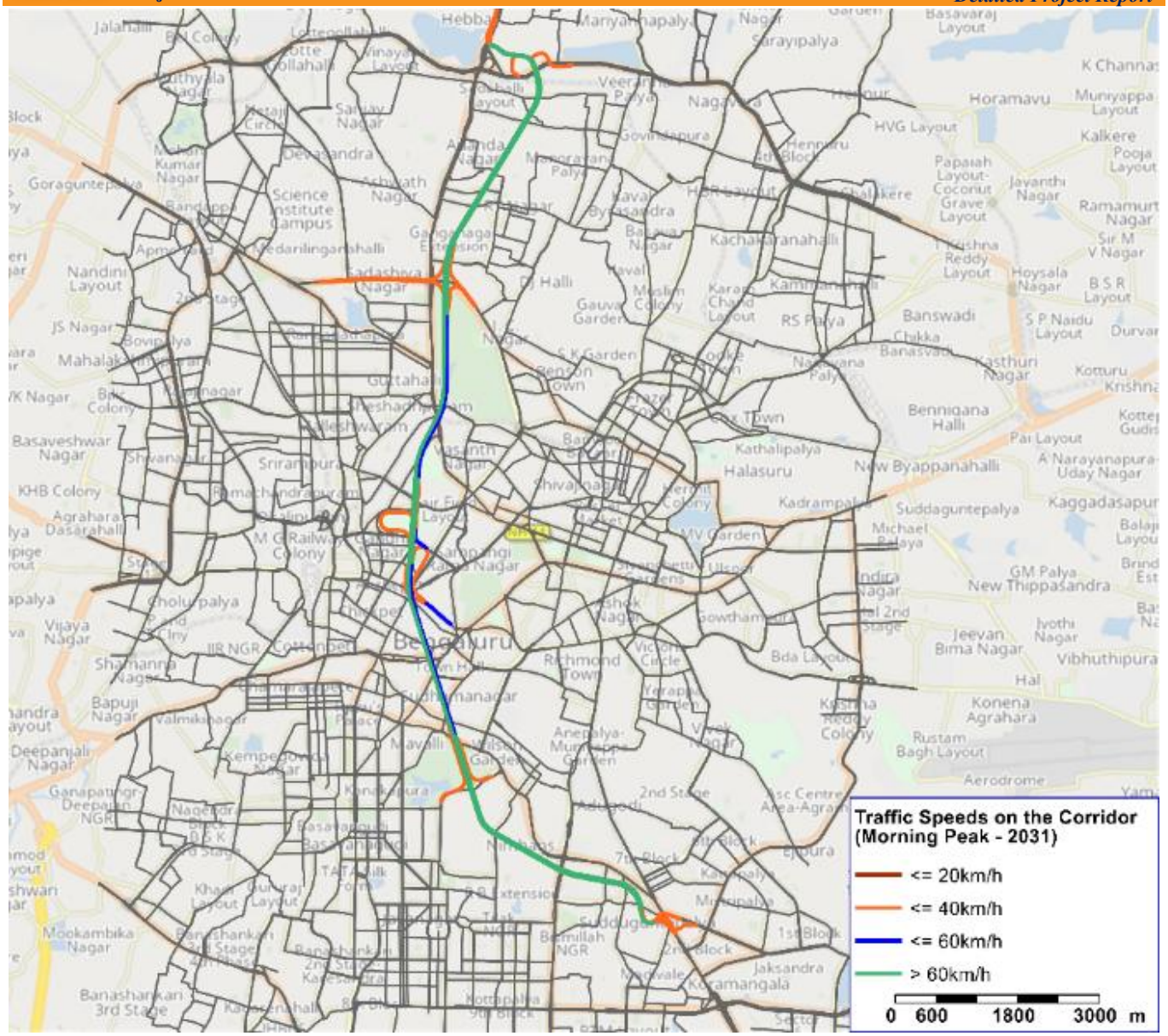


Figure 86: Traffic Speeds on the Corridor (Morning Peak -2031)

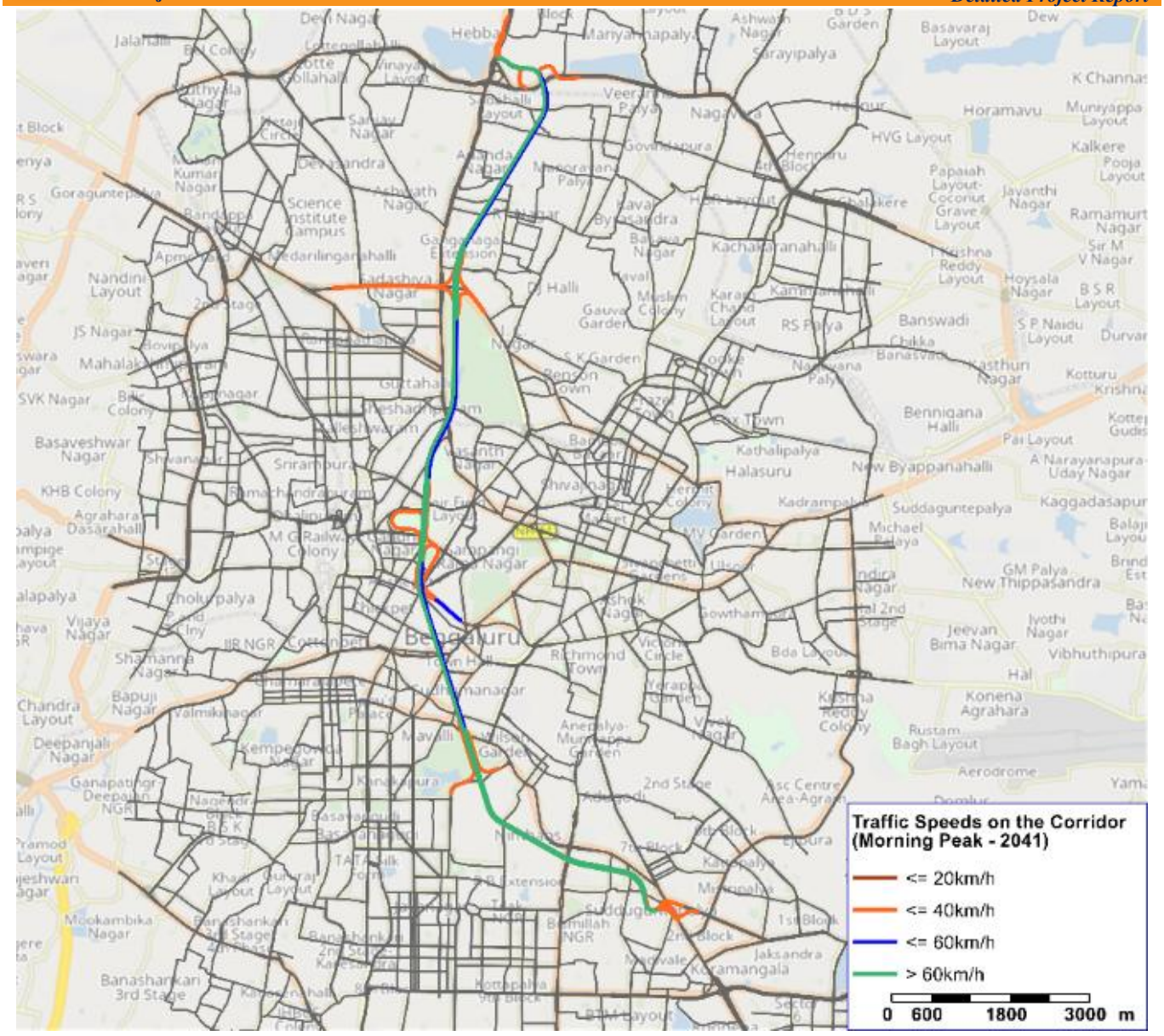


Figure 87: Traffic Speeds on the Corridor (Morning Peak -2041)

In 2041, only section 4 is expected to operate at more than 60 km/hr and other sections 1,2 and 3 which are expected to operate between 40-60kmph for the direction North to South.

Figure below shows the snapshot for road network where volume is expected to reduce or increase due to the proposed corridor. The green coloured bars show the reduction in traffic volumes due to the proposed corridor on the adjacent network.

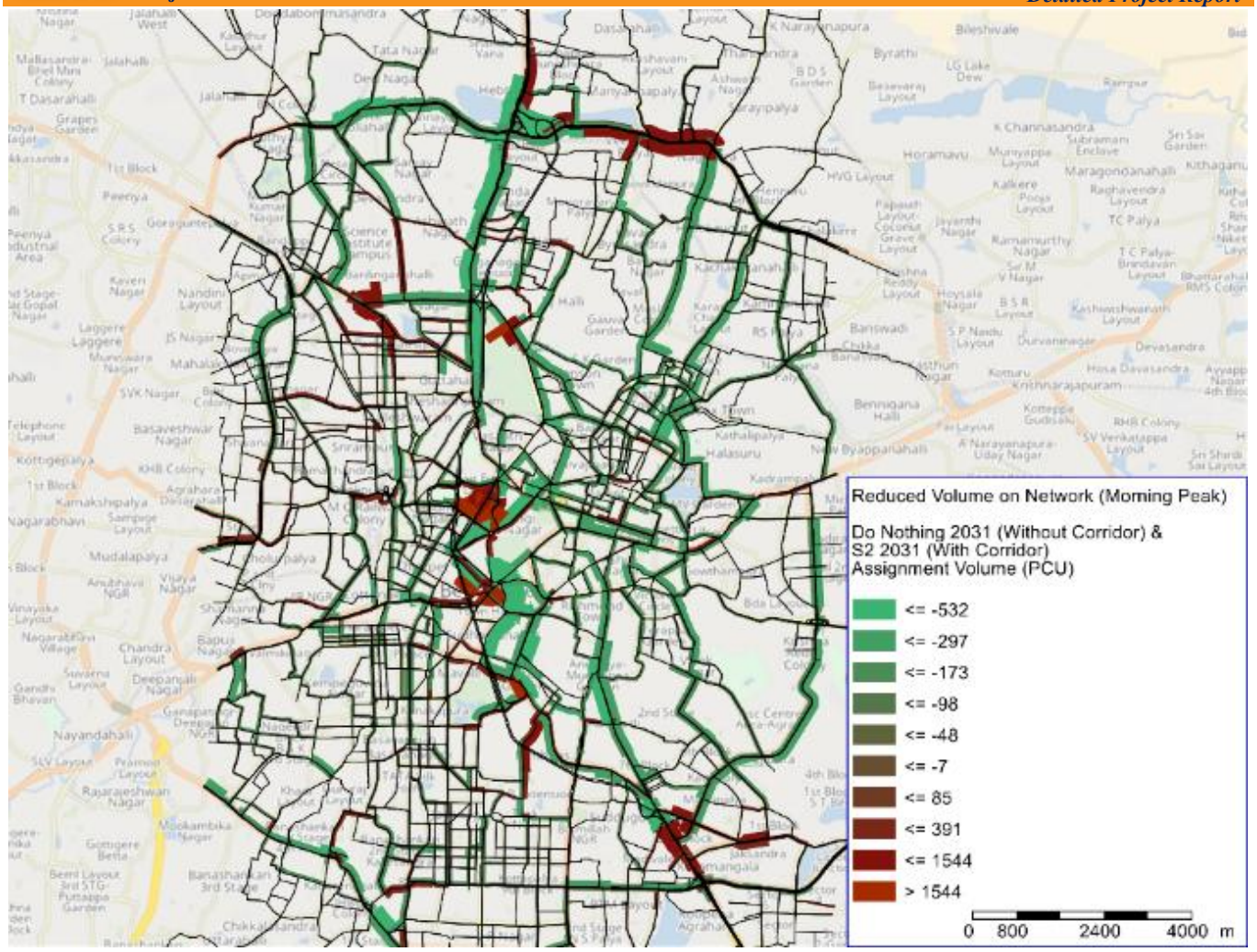


Figure 88: Road network with reduced volume after corridor (2031)

7.14.1 Impact of North-South Corridor on Critical Junctions

The introduction of North-South Corridor will impact the road network especially on immediate vicinity due to the traffic entering and exiting through ramps. These critical access/egress junctions were identified that are getting impacted from the proposed North-South Corridor below three mentioned images. Re-assessment of junction capacity and need for any capacity augmentation measures on the identified junctions may be required near the entry/exit ramps of the proposed corridor.

Figure 89: Critical Junctions impacted by N-S Corridor (A)

Figure 90: Critical Junctions impacted by N-S Corridor (B)

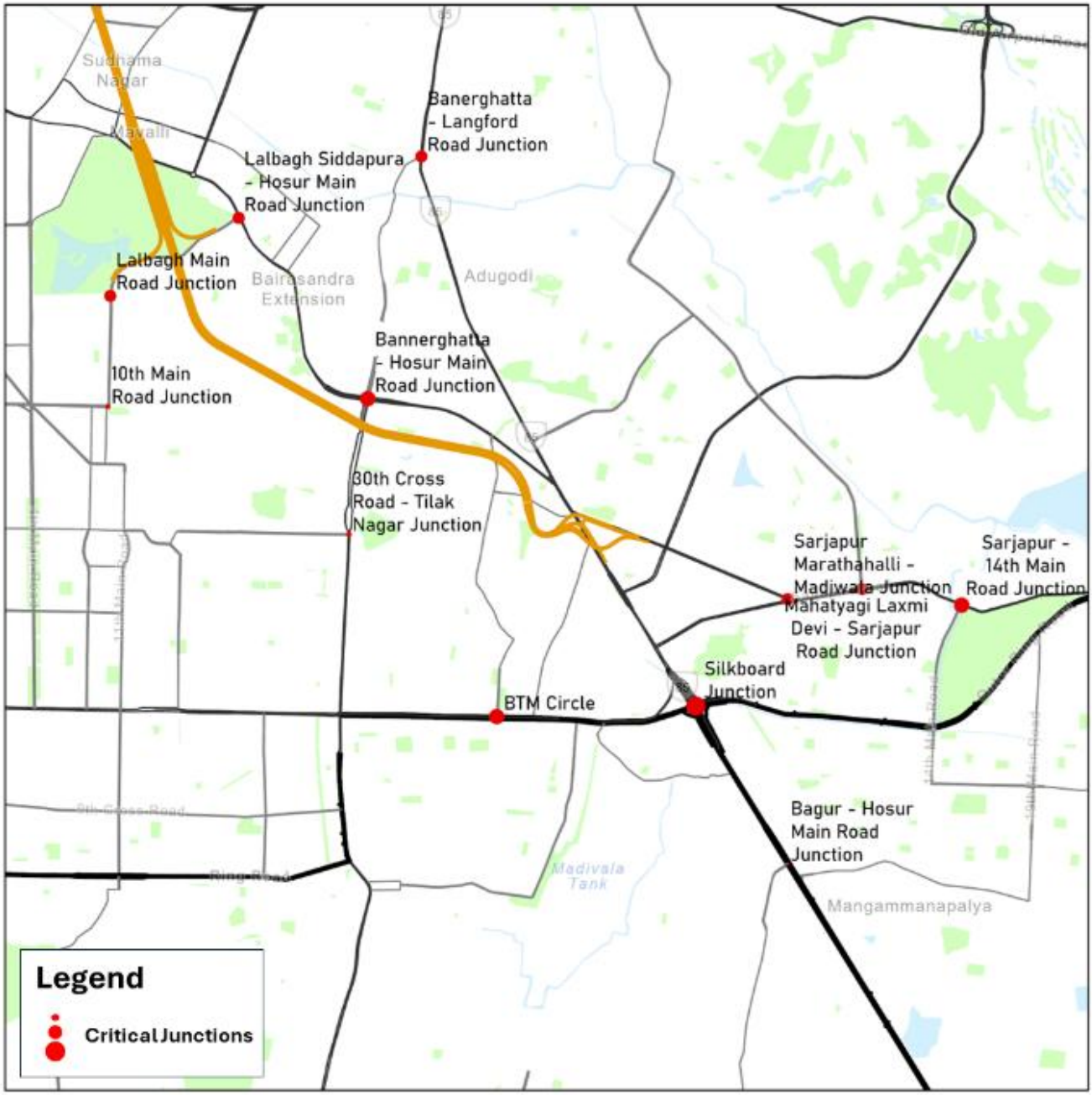


Figure 91: Critical Junctions impacted by N-S Corridor (C)

7.14.2 Estimated Travel Time Comparison - Without Corridor and With Corridor

Travel time is considered as an important metric to compare the traffic flow before and after the construction of a transport infrastructure. For this assessment, three Origin-Destination Pairs were analyzed and compared to assess the travel times pre-and-post construction of North-South Corridor. These Origin-Destination Pairs are:

A. Hebbal to Silkboard Junction

B. Silkboard Junction to Hebbal

C. Hebbal to Vidhan Soudha

Table 71: Estimated Travel Time Comparison - Without and With Corridor

Route	Length (in km) (without corridor)	Travel Time (without corridor)	Travel Time (with corridor)
Hebbal to Silkboard Junction	~18	~1 hr 12 min	~34 min
Silkboard Junction to Hebbal	~18	~1 hr 26 min	~34 min
Hebbal to Vidhan Soudha	~9	~30 min	~16 min

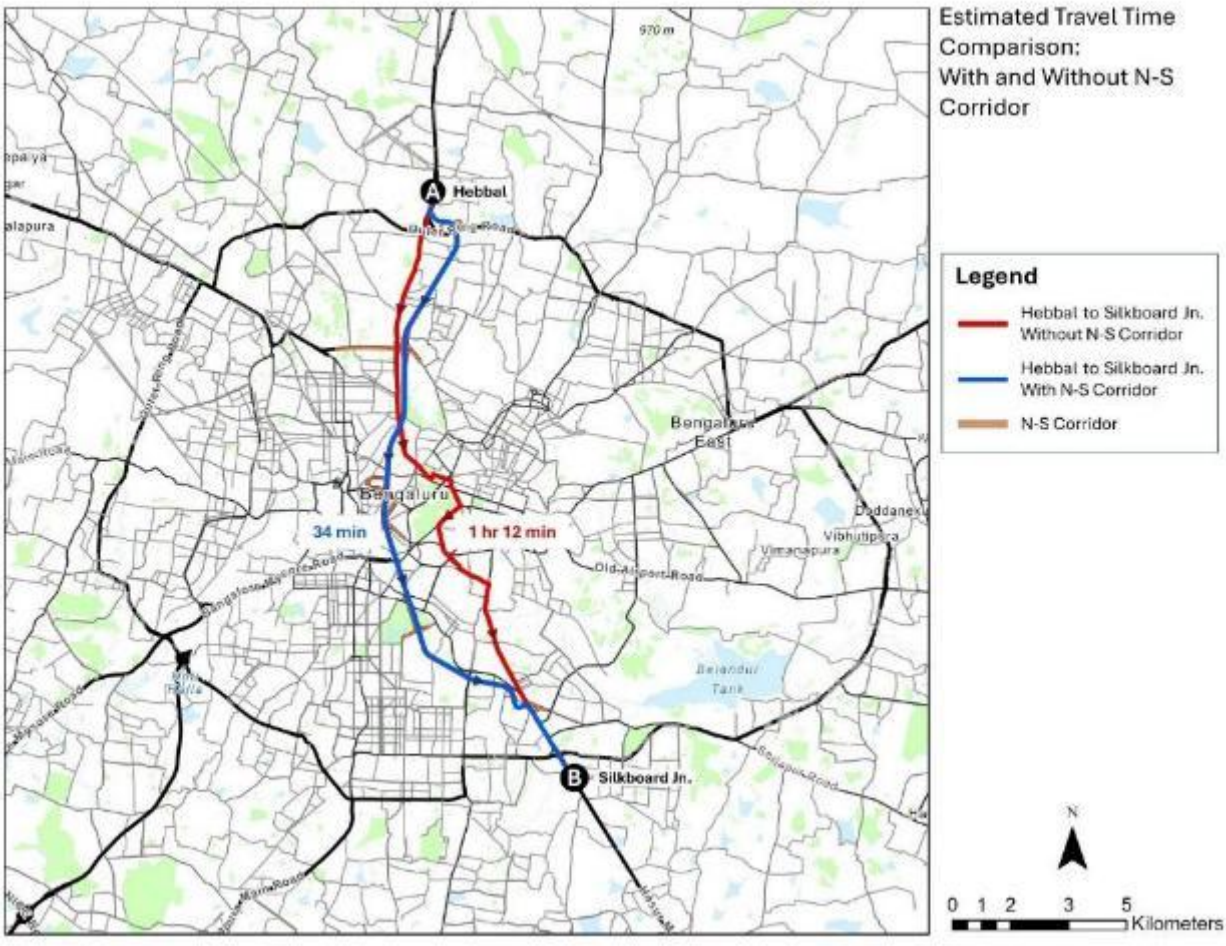


Figure 92: Estimated Travel Time Comparison for Hebbal - Silkboard Junction (With and Without Corridor)

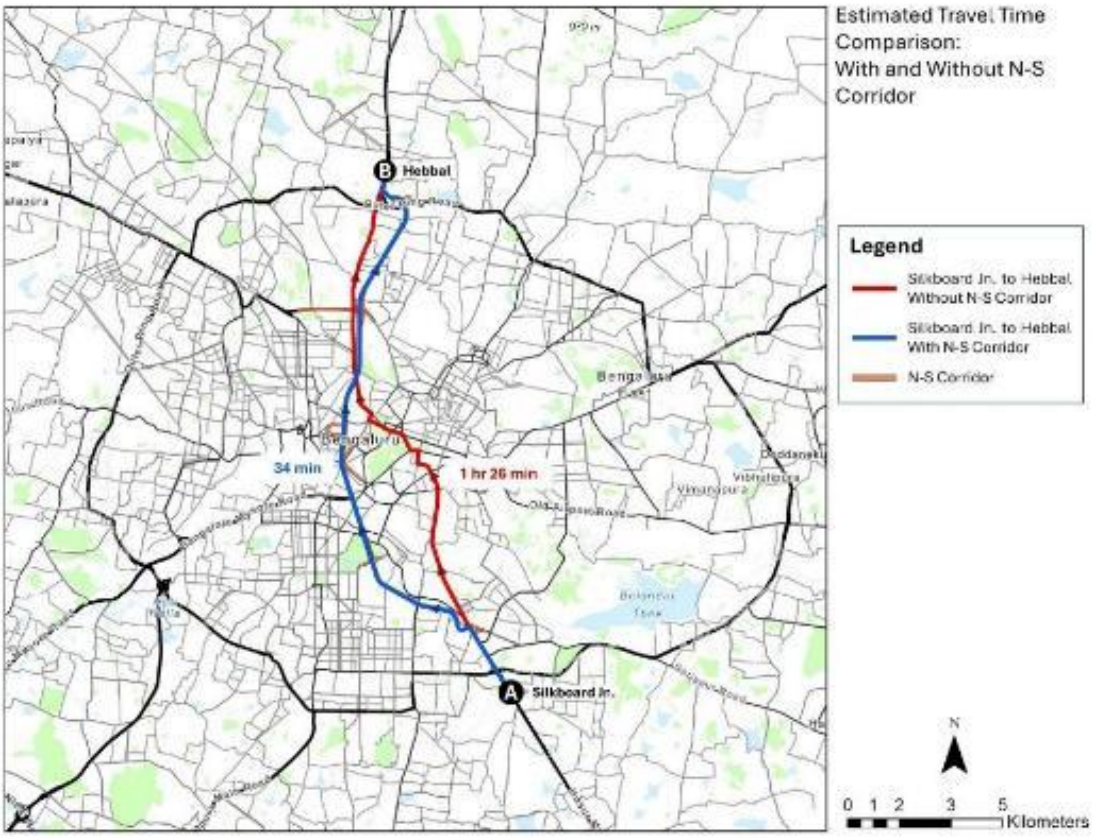


Figure 93: Estimated Travel Time Comparison for Silkboard - Hebbal Junction (With and Without Corridor)

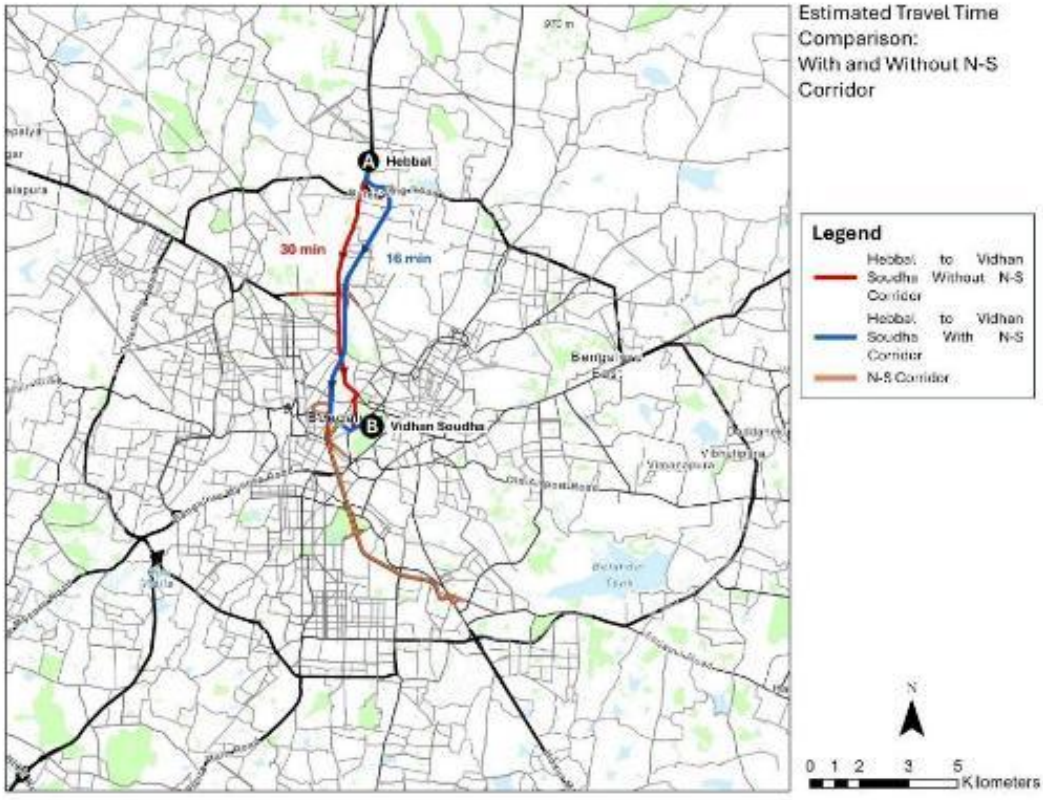


Figure 94: Estimated Travel Time Comparison for Hebbal – Vidhan Soudha (With and Without Corridor)

Table 72: Total Travel Time Savings – Morning Peak Hour

Travel Time Savings (in mins) – Morning Peak Hour		
	2031	**2041**
Total travel time savings during peak hour	1,56,614 mins	2,40,391 mins
Total travel time savings per vehicle using the corridor	12.55 mins	14.44 mins

Above table shows the total estimated travel time savings with corridor for the years 2031 and 2041. It is estimated that on average per vehicle approximately 12-13 mins for year 2031 and approximately 14-15 mins for year 2041 will be saved for the vehicle using the corridor as opposed to using another road network.

From the above-discussed analysis, it is estimated that the construction of the proposed North-South Corridor will facilitate mobility throughout the city and will reduce travel time for certain Origin-Destination pairs and improve flow on certain corridors in the city. However, as shown in level of service maps in Annexure 7.16, with the increase in the number of motorized vehicles in the past two decades, the planned public transport augmentation proposals needs to play a major role in overall decongestion of the city network.

7.15 Annexure

7.15.1 TMC Diagrams of Surveyed Locations during peak hour

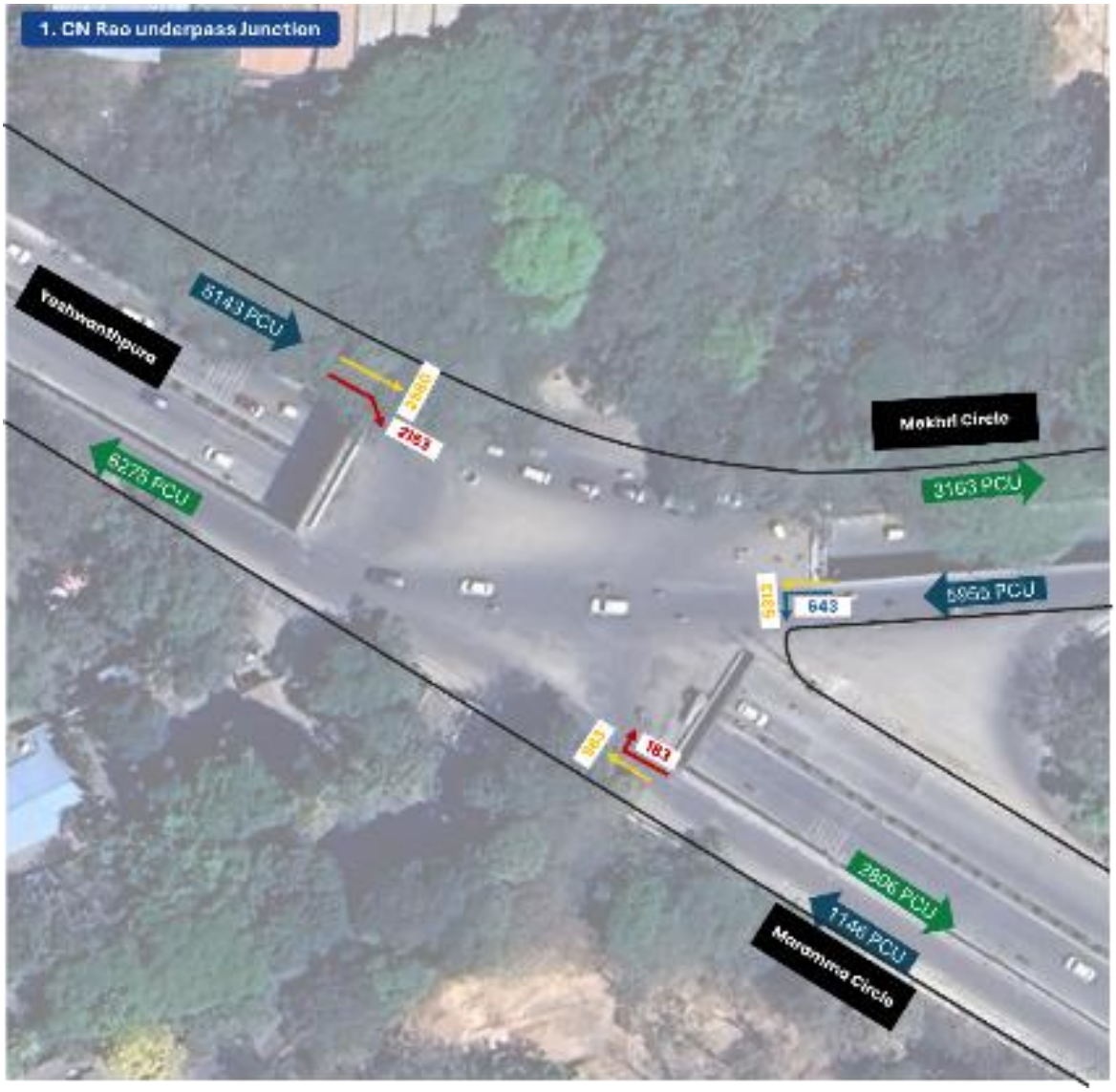


Figure 95: TMC at CN Rao Underpass Junction

Figure 96: TMC at Bengaluru Cantt Junction

Figure 97: TMC at Basaveshwara Circle

Figure 98: TMC at KR Circle

Figure 99: TMC at Cubbon Park Junction

Figure 100: TMC at Shoolay Circle

Figure 101: TMC at Lalbagh Chowk

7.16 Level of Service Maps

7.16.1 Level of Service - Base Year

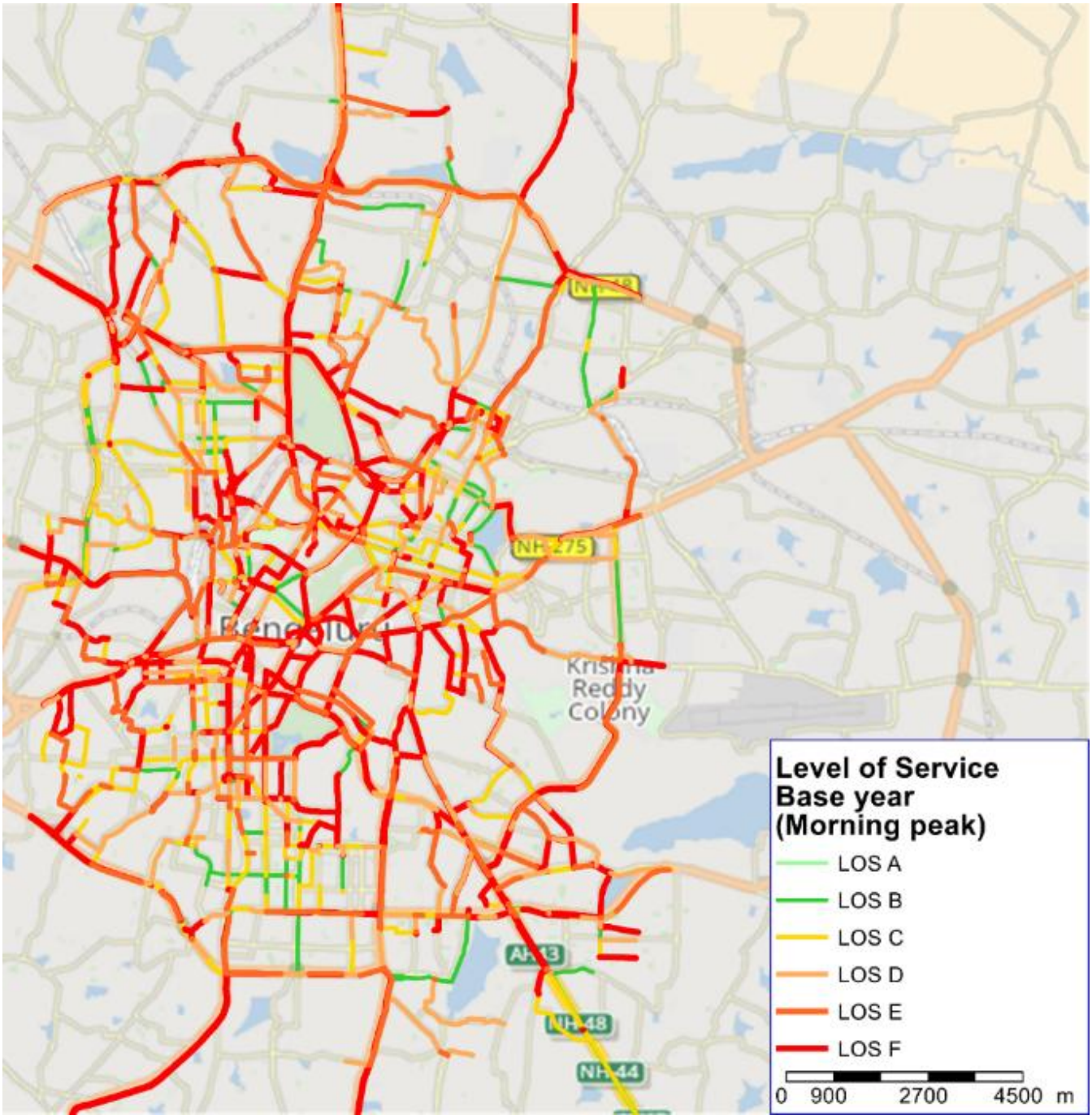


Figure 102: Level of Service - Base Year (Morning Peak)

Above figure indicates the mid-block estimated Level of Service for the base year model. For majority of the roads fall within LOS E and LOS F for the base year i.e., year 2024. This reflects that the volume on these roads exceeds the design capacity and a highly congested scenario during the peak hour.

7.16.2 Level of Service – Do Nothing Scenario 2 for 2031 and 2041 (Without Corridor)

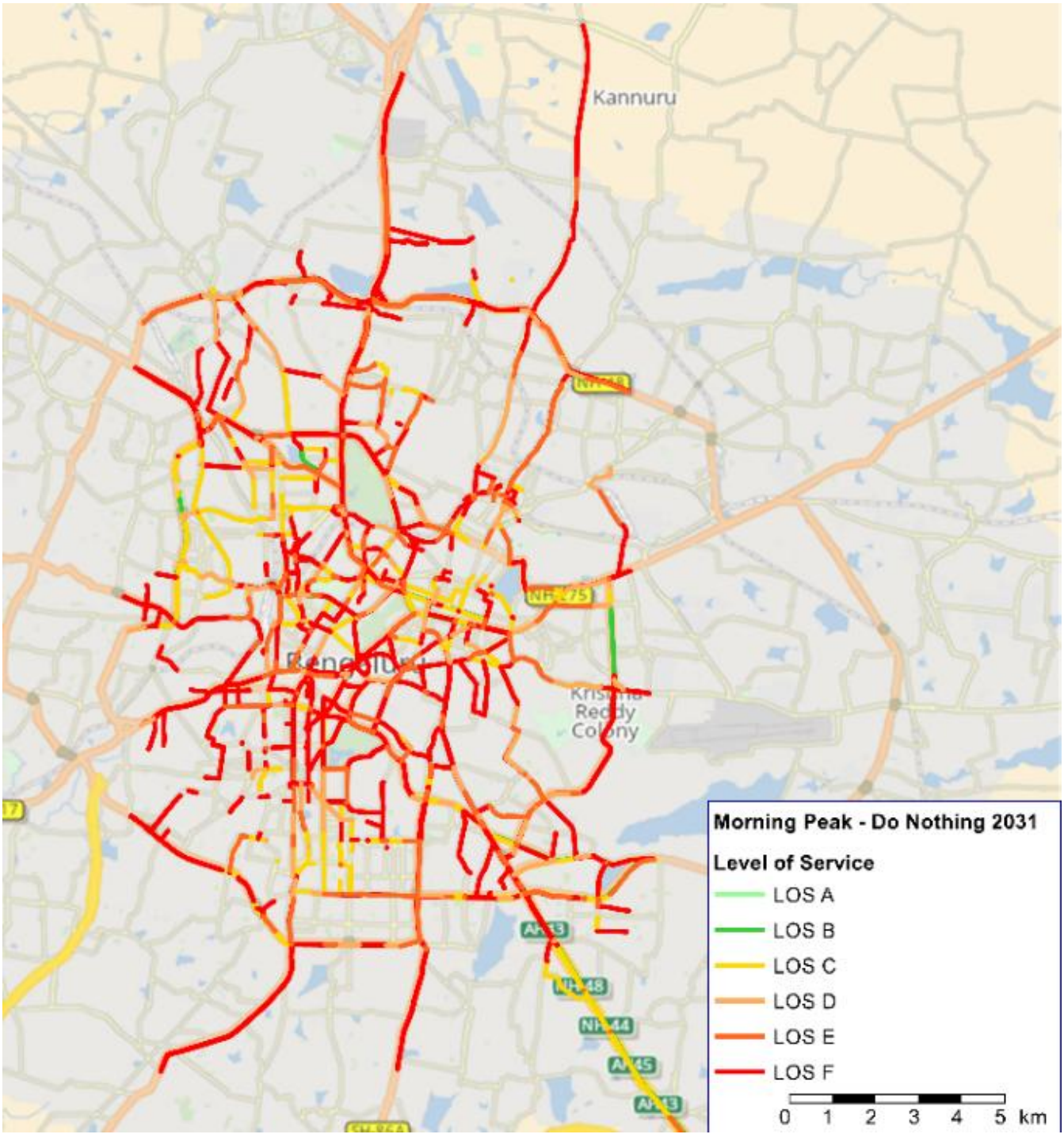


Figure 103: LOS - Road Network (S2 – Without Corridor 2031)

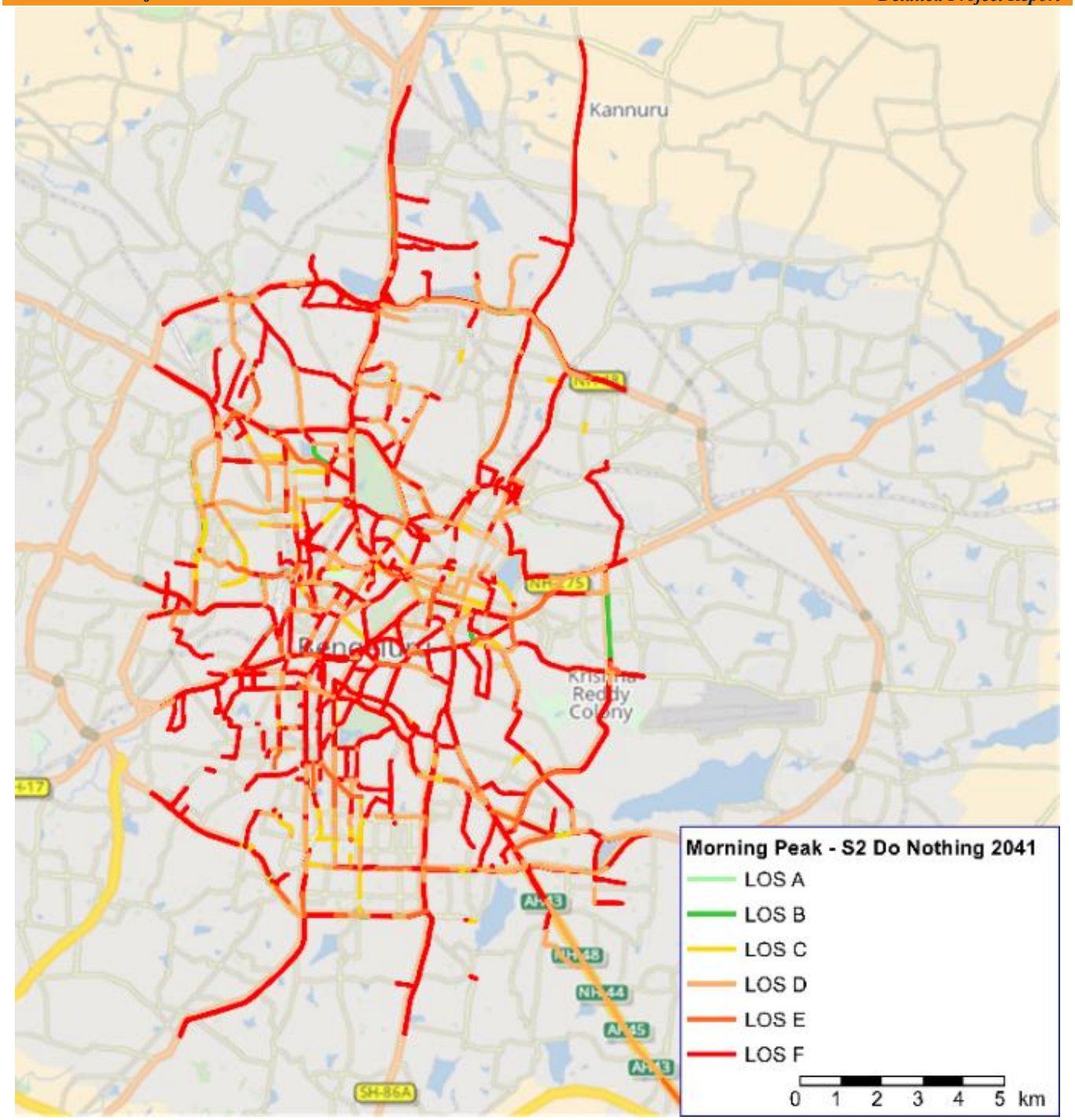


Figure 104: LOS - Road Network (S2 – Without Corridor 2041)

The map shown in Above two figure shows the Level of Service for Do Nothing Scenario 2 (Without Corridor) for the Years 2031 and 2041.

Below two figures shows the Level of Service for Do Nothing Scenario 3 (Without Corridor) for the Years 2031 and 2041.

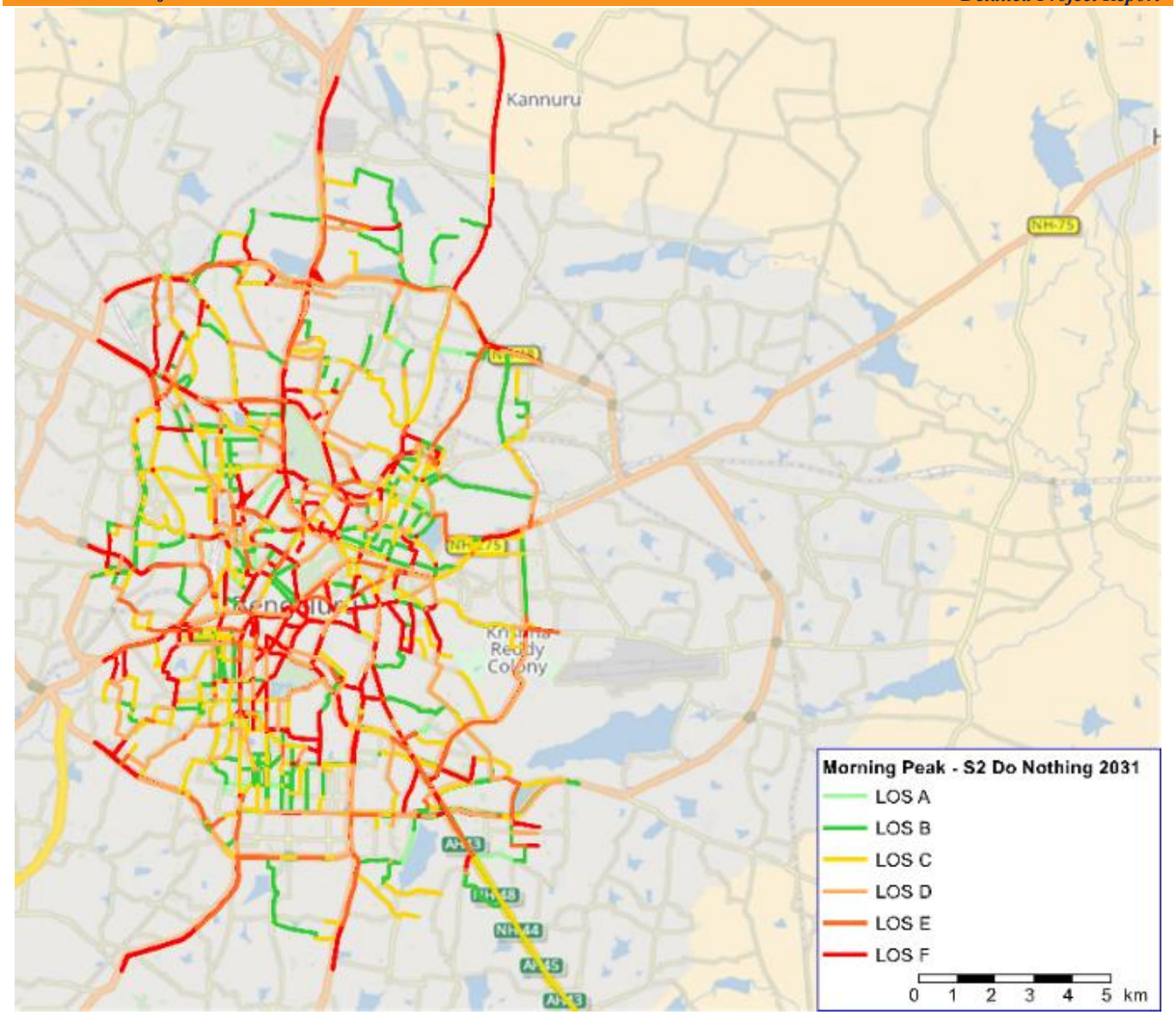


Figure 105: LOS - Road Network (S3 – Without Corridor 2031)

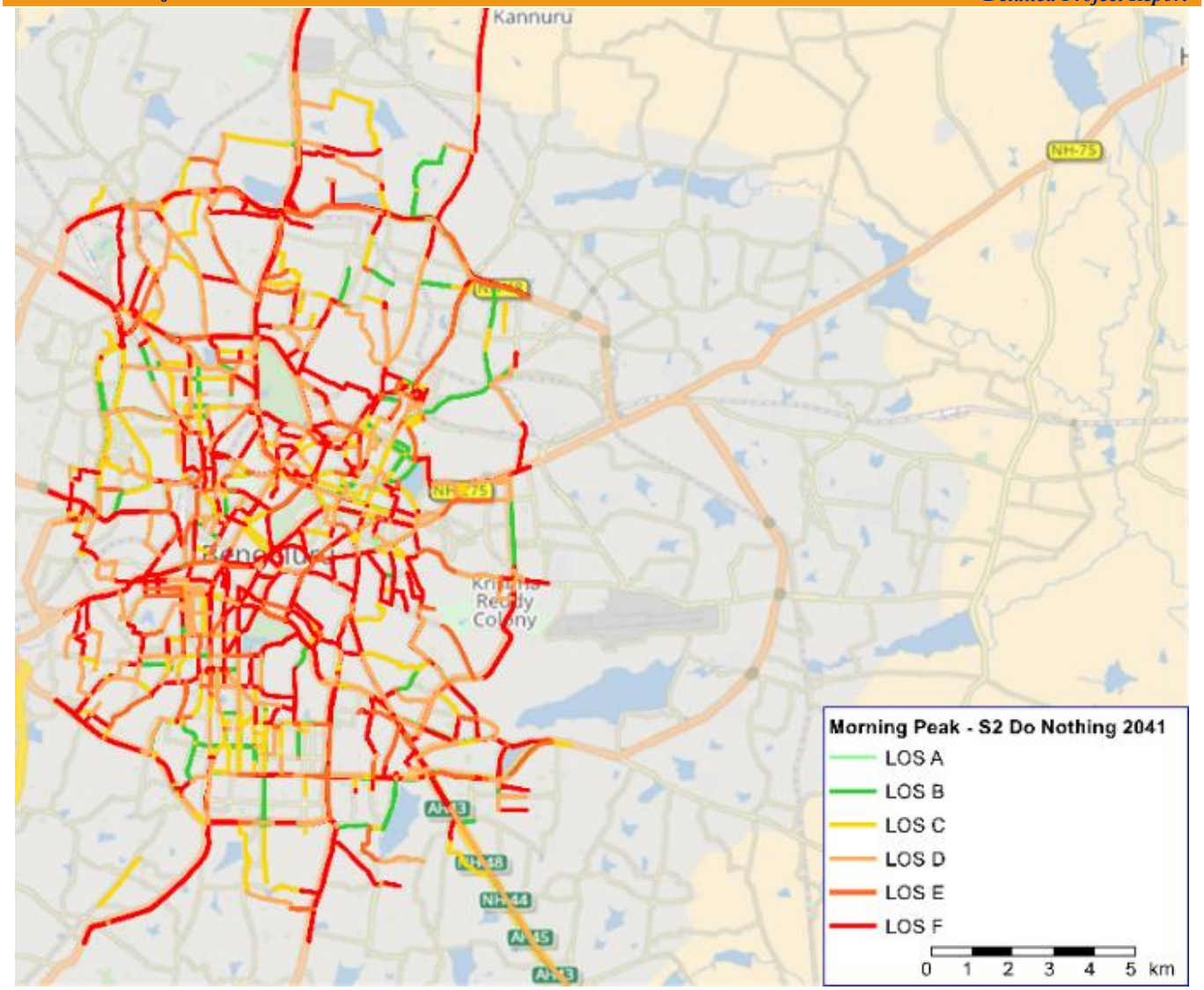


Figure 106: LOS - Road Network (S3 – Without Corridor 2041)

It can be observed from above two figured that parts of the road network are less congested as compared to Scenario 2. This is primarily because of the high modal share assumed in this scenario for Public Transport in Scenario 3. Without assuming any further road network augmentation proposals, the overall level of service is expected to above design service volumes for most of the network during the peak hours.

7.16.3 Corridor Level of Service –Scenario 2 for 2031 and 2041

Below two figures shows the Level of Service on the Corridor for the Morning Peak Hour for the Years 2031 and 2041. It is expected that in year ss2031, most of the Sections and Ramps are at LOS A and LOS B apart from Section 2 and Section 3 Towards Bengaluru are at LOS C along with Ramp R, Ramp F, Ramp K, Ramp V and Ramp M.

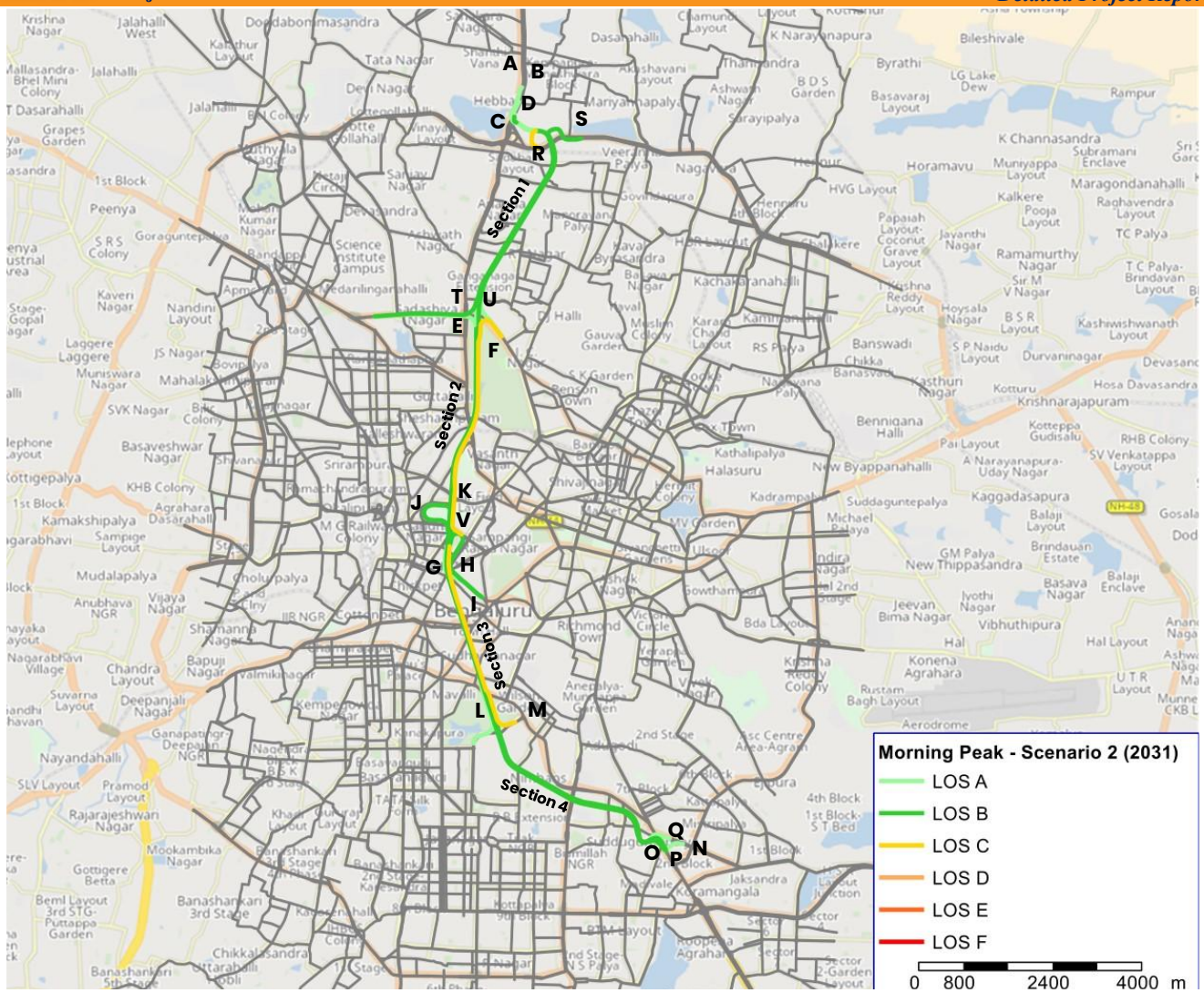


Figure 107: Level of Service on Corridor - S2 Morning Peak Hour (2031)

In 2041, LOS D is observed for Ramp F, Ramp K, Ramp V and LOS E on Ramp M. Among Mid-Block Sections, LOS D is observed for Section 2 Towards Bengaluru and LOS D for Section 3 Towards Bengaluru.

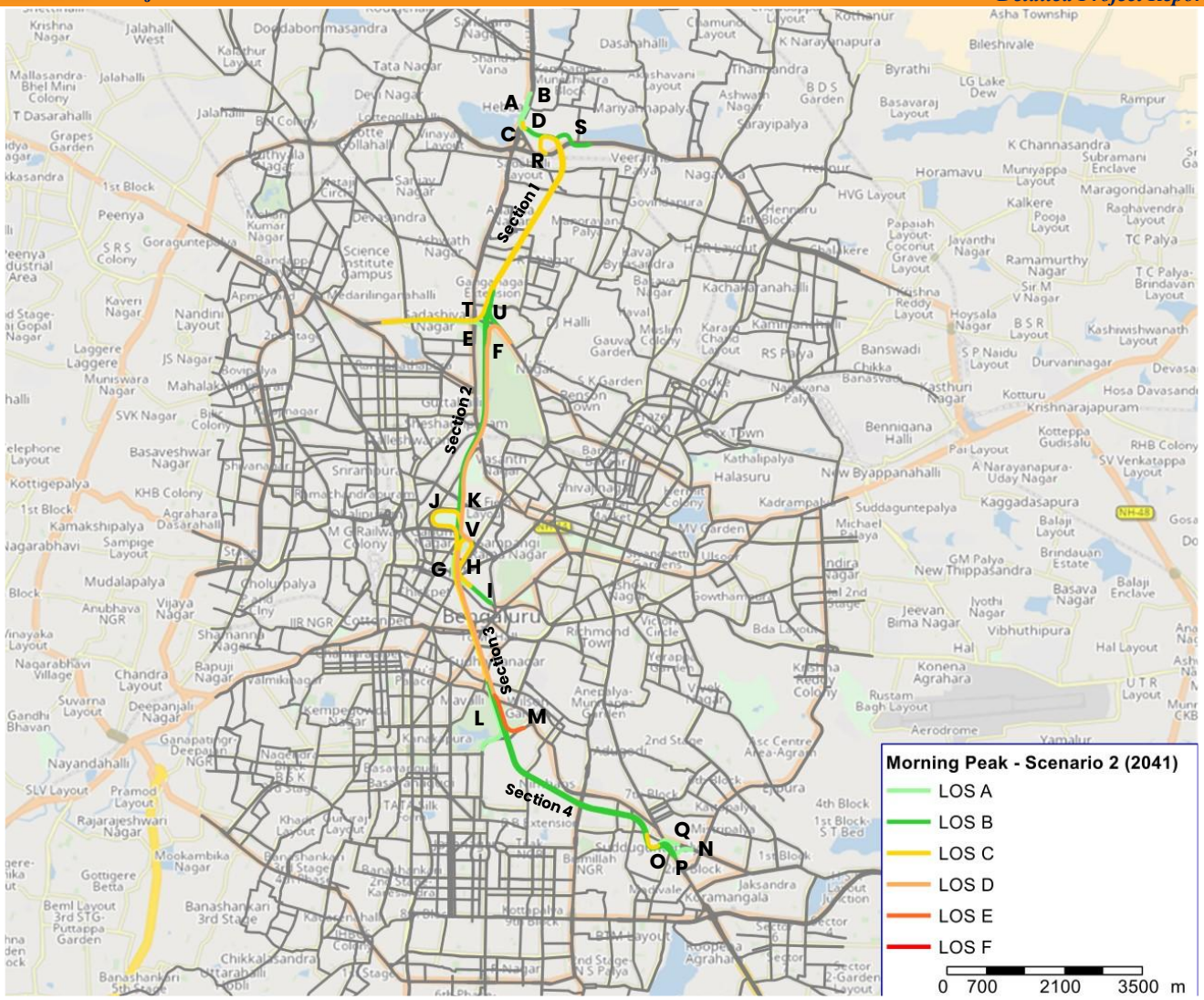


Figure 108: Level of Service on Corridor - S2 Morning Peak Hour (2041)

7.17 Section and Ramp Volumes for morning peak hour in the proposed North-South Corridor for 2031 and 2041 (Without Toll) (Alignment Option 2)

Table 73: Projected Traffic on the corridor (alignment option 2)

Average Traffic on each Section	Ramp/Section	Morning Peak Hour (PCU)					
		S1	S2	S3	S1	S2	S3
		Year 2031 (Without Toll)	Year 2031 (Without Toll)	Year 2031 (Without Toll)	Year 2041 (Without Toll)	Year 2041 (Without Toll)	Year 2041 (Without Toll)
Section 1	**Towards Airport**	1416	1139	1157	1915	1665	1318
	Towards Bengaluru City	1535	1343	1190	1850	1621	1356
	Ramp A (Main Exit)	991	797	810	1341	1165	923
	Ramp B (Main Entry)	537	470	416	647	567	475
	Ramp C (Service Exit)	425	342	347	575	499	395
	Ramp D (Service Entry)	998	873	773	1202	1054	881
	Ramp E	1009	787	568	1253	1057	845
	Ramp F	3450	3065	2767	3847	3543	3271
Section 2	**Towards Airport**	2045	1696	1477	2566	2244	1814
	Towards Bengaluru City	6840	6151	5448	7712	7041	6287
	Ramp G	759	459	497	1206	955	698
	Ramp H	3711	3486	2982	4031	3755	3321
	Ramp I	4470	3946	3480	5238	4709	4018
	Ramp J	2464	1998	1176	3046	2693	1972
	Ramp K	2829	2507	2179	3113	2895	2522
Section 3	**Towards Airport**	4129	3464	2405	5009	4460	3437
	Towards Bengaluru City	5866	5388	4760	6614	6023	5426
	Ramp L	1315	1134	912	1527	1436	1184
	Ramp M	3920	3656	3383	4234	4018	3810
Section 4	**Towards Airport**	2814	2330	1493	3481	3024	2252
	Towards Bengaluru City	1946	1732	1377	2381	2005	1615
	Ramp N	2814	2330	1493	3481	3024	2252
	Ramp O	2587	2368	1931	3124	2627	2240
	Ramp P	1305	1096	823	1637	1383	991

7.18 Origin-Destination (OD) Pairwise Ramp Volumes for morning peak hour in the proposed North-South Corridor for 2027-28, 2031, 2037-38, 2041, 2047-48, 2051 and 2057-58 (Alignment Option 3)

Table mentioned below shows the project traffic OD pair wise for scenario 2 and alignment option 3. Projection for all years except 2031 and 2041 are interpolated/extrapolated using the 2031 and 2041 values.

Table 74: OD Pair wise projected traffic volumes

From Hebbal to Silk Board				Morning Peak (2027-28)	Morning Peak (2031)	Morning Peak (2037-38)	Morning Peak (2041)	Morning Peak (2047-48)	Morning Peak (2051)	Morning Peak (2057-58)
S. No.	From	To	Travel Length (km)	CAR	CAR	CAR	CAR	CAR	CAR	CAR
1	Hebbal (km 0.000) (Main & Service Road)	Silk Board Junction on Hosur Road	16.693	181	196	218	233	255	270	292
		Sarjapur/ HSR layout (Ring Road)	16.386	126	136	152	162	178	188	204
		Hosur Main Road (Wilson Garden)	12.798	221	239	266	284	311	329	356
		Seshadri Road (Towards KR Circle)	9.051	455	492	548	585	641	678	734
		Palace Ground (Mekhri Circle)	5.773	478	632	862	1016	1246	1400	1630
2	ORR (km 1.300) from KR Puram	Silk Board Junction on Hosur Road	16.204	169	183	204	218	239	253	274
		Sarjapur/ HSR layout (Ring Road)	15.897	33	39	47	53	61	67	75
		Hosur Main Road (Wilson Garden)	12.309	747	808	900	961	1053	1114	1206
		Seshadri Road (Towards KR Circle)	8.562	165	315	541	691	917	1067	1293
		Palace Ground (Mekhri Circle)	5.284	22	27	34	39	46	51	58
3	Mekhri Circle (5.400)	Silk Board Junction	12.548	374	412	470	508	566	604	662
		Sarjapur/ HSR layout (Ring Road)	12.241	167	181	201	215	235	249	269

From Hebbal to Silk Board				Morning Peak (2027-28)	Morning Peak (2031)	Morning Peak (2037-38)	Morning Peak (2041)	Morning Peak (2047-48)	Morning Peak (2051)	Morning Peak (2057-58)
S. No.	**From**	**To**	**Travel Length (km)**	**CAR**	**CAR**	**CAR**	**CAR**	**CAR**	**CAR**	**CAR**
		Hosur Main Road (Wilson Garden)	8.653	185	327	539	681	893	1035	1247
		Seshadri Road (Towards KR Circle)	4.906	1539	1586	1656	1703	1773	1820	1890
4	Race Course (km 9.100) from palace rd.	Silk Board Junction	9.893	316	398	521	603	726	808	931
		Sarjapur/ HSR layout (Ring Road)	9.586	190	213	248	271	306	329	364
		Hosur Main Road (Wilson Garden)	5.998	1150	1211	1302	1363	1454	1515	1606
1	Silk Board (km 16.693)-Hosur	Hebbal (Main & Service Rd.)	16.68	264	326	418	480	572	634	726
		ORR (towards KR Puram) (km 1.100)	16.03	276	299	333	356	390	413	447
		CV Raman Road (Mekhri Circle) (km 5.150)	13.441	223	275	352	404	481	533	610
		Race Course Road (9.000)	9.544	662	738	853	929	1044	1120	1235
2	Sarjapur/ HSR layout (Ring Road) (km 16.386)	Hebbal (Main & Service Rd.)	16.924	55	61	70	76	85	91	100
		ORR (towards KR Puram) (km 1.100)	16.274	83	97	118	132	153	167	188
		CV Raman Road (Mekhri Circle)	13.685	165	179	199	213	233	247	267
		Race Course Road (9.000)	9.788	456	504	577	625	698	746	819
3	Jayanagar (From Ashoka Pillar) (km 11.600)	Hebbal (Main & Service Rd.)	13.017	41	50	63	72	85	94	107
		ORR (towards KR	12.367	15	21	29	35	43	49	57

From Hebbal to Silk Board				Morning Peak (2027-28)	Morning Peak (2031)	Morning Peak (2037-38)	Morning Peak (2041)	Morning Peak (2047-48)	Morning Peak (2051)	Morning Peak (2057-58)
S. No.	**From**	**To**	**Travel Length (km)**	**CAR**	**CAR**	**CAR**	**CAR**	**CAR**	**CAR**	**CAR**
		Puram) (km 1.100)								
		CV Raman Road (Mekhri Circle)	9.778	50	53	57	60	64	67	71
		Race Course Road (9.000)	5.881	41	220	488	667	935	1114	1382
4	Race Course (km 7.05) from Palace Rd.	Hebbal (Main & Service Rd.)	9.518	42	48	58	64	74	80	90
		ORR (towards KR Puram) (km 1.100)	8.868	526	569	634	677	742	785	850
		CV Raman Road (Mekhri Circle)	6.279	61	75	96	110	131	145	166
5	CV Raman Road (km 4.700)	Hebbal (Main & Service Rd.)	6.601	455	569	739	853	1023	1137	1307
		ORR (towards KR Puram) (km 1.100)	5.951	889	998	1161	1270	1433	1542	1705

7.19 Section and Ramp-wise volumes for Horizon Years with Level of Service

The Level of Service in the two tables mentioned below has been calculated considering the capacities mentioned in INDO-HCM, considering the capacities for Mid-Block Sections as 6900 PCU and reduced capacities for ramps.

Table 75: Level of service on the corridor (morning peak)

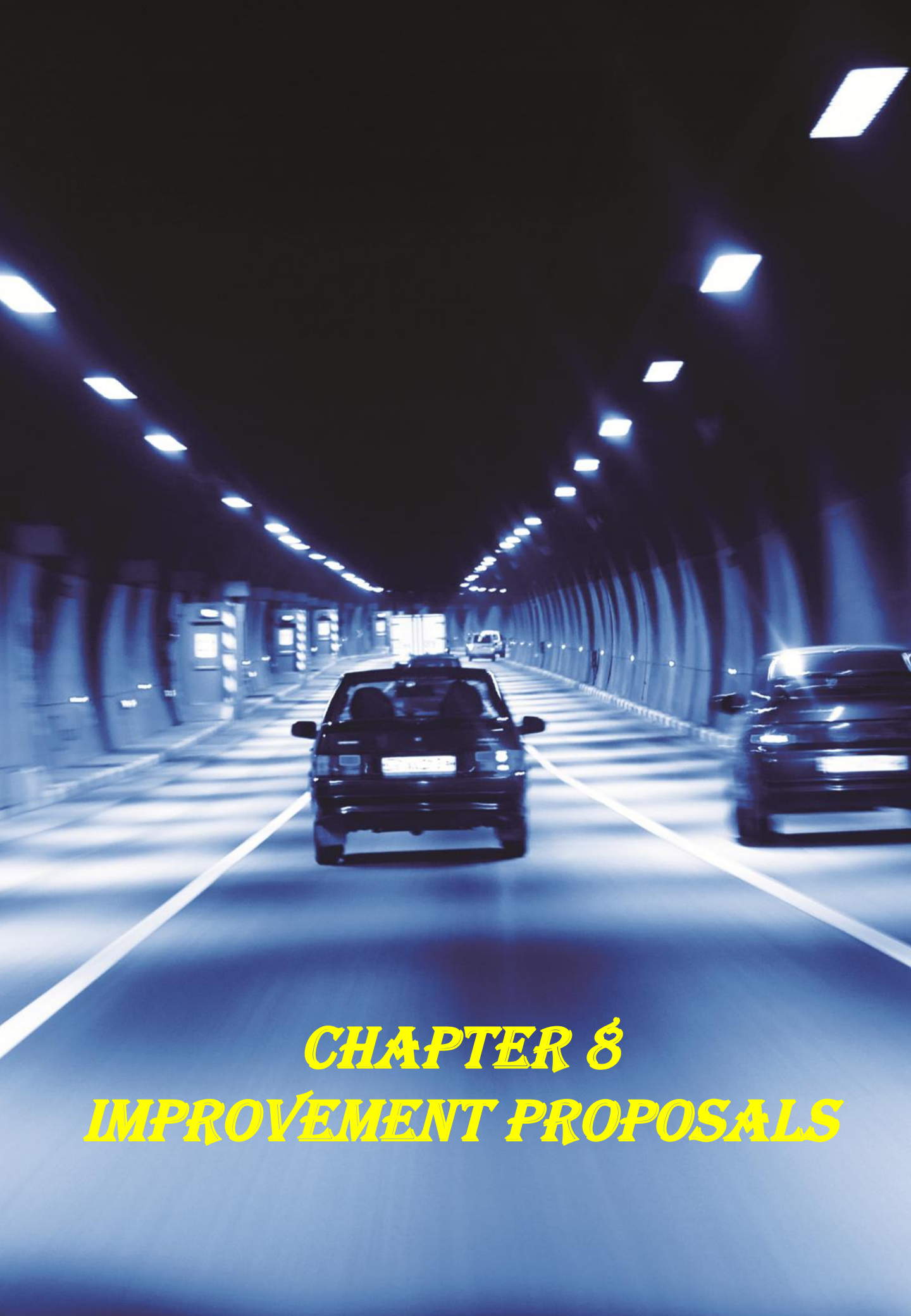
Traffic Volume During Morning Peak Hour		2027-28			2031			2037-38			2041		
	Location	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**
Section 1	**Towards Airport**	2804	0.41	LOS B	3038	0.44	LOS B	3624	0.53	LOS C	4015	0.58	LOS C
	Towards Bengaluru City	2785	0.40	LOS B	3067	0.44	LOS B	3772	0.55	LOS C	4242	0.61	LOS C
	Ramp A (Main Exit)	981	0.28	LOS B	1063	0.30	LOS B	1268	0.36	LOS B	1405	0.40	LOS B
	Ramp B (Main Entry)	544	0.12	LOS A	593	0.13	LOS A	716	0.16	LOS A	798	0.18	LOS A
	Ramp C (Service Exit)	1822	0.52	LOS C	1975	0.56	LOS C	2356	0.67	LOS C	2610	0.75	LOS C

Traffic Volume During Morning Peak Hour		2027-28			2031			2037-38			2041		
	Location	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**
	Ramp D (Service Entry)	1010	0.23	LOS A	1102	0.25	LOS A	1330	0.30	LOS B	1482	0.33	LOS B
	Ramp E	533	0.19	LOS A	582	0.21	LOS A	705	0.26	LOS B	787	0.29	LOS B
	Ramp F	2362	0.67	LOS C	2506	0.71	LOS C	2867	0.82	LOS D	3107	0.89	LOS D
	Ramp R	1867	0.53	LOS C	1984	0.57	LOS C	2276	0.65	LOS C	2470	0.71	LOS C
	Ramp S	1230	0.28	LOS B	1372	0.31	LOS B	1726	0.39	LOS B	1962	0.44	LOS B
	Ramp T	1434	0.41	LOS B	1567	0.45	LOS B	1901	0.54	LOS C	2123	0.61	LOS C
	Ramp U	564	0.21	LOS A	659	0.24	LOS A	897	0.33	LOS B	1055	0.38	LOS B
Section 2	**Towards Airport**	1903	0.28	LOS B	2053	0.30	LOS B	2429	0.35	LOS B	2679	0.39	LOS B
	Towards Bengaluru City	4583	0.66	LOS C	4914	0.71	LOS C	5742	0.83	LOS D	6294	0.91	LOS D
	Ramp G	654	0.15	LOS A	692	0.16	LOS A	787	0.18	LOS A	851	0.19	LOS A
	Ramp H	1722	0.39	LOS B	1822	0.41	LOS B	2071	0.46	LOS B	2237	0.50	LOS C
	Ramp I	2376	0.34	LOS B	2514	0.36	LOS B	2858	0.41	LOS B	3088	0.45	LOS B
	Ramp J	1280	0.37	LOS B	1462	0.42	LOS B	1917	0.55	LOS C	2221	0.63	LOS C
	Ramp K	2252	0.64	LOS C	2393	0.68	LOS C	2745	0.78	LOS D	2979	0.85	LOS D
	Ramp V	3532	0.51	LOS C	3855	0.56	LOS C	4662	0.68	LOS C	5200	0.75	LOS D
Section 3	**Towards Airport**	2529	0.37	LOS B	2823	0.41	LOS B	3559	0.52	LOS C	4049	0.59	LOS C
	Towards Bengaluru City	4053	0.59	LOS C	4343	0.63	LOS C	5068	0.73	LOS C	5552	0.80	LOS D
	Ramp L	226	0.06	LOS A	344	0.10	LOS A	638	0.18	LOS A	834	0.24	LOS A
	Ramp M	2416	0.69	LOS C	2585	0.74	LOS C	3007	0.86	LOS D	3289	0.94	LOS E
Section 4	**Towards Airport**	2302	0.33	LOS B	2479	0.36	LOS B	2921	0.42	LOS B	3215	0.47	LOS B
	Towards Bengaluru City	1637	0.24	LOS A	1758	0.25	LOS B	2061	0.30	LOS B	2263	0.33	LOS B
	Ramp N	792	0.18	LOS A	841	0.19	LOS A	964	0.22	LOS A	1046	0.23	LOS A
	Ramp O	1511	0.34	LOS B	1638	0.37	LOS B	1957	0.44	LOS B	2169	0.49	LOS B
	Ramp P	1099	0.31	LOS B	1189	0.34	LOS B	1413	0.40	LOS B	1562	0.45	LOS B
	Ramp Q	537	0.15	LOS A	569	0.16	LOS A	648	0.19	LOS A	701	0.20	LOS A

Table 76: Level of service on the corridor (Morning peak)

Traffic Volume During Morning Peak Hour		2047-48			2051			2057-58		
	Location	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**
Section 1	**Towards Airport**	4445	0.64	LOS C	4992	0.72	LOS C	5266	0.76	LOS D
	Towards Bengaluru City	4759	0.69	LOS C	5417	0.79	LOS D	5746	0.83	LOS D
	Ramp A (Main Exit)	1556	0.44	LOS B	1747	0.50	LOS B	1843	0.53	LOS C

Traffic Volume During Morning Peak Hour		2047-48			2051			2057-58		
	Location	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**	**PCU (Cars)**	**V/C**	**LOS**
	Ramp B (Main Entry)	888	0.20	LOS A	1003	0.22	LOS A	1060	0.24	LOS A
	Ramp C (Service Exit)	2889	0.83	LOS D	3245	0.93	LOS D	3423	0.98	LOS E
	Ramp D (Service Entry)	1649	0.37	LOS B	1862	0.42	LOS B	1969	0.44	LOS B
	Ramp E	877	0.32	LOS B	992	0.36	LOS B	1049	0.38	LOS B
	Ramp F	3371	0.96	LOS E	3708	1.06	LOS F	3876	1.11	LOS F
	Ramp R	2684	0.77	LOS D	2956	0.84	LOS D	3092	0.88	LOS D
	Ramp S	2222	0.50	LOS B	2552	0.57	LOS C	2717	0.61	LOS C
	Ramp T	2368	0.68	LOS C	2679	0.76	LOS D	2835	0.81	LOS D
	Ramp U	1229	0.45	LOS B	1451	0.53	LOS C	1562	0.57	LOS C
Section 2	**Towards Airport**	2954	0.43	LOS B	3305	0.48	LOS B	3480	0.50	LOS C
	Towards Bengaluru City	6901	1.00	LOS F	7674	1.11	LOS F	8060	1.17	LOS F
	Ramp G	921	0.21	LOS A	1010	0.23	LOS A	1055	0.24	LOS A
	Ramp H	2420	0.54	LOS C	2652	0.59	LOS C	2768	0.62	LOS C
	Ramp I	3341	0.48	LOS B	3662	0.53	LOS C	3823	0.55	LOS C
	Ramp J	2555	0.73	LOS C	2980	0.85	LOS D	3193	0.91	LOS D
	Ramp K	3237	0.92	LOS D	3565	1.02	LOS F	3729	1.07	LOS F
	Ramp V	5792	0.84	LOS D	6545	0.95	LOS E	6922	1.00	LOS F
Section 3	**Towards Airport**	4588	0.66	LOS C	5275	0.76	LOS D	5618	0.81	LOS D
	Towards Bengaluru City	6084	0.88	LOS D	6761	0.98	LOS E	7100	1.03	LOS F
	Ramp L	1050	0.30	LOS B	1324	0.38	LOS B	1461	0.42	LOS B
	Ramp M	3599	1.03	LOS F	3993	1.14	LOS F	4190	1.20	LOS F
Section 4	**Towards Airport**	3539	0.51	LOS C	3951	0.57	LOS C	4157	0.60	LOS C
	Towards Bengaluru City	2485	0.36	LOS B	2768	0.40	LOS B	2909	0.42	LOS B
	Ramp N	1136	0.25	LOS B	1251	0.28	LOS B	1308	0.29	LOS B
	Ramp O	2403	0.54	LOS C	2700	0.61	LOS C	2849	0.64	LOS C
	Ramp P	1726	0.49	LOS B	1935	0.55	LOS C	2039	0.58	LOS C
	Ramp Q	759	0.22	LOS A	833	0.24	LOS A	870	0.25	LOS A



CHAPTER 8
IMPROVEMENT PROPOSALS

CHAPTER 8: IMPROVEMENT PROPOSALS

8.1 General

This chapter describes the various improvement proposals and their necessities to upgrade the existing carriageway facility of project road into two/four lane with paved shoulder in accordance with the Indian standard configuration and design standards proposed for the project road. These improvement proposals are based on the findings of various engineering features carried out on the project roads such as Traffic Survey and Analysis, Inventory Data and Geotechnical & Geophysical Investigations.

The improvement proposals for proposed widening include the provisions for the following major items:

a) Main Tunnel (Twin tube uni-directional TBM tunnel, Cut & Cover, Open Cut)

b) Entry/ Exit ramps (NATM tunnel, Cut & Cover, Open Cut)

c) Tunnel Cross Passages

d) Traffic Control and Safety Measures

e) Intermodal connectivity, Bus Stops/ Parking Spaces/Fee Market Spaces at Shaft Locations

8.2 Design Standards

8.2.1 Geometric Design

8.2.1.1 General

Geometric design of a highway is the process whereby the layout of the road in specific terrain is designed to meet the needs of the road users keeping in view the road function, type and volume of traffic, potential traffic hazards and safety as well as convenience of the road users. The principal areas of control for fulfilment of this objective are- the horizontal alignment, vertical alignment and the road cross-section.

The Consultants have referred to the latest IRC publications and MORT&H circulars regarding design standards for National Highways in India. After careful review of all available data and requirements of the project road the proposed Design Standards for adoption on the project road have been recommended.

8.2.1.2 Design Speed

The project road passes through plain terrain. For geometric design of the highway, design speed is used as an index which links road function, traffic flow and terrain. An appropriate design speed should correspond to general topography and adjacent land use. The speed selected for design should also cater to travel needs and behaviour of the road users.

The design speed corresponding to the type of terrain as Per IRC 86-2018, Highway Capacity Manual *(Indo-HCM)*-2012-17 published by the CRRI is as under:

Table 77: Design Speed Standards

Class of Urban Road	Design Speed
Urban Expressway (Tunnel)	80 KMPH
Ramps	40/50 KMPH

8.2.1.3 Levels of Service (LOS)

The Level of Service (LOS) characterizes the operating conditions on the roadway in terms of traffic performance measures related to speed and travel time, freedom to manoeuvre, traffic interruptions, and comfort and convenience. The levels of service range from level-of-service A (least congested) to level-of-service F (most congested). The Highways Capacity Manual (HCM) provides the following levels of service definitions:

Table 78: Standards for Level of Service

Level of Service (LOS)	General Operating Conditions
A	Free flow
B	Reasonably free flow

Level of Service (LOS)	General Operating Conditions
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

Considering the importance of the highway, whereas Level of Service (LOS) 'B' is desirable and level of service up to LOS- 'C' may be acceptable./ Highway Capacity Manual *(Indo-HCM)*-2012-17 published by the CRRI.

8.3 Main Tunnel

A twin tube uni-directional tunnel has been proposed for connecting the northern part to the southern part of Bengaluru City. The project alignment starts from Hebbal Esteem Mall junction and terminates at Silk Board KSRP Junction. The alignment details are discussed in Executive Summary and Chapter 5 of this report.

Package wise Details,

Table 79: Brief Details of Package 1

Description	Details	Description	Details
Start Tube 1	0+000	Start Tube 2	0+000
End Tube 1	8+748	End Tube 2	8+725
Length	8748 m	Length	8725 m
TBM Length Tube 1	7206 m	TBM Length Tube 2	7195 m
Shaft Length Tube 1	205 m	Shaft Length Tube 2	200 m
Cut and Cover Length Tube 1	837 m	Cut and Cover Length Tube 2	830 m
Open Cut Length Tube 1	500 m	Open Cut Length Tube 2	500 m

For Entry and Exit Ramps (Package 1)	
Description	**Details**
Cut and Cover	1820 m
Open Cut	1524 m
NATM	4120 m
In Shaft	52 m

Table 80: Brief Details of Package 2

Description	Details	Description	Details
Start Tube 1	8+748	Start Tube 2	8+725
End Tube 1	16+745	End Tube 2	16+571
Length Tube 1	7997 m	Length Tube 2	7846 m
TBM Length Tube 1	7042 m	TBM Length Tube 2	7044 m
Shaft Length Tube 1	300 m	Shaft Length Tube 2	301 m
Cut and Cover Length Tube 1	425 m	Cut and Cover Length Tube 2	250 m
Open Cut Length Tube 1	230 m	Open Cut Length Tube 2	251 m

For Entry and Exit Ramps (Package 2)	
Description	**Details**
Cut and Cover	2108 m
Open Cut	1391 m
NATM	5531 m

8.3.1 For Bored Tunnels

Lining Type and Geometry

The finished inner diameter for the Underground Vehicular Tunnel is considered as 13.500 m with a thickness of 550 mm. Universal configuration of the segment is considered with 9+1 arrangement. The

typical bored tunnel cross-section is shown in TCS-1 given later in the chapter along with their TCS Schedule.

Design Considerations

The segments shall be designed to ensure that the full design life of 100 years is achieved. The design method for the analysis of the bored tunnel linings shall be done considering the interaction between the lining and the ground, the deflection of the lining and the redistribution of the loading dependent upon the relative flexibility of the lining, the variability and the compressibility of the ground, with this, the design shall take into account all additional loads, stresses and strains imposed by or on to adjacent Existing Building Structure (EBS).

The Loads acting on the lining include earth pressure, water pressure, dead load, reactions, surcharge & seismic forces. The lining shall also be checked to resist the various loads arising due to handling, stacking, temporary grout load pressure, TBM thrust, Load on Bolts & erector, gasket forces etc.,

The pre-cast concrete linings are designed in accordance with IS 456 However other International Codes may be used in addition to the Indian Standard as and when required.

The Analysis methods, Material and design calculation is mentioned in Design Report which is submitted as Volume II-B

8.3.2 For NATM Tunnel

As per the General arrangement Drawings prepared , there are two types of NATM sections available. i.e., Regular Cross Section and Regular Cross Section (VCP) which are use for the project. The NATM Tunnel is presented as TCS-5 and their Schedules which are mentioned later in chapter.

Design Considerations

The Tunnel tube is proposed to be constructed according to New Austrian Tunnelling Method (NATM) excavation in different weathering grade of rock mass. Ground excavations require the use of structural supports, to establish equilibrium and to limit the displacements around the excavation and at surface. The tunnel will be supported with primary support for temporary condition and a cast in-situ concrete as a permanent support. Primary support design has been done by considering site ground condition. The design has been performed for the combination of different load cases analyzed in STAAD. The Analysis methods, Material and design calculation is mentioned in Design Report which is submitted as Volume II-B

8.3.3 Cut and Cover Section

The Cross Sections of C&C Structures (C&C section of Intermediate Lane, 2 lane and 3 lane) will be used as described Typical Cross Sections which are presented later in chapter. C&C Structures will have side walls, Bottom Slab and top slab with Reinforced Concrete Structure in which Bottom Slab of 1.0 m thick (2-lane) & 1.2m thick (3-lane) will casted over 0.2 m thick PCC and Side wall of 1.0 m thick (2-lane) & 1.2m thick (3-lane) and top slab with 1.0 m thick (2-lane) & 1.2m thick (3-lane).

The Analysis methods, Material and design calculation are mentioned in Design Report which is submitted as Volume II-B

8.3.4 Open Cut Section

The Sections of RAMP Structures (Ramp section of Intermediate Lane, 2 lane and 3 lane) will be used as described in the TCS Schedules later in chapter. RAMP Structures will have side walls and Bottom Slab with Reinforced Concrete Structure in which Bottom Slab of 1 m thick will be casted over 0.2 m thick PCC and Side wall of 1m with roofing C/W pipe truss and approved grade polycarbonate roofing sheets. For Ramp wall height more than 6.5m, a beam 0.6m X 0.6m Beam at 6m spacing has been proposed.

The Analysis methods, Material and design calculation is mentioned in Design Report which is submitted as Volume II-B.

8.4 Proposed Typical Cross Section and TCS Schedules

The TCS Schedules are presented along with the figures of alignment at their corresponding locations for better understanding. The TCS Schedules have been provided separately for Package 1 and Package 2. The typical Cross Section and its TCS Schedules are mentioned below.

8.4.1 TCS Schedules for Package 1

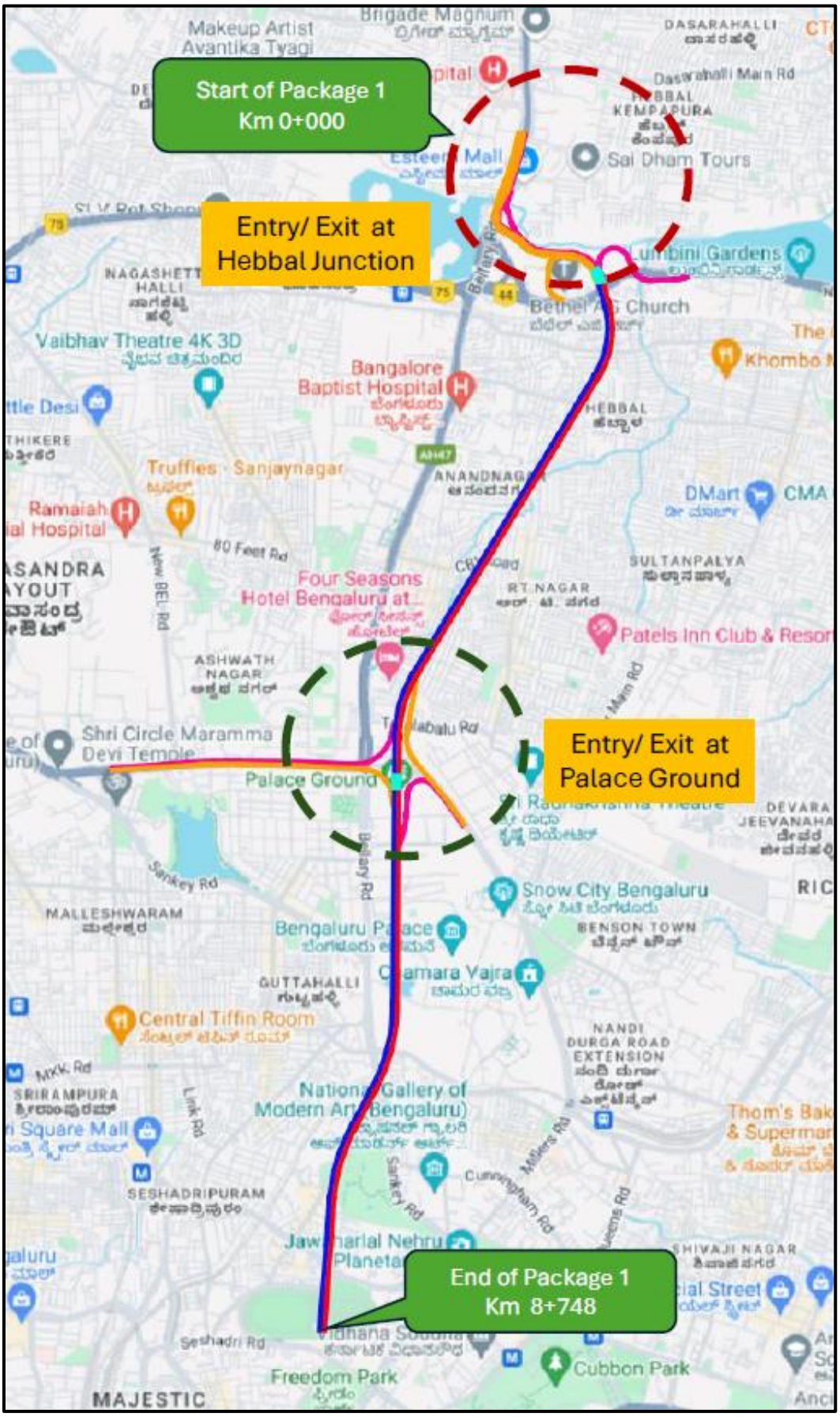


Figure 109: Package 1 Alignment

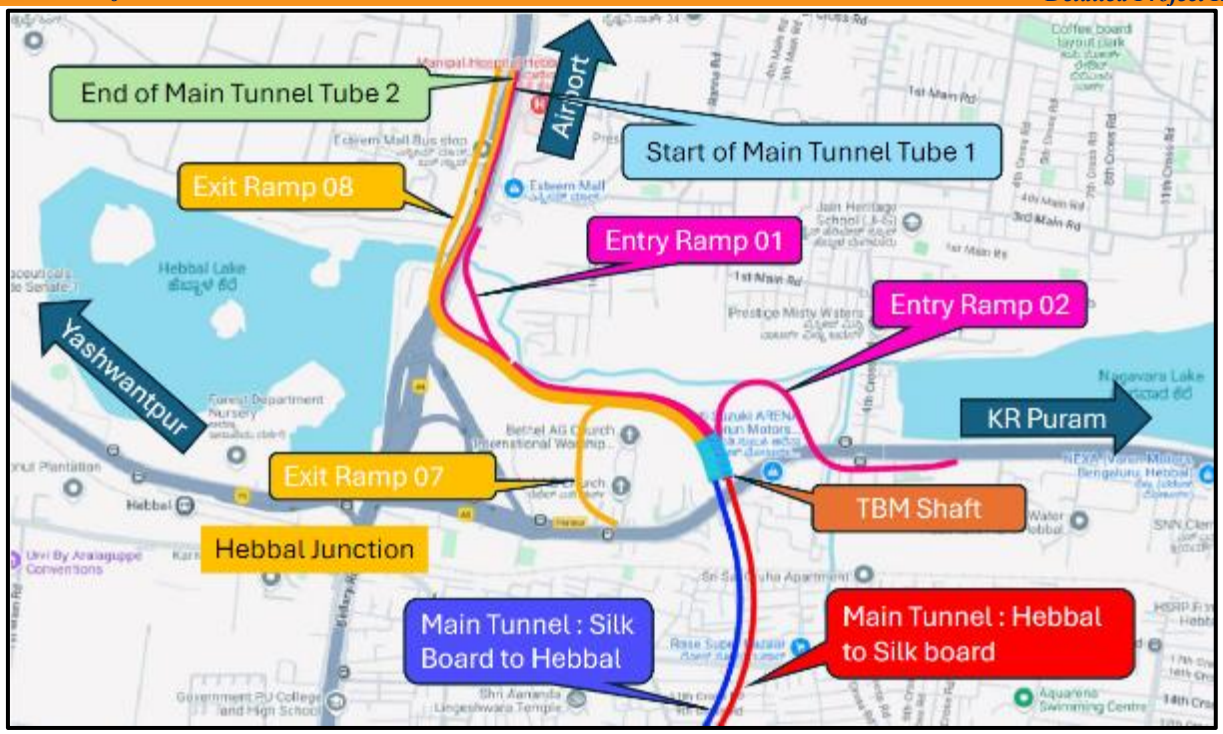


Figure 110: Ramps at Hebbal Junction

Table 81: TCS Schedule at Hebbal Junction

Main Tunnel with Entry and Exits						
At Hebbal Side						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
Portion Common at Hebbal Side to Tube-1 and Tube-2						
1	0+000	0+400	400	TCS-07	Open Cut	2+2 Lane
2	0+400	0+550	150	TCS-08	Cut and Cover	2+2 Lane
3	0+550	0+770	220	TCS-09	Cut and Cover	3+2 Lane
4	0+770	0+870	100	TCS-10	Open Cut	3+3 Lane
5	0+870	1+123	253	TCS-14	Cut and Cover	3+3 Lane
TBM Tunnel						
TBM Tunnel Tube 1 (Hebbal to Silk Borad)						
1	1+123	1+337	214	TCS-06	Cut and Cover	3 Lane
2	1+337	1+442	105	SHAFT	TBM SHAFT	
3	1+442	5+026	3584	TCS-1	TBM Tunnel	3 Lane
4	5+026	5+126	100	SHAFT	TBM SHAFT	
5	5+126	8+748	3622	TCS-1	TBM Tunnel	3 Lane
TBM Tunnel Tube 2 (Silk Borad to Hebbal)						
1	1+123	1+330	207	TCS-06	Cut and Cover	3 lanes
2	1+330	1+430	100	SHAFT	TBM SHAFT	
3	1+430	5+004	3574	TCS-1	TBM Tunnel	3 Lane
4	5+004	5+104	100	SHAFT	TBM SHAFT	
5	5+104	8+725	3621	TCS-1	TBM Tunnel	3 Lane
Intermediate Ramps						
Entry and Exit Ramps at Hebbal						
Entry Ramp 1 (Hebbal Service Road)						
1	0+000	0+100	100	TCS-4	Open Cut	2 Lane

2	0+100	0+341	241	TCS-4	Open Cut	2 Lane
1	0+000	0+150	150	TCS-3A	Cut and Cover	2 Lane
Entry Ramp 2 (From ORR To Main Tunnel Towards Silk Board/ Sarjapur road)						
1	0+000	0+140	140	TCS-4	Open Cut	2 Lane
2	0+140	0+200	60	TCS-3A	Cut and Cover	2 Lane
3	0+200	0+570	370	TCS-3	Cut and Cover	2 Lane
4	0+570	0+762	192	TCS-5	NATM Tunnel	2 Lane
5	0+762	0+814	52	-	In Shaft	2 Lane
Exit Ramp 7 (From Main Tunnel to ORR Towards ORR (Outer Ring Road))						
1	0+000	0+180	180	TCS-3	Cut and Cover	2 Lane
2	0+180	0+200	20	TCS-3A	Cut and Cover	2 Lane
3	0+200	0+415	215	TCS-4	Open Cut	2 Lane
Exit Ramp 8 (Hebbal Service Road)						
1	0+000	0+150	150	TCS-3A	Cut and Cover	2 Lane
2	0+150	0+548	398	TCS-4	Open Cut	2 Lane

Note: TCS Schedule should be read along with TCS and Drawings

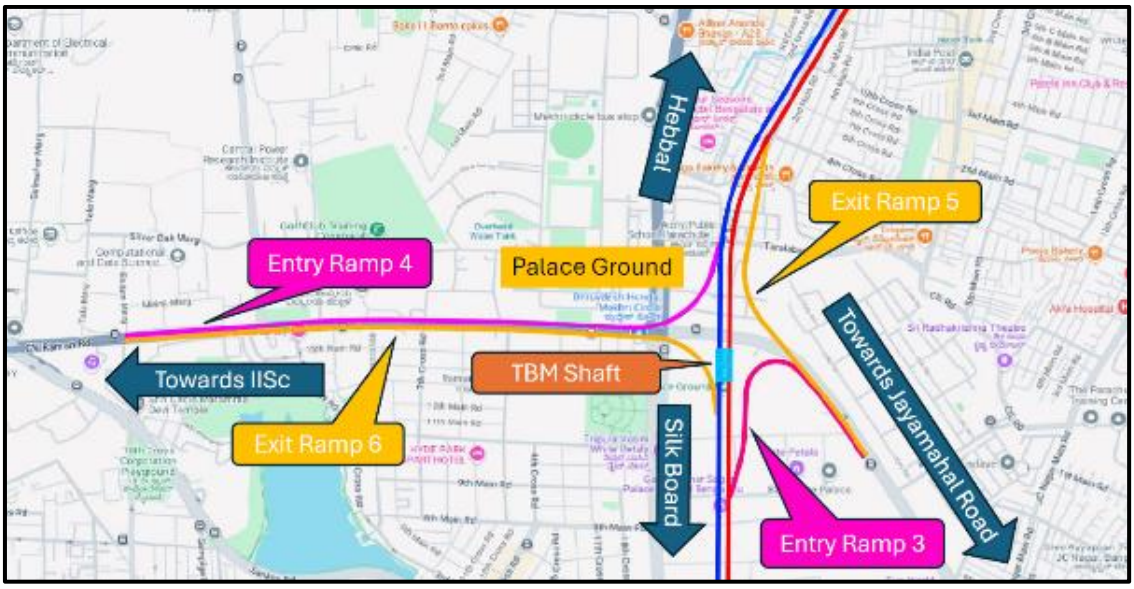


Figure 111: Ramps at Mekri Circle/Palace Ground

Table 82: TCS Schedule at Mekri Circle/Palace Ground

Intermediate Ramps						
Palace Ground						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
Portion Common for Entry Ramps 3 and Exit Ramps 5						
1	0	170	170	TCS-11	Open Cut	2 x Intermediate Lane
2	170	290	120	TCS-12	Cut and Cover	2 x Intermediate Lane
Entry Ramp 03 (From Jaya Mahal Road)						
1	0+290	0+370	80	TCS-13	Cut and Cover	Intermediate Lane
2	0+370	0+871	501	TCS-15	NATM Tunnel	Intermediate Lane
Exit Ramp 5 (From Main Tunnel to Jaymahal Road Towards Jaymahal Road)						
1	0+290	0+370	80	TCS-13	Cut and Cover	Intermediate Lane
2	0+370	1+110	740	TCS-15	NATM Tunnel	Intermediate Lane

Intermediate Ramps						
Palace Ground						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
Portion Common to Entry 4 and Exit 6 (On CV Raman Road)						
1	0+000	0+260	260	TCS-11	Open Cut	2 x Intermediate Lane
2	0+260	0+310	50	TCS-12A	Cut and Cover	2 x Intermediate Lane
3	0+310	0+330	20	TCS-12	Cut and Cover	2 x Intermediate Lane
Entry Ramp 4 (From CV Raman Road to Main Tunnel Towards Hebbal)						
1	0+330	0+600	270	TCS-13	Cut and Cover	Intermediate Lane
2	0+600	1+945	1345	TCS-15	NATM	Intermediate Lane
Exit Ramp 06 (From Silk Board Towards C V Raman Road)						
1	0+330	0+600	270	TCS-13	Cut and Cover	Intermediate Lane
2	0+600	1+942	1342	TCS-15	NATM	Intermediate Lane

Note: TCS Schedule should be read along with TCS and Drawings

8.4.2 Proposal of Structures for Package 1

The following Structure is proposed for the package 1.

Sr. No.	Chainage	Type of Structure	Size of Structure	Remarks
1	Km 0+200 (at Hebbal)	Box (2 Cell)	Width: 10.950 m	Diversion of Existing Cross Drainage
2	Km 0+288 (at Entry Ramp 03 on ORR)	Box Structure	Width: 5m+10.750m+5m : 20.750 (23.054 m Skew length)	Aqueduct Structure

8.4.3 TCS Schedules for Package 2

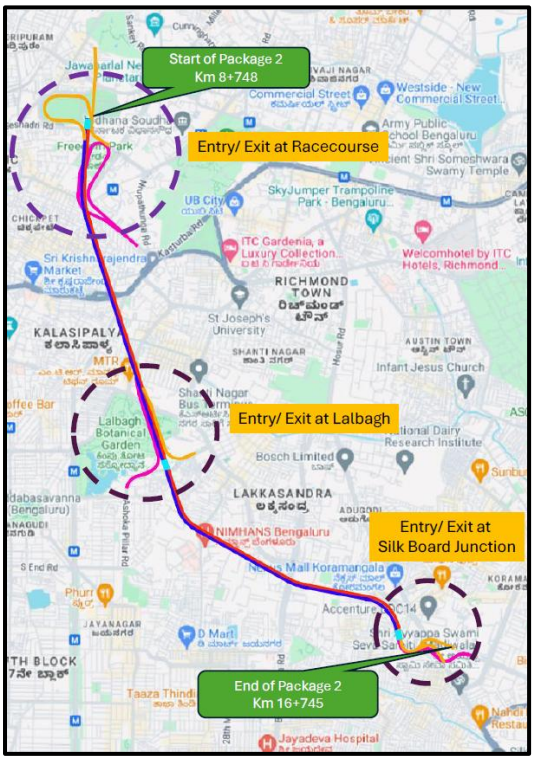


Figure 112: Package 2 Alignment

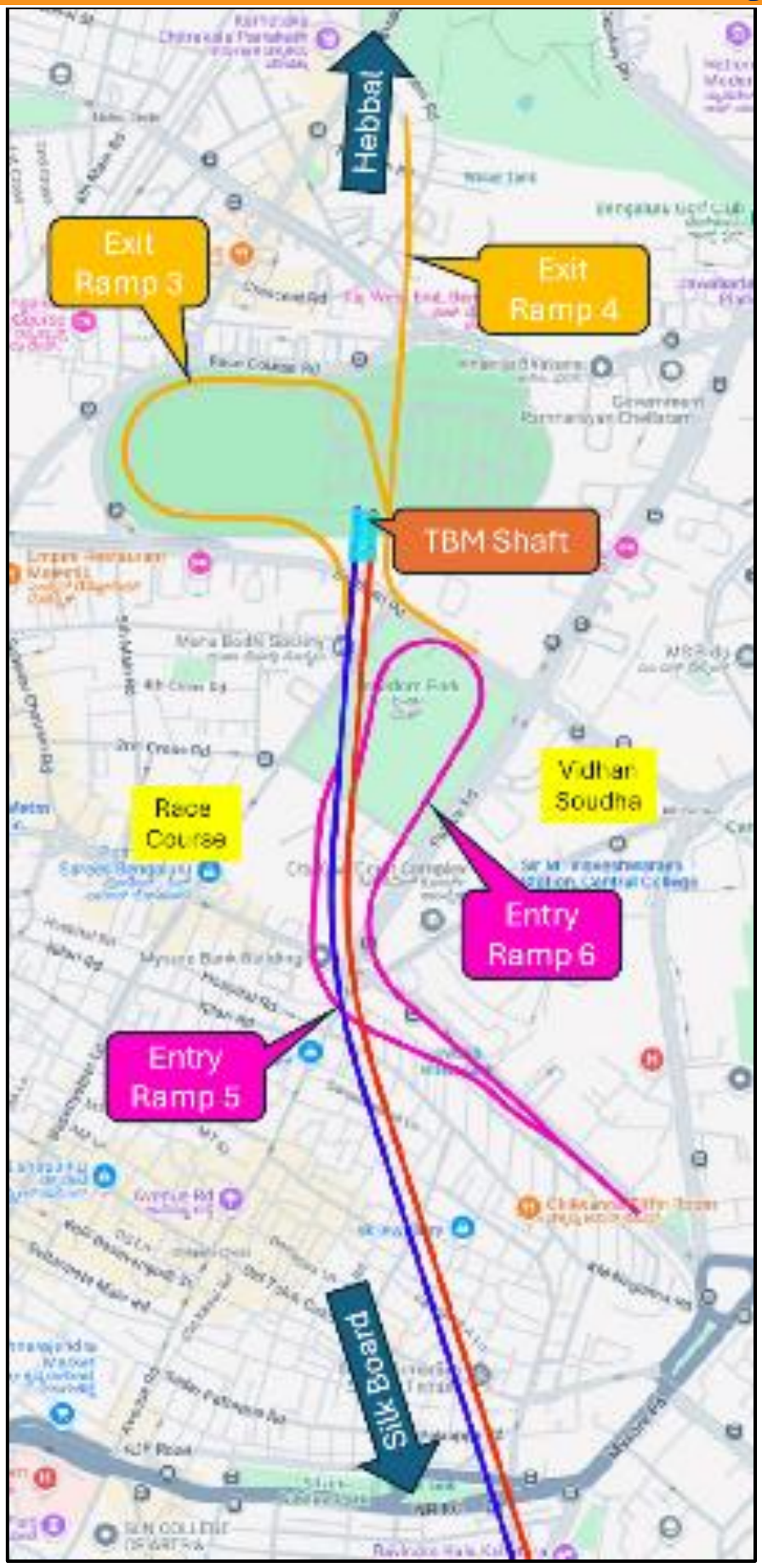


Figure 113: Ramps at Racecourse

Table 83: TCS Schedule at Racecourse

Intermediate Ramps						
At Racecourse						
Sr. No.	Chainage		Length	TCS	TCS Type	Lane Configuration
	From	To				
Common Ramp for Entry and Entry 6 from District Officer Road (CSI Hudson Memorial Church)						
1	0+000	0+130	130	TCS-02	Open Cut	3 Lane
2	0+130	0+162	32	TCS-06	Cut and Cover	3 Lane
Entry Ramp 5 (Towards Hebbal Junction)						
1	0+162	0+270	108	TCS-03	Cut and Cover	2 Lane
2	0+270	1+197	927	TCS-05	NATM Tunnel	2 Lane
Entry Ramp 6 (Towards Silk Board Junction)						
1	0+162	0+270	108	TCS-03	Cut and Cover	2 Lane
2	0+270	1+783	1513	TCS-05	NATM Tunnel	2 Lane
Portion Common to Exit Ramp-5 & Exit Ramp 6						
1	0+840	1+141	301	TCS-02	Open Cut	3 Lane
2	0+820	0+840	20	TCS-06A	Cut and Cover	3 Lane
3	0+790	0+820	30	TCS-06	Cut and Cover	3 Lane
Exit Ramp-4 (From Hebbal Towards KR Circle On Seshadri Road)						
1	0+000	0+610	610	TCS-05	NATM	2 Lane
2	0+610	0+790	180	TCS-03	Cut and Cover	2 Lane
Exit Ramp-3 (From Silk Board KR Circle On Seshadri Road)						
1	0+000	**0+575**	575	TCS-05	NATM	2 Lane
2	**0+575**	1+465	890	TCS-03	Cut and Cover	2 Lane

Note: The TCS Schedule is to be read along with Drawing Volume

Typical Cross Sections have been presented in Chapter 8 of this report and Drawing Volume of the DPR.

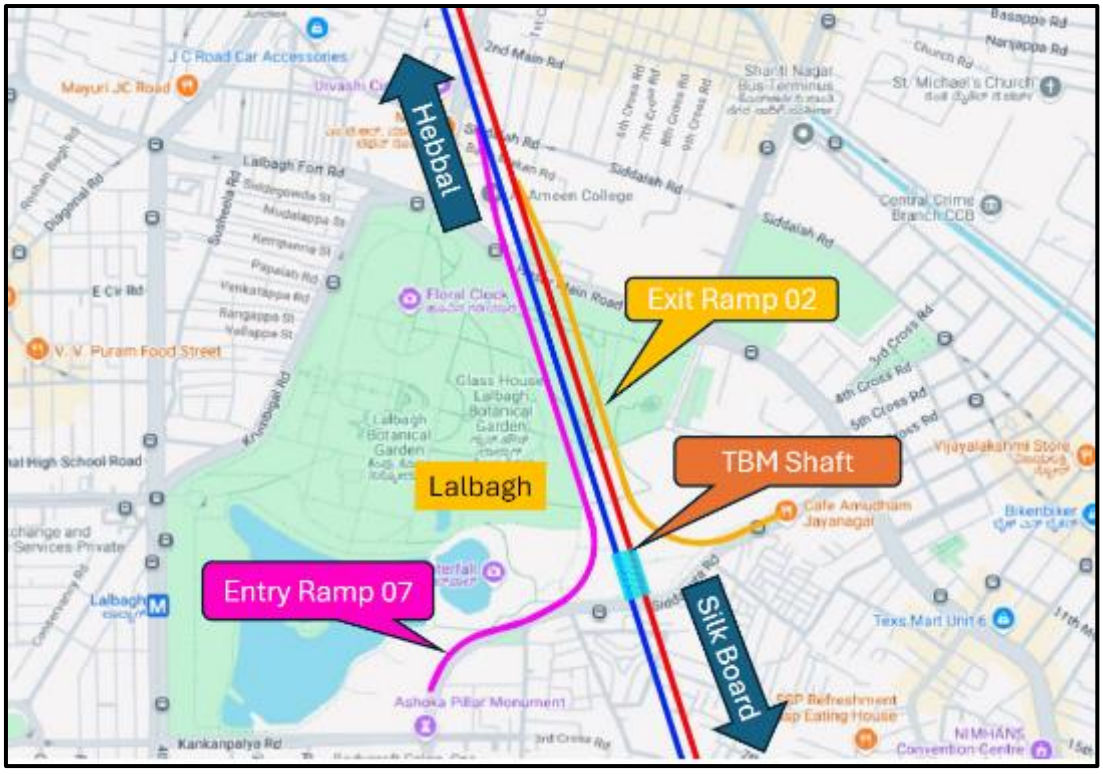


Figure 114: Ramps at Lalbagh

Table 84: TCS Schedule at Lalbagh

Intermediate Ramps						
At Lalbagh						
Exit Ramp 2 (Towards Siddapura Road near Wilson Garden)						
Sr. No.	Chainage		Length	TCS	TCS Type	Lane Configuration
	From	To				
1	0+000	0+900	900	TCS-05	NATM Tunnel	2 Lane
2	0+900	0+960	60	TCS-03	Cut and Cover	2 Lane
3	0+960	1+081	121	TCS-04	Open Cut	2 Lane
Entry Ramp 7 (From Siddapura Road near Ashok Pillar)						
1	0+000	0+130	130	TCS-04	Open Cut	2 Lane
2	0+130	0+160	30	TCS-03A	Cut and Cover	2 Lane
3	0+160	0+410	250	TCS-03	Cut and Cover	2 Lane
4	0+410	1+416	1006	TCS-05	NATM	2 Lane

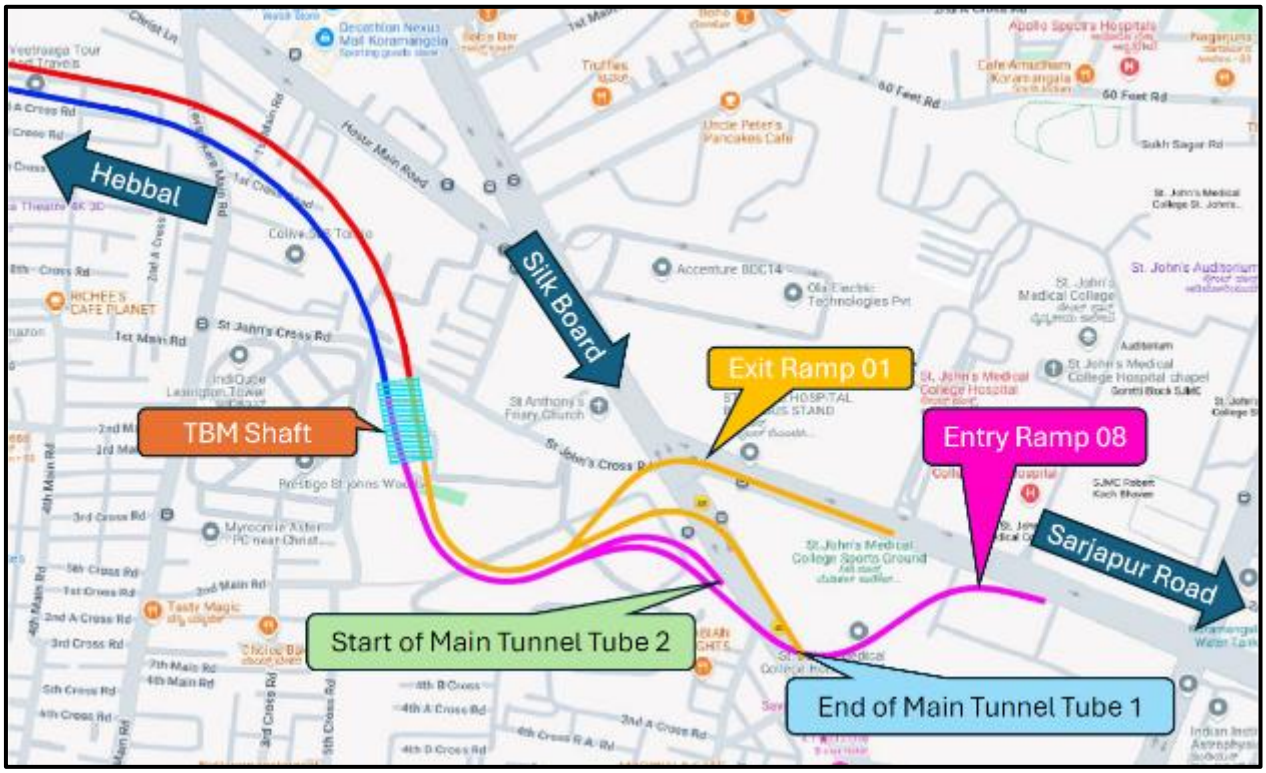
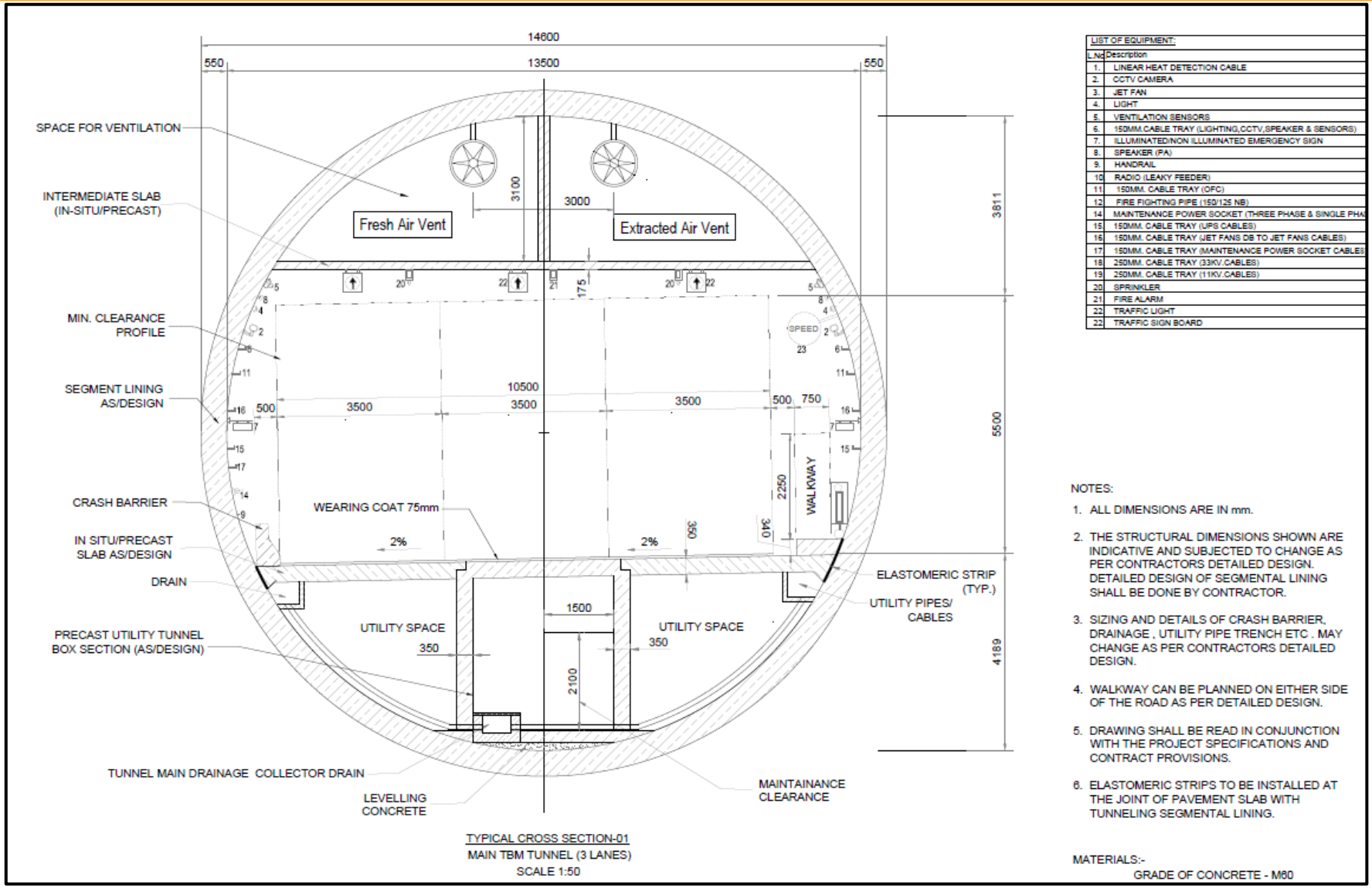


Figure 115: Ramps at Silk Board

Table 85: TCS Schedule for TBM Tunnel and Ramps at Silk Board

Main Tunnel with Entry and Exits						
TBM Tunnel						
TBM Tunnel Tube 1 (Hebbal to Silk Borad)						
Sr. No.	Chainage		Length	TCS	TCS Type	Lane Configuration
	From	To				
1	8+748	8+848	100	SHAFT	TBM SHAFT	
2	8+848	12+625	3777	TCS-1	TBM Tunnel	3 Lane
3	12+625	12+725	100	SHAFT	TBM SHAFT	
4	12+725	15+990	3265	TCS-1	TBM Tunnel	3 Lane
5	15+990	16+090	100	SHAFT	TBM SHAFT	
6	16+090	16+155	65	TCS-6	Cut and Cover	3 Lane

TBM Tunnel Tube 2 (Silk Borad to Hebbal)						
1	8+725	8+824	99	SHAFT	TBM SHAFT	
2	8+824	12+612	3788	TCS-1	TBM Tunnel	3 Lane
3	12+612	12+712	100	SHAFT	TBM SHAFT	
4	12+712	15+968	3256	TCS-1	TBM Tunnel	3 Lane
5	15+968	16+070	102	SHAFT	TBM SHAFT	
6	16+070	16+140	70	TCS-6	Cut and Cover	3 Lane
At Silk Board Side						
Portion Common to Tube-1 and Tube-2 At Silk Board Side						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
1	**Tube-2 16+140** (Tube-1 16+155)	Tube-2 16+320 (Tube-1 16+315)	180	TCS-14	Cut and Cover	3+3 Lane
2	Tube-2 16+320 (Tube-1 16+315)	Tube-2 16+350 (Tube-1 16+345)	30	TCS-10	Open Cut	3+3 Lane
Tube 2 (Silk Board to Hebbal)						
1	16+350	16+571	221	TCS-4	Open Cut	2 Lane
Tube 1 (Hebbal to Silk Board)						
3	16+345	16+357	12	TCS-02	Open Cut	3 Lane
4	16+357	16+400	43	TCS-4	Open Cut	2 Lane
5	16+400	16+600	200	TCS-03A	Cut and Cover	2 Lane
6	16+600	16+745	145	TCS-4	Open Cut	2 Lane
Intermediate Ramps						
Exit and Entry Ramps at Silk Board.						
Sr. No.	**Chainage**		**Length**	**TCS**	**TCS Type**	**Lane Configuration**
	From	**To**				
Entry Ramp 8 (From Sarjapur Road)						
1	0+000	0+190	190	TCS-4	Open Cut	2 Lane
2	0+190	0+390	200	TCS-03A	Cut and Cover	2 Lane
3	0+390	0+654	264	TCS-4	Open Cut	2 Lane
Exit Ramp 1 (Towards Sarjapur Road)						
1	0+000	0+050	50	TCS-4	Open Cut	2 Lane
2	0+050	0+250	200	TCS-03A	Cut and Cover	2 Lane
3	0+250	0+455	205	TCS-4	Open Cut	2 Lane



LIST OF EQUIPMENT:	
L No	Description
1.	LINEAR HEAT DETECTION CABLE
2.	CCTV CAMERA
3.	JET FAN
4.	LIGHT
5.	VENTILATION SENSORS
6.	150MM.CABLE TRAY (LIGHTING,CCTV,SPEAKER & SENSORS)
7.	ILLUMINATED/NON ILLUMINATED EMERGENCY SIGN
8.	SPEAKER (PA)
9.	HANDRAIL
10	RADIO (LEAKY FEEDER)
11	150MM. CABLE TRAY (OFC)
12	FIRE FIGHTING PIPE (150/125 NB)
14	MAINTENANCE POWER SOCKET (THREE PHASE & SINGLE PHA
15	150MM. CABLE TRAY (UPS CABLES)
16	150MM. CABLE TRAY (JET FANS DB TO JET FANS CABLES)
17	150MM. CABLE TRAY (MAINTENANCE POWER SOCKET CABLES
18	250MM. CABLE TRAY (33KV.CABLES)
19	250MM. CABLE TRAY (11KV.CABLES)
20	SPRINKLER
21	FIRE ALARM
22	TRAFFIC LIGHT
23	TRAFFIC SIGN BOARD

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF SEGMENTAL LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.
6. ELASTOMERIC STRIPS TO BE INSTALLED AT THE JOINT OF PAVEMENT SLAB WITH TUNNELING SEGMENTAL LINING.

MATERIALS:-
GRADE OF CONCRETE - M60

Figure 116: TCS-1, TBM Tunnel Cross-Section

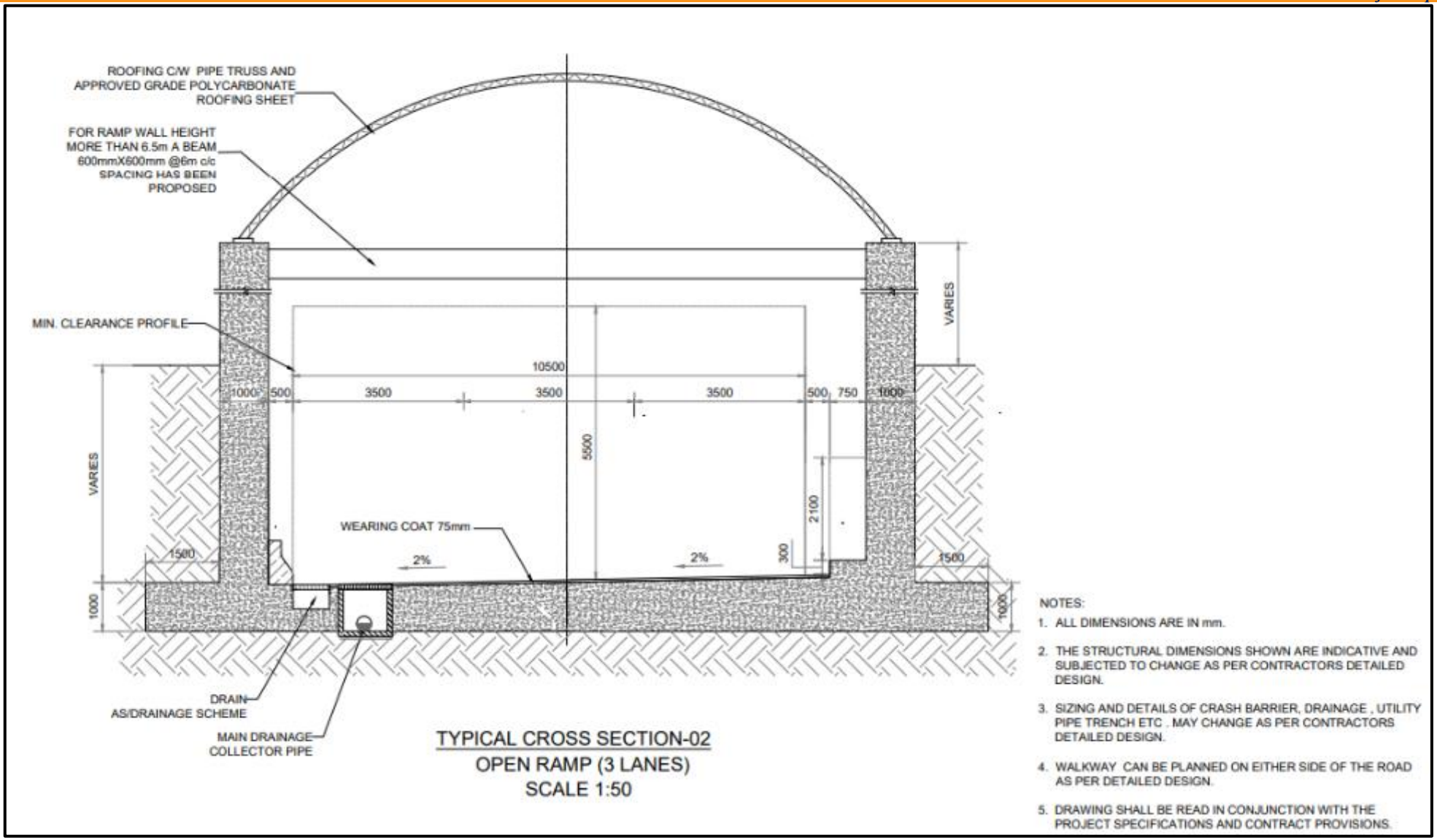


Figure 117: TCS-2, 3 lane Open Cut Section

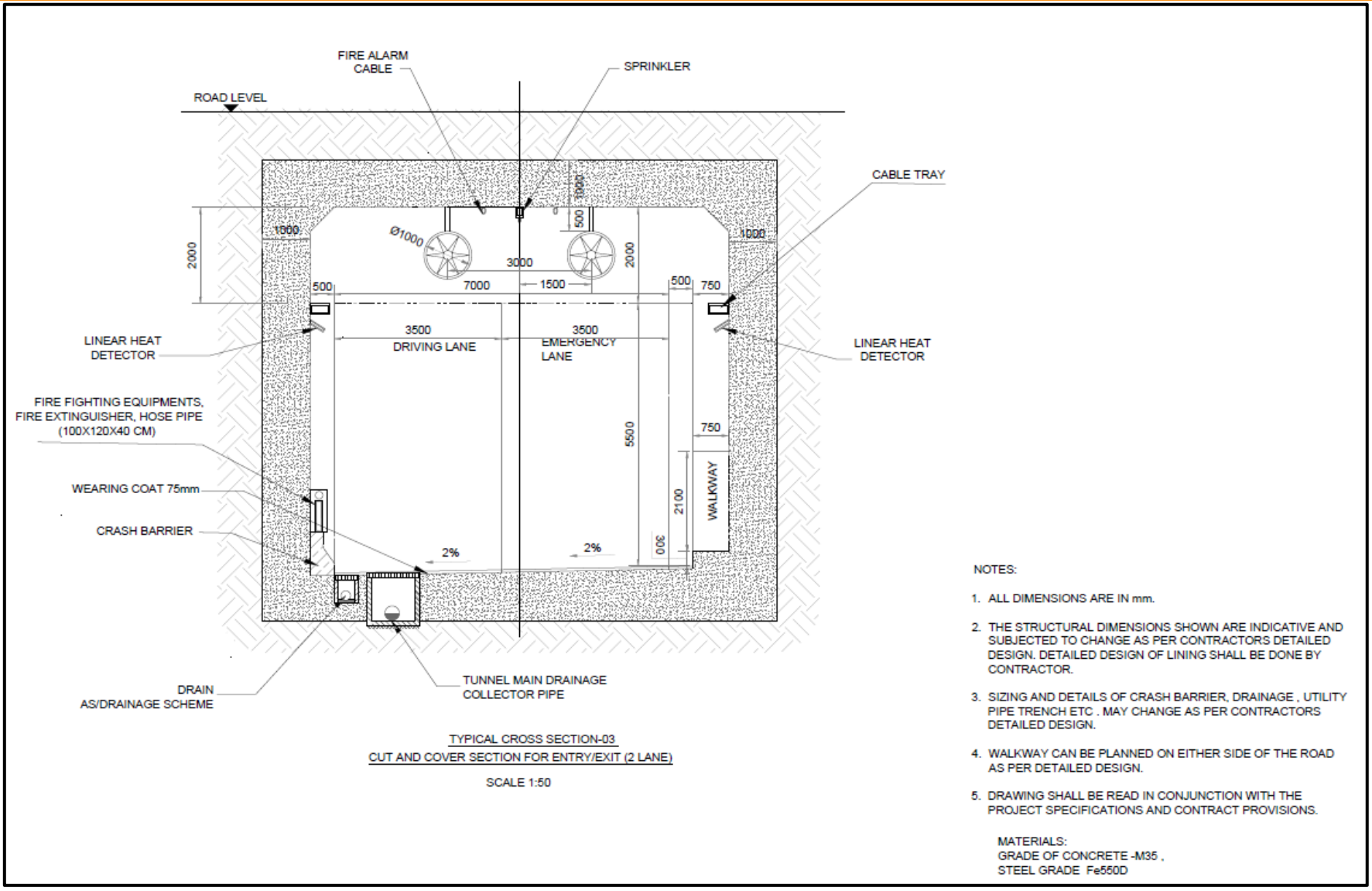


Figure 118: TCS-3, 2 lane Cut & Cover Section

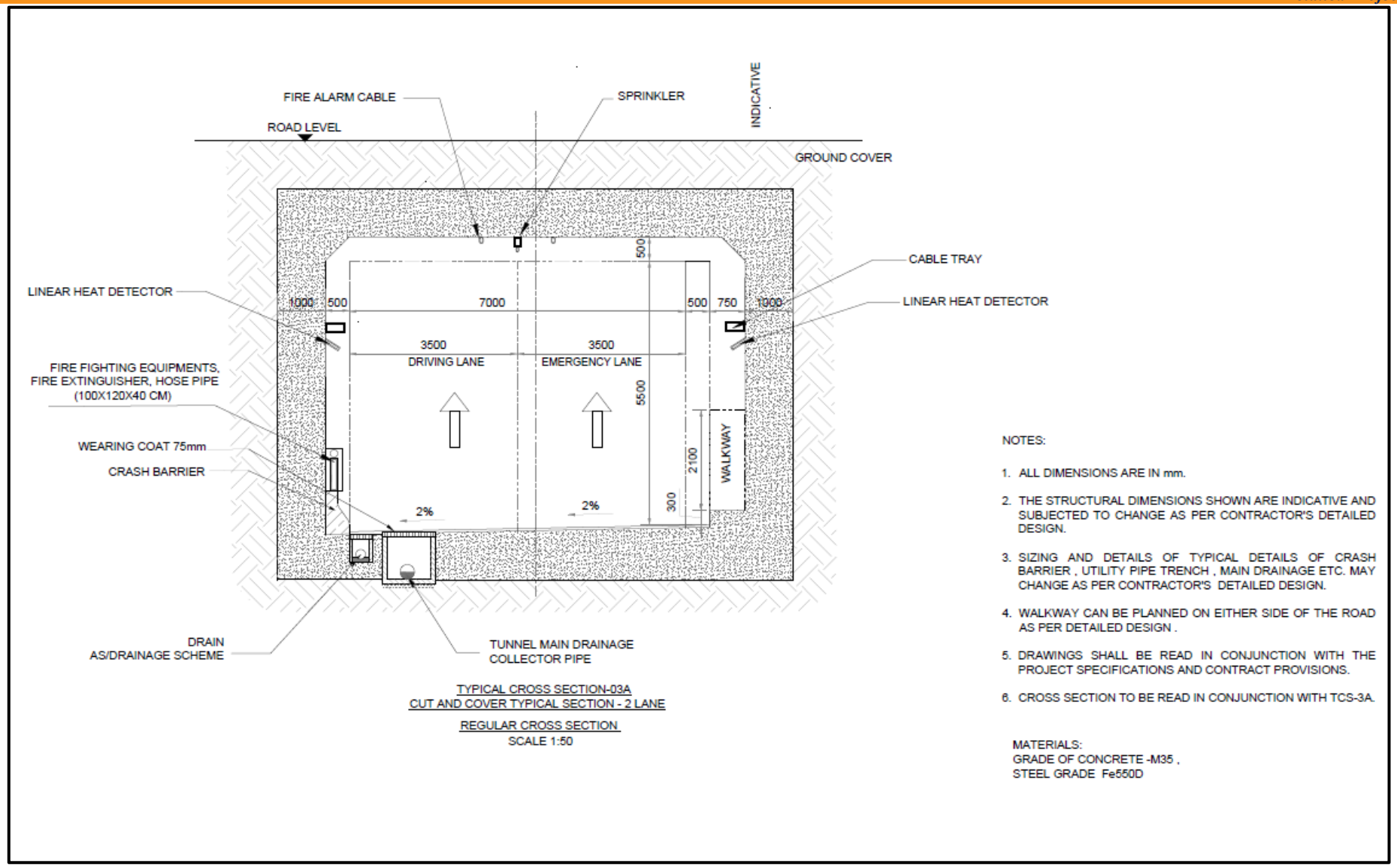


Figure 119: TCS-03A, 2 lanes Cut and Cover

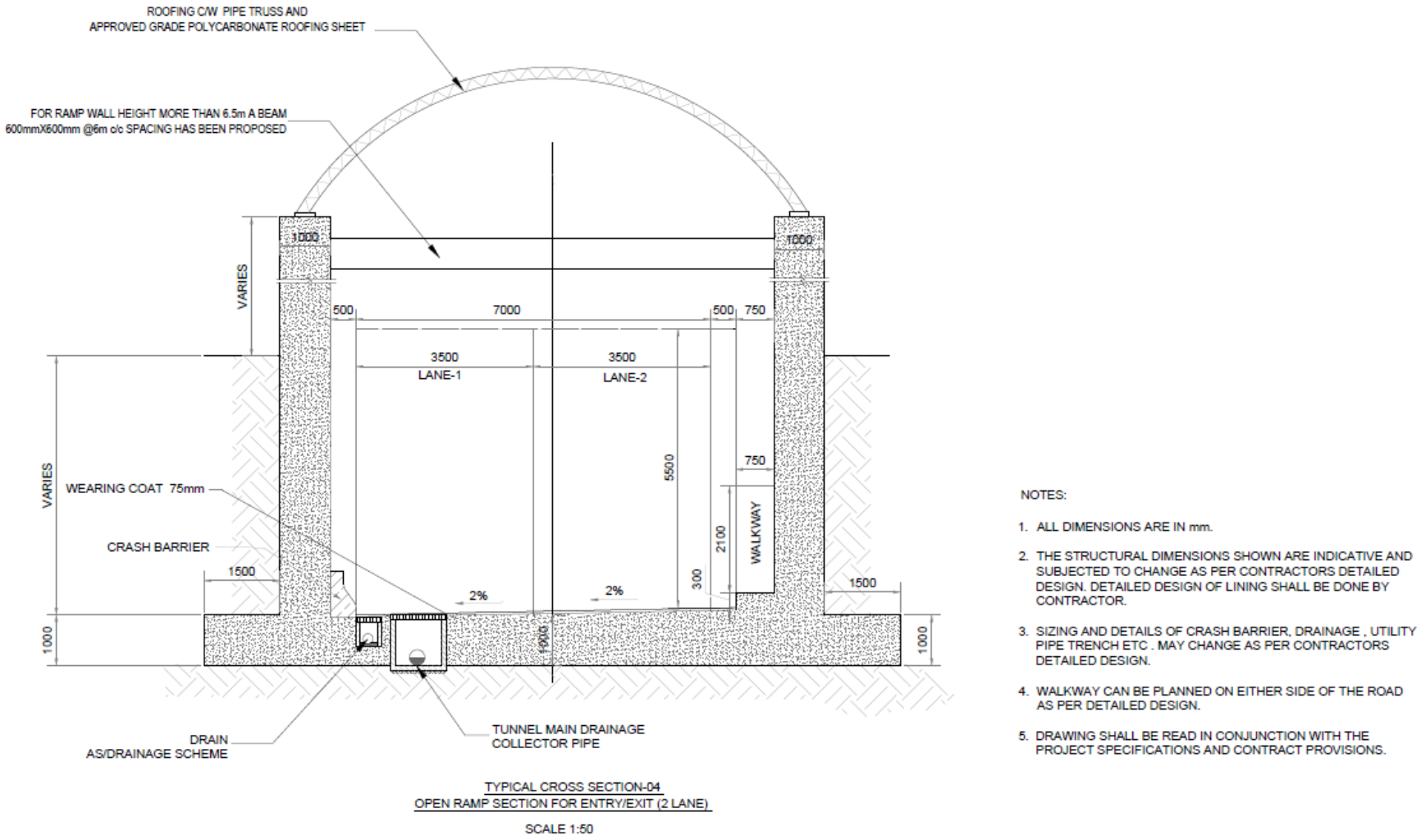
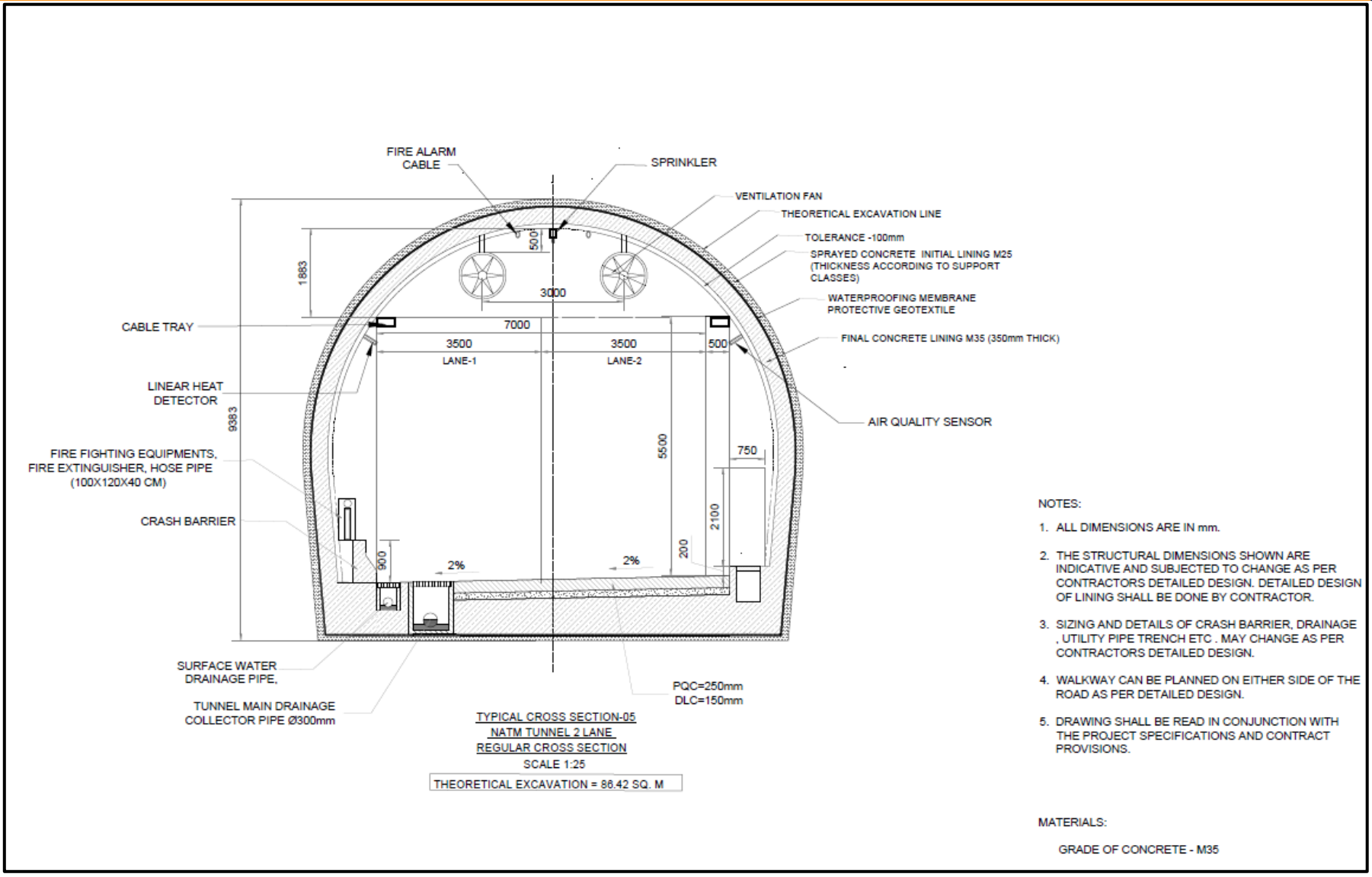


Figure 120: TCS-4, 2 lane Open Cut Section



TYPICAL CROSS SECTION-05
NATM TUNNEL 2 LANE
REGULAR CROSS SECTION
SCALE 1:25

THEORETICAL EXCAVATION = 86.42 SQ. M

NOTES:

1. ALL DIMENSIONS ARE IN mm.
2. THE STRUCTURAL DIMENSIONS SHOWN ARE INDICATIVE AND SUBJECTED TO CHANGE AS PER CONTRACTORS DETAILED DESIGN. DETAILED DESIGN OF LINING SHALL BE DONE BY CONTRACTOR.
3. SIZING AND DETAILS OF CRASH BARRIER, DRAINAGE , UTILITY PIPE TRENCH ETC . MAY CHANGE AS PER CONTRACTORS DETAILED DESIGN.
4. WALKWAY CAN BE PLANNED ON EITHER SIDE OF THE ROAD AS PER DETAILED DESIGN.
5. DRAWING SHALL BE READ IN CONJUNCTION WITH THE PROJECT SPECIFICATIONS AND CONTRACT PROVISIONS.

MATERIALS:

GRADE OF CONCRETE - M35

Figure 121: TCS-5, 2 Lane NATM Section

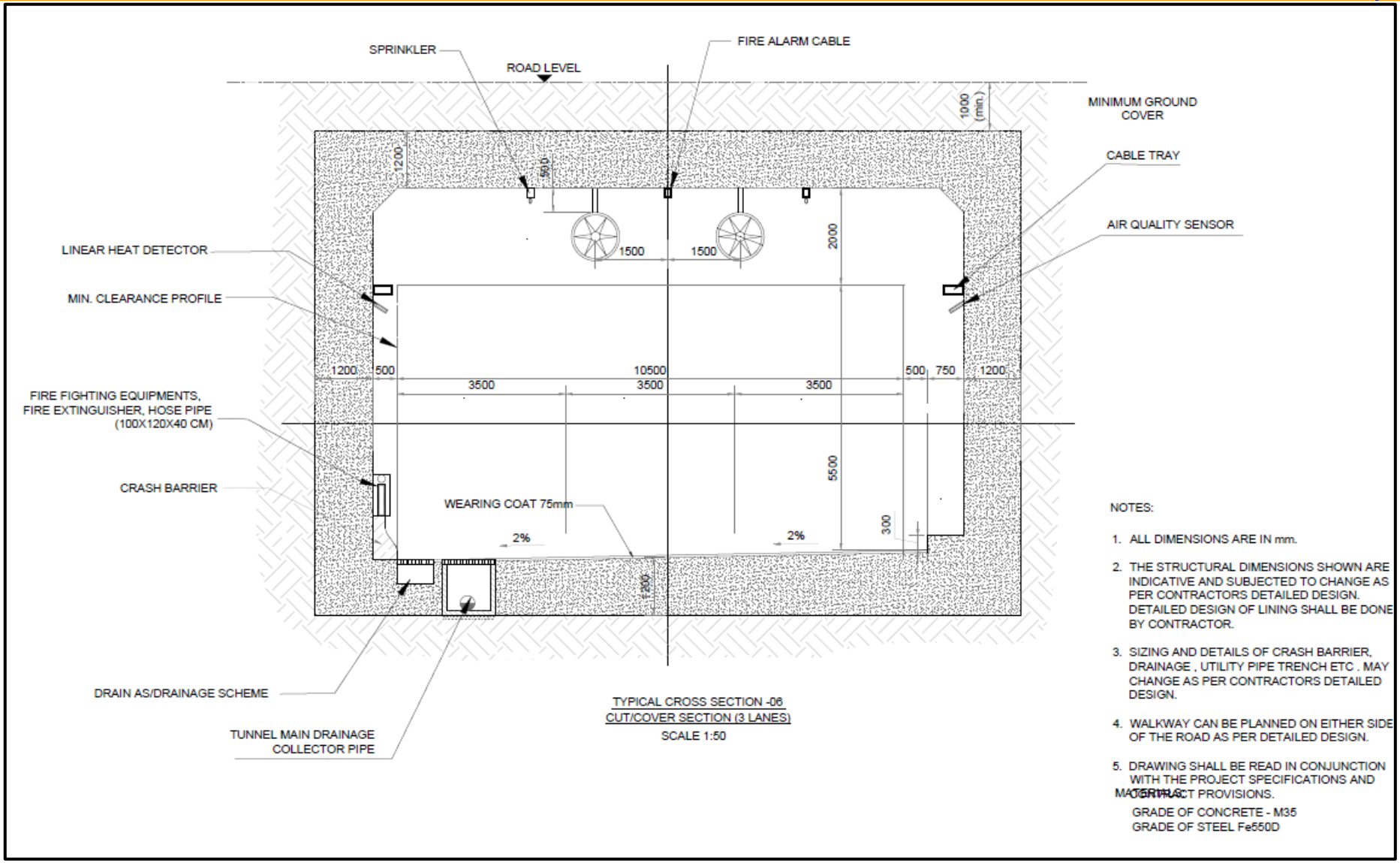


Figure 122: TCS-6, 3 Lane Cut and Cover Section

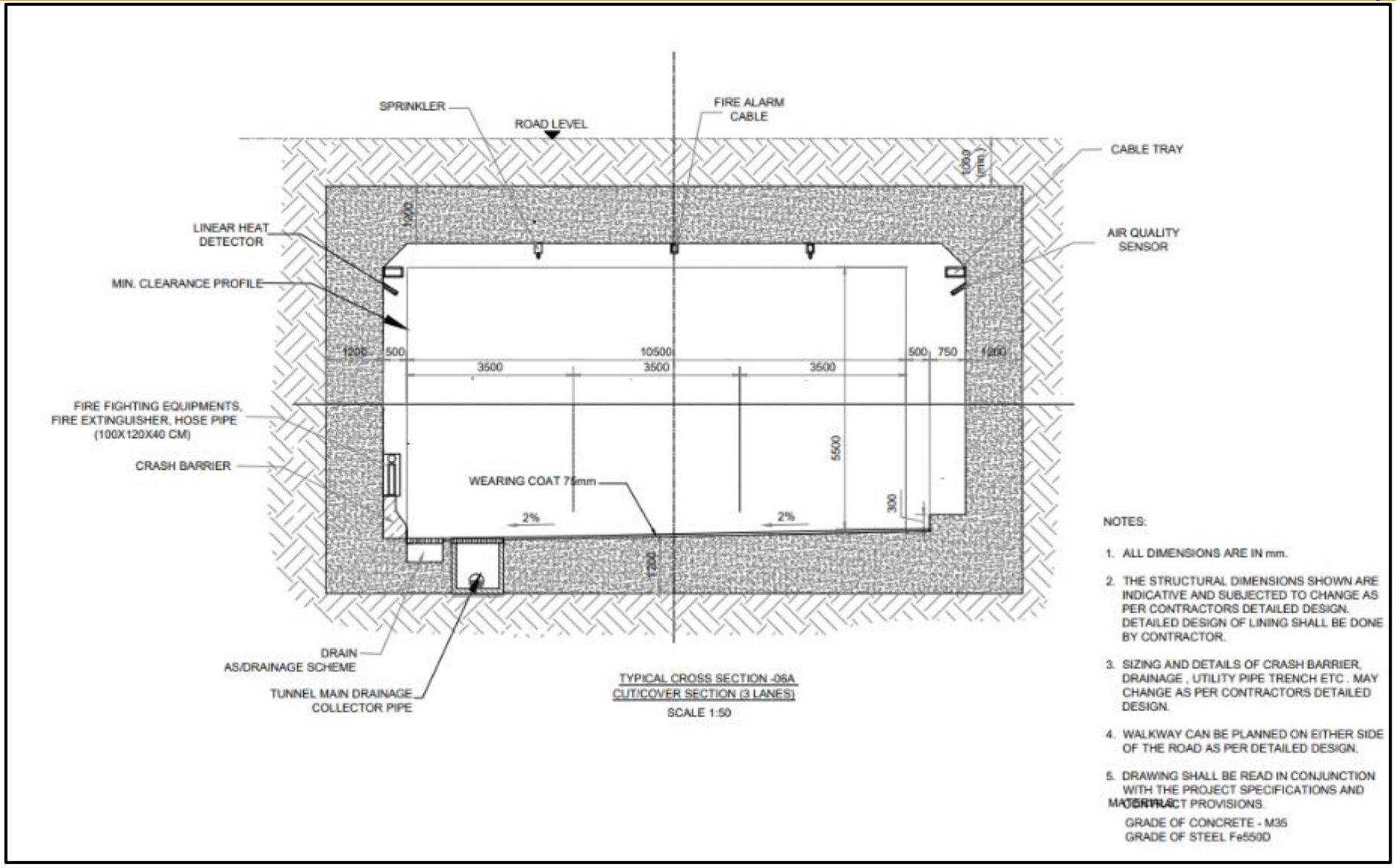


Figure 123: TCS-6A, 3 Cut and Cover Section

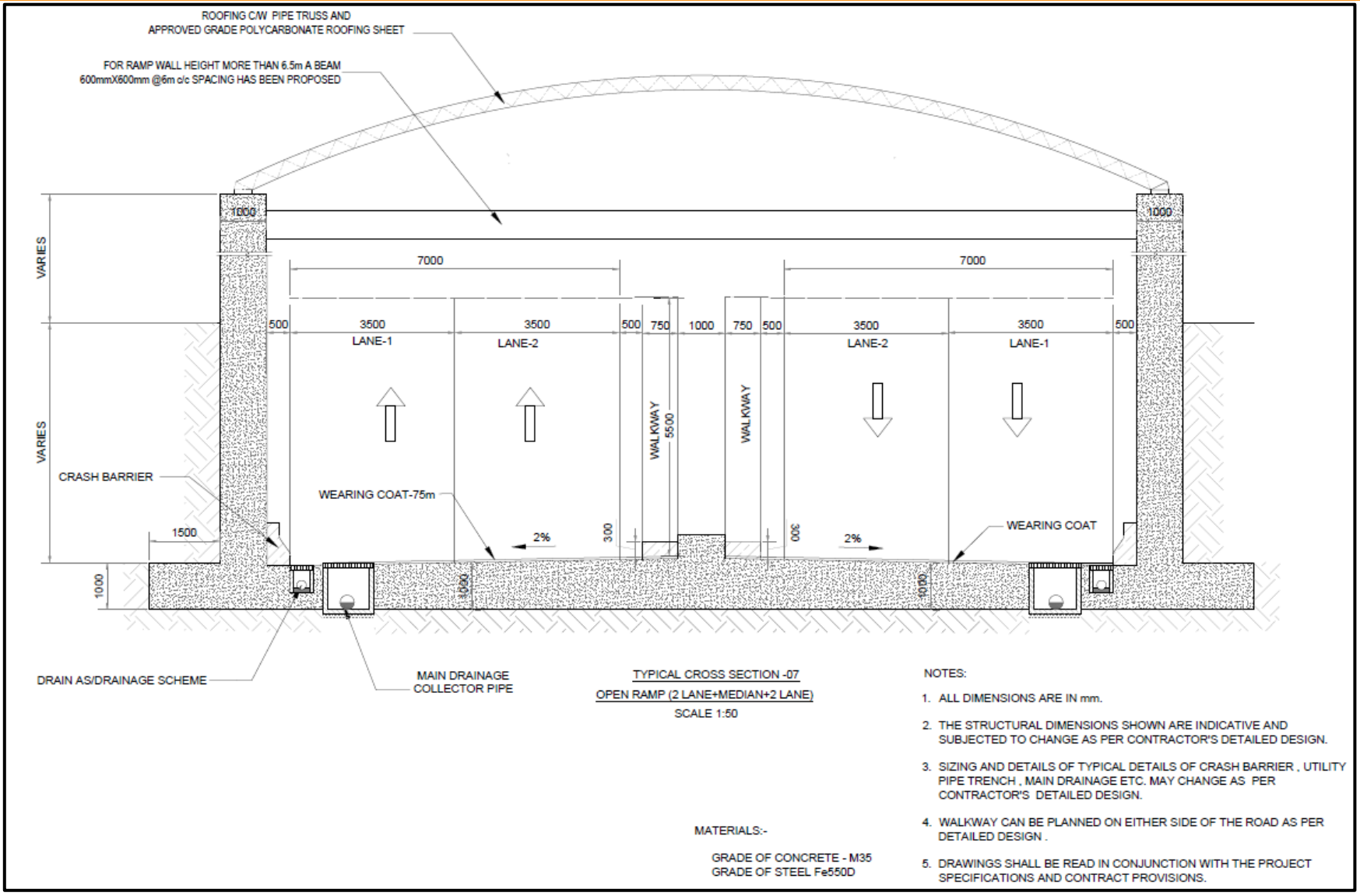


Figure 124: TCS-7, 2+2 lane Open Cut Section

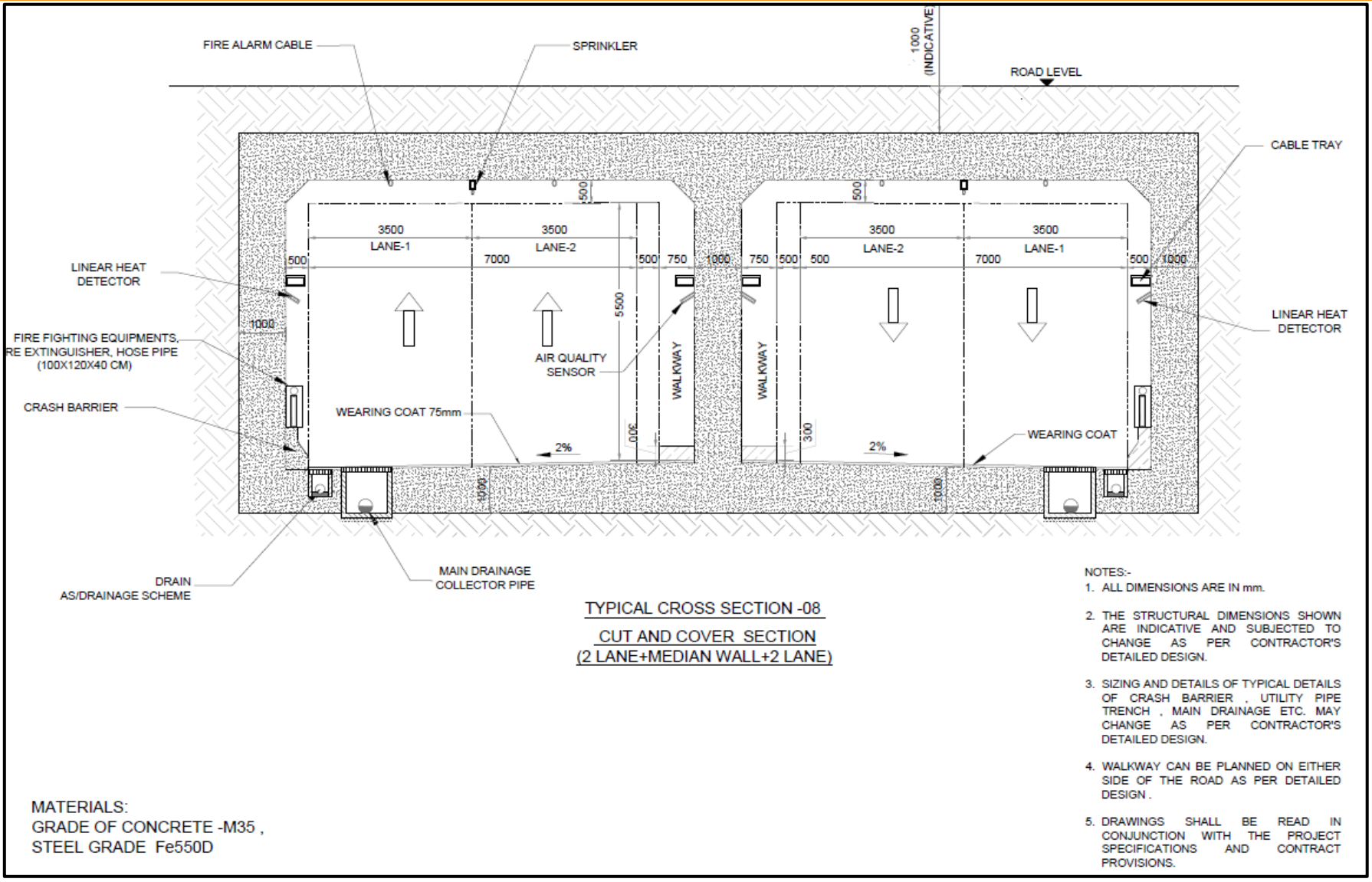


Figure 125: TCS-8, 2+2 Lane Cut and Cover Section

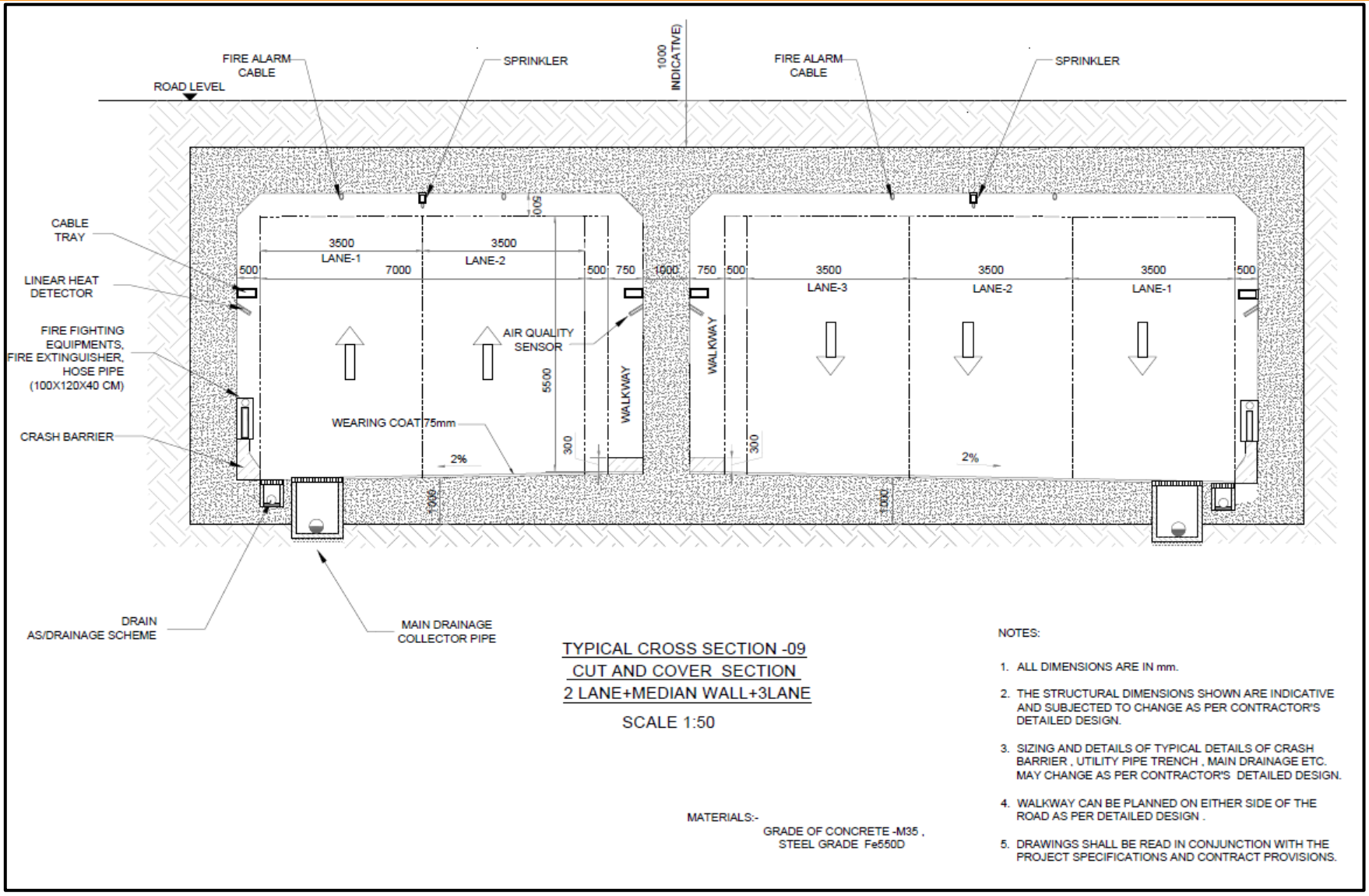


Figure 126: TCS-9, 2+3 Lane Cut and Cover Section

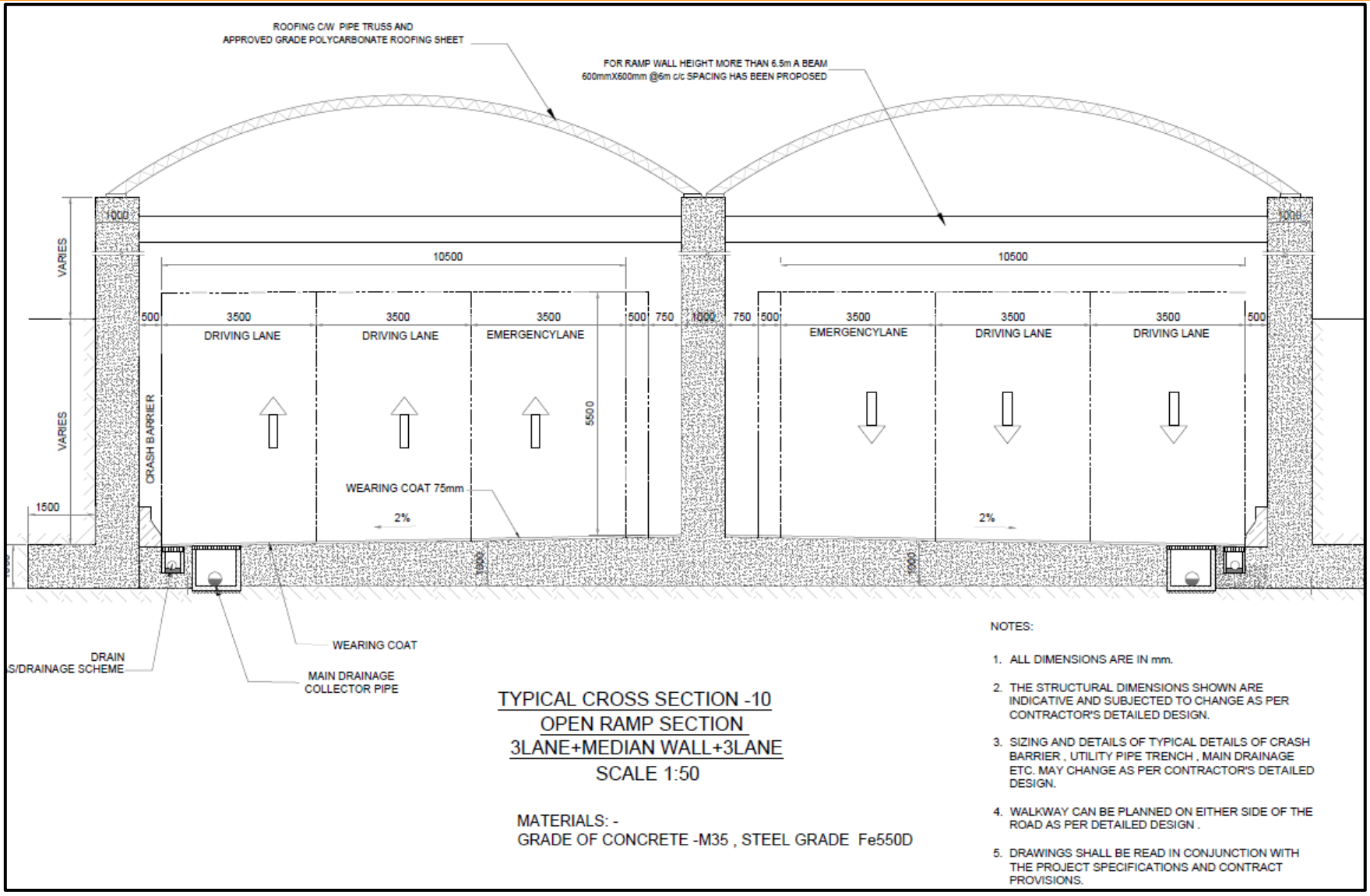


Figure 127: TCS-10, 3+3 Lane Open Cut Section

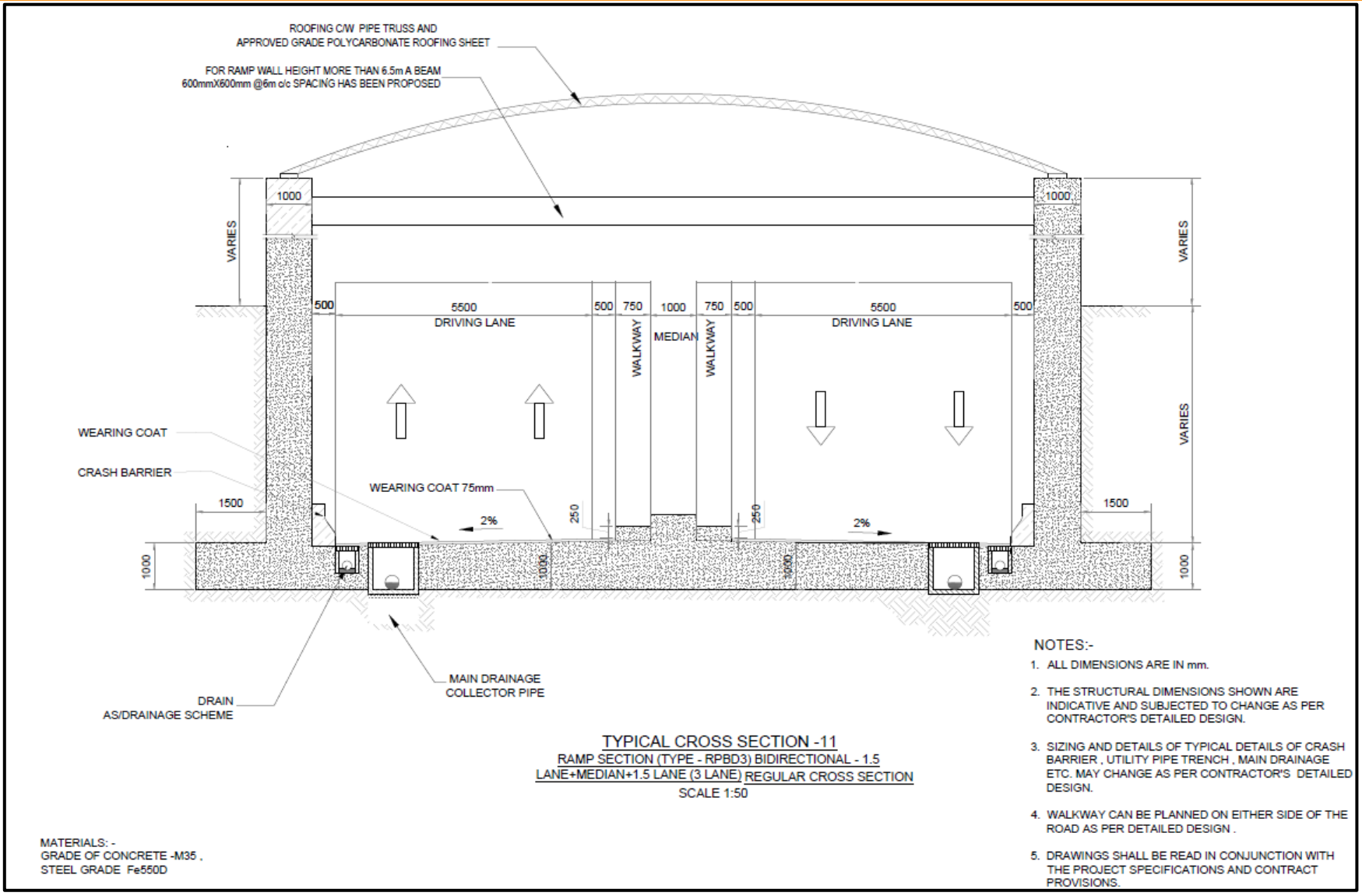


Figure 128: TCS-11, 2 x Intermediate Lane Open Cut Section

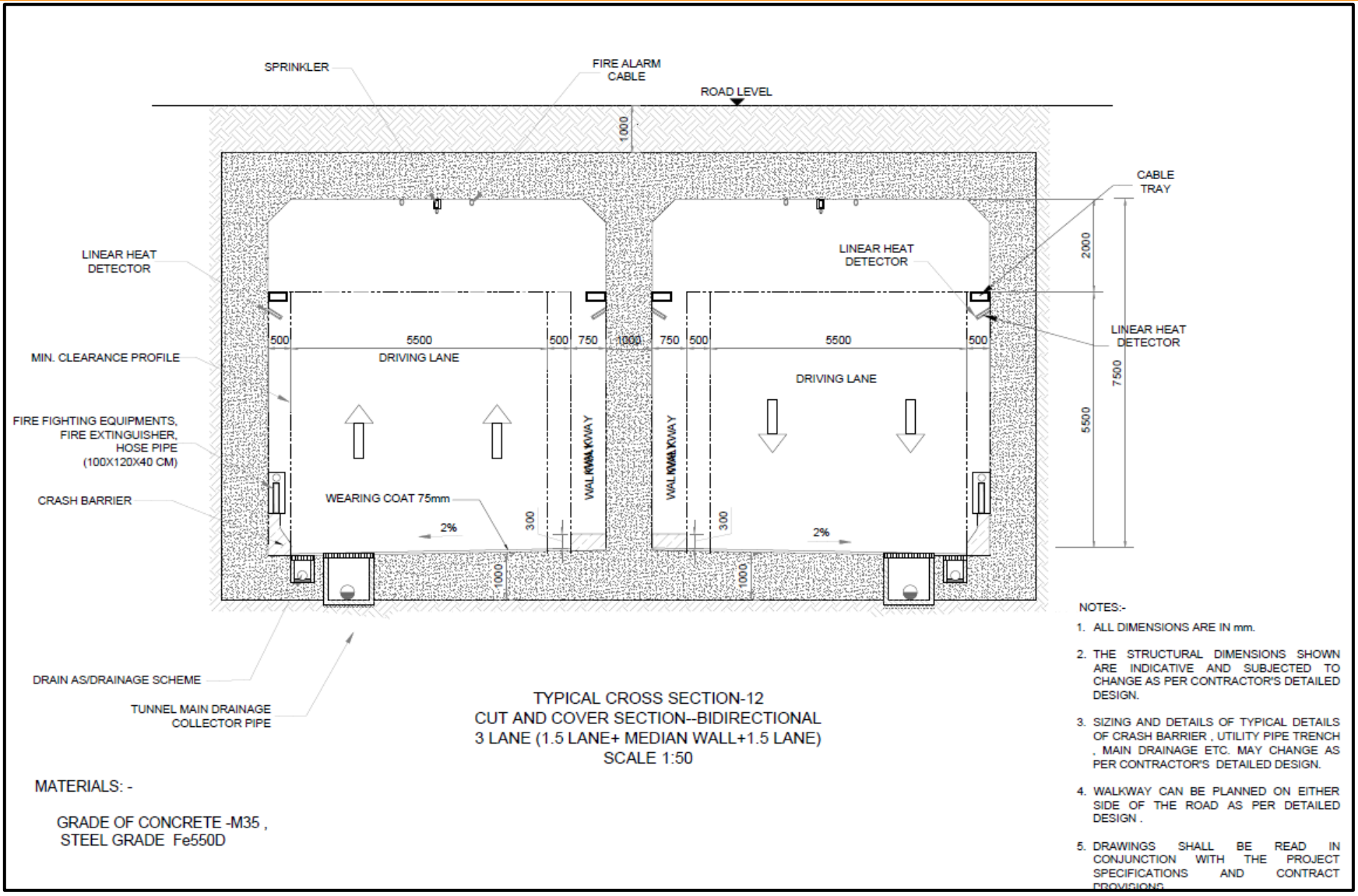


Figure 129: TCS-12, 2 x Intermediate Lane Open Cut and Cover Section

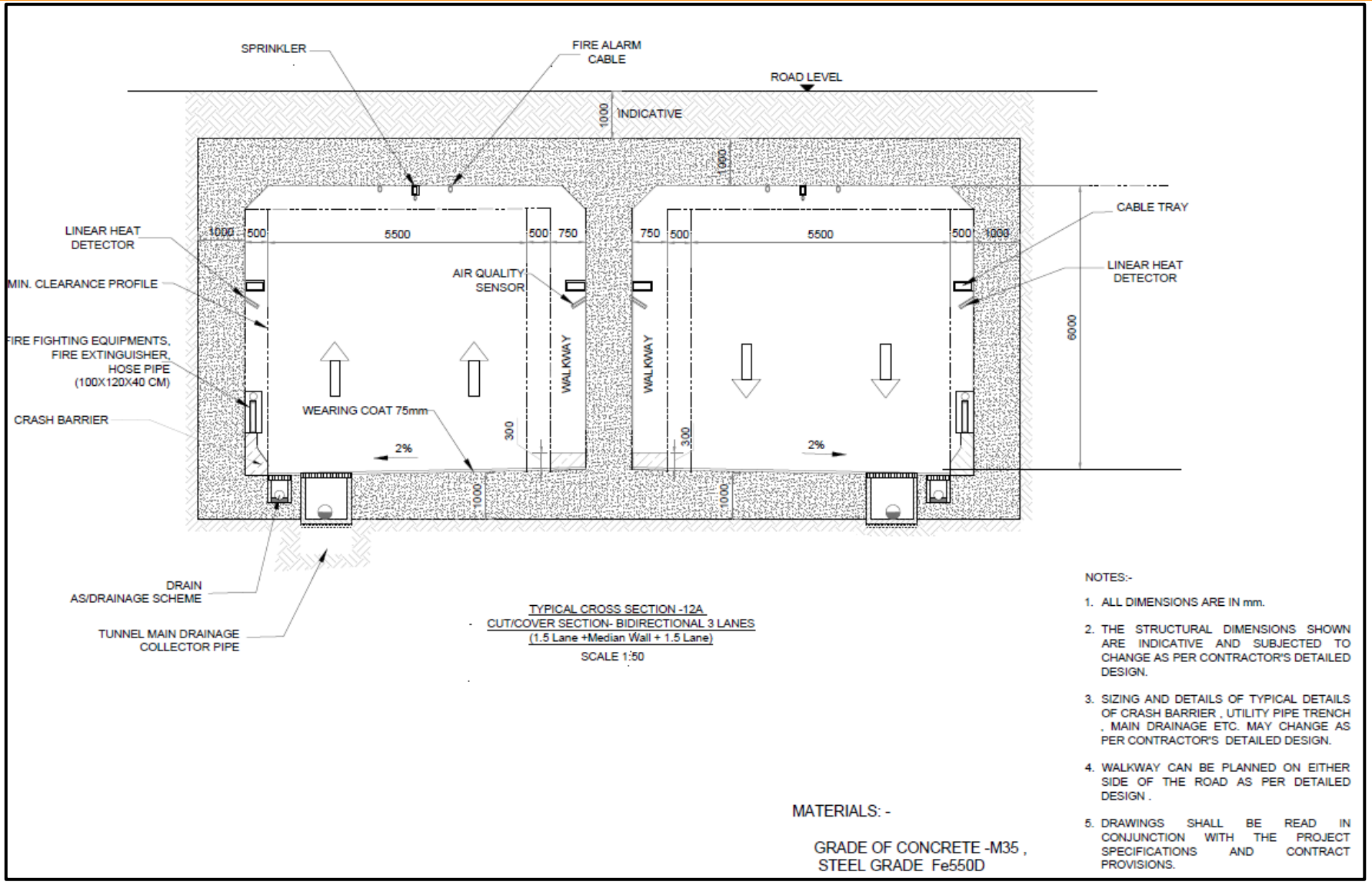


Figure 130: TCS-12A, 2 x Intermediate Lane Open Cut and Cover Section

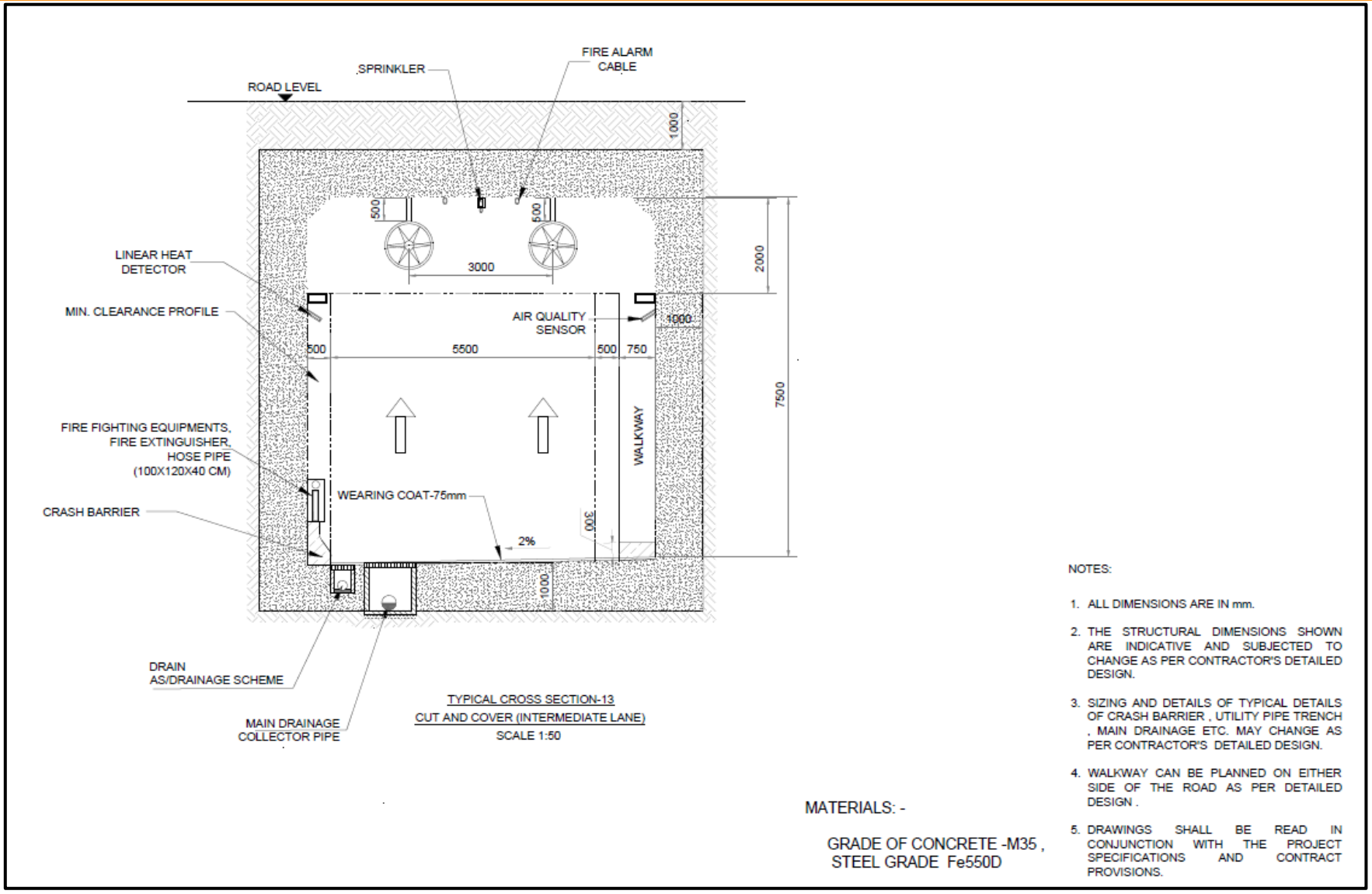


Figure 131: TCS-13, Intermediate Lane Cut and Cover Section

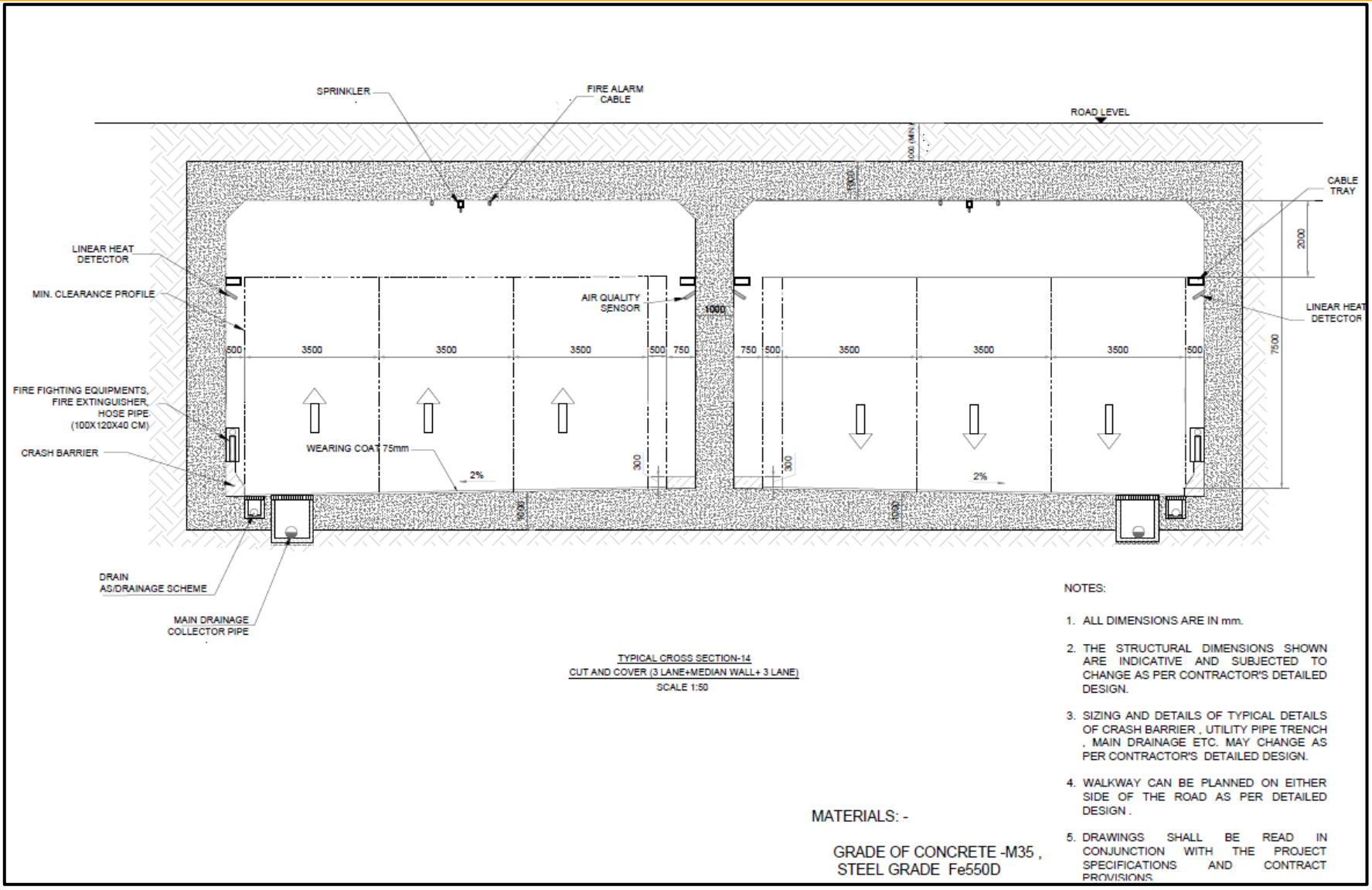


Figure 132: TCS-14, 3+3 Lane Cut & Cover Section

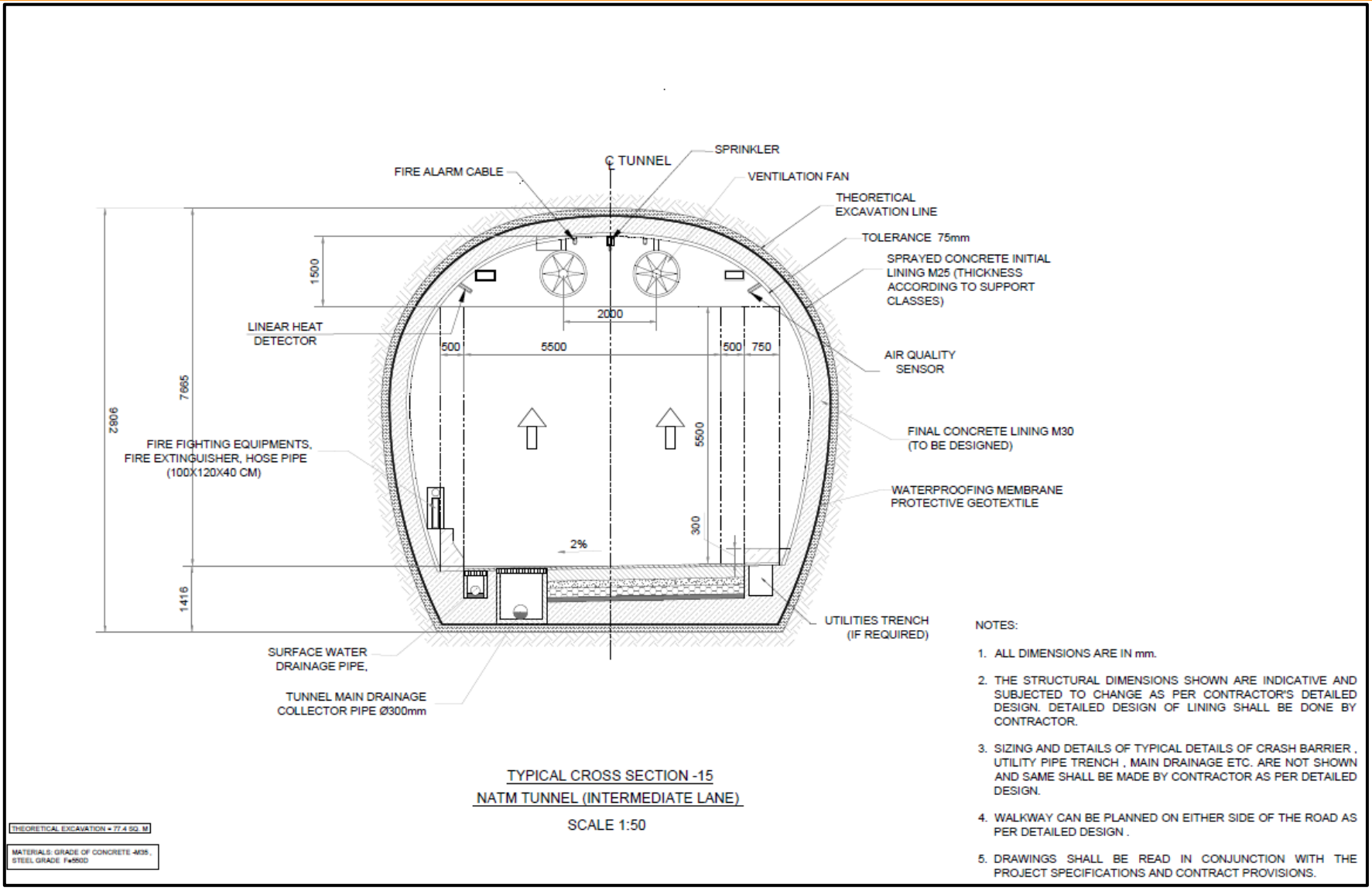


Figure 133: TCS-15, Intermediate Lane NATM Section

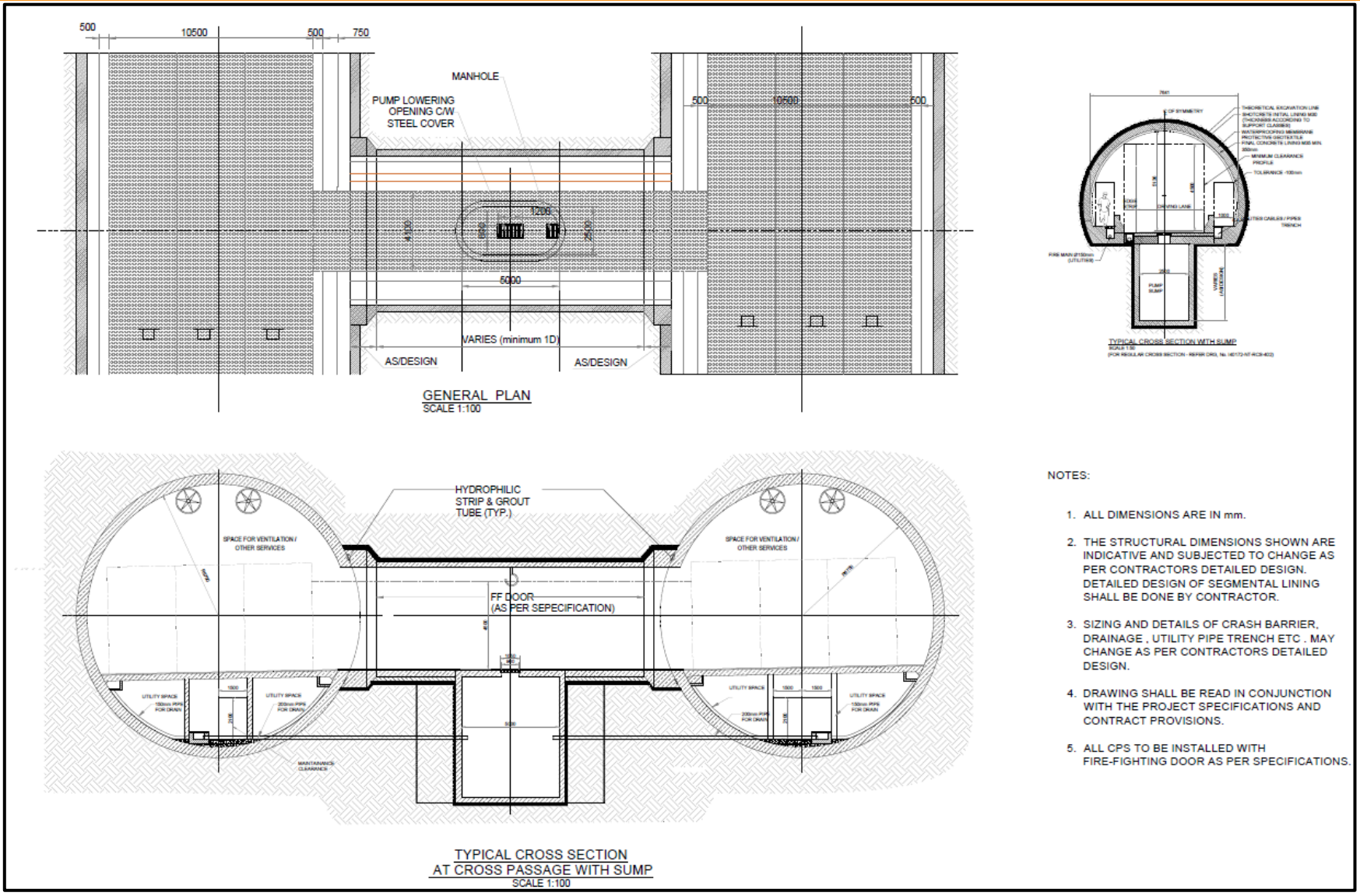


Figure 134: Typical Cross Section for Cross Passages

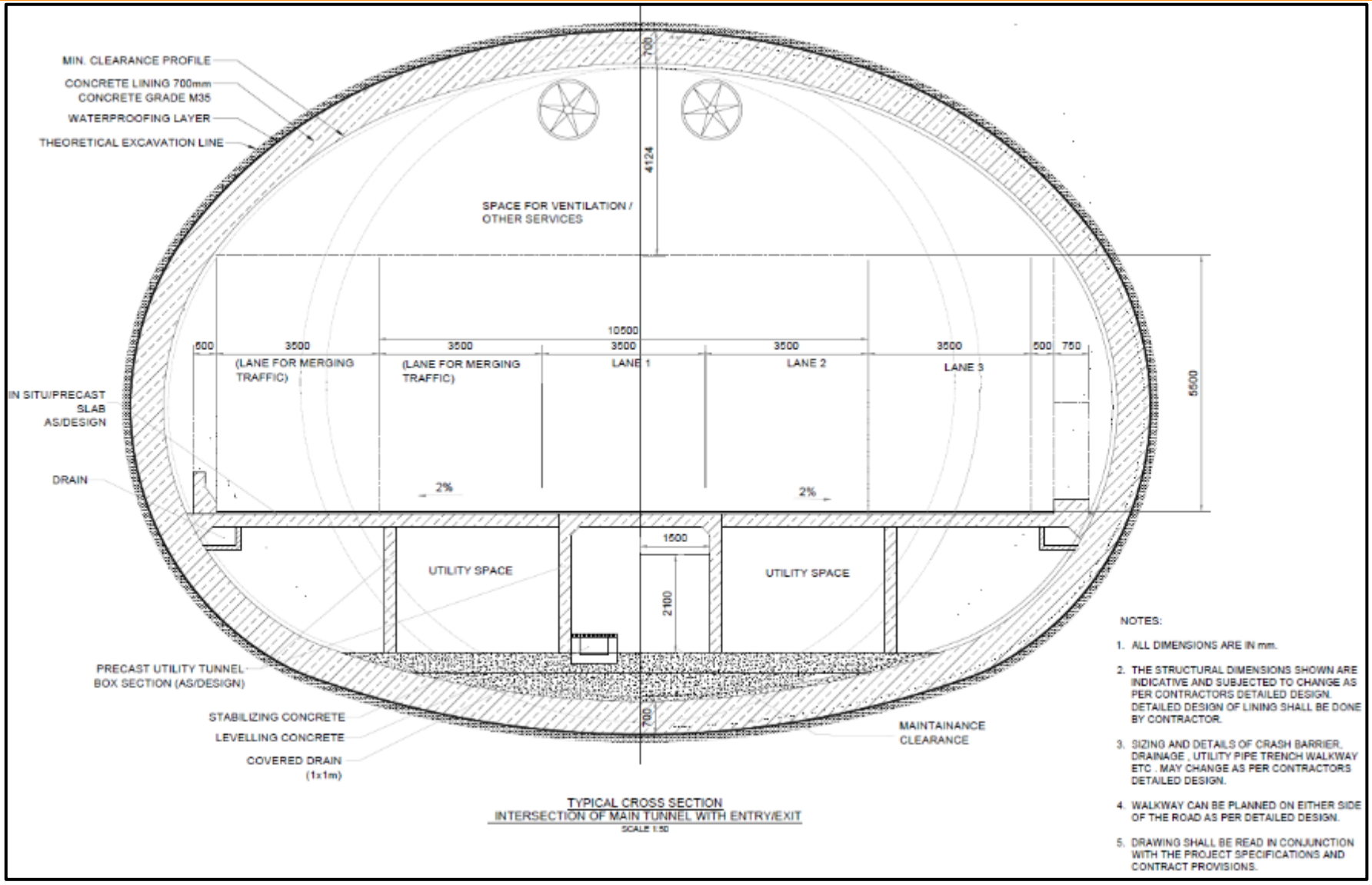


Figure 135: Typical Cross Section for merger section of Entry/ Exit Ramps & Main Tunnel

8.5 Tunnel spacing

The clear distance between the twin tubes shall be kept depending upon the type of strata and structural stability of the tunnel subject. However, the c/c spacing between the twin tubes shall not be less than two times the diameter of tunnel.

Clear distance between both tunnel: 15.4 m

C/C distance between both Tunnel: 30 m

8.6 Cross Passage

As per IRC:SP:91-2019 the twin tube tunnels shall be connected by a cross passage at every 500 m for emergency evacuation in the event of an incident/accident in one of the tubes. The cross passage shall have provision for one traffic lane, edge strip of 0.60 m, crash barriers and walkways on either side. In normal conditions the cross passage shall be closed.

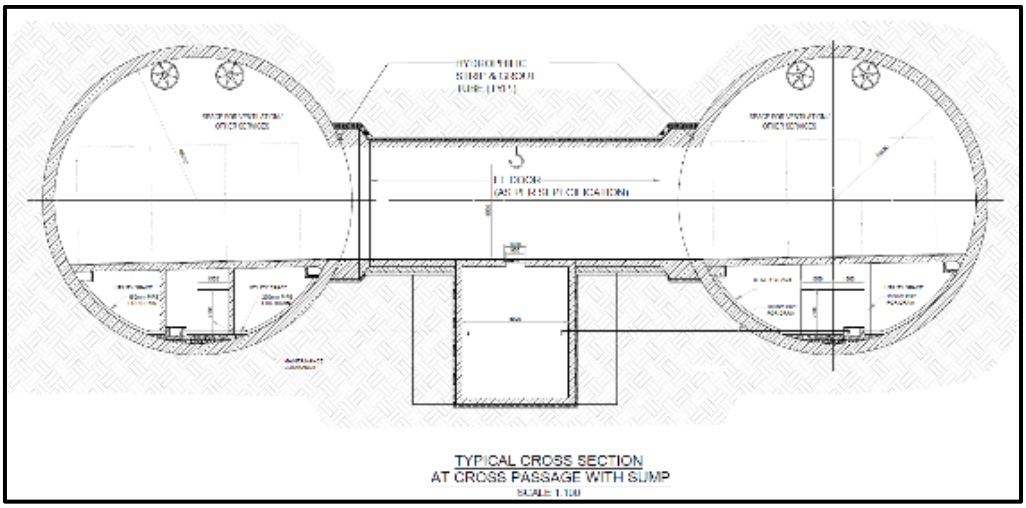


Figure 136: Typical Cross Section for Tunnel Cross Passage

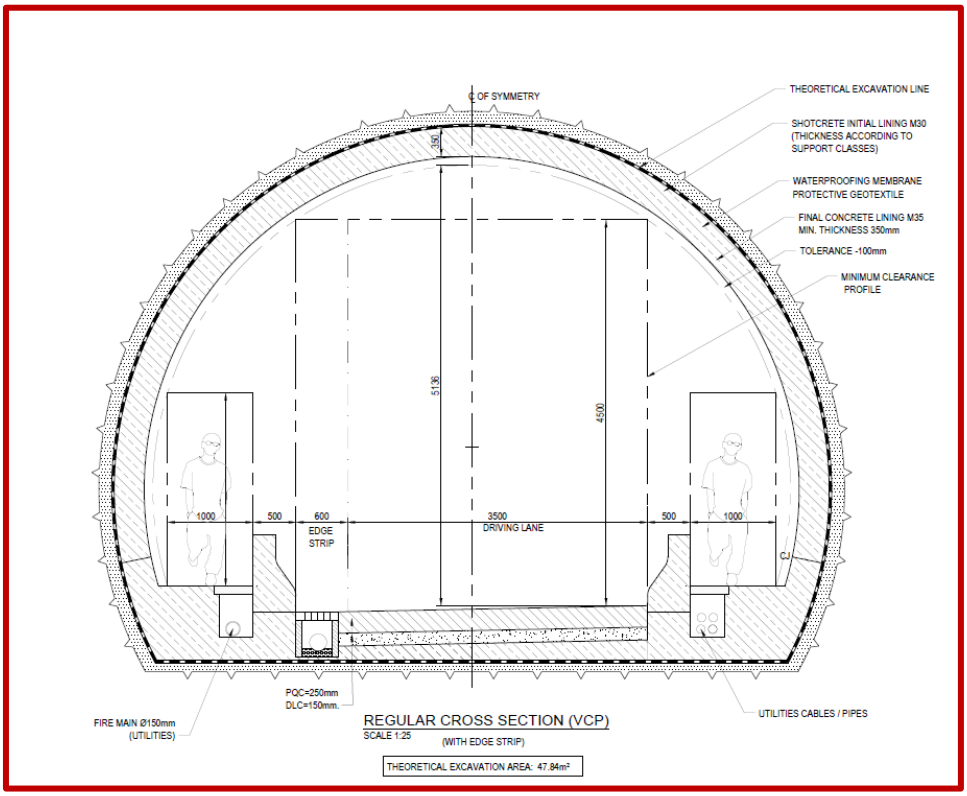


Figure 137: TCS for Tunnel Cross Passage

8.7 Water Proofing

Considering the urban environment, the tunnels in this project has been designed as watertight (tanked system) that means ground water is not allowed to drain. Different approaches for waterproofing is considered. However, depending on the construction type the following options has been considered

8.7.1 TBM bored tunnels

All TBM bored tunnels are proposed to have precast segmental lining. The joint of segmental lining i.e, radial and circumferential joints require to have composite gasket as per the project specifications. Composite type gasket shall include single strip containing hydrophilic strip pasted/ extruded over an EPDM strip. Gasket as part of the TBM operation gets compressed and provides the required water tightness.

8.7.2 b. NATM Tunnels

All NATM tunnels are proposed to have cast in situ secondary lining to be installed as per the design and construction methodology. Water tightness of NATM lining can be achieved by following method in combination or standalone.

a. Waterproofing membrane, that is applied over the primary support along with smoothening layer and geotextile fleece.

b. Sprayed membrane, that is applied by spraying over the primary support on undulated surface without smoothening layer. And it does not require geotextile fleece.

c. Waterproofing admixture, which may include crystalline admixture or similar to reduce the concrete permeability to an acceptable level as defined by the project specifications. Such admixtures also pose self-healing characteristics i.e. any moisture ingress through cracks can be blocked.

d. The treatment of construction joints using waterstop bars.

8.7.3 Cut & Cover and Ramps

All C&C tunnels and Ramps are proposed to have cast in situ box/ U structure. Water tightness of structure can be achieved by application of waterproofing membrane on the external boundary of structure and/or with addition of waterproofing admixture. All construction joints to be treated with water stop bars.

8.8 Tunnel Drainage System

The tunnel drainage system has been provided to cover all sorts of water which may reach the tunnels such as road surface spillage, cleaning water, ground water seepage, firefighting or rainwater etc. It is important to control the spills at source level, however, tunnels cannot be assumed dry at all times. Therefore, continuous drainage shall be provided to collect those water and channelize it to the designated sumps from where it can be mechanically discharged to nearest municipal drains through the project shaft.

8.8.1 Drain and sumps in Open Ramp zone:

The entry of surface ground water shall be restricted by appropriate measures in at grade highway design so that it does not reach the falling grade of ramp area and unnecessarily increase the drainage efforts of tunnel. Also, the canopy roof structure shall be installed to minimize the entry of rainwater. Still some amount of rain water and ground water seepage can find access to ramp area and same shall be collected in the side drain of ramp. A central drain in case required, may also be constructed. A sump of suitable size shall be constructed at the interface of ramp and cut & cover section and water from this sump can directed to nearest municipal drain by pumping

8.8.2 Drainage in Cut & Cover tunnels:

The cut & cover section can expect ground water seepage and road spillage from cleaning, running vehicles or firefighting. The side drainage shall run along the Cut & cover tunnels to collect the water. A central drain connecting the surface drain to carry water along the C&C stretch is proposed. The central drain of C&C section will merge with the central drain of NATM or TBM section. The pipe and manhole arrangement will remain similar to ramp section that means the manhole spacing between 50 to 75m with a size of minimum 400mm x 400mm. The side drain shall be connected with central drain at every manhole point

8.8.3 Drainage in NATM tunnels:

NATM tunnels are also designed as tanked structures i.e. all around water proofing of inner lining. Similar to C&C tunnels the sources of water inside NATM tunnels can include ground seepage, road spillage from cleaning, running vehicles or firefighting. The side drainage shall run along the NATM tunnels to collect the water. A central drain connecting the surface drain at manhole spacing to carry water along the tunnel stretch is proposed. The central drain of NATM tunnels will merge with the central drain of TBM section. The pipe and manhole arrangement will remain similar to C&C tunnels that means the manhole spacing between 50 to 75m with a size of minimum 400mm x 400mm. The side drain shall be connected with central drain at every manhole point

8.8.4 Drainage in TBM bored tunnels:

TBM bored tunnel have a large space available below the road deck. That space can be utilized to convey various projects and commissioned utilities between the shafts and to the surface. The tunnel's main drainage will run at the base of utility tunnel which shall collect all the water from NATM/ C&C tunnels and drop it in the sump situated in cross passages. At the road level sources of water in TBM tunnel are ground seepage, road spillage from cleaning, running vehicles or firefighting. The side drainage shall run along the pavement to collect these water and will drop to the central drain through a pipe running along the lining surface. The connecting pipe of minimum 150mm dia to be placed at the spacing of approximately 50m. The central drain shall be a covered drain which will have connection to sump situated at lowest points along the tunnel. Two CPs with sump between the shafts are proposed to have more efficient drainage scheme and drain size. Sump inside the CP shall be equipped with riser pipe and pump to drain the accumulated water to the surface. The pump shall be connected with SCADA for start stop cycle, which should facilitate the automatic start of sump pump as per the capacity of sump storage and pump performance. The water from sump shall be drained to nearest municipal drain through the shafts.

8.9 Vertical Shaft

A vertical shaft for a tunnel is a critical infrastructure component that connects the surface to underground passageways, serving multiple essential functions. Primarily, it provides access for workers and equipment, enabling the efficient movement of personnel and materials to and from the tunnel. Additionally, these shafts play a vital role in ventilation, ensuring a continuous flow of fresh air to maintain safe working conditions below ground. The design of a vertical shaft typically considers factors such as depth, diameter, and structural integrity, often employing methods like drilling and blasting or cut-and-cover techniques for construction. Safety is paramount, with rigorous monitoring for ground stability and water ingress, as well as clear emergency egress routes for personnel. Overall, vertical shafts are indispensable in facilitating safe and efficient underground operations in tunneling projects. Intermodal facilities are to be developed at shaft location whose details are provided later in chapter.

Vertical Shafts has been provided at five locations i.e., Hebbal, Palace Ground, Race Course, Lalbagh and Silk Board. Dimensions of Vertical shafts are 100m x 50m.

8.9.1 Refuge Parking

The Refuse Parking shall be designed and constructed in accordance with relevant standards and specifications and shall be provided at the locations as indicated above at the extreme left edge of Shaft Location.

8.9.2 Control buildings

All the shaft locations shall be developed as a 5 level intermodal Hubs which will house level for services such as SCADA and others control systems required during operation and maintenance of the project. The lowest level will have plate form for deboarding and onboarding on Electrical buses, 3rd level shall cater to car parking and upper two levels have the commercial spaces. The building shall be completed with the construction in all respects including firefighting, lighting, air conditioning and also design the control services (ventilation, firefighting etc.) for the operation and maintenance of Tunnel Highway including the development of lobby level space for internal & external vehicular movement, land scaping complete in all respects.

8.10 Traffic Control and Safety Measures

Road Marking & Traffic Signs

Road markings will be made for centre and edge lines using reflective thermoplastic paints. Appropriate road markings will also be provided at junctions and crossings. Road signs are to placed according to IRC: 67-2012. The signs are to be placed on embankment so that extreme edge of sign would be 2.0 m away from the edge of the carriageway. The location of each sign is to be decided in accordance with the guidelines there in.

Illumination

Tunnel illumination/lighting shall be designed and provided as per MoRTH Guidelines for

Expressway, Chapter 13.5 for Tunnel Lighting.

Tunnel Furnishing

Provisions shall be made for installation of tunnel furnishing such as sign boards, firefighting arrangements, cable trays for telephone and power lines etc. in consultation with relevant local authorities.

Signages and Carriageway Markings

Variable messages signs inside the tunnel shall be provided for the information of traffic of lane blockage/closure due to incidents related to vehicles/non-vehicles, weather and human hazards etc. or maintenance operations as also to warn of possible hazard ahead due to any abnormal situation. Signage system shall be complemented by providing traffic lights above each lane at the entry portal end and inside. Signages indicating distance travelled, distance/ direction to an exit on evacuation route shall be provided inside the tunnel.

Tunnel carriageway markings consisting of a discontinuous line separating the traffic lanes and continuous line separating the lateral traffic lane from the paved shoulder and emergency lay-bye shall have good day/night visibility and conform to IRC:35. The markings shall be done by means of self-propelled machine which has a satisfactory cut-off capable of applying broken line automatically.

Ventilation

Tunnel ventilation systems should provide adequate in-tunnel air quality during normal and congested traffic operations and support the self-evacuation and rescue efforts during emergency incidents. Separately, the tunnel ventilation capacity requirements for emergency ventilation (typically for the control of smoke and hot gases during fire) must also be assessed and the system designed accordingly.

Detailed design of ventilation shall be carried out as per IRC:SP:91 keeping in view the length, shape, size, tunnel environs and complexion of the likely traffic for which tunnel has been designed. The details of design of Tunnel Ventilation system has been given in Volume II-D.

8.11 Inter Model Interchange Hubs

As part of the project, shafts along with Intermediate stations are proposed at five locations along the tunnel alignment: Hebbal Junction, Mekhri Circle, Race Course Road, Lalbagh, and Silk Board Junction. These shafts serve critical purposes, including ventilation, emergency services, and support facilities. Each shaft will be designed to accommodate essential services and ensure compliance with safety and operational standards.

Each of these locations will feature:

- **Bus Stands**: To facilitate seamless integration with public transport.
- **Auto and Taxi Stands**: To enhance last-mile connectivity for commuters.
- **Landscaping**: To create aesthetically pleasing urban spaces.
- **Commercial Activity at Podium Level**: Retail and service outlets will cater to commuters' needs while generating economic activity.

Shaft Extension: Below the podium level, the shaft will extend approximately 30 meters down to connect to the tunnel, housing critical services such as ventilation, utility management, and emergency

infrastructure.

8.11.1 Need of Intermediate Stations

The intermediate stations at Hebbal Junction, Mekhri Circle, Race Course, Lalbagh, and Central Silk Board play a pivotal role in the success of the tunnel project by serving as critical access and egress points for passengers. These stations are strategically located near major urban and transit hubs to maximize connectivity and usage. They are designed to provide essential passenger amenities, including retail spaces, waiting areas, ticketing counters, and restrooms, ensuring a comfortable and user-friendly commuting experience. Parking facilities at these stations accommodate private vehicles, encouraging park-and-ride behaviour and reducing surface-level congestion, especially at high-traffic areas like Hebbal Junction and Central Silk Board.

In addition to passenger convenience, these stations support the operational requirements of the tunnel system. They house essential services and utilities such as power, ventilation, and drainage, while also acting as monitoring and maintenance hubs. From a safety perspective, they provide critical emergency response infrastructure, such as escape routes and firefighting access, which is vital in densely populated areas like Lalbagh and Race Course. The stations also facilitate traffic redistribution by offering an efficient alternative to road-based transport, alleviating notorious traffic bottlenecks at places like Mekhri Circle.

Moreover, these stations are designed to integrate seamlessly with Bengaluru's broader transportation network, enhancing multimodal connectivity. For instance, Hebbal Junction and Central Silk Board, being major transit nodes, will connect the tunnel system with buses, metro, and rail, supporting regional mobility. The inclusion of retail spaces and commercial activities promotes Transit-Oriented Development (TOD), transforming these stations into vibrant urban nodes while generating additional revenue through public-private partnerships. This revenue offsets project costs and boosts economic viability.

The intermediate stations not only ensure the functional success of the tunnel project but also contribute significantly to Bengaluru's urban development by improving mobility, reducing congestion, enhancing safety, and fostering sustainable transit practices. They exemplify a holistic approach to urban infrastructure that prioritizes both commuter convenience and the city's long-term development goals.

8.11.2 Existing situation analysis at the five locations

8.11.2.1 Hebbal Junction

Figure 138: Shaft at Hebbal Junction

Hebbal Junction is one of Bengaluru's busiest traffic nodes, serving as a critical gateway to northern Bengaluru and the primary corridor to Kempegowda International Airport. Its strategic location at the

confluence of several key roads makes it a focal point for both intra-city and inter-city traffic. However, the junction is plagued with significant mobility and infrastructure challenges.

a) Traffic Congestion

- **High Traffic Volumes**: Hebbal Junction experiences extremely high traffic volumes, with thousands of vehicles passing through daily. This includes private cars, two-wheelers, public buses, and heavy goods vehicles.
- **Peak Hour Gridlock**: Congestion is particularly severe during peak hours (morning and evening), with vehicles queuing for long durations on feeder roads and the Outer Ring Road. Delays often exceed 30 minutes during rush hours.
- **Insufficient Road Infrastructure**: The existing Hebbal Flyover, though designed to alleviate congestion, is overburdened and unable to handle the current traffic demand. This leads to traffic spillovers onto adjacent roads.

b) Connectivity Challenges

- **Multiple Converging Roads**:
  - Outer Ring Road (ORR): Facilitates intra-city movement and connects to major hubs like Yeshwanthpur, KR Puram, and Sarjapur.
  - Ballari Road (NH 44): Serves as the arterial route to the airport and northern Karnataka cities.
  - Connecting Roads: Local roads from residential areas like RT Nagar and Sanjaynagar merge at the junction, adding to the congestion.
- **Poor Integration with Public Transport**: Despite its importance, Hebbal Junction lacks seamless integration with BMTC bus services, metro connectivity, and other public transport modes. Commuters often face difficulties switching between modes.

c) Inadequate Pedestrian and Cycling Infrastructure

- **Lack of Safe Pedestrian Facilities**: Sidewalks are either missing or poorly maintained, forcing pedestrians to navigate through busy vehicle lanes.
- **Cyclist Challenges**: With no dedicated cycling lanes, cyclists must share space with motorized vehicles, increasing the risk of accidents.

d) Parking Issues

- **Illegal Parking**: The area around Hebbal Junction lacks organized parking spaces, leading to haphazard and unauthorized parking on roadsides.
- **Spillover Effect**: Vehicles parked on approach roads and flyover ramps further exacerbate traffic congestion.

e) Impact on Surrounding Areas

- **Residential and Commercial Zones**: Hebbal Junction is surrounded by densely populated residential areas such as RT Nagar, Nagavara, and Hebbal. Commercial establishments, including tech parks and retail hubs, also add to traffic demand.
- **Growth of Airport Traffic**: The junction serves as the primary route to Kempegowda International Airport. Increasing air passenger traffic adds to vehicular demand, especially during early morning and late-night hours.

f) Safety Concerns

- **High Accident Rates**: The chaotic nature of traffic flow, combined with poor road design and lack of enforcement, results in frequent accidents.
- **Emergency Response Delays**: Congestion at Hebbal Junction often delays emergency services like ambulances and fire trucks, which rely on this critical corridor for swift movement.

g) Infrastructure Limitations

- **Underutilization of Existing Flyover**: The Hebbal Flyover was originally designed for lower traffic volumes and now struggles to accommodate the increasing demand. The single-tier flyover layout limits its capacity.
- **No Dedicated Bus Lanes**: BMTC buses must share lanes with other vehicles, leading to delays in public transport services.

8.11.2.2 Mekhri Circle

Figure 139: Shaft at Mekri Cirle.

Mekhri Circle is a key transit point in Bengaluru, connecting northern Bengaluru to the city center through Ballari Road (NH 44). It serves as a vital junction for commuters traveling between residential areas like Sadashivanagar and RT Nagar and commercial zones such as MG Road, Vasanth Nagar, and Cunningham Road. Despite its importance, the area faces several challenges that hinder smooth traffic flow and urban functionality.

a) Traffic Congestion

- **High Traffic Density**: Mekhri Circle handles heavy traffic, including private cars, two-wheelers, public buses, and goods vehicles. Peak-hour congestion is particularly severe, with delays lasting up to 20–30 minutes during mornings and evenings.
- **Underpass Limitations**: The Mekhri Circle underpass, designed to alleviate surface-level congestion, is overburdened and struggles to accommodate increasing vehicular loads, leading to bottlenecks.
- **Feeder Road Overflows**: Feeder roads from Sadashivanagar, Palace Grounds, and Jayamahal Road add to the traffic burden, contributing to gridlocks

b) Public Transport Issues

- **BMTC Bus Operations**: While BMTC buses pass through Mekhri Circle, there is no dedicated infrastructure such as bus bays or bus priority lanes, causing delays for public transport users.
- **Lack of Multimodal Integration**: There is no direct integration with metro services or other public transport systems, making it difficult for commuters to switch between modes efficiently.

c) Pedestrian and Cyclist Challenges

- **Unsafe Pedestrian Environment**: Sidewalks are either too narrow or encroached upon, leaving pedestrians to navigate through busy traffic.
- **Cycling Infrastructure**: There are no dedicated cycling lanes, making the area unsafe for non-motorized transport users.

d) Parking Issues

- **Haphazard Parking**: The lack of designated parking spaces around Mekhri Circle results in unauthorized parking on feeder roads and near commercial establishments.
- **Increased Road Occupancy**: Parked vehicles encroach on already constrained road space, further aggravating congestion.

e) Safety Concerns

- **Frequent Accidents**: The chaotic nature of traffic, combined with the lack of proper signage and road discipline, leads to frequent minor and major accidents.
- **Emergency Delays**: Traffic congestion on Ballari Road and surrounding feeder roads delays the movement of emergency vehicles, including ambulances and fire services.

f) Connectivity Challenges

- **Critical Node for Airport Traffic**: Mekhri Circle serves as a major transit point for vehicles heading to Kempegowda International Airport. Congestion at the junction often causes delays for airport-bound traffic.
- **Restricted Access to Nearby Areas**: Localities like Sadashivanagar and Jayamahal face accessibility issues due to the clogged road network, impacting residents' mobility.
- **Inefficient Flow**: The lack of advanced traffic management systems leads to inefficiencies in vehicular movement, with traffic signals and roundabouts often unable to handle peak-hour demand.

g) Impact on Surrounding Areas

- **Residential Impact**: Sadashivanagar, a prime residential area near Mekhri Circle, is directly affected by traffic congestion and noise pollution.
- **Commercial Activity**: Businesses in the area face logistical challenges due to poor accessibility and parking shortages.
- **Tourist Attractions**: Proximity to Palace Grounds and Vasanth Nagar means additional traffic inflow during events or functions, worsening congestion.

h) Infrastructure Constraints

- **Underpass Design Limitations**: The Mekhri Circle underpass caters only to through traffic on Ballari Road, while vehicles from other directions face delays at the surface-level intersection.
- **No Dedicated Freight Corridor**: The junction often sees freight vehicles competing for space with passenger traffic, further slowing movement.

8.11.2.3 Race Course

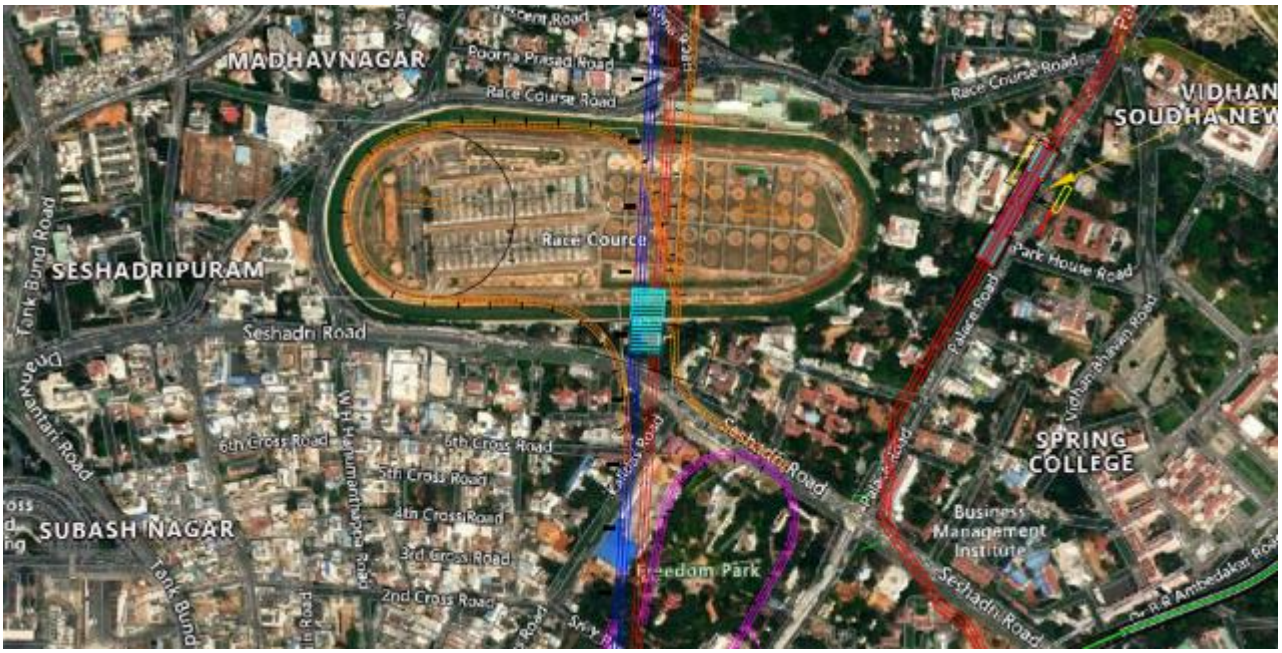


Figure 140: Shaft at Race-Course

The Race Course area in Bengaluru is a prominent urban node, strategically located near major transit and administrative hubs. It houses the Bangalore Turf Club (BTC) and lies in proximity to the Bengaluru City Railway Station, Majestic Bus Terminal, and key commercial zones like Cunningham Road and MG Road. Despite its importance, the area faces significant urban and mobility challenges, making it a prime candidate for infrastructure improvement

a) Traffic Congestion

- **High Vehicular Volume**: The roads around Race Course witness a heavy mix of traffic, including private cars, two-wheelers, buses, and goods vehicles. Peak-hour congestion is severe, especially on Race Course Road, which serves as a major arterial road connecting north and central Bengaluru.
- **Proximity to Majestic Area**: The area's closeness to Bengaluru's central transit hub (Majestic) amplifies traffic volumes, as vehicles from the railway station, intercity bus terminal, and metro stations converge here.
- **Event-Based Traffic**: Events at the Bangalore Turf Club periodically result in sudden spikes in traffic, overwhelming the already burdened road network.

b) Public Transport Challenges

- **Overcrowded Bus Network**: BMTC buses passing through the area often face delays due to congestion, reducing the reliability of public transport.
- **Lack of Direct Metro Integration**: Although the area is near metro lines, there is no direct integration of Race Course Road with the metro system, forcing commuters to rely on other modes of transit.
- **Inefficient Intermodal Connectivity**: Commuters transitioning between buses, trains, and other modes face challenges due to the lack of seamless connections and clear signage.

c) Pedestrian and Cyclist Issues

- **Inadequate Footpaths**: Sidewalks along Race Course Road are narrow, poorly maintained, and often encroached upon by vendors and parked vehicles, leaving little space for pedestrians.
- **Unsafe Crossings**: The absence of pedestrian bridges or underpasses makes crossing the road hazardous, especially during peak hours.

- **Cycling Infrastructure**: There are no dedicated cycling lanes, discouraging non-motorized transport and increasing the risk for cyclists sharing the road with motor vehicles.

d) Parking Issues

- **Haphazard Parking**: Unauthorized parking is rampant on Race Course Road and surrounding areas, particularly during events at the Turf Club.
- **Inadequate Parking Infrastructure**: The lack of organized parking spaces leads to vehicles spilling over onto roads, further reducing traffic flow efficiency.

e) Safety Concerns

- **Frequent Accidents**: The chaotic traffic flow and absence of proper pedestrian crossings result in frequent accidents involving vehicles and pedestrians.
- **Emergency Delays**: The congestion around the area often delays the movement of emergency vehicles, such as ambulances heading to nearby hospitals.

f) Connectivity Issues

- **Critical Transit Node**: Race Course Road connects key areas such as Malleshwaram, MG Road, and the Majestic area, making it vital for commuter traffic. Congestion at this location creates ripple effects across the city's road network.
- **Airport Traffic**: The road serves as a corridor for travelers heading to and from Kempegowda International Airport, adding to its traffic load.

g) Impact on Nearby Areas

- **Commercial Zones**: The proximity to commercial areas like Cunningham Road and MG Road increases traffic inflow, especially during business hours.
- **Residential Areas**: Nearby residential neighborhoods, including parts of Seshadripuram, are affected by noise, air pollution, and restricted mobility due to the constant traffic flow.
- **Tourism and Leisure Activities**: The Turf Club and nearby hotels attract tourists, further adding to the area's vehicular and pedestrian traffic.

h) Infrastructure Constraints

- **Lack of Advanced Traffic Management**: The existing traffic signal systems are outdated and unable to adapt dynamically to changing traffic volumes.
- **Insufficient Road Width**: Race Course Road has limited capacity to handle the increasing traffic demand, with no scope for road widening due to surrounding developments.

8.11.2.4 Lalbagh

Figure 141: Shaft at Lalbagh

Lalbagh, located in the heart of Bengaluru, is one of the city's most iconic landmarks, known for its botanical gardens, heritage value, and recreational significance. It attracts thousands of visitors daily, including tourists, local residents, and students. Despite its prominence, the area around Lalbagh faces significant mobility and infrastructure challenges, exacerbating traffic congestion and urban inefficiencies.

a) Traffic Congestion

- **High Visitor Footfall**: Lalbagh Main Gate and its surrounding roads experience heavy traffic due to the constant flow of visitors, especially during weekends, holidays, and annual events like the Flower Show.
- **Narrow Access Roads**: Roads like Lalbagh Road and JC Road, which provide primary access to the gardens, are narrow and unable to accommodate the high volume of vehicles, leading to frequent bottlenecks.
- **Intersection Overload**: The proximity of the Lalbagh West Gate to major intersections like Minerva Circle and Wilson Garden Junction results in a concentration of traffic, causing delays and long queues.

b) Public Transport Issues

- **Overloaded Bus Stops**: BMTC buses serving the area often struggle with overcrowding, and there is a lack of designated bus bays to manage the high number of passengers.
- **Limited Metro Access**: While the Lalbagh Metro Station is nearby, the connectivity between the metro and Lalbagh's main gates is inadequate, forcing visitors to rely on private vehicles or autos.
- **Lack of Feeder Services**: Absence of efficient last-mile connectivity options like shuttle services between the metro station and Lalbagh's multiple gates creates accessibility challenges.

c) Parking Issues

- **Inadequate Parking Facilities**: Parking spaces near Lalbagh are limited, and the existing lots are often overwhelmed, especially during peak visitation periods.
- **Unauthorized Parking**: Vehicles are frequently parked along roadsides and in unauthorized areas, reducing road capacity and causing additional congestion.
- **Spillover into Residential Areas**: The lack of designated parking zones leads to parking overflow into nearby residential streets, inconveniencing local residents.

d) Pedestrian and Cyclist Challenges

- **Encroached Footpaths**: Sidewalks near Lalbagh are often encroached upon by street vendors and parked vehicles, forcing pedestrians to walk on busy roads.
- **Unsafe Crossings**: The roads surrounding Lalbagh lack sufficient pedestrian crossings or traffic-calming measures, making it dangerous for visitors to access the gardens.
- **No Cycling Infrastructure**: Despite the popularity of cycling within Lalbagh, there are no dedicated cycling lanes or facilities in the surrounding areas.

e) Connectivity Issues

- **Key Urban Node**: Lalbagh is located near major commercial and residential zones, making it a significant transit point for daily commuters and visitors. Congestion in the area disrupts traffic flow on surrounding roads like KR Road, JC Road, and Lalbagh Road.
- **Regional Connectivity**: Being close to central Bengaluru, the area acts as a link between southern and central parts of the city, further increasing traffic demand.

f) Impact on Surrounding Areas

- **Commercial Activity**: Shops, eateries, and vendors near Lalbagh attract additional vehicular and pedestrian traffic, adding to congestion.
- **Residential Areas**: Neighborhoods like Wilson Garden and Basavanagudi are affected by the

traffic and parking overflow, impacting the quality of life for local residents.

- **Tourism and Education**: Lalbagh's role as a tourist attraction and educational site for students adds to the complexity of managing mobility in the area.

g) Infrastructure Constraints

- **Limited Road Capacity**: The surrounding road network lacks the capacity to handle the high volume of vehicles, with minimal scope for expansion due to dense urban development.
- **Outdated Traffic Management**: The area relies on conventional traffic lights and lacks advanced traffic management systems, resulting in inefficient traffic flow.
- **No Dedicated Freight Corridors**: Commercial delivery vehicles accessing nearby shops and businesses share road space with passenger vehicles, slowing down traffic.

8.11.2.5 Central Silk Board

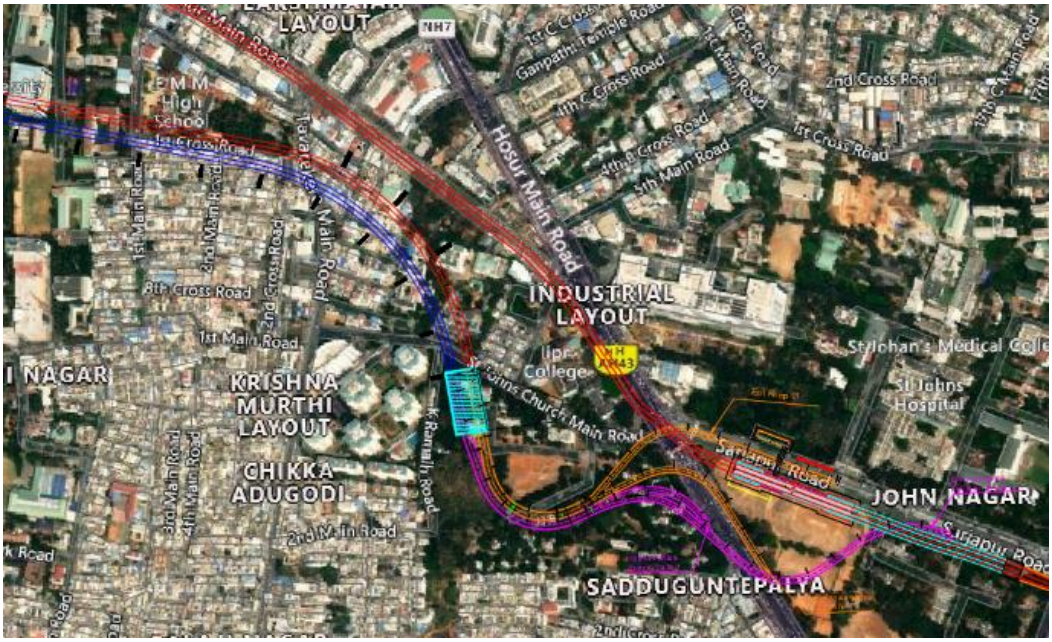


Figure 142: Shaft at Silk Board

Central Silk Board (CSB) is one of Bengaluru's most infamous traffic choke points and a critical transit node. Situated at the junction of the Outer Ring Road (ORR) and Hosur Road (NH 44), it connects southeastern Bengaluru to the IT corridor, residential neighborhoods, and the city center. Despite its importance, the area faces severe mobility and infrastructure challenges, making it a hotspot for urban inefficiencies.

a) Traffic Congestion

- **High Traffic Volumes**: Central Silk Board handles one of the highest vehicular traffic volumes in Bengaluru, with a mix of private cars, two-wheelers, BMTC buses, cabs, and heavy goods vehicles.
- **Peak Hour Gridlocks**: Congestion is especially severe during peak hours, with vehicles queuing for up to 45–60 minutes, causing delays across surrounding roads.
- **Outer Ring Road Bottleneck**: The ORR, which connects major IT hubs like Marathahalli and Whitefield, funnels massive traffic through CSB, leading to frequent gridlocks.
- **Intersection Overload**: The junction handles vehicles from multiple directions, including Hosur Road, Silk Board Flyover, and feeder roads from nearby residential and commercial areas, creating chaotic traffic flows.

b) Public Transport Challenges

- **Overcrowded BMTC Bus Stops**: Central Silk Board is a major node for BMTC buses, but the bus stops lack adequate space and infrastructure to handle the passenger load efficiently.
- **Limited Metro Connectivity**: The nearest metro station (Rashtriya Vidyalaya Road as of now, Since the Yellow Line metro is not operational yet) is far from the junction, and the lack of direct metro access forces commuters to rely on road transport.
- **First and Last-Mile Connectivity Issues**: Feeder services for buses and metro are inadequate, leaving commuters dependent on private vehicles and shared cabs, adding to congestion.

c) Parking Issues

- **Unauthorized Parking**: The lack of organized parking facilities near CSB leads to vehicles being parked along roads and service lanes, further reducing road capacity.
- **Overflow from Adjacent Areas**: Parking demand from nearby IT parks, commercial establishments, and residential areas spills over onto roads near the junction.

d) Pedestrian movement

- **Unsafe Pedestrian Environment**: The heavy traffic and lack of dedicated pedestrian infrastructure make it extremely hazardous for people to walk across the junction.
- **Encroached Footpaths**: Existing sidewalks are narrow, poorly maintained, and often encroached upon by street vendors or illegally parked vehicles.

e) Environmental Concerns

- **Air Pollution**: Prolonged idling in traffic jams contributes to high levels of air pollution, making CSB one of the most polluted areas in Bengaluru.
- **Noise Pollution**: Constant honking and vehicular movement create a noisy environment, affecting both commuters and nearby residents.
- **Heat Island Effect**: The lack of green cover and excessive vehicular emissions contribute to localized temperature increases, exacerbating urban heat island effects.

f) Safety Concerns

- **Frequent Accidents**: The chaotic traffic flow and absence of proper lane discipline result in frequent accidents involving both vehicles and pedestrians.
- **Emergency Delays**: Ambulances and fire services face significant delays while navigating through the junction, posing risks during emergencies.

g) Connectivity Challenges

- **Key Transit Node**: CSB connects the IT corridor with other parts of Bengaluru, serving as a critical link for commuters traveling between areas like Electronic City, Marathahalli, and Whitefield. Congestion at this point disrupts citywide traffic flow.
- **IT Corridor Dependence**: With thousands of tech workers commuting daily, the area sees heavy traffic inflows and outflows, especially during office hours.
- **Regional and Intercity Traffic**: Being located on NH 44, the junction also handles intercity traffic bound for Tamil Nadu and other southern states, adding to the load.

h) Impact on Surrounding Areas

- **Residential Neighborhoods**: Areas like HSR Layout, BTM Layout, and Bommanahalli face congestion spillovers, parking issues, and pollution due to the proximity to CSB.
- **Commercial Activity**: Nearby commercial zones and tech parks add significant vehicular and pedestrian traffic to the already overburdened junction.
- **School and Institutional Impact**: Schools and colleges in the vicinity experience delays for

students and staff due to traffic snarls.

i) Infrastructure Constraints

- **Flyover Limitations**: The Silk Board Flyover, designed to decongest the area, is insufficient to handle current traffic volumes and offers no segregation of local and through traffic.
- **Inadequate Road Width**: Roads and service lanes near the junction lack the capacity to handle the increasing vehicular demand, with little scope for widening due to surrounding developments.

8.11.3 Requirements at the Terminal / Intermediate Stations

- **Integration with Public Transport**: Seamless connectivity with the existing BMTC bus services and provision for feeder services to nearby residential and commercial areas.
- **Auto and Taxi Stands**: Organized areas for auto-rickshaws and taxis to improve last-mile connectivity.
- **Pedestrian Infrastructure**: Designated walkways, elevators, and escalators to ensure smooth pedestrian movement and accessibility for people with disabilities.
- **Retail and Commercial Spaces**: Small retail outlets, food courts, and kiosks to cater to passenger needs.
- **Emergency Facilities**: First aid rooms, fire safety systems, and evacuation plans for emergency situations.
- **Multi-modal Integration at (Hebbal Junction, Mekhri Circle and Central Silk Board)**: Direct links to bus and railway networks, ensuring easy transfer between different modes of transport.
- **Parking Infrastructure**: Sufficient parking spaces for private vehicles, with clear segregation for long-term and short-term parking needs.
- **Green Features**: Energy-efficient lighting, rainwater harvesting, and landscaping to enhance the terminal's sustainability.
- **Access Control**: Managed entry and exit points to ensure smooth flow of passengers and vehicles.

8.11.4 Details about the Facilities

a) **Podium-Level Features**

- **Bus Stands**: Dedicated bays for BMTC buses, ensuring smooth boarding and alighting processes.
- **Auto and Taxi Stands**: Organized areas to facilitate last-mile connectivity, reducing road clutter and enhancing commuter convenience.
- **Skywalk**: Connecting the Shaft at Mekhri circle and the Nearest metro station, which help in the movement of Pedestrian and also buggies.
- **Retail and Commercial Spaces**: Shops, kiosks, food courts, and essential service outlets to cater to daily commuter needs and generate economic activity.
- **Landscaped Plazas**: Open areas with green spaces, seating, and pedestrian pathways to create a relaxing urban environment.
- **Drop-Off Zones**: Designated zones for private vehicles and shared mobility options for quick and efficient passenger movement.

b) **Parking Infrastructure**

- **Car Parking**: Ample parking facilities for four-wheelers and two-wheelers (at podium level), with separate zones for short-term and long-term parking.
- **EV Charging Stations**: Dedicated spaces for electric vehicle charging to promote sustainable mobility.

c) **Safety and Accessibility Features**

- **Emergency Exits**: Strategically placed and clearly marked escape routes for quick evacuation during emergencies.
- **Surveillance Systems**: CCTV cameras and security personnel to ensure passenger safety.
- **Universal Accessibility**: Elevators, escalators, ramps, and tactile pathways for differently-abled and elderly passengers.

8.11.5 Facilities Inside the Shaft

a) **Ventilation Systems**

- **Air Quality Management**: Advanced ventilation systems to maintain optimal air quality within the tunnel and shafts.
- **Exhaust Systems**: High-capacity exhaust systems to remove pollutants and ensure safe air circulation.

b) **Emergency Infrastructure**

- **Fire Suppression Systems**: Fire detection and suppression systems to handle emergencies effectively.
- **Emergency Lifts**: High-capacity lifts for evacuation and movement of personnel and equipment.

c) **Utility Services**

- **Power Supply Systems**: Backup power generators and uninterrupted power supply units.
- **Water Management**: Systems for drainage, potable water supply, and firefighting water reserves.
- **Communication Systems**: Intercoms and emergency communication systems for coordination during critical situations.

8.11.6 Transit-Oriented Development (TOD)

Transit-Oriented Development (TOD) is a planning and design approach that promotes high-density, mixed-use development within a walkable distance of public transit stations. It integrates land use and transportation planning to encourage public transit usage, reduce reliance on private vehicles, and create vibrant, sustainable urban environments. TOD prioritizes pedestrian and bicycle-friendly infrastructure, public spaces, and seamless connectivity between transit stations and surrounding neighborhoods.

8.11.6.1 Need for TOD in the Tunnel Project

The proposed tunnel project in Bengaluru, along with its five intermediate stations (Hebbal Junction, Mekhri Circle, Race Course, Lalbagh, and Central Silk Board), provides a significant opportunity to incorporate TOD principles. The following points outline the need for TOD in this project:

- **Encouraging Public Transit Use**

  TOD can increase the efficiency and usage of the proposed tunnel network by creating well-connected and vibrant urban spaces around the intermediate stations. High-density development near these stations will promote public transit as the preferred mode of transportation, reducing congestion on roads and the carbon footprint.

- **Reducing Traffic Congestion**

  Bengaluru faces severe traffic congestion, especially around major intersections and transit hubs. TOD can alleviate this issue by reducing the dependency on private vehicles through improved public transport infrastructure and creating mixed-use developments that bring residential, commercial, and recreational activities closer to transit stations.

- **Efficient Land Use**

  TOD optimizes land use by focusing development around transit stations, preventing urban sprawl,

and ensuring that land is utilized effectively. This approach can help maximize the potential of land around the five intermediate stations, integrating housing, offices, and retail spaces into a cohesive urban environment.

- **Walkable and Liveable Neighbourhoods**

  TOD emphasizes pedestrian-friendly infrastructure, such as walkways, bicycle lanes, and safe crossings, which enhance the liability of neighbourhoods. This aligns with the need for creating well-connected and accessible environments around the intermediate stations.

- **Economic Growth**

  TOD can drive economic growth by attracting businesses, investors, and tourists to areas around the transit stations. The presence of mixed-use developments, retail spaces, and public amenities can generate employment opportunities and stimulate the local economy.

- **Sustainability and Climate Resilience**

  By reducing reliance on private vehicles and promoting compact urban development, TOD contributes to environmental sustainability. It minimizes energy consumption, reduces greenhouse gas emissions, and helps cities adapt to climate change.

- **Seamless Multimodal Integration**

  TOD ensures smooth integration between different modes of transport, such as metro, buses, bicycles, and pedestrian pathways. For the tunnel project, TOD can enhance connectivity between the proposed stations and the city's existing and future transit systems, ensuring last-mile connectivity.

- **Enhanced Real Estate Value**

  Proximity to well-designed transit stations increases the value of surrounding properties. TOD around the five proposed stations can attract premium residential and commercial developments, creating a thriving urban landscape.

Figure 143: TOD Components

8.11.6.2 Application of TOD in the Project

1. **Hebbal Junction**: High-density residential and commercial development integrated with bus services and proposed metro lines.
2. **Mekhri Circle**: Mixed-use development to balance residential areas with retail and office spaces, supported by pedestrian pathways.
3. **Central Silk Board**: Employment hubs and residential developments supporting the IT corridor and commuter demand.

8.11.7 Codes and Applicable Bye-laws

8.11.7.1 Bengaluru Development Authority (BDA) Guidelines

The Bengaluru Development Authority (BDA) guidelines, as outlined in the **Master Plan 2031**, govern the planning and development of urban infrastructure projects to ensure sustainable growth and efficient land use. For the Bengaluru Tunnel Project, the following BDA guidelines are applicable:

a) **Land Use and Zoning Regulations**:

- The alignment and terminals of the tunnel must comply with the designated land use categories (e.g., transportation, commercial, or public utility) specified in the zoning plan.
- Any changes to the existing land use must be approved through the appropriate zoning reclassification process.

b) **Setbacks and Building Lines**:

- Terminals and shafts must adhere to prescribed setbacks to ensure safety and compatibility with nearby structures.
- Adequate buffer zones must be maintained between the shafts and sensitive areas like residential zones, heritage sites, and water bodies.

c) **Height Restrictions**:

- Building heights around terminals must comply with aviation safety and heritage conservation norms, especially near Lalbagh and Race Course.

d) **Traffic and Transportation Integration**:

- Terminals should facilitate seamless connectivity with metro stations, bus stops, and major roads.
- Provisions for parking, pedestrian pathways, and cycle tracks must align with BDA's sustainable transport goals.

e) **Public Amenities**:

- Adequate public amenities, such as restrooms, drinking water facilities, and first aid rooms, should be included in the terminal designs.

Table 86: round coverage and FAR ratio for Public and Semi Public Zone as per BDA 2031

Sr. No.	Size od Plot (sqm)	Max Ground Coverage	Max Allowable FAE
1	Up to 500	6%	1.5
2	Up to 1000	55 %	1.75
3	Above 1000 Up to 2000	50 %	2.00
4	Up to 2000	45 %	2.25

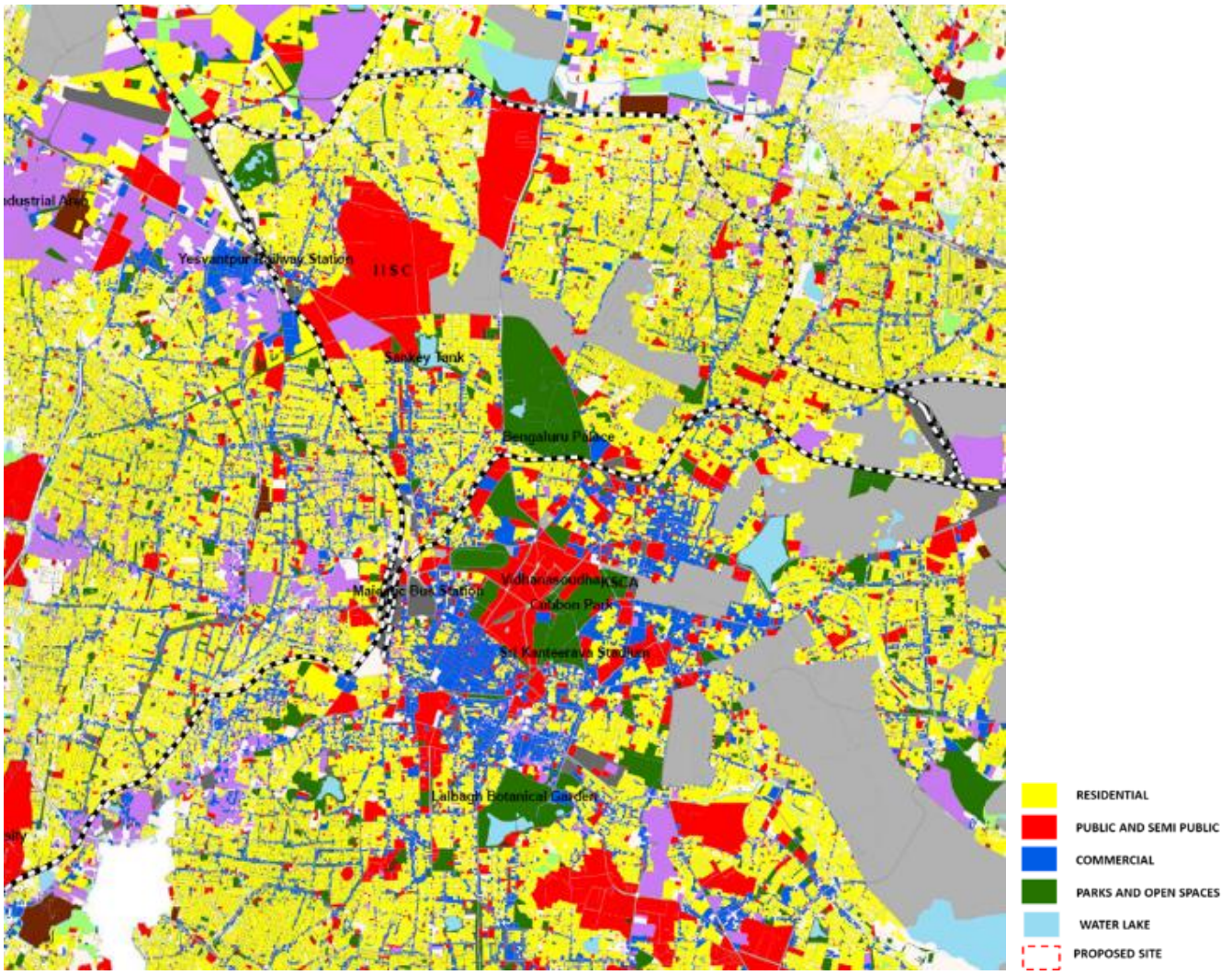


Figure 144: Located shafts in Land Use Pattern(1)

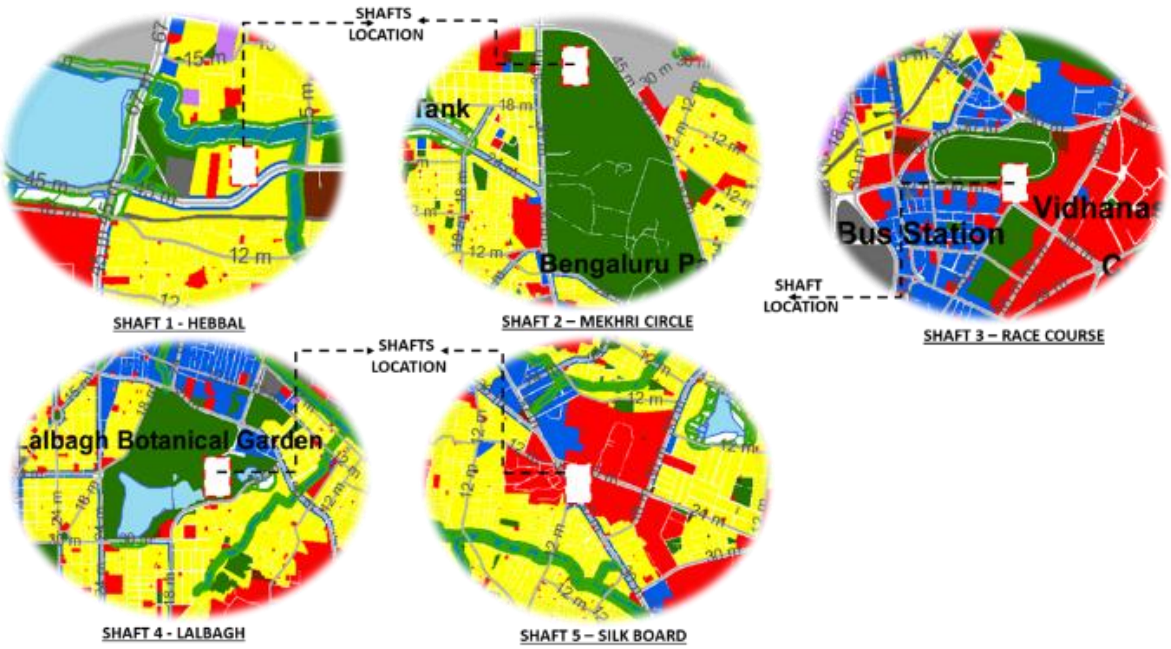


Figure 145: Located shafts in Land Use Pattern (2)

8.11.7.2 Transit-Oriented Development (TOD) Guidelines

Transit-Oriented Development (TOD) is a key strategy under the Ministry of Housing and Urban Affairs (MoHUA) and Karnataka's urban transport policy. It focuses on creating compact, walkable communities centered around transit hubs to reduce reliance on private vehicles and promote sustainable urban growth. The TOD guidelines applicable to this project are as follows:

a) **High-Density, Mixed-Use Development**:

- Encourage vertical growth around terminals to accommodate residential, commercial, and institutional uses within walking distance of transit stations.
- Promote mixed-use developments that integrate housing, offices, retail, and recreational spaces.

b) **Pedestrian and Non-Motorized Transport (NMT) Infrastructure**:

- Develop wide, shaded pedestrian pathways and safe crossings near terminals to encourage walking.
- Introduce dedicated cycling tracks and bicycle parking to support non-motorized transport options.

c) **Multimodal Connectivity**:

- Terminals must act as multimodal hubs, integrating metro, bus, auto, and taxi services.
- Provision for feeder bus services and last-mile connectivity options like e-scooters and shared mobility solutions.

d) **Public Realm and Urban Design**:

- Incorporate landscaped plazas, green spaces, and public art installations around terminals to enhance the public realm.
- Ensure terminals blend aesthetically with the surrounding urban fabric, particularly in heritage-sensitive areas like Lalbagh.

e) **Parking Management**:

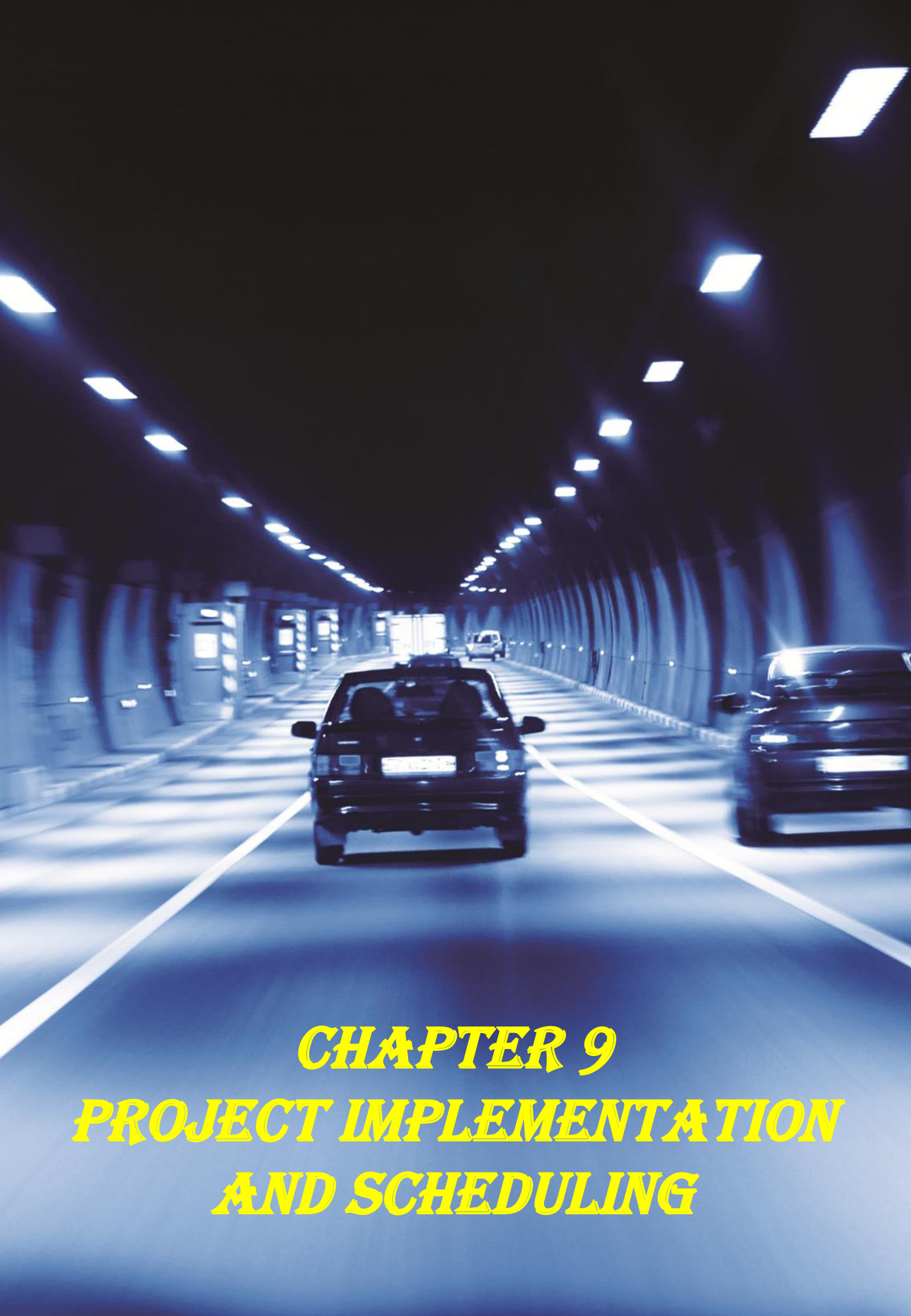
- Implement smart parking solutions, with a focus on multi-level parking to minimize land use for surface parking.
- Encourage park-and-ride facilities to reduce congestion in core city areas.

f) **Environmental Sustainability**:

- Incorporate green building practices, such as solar energy systems, energy-efficient designs, and rainwater harvesting.
- Reduce vehicular emissions by promoting public transport and non-motorized mobility.

g) **Economic and Social Benefits**:

- Leverage TOD zones to create employment opportunities and attract investments.
- Facilitate local economic growth by encouraging small businesses and retail outlets near terminals.



CHAPTER 9
PROJECT IMPLEMENTATION AND SCHEDULING

CHAPTER 9: PROJECT IMPLEMENTATION AND SCHEDULING

9.1 Construction Time and phasing

The project is proposed to be completed in 50 months considering methodology of construction and the time required for procurement, transportation, mobilization and initial drive of Tunnel Boring Machines (TBM). It is presumed that 4 TBMs shall be driven for each package simultaneously.

The preliminary workplan has been attached as an Annexure.

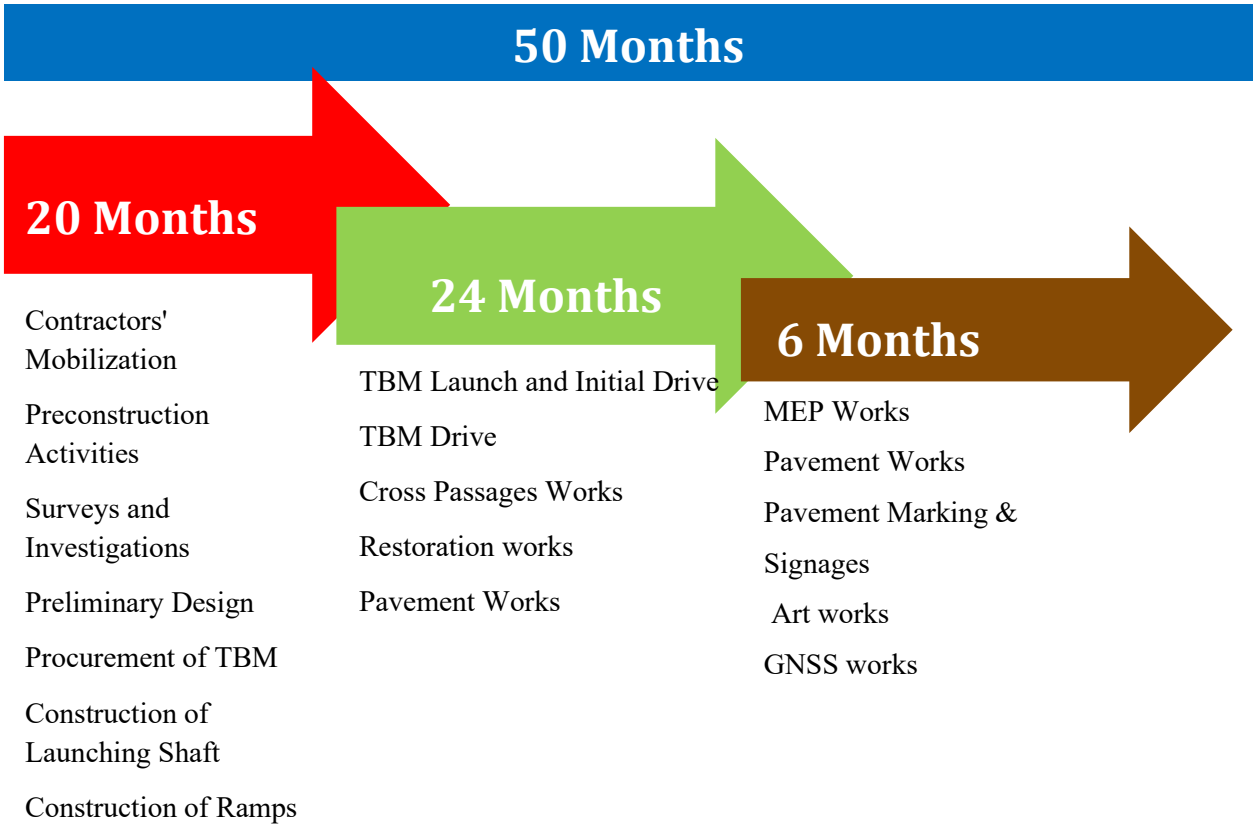


Figure 146: Phasing and Construction Time

9.2 Implementation Schedule

The construction schedule is prepared to understand the time frame required for the successful completion of the project. Major construction activities have been identified for the project and allotted with time duration based on industry inputs and engineering judgement. Like any other infrastructure project, the time frame gets directly proportional to work fronts that can be created. Client inputs are also taken on board to optimize the cost and time frame of the project. Infrastructure projects are highly sensitive to time allocation, as the project cost also get affected if resources are tweaked to optimize the timeframe. It may be emphasized that tunnel projects being liner in nature have limited scope of optimization as the progress of tunnel excavation and logistics usually control the plan. Major activities that will be required to finish the projects are identified as below, some activities can go in parallel whereas some others can start only after finish of their predecessor activity. A macro plan for project completion is attached in an annexure to read along with following explanation.

Mobilization: Concessional after getting the LOA requires to mobilize various resources to kick start the project including manpower and machineries. The contractor shall also prepare and submit various schedules and planning at this stage for full mobilization and work completion. A time frame of 30 days is usually required for this activity.

Field Survey and Investigations: Tunneling project requires various studies such as topographic study, geotechnical study, survey of existing buildings and utilities etc. Six months time frame is important for all

surveys. Here the critical inputs for preliminary design shall be targeted with urgency as some other investigations, even if takes more time will not impact the overall program.

Preliminary design of temporary and permanent works: From design side it is very critical to focus on aspects which impact the overall planning and resourcing of construction team. This shall be done in parallel to investigation with a time frame of 4 months.

Design of enabling works: As soon as the initial data of field survey is available, enabling works design shall be carried out. That should include various contractor's facilities for the project, casting yard, utility diversion etc. A time frame of 2 months is allocated for this and running parallel to the investigation stage.

Detailed design of temporary and permanent works: this is a time-consuming part of design and may run for several months on an iterative basis. Contractors shall schedule the priorities as per the work fronts. A time frame of 300 days is allotted for it.

TBM Manufacturing, FAT and mobilization to site: This activity is on the critical path for this project. The contractor shall order the TBMs as soon as on mobilization. The investigation into the design of various parts of TBMs shall continue so that machines can be manufactured and delivered in 20 months. The contractor shall look for manufacturer which can fulfill the technical and time requirement of project.

Segment Mould Manufacturing: Mould manufacturing for precast segments is important activity as these are manufactured on demand by limited fabricators worldwide. This activity is related to detailed design of precast elements. A time frame of 6 months shall be allocated for this.

Utility Diversion tree cutting etc: Various field activities to start the construction work is required e.g. utility diversion, tree cutting etc. they are not much time consuming however permissions and liasoning is very important.

Casting yard setup: 4 months time frame is allowed for casting yard setup. This should be fully functional before the arrival of casting moulds.

Construction of Launch Shaft: The construction of launch shafts shall be priorities so that machines when arrive are directly launched. Considering the 20-month time frame from machines, temporary works of shafts is not seen on critical path as such. However, the planning and construction of shaft is a very critical item and shall be addressed in that way.

Cut & Cover and Ramp Construction: Cut & cover works are typical involving earth work, secant pile and anchors. There are several example of similar kinds in Bangalore and these activity to go parallel with shafts and other work. As such its not expected to go on a critical path as resources can be augmented to finish early. 20 months for temporary work is allotted.

TBM Launch and Initial drive: Once TBM machines arrive sat site, they required to be launches and slowly progressed in the initial drive. Two months time frame is allotted for this. Two machines are to be launched at the same time for different shafts. Subsequently 2 more machines shall be launched after completion of initial drive of first 2 machines.

TBM drives: This activity is with the maximum duration and hence any optimization here would help the project duration. For regular drive 150m/ month progress is anticipated. The time frame for 4 TBM drives is about 24 months. This activity will also has other activities behind like installation of utility box and intermediate slab etc.

Cut & cover and ramp in entry exit area: the entry exits can be taken up in parallel to main tunnel. it is expected that 20 months are more than sufficient to finish the temporary works of entry exits cut & cover and ramps.

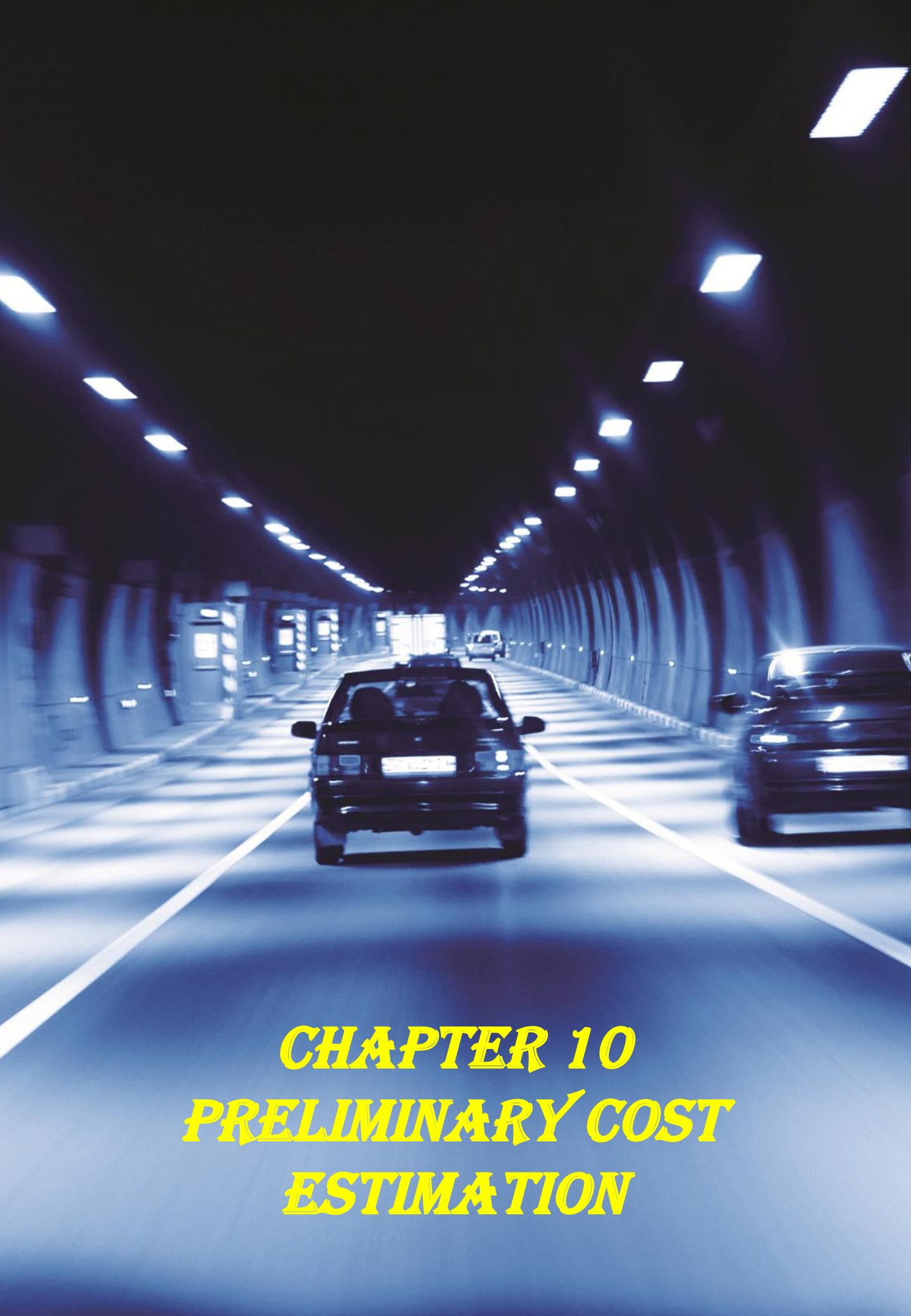
NATM tunnels: NATM tunnels in entry exits can start only after cut & cover temporary work is over as that will provide the launch area for NATM excavation. Once started 20 months time frame is safely considered for its completion. The activities of entry exits is not expected to fall on critical path and can be easily finished before the completion of TBM drives.

Cross Passage: Cross Passage works is usually the most time restricted activity of the underground project since it can only begin when TBM on both sides have passed and there is no logistic issue. here considering

the large diameter of TBM the cross-passage activity will run in parallel to TBM drive. A total of 12 months are allotted for this.

Permanent works: the permanent lining of NATM, various finish work of civil components in shafts and main tunnel etc. shall continue after the completion of TBM drive. Two months after TBM drive shall be allotted for this.

E&M and Ventilation works : Total time frame for E& M and ventilation works is expected about 20 months. However, a major portion of this shall be taken up parallel to TBM drive. After completion of TBM drive, 6 months' time frame is required to complete the in all respect.



CHAPTER 10
PRELIMINARY COST ESTIMATION

CHAPTER 10: PRELIMINARY COST ESTIMATION

10.1 Methodology

1. **Three-lane Road TBM Bored Twin-Tunnel** - The mechanized tunnelling method, i.e. using Tunnel Boring Machines (TBMs) is proposed for excavation and construction of the main three-lane road tunnel. The selection of TBM shall be done by the concessionaire based on the detailed evaluation of project conditions of detailed geological and adjacent structure condition survey. The TBMs shall be launched and retrieved from the Shafts of size 50mx100m each, two shafts are proposed on the either end of the project i.e. at Hebbal and Silk board junction, remaining three are suitably located to divide the tunnels stretches in manageable TBM drives and ventilation strategy of operational case. These shafts shall be used for logistic supplies and muck removal also. The estimates of TBM tunnels are prepared based on the market rates of important components such as tunnel boring machines and consumables. References for various civil components e.g. segment, manufacturing, utility boxes etc. have been taken from similar projects.

   The vertical alignment of TBM drives is engineered in such a way to minimize the impact on surface structure and conflict with other underground infrastructure like metro tunnels. A minimum cover of one diameter is proposed at the shaft locations for safe launch/ retrieval.

2. **Ramp and Cut & Cover Sections:** The project lengths beyond the extent of the shafts at Hebbal and Silkboard, are planned with cut & cover tunnels. Further, the locations where cut and cover method is not feasible due to less cover over the tunnel, and the open ramps are proposed. Considering the ground water condition, excavation in soil is proposed using secant piles supported with anchors. In rock strata at lower levels of excavation open slopes supported with rock bolts and sprayed concrete are considered. The cost of cut-and-cover and open-ramp sections are determined based on cross-sections, plans considering both the temporary support and permanent work.

3. **TBM Lowering Shaft:** Preliminary locations for Tunnel Boring Machine (TBM) launching/Retrieval Shafts have been identified, and the necessary quantities for cost estimation are worked out in a similar way as cut & cover temporary works. These shafts shall be utilized for bus stations, parking lots, property development and facilities of ventilation and MEP services for tunnels. The cost of permanent works to be constructed inside shafts is worked out separately, based on the unit rate of buildings of similar nature.

4. **Intermediate Entry and Exits:** There are 12 numbers of entry and exits planned along with the project alignment as per the traffic study of the area. These entry exits will have varying sections of open ramp and cutting & cover that will lead to NATM tunnels. The entry/ exits are connected to main tunnels either in shaft or bored tunnel area. The estimation of cut & cover and open ramp sections are done in similar way to the main tunnel. Estimation of NATM tunnels comprising the temporary works e.g. mining and support of tunnels, mucking etc. and permanent work like concrete inner lining. The quantity take off is done as per the DPR design of NATM tunnels.

5. **NATM Tunnel-** In the stretches where the cover over the tunnel is sufficient, geology is favorable, and the above ground structures are scarce, NATM tunnel has been considered between cut and cover and bored tunnels. Controlled blasting method is envisaged for NATM excavation with suitable support.

6. **Multimodal Hubs-** Multimodal hubs are planned at the shaft locations for interconnectivity with other modes of transport like Metro, buses, and IPT along with the stacked parking facility, bus stations and control centres of MEP and Tunnel Ventilation.

7. **Road wearing coat and pavement:** 75 mm thick RCC wearing coat is considered over the base slab in the bored tunnel, cut and cover tunnel and open ramps. Pavement quality Concrete over DLC has been considered for NATM tunnel.

8. **Traffic Signs & Road Appurtenances:** Quantities for traffic signs, markings, and other project-related facilities (such as road accessories) are calculated from the plan drawings, and costs are determined accordingly.

9. **Electromechanical System:** Highway tunnels require various installations to ensure the safety of commuters in the underground environment. The MEP services include main power supply system, power backup system, UPS system, Lighting system, Surveillance system, Incident Detection System, Public address (PA) system, Tunnel radio, Emergency Call Network, Supervisory Control and Data Acquisition (SCADA) system etc. The estimation of MEP items is done as per project specific proposal and designs.
10. **Tunnel Ventilation System and Fire Fighting system:** The transverse type of mechanical ventilation system is considered for the tunnel lengths/section having lengths more than 2000 m, longitudinal type ventilation system has been considered for the sections between 500m and 2000m and natural ventilation has been considered for section less than 500m length as per IRC: SP:91-2019. Suitable air monitoring systems have also been considered. Fire detection, fire alarm and firefighting systems have been provided. Fire check doors Fe25/Fe400 have been considered for cross passages.
11. **Land acquisition, Utility Shifting and Restoration:** In the Cost Estimate, provision has also been made for land acquisition and utility shifting, in addition to direct construction costs.
12. **Tree cutting, Transplantation and Artwork:** In the Cost Estimate, provision has also been made for tree cutting/transplantation wherever unavoidable, and the Artwork at the entries and exits.

10.2 Unit Rates of Materials:

1. The cost of materials is referenced from a combination of government-issued data and market rates.
2. The Government data referenced for rates of items include.
    a. Karnataka PWD Schedule of Rates (SOR) for Road & Bridges 2023-24, Zone 1
    b. MoRTH Standard Data Book, 2019
    c. CPWD Plinth area Rates 2023
    d. CPWD Schedule of Rates 2023
3. Rates of items have also been referenced to similar recent projects.
4. Rates of items have also been referenced to market rates.
5. Rates of GNSS tolling system have not been established in India, these rates are based on item market rate.
6. A transportation lead of 45 km is assumed for muck disposal and concrete/precast concrete items.
7. The cost of TBMs is based on an inquiry from Herrenknecht AG considered

10.3 Labour Rates:

Labour rates are determined according to the Karnataka PWD Schedule of Rates (SOR) for Road & Bridges 2023-24. Supervision rates are based on prevailing market conditions.

10.4 Plant & Machinery Rates

Rates for plant and machinery are primarily sourced from the MoRT&H Standard Data Book 2019, with escalations applied to reflect 2024 prices using the wholesale price index. For items not covered in the data book or Karnataka SOR, market rates are used. The rates of TBM tunnel-related machinery are based on market rates.

10.5 Centage Charges: Overheads, Contractor's Profit, and Other Components:

1. Overhead costs for road tunnel works are based on the MoRT&H Standard Data Book.
2. Contractor's profit is considered as 10%.
3. GST is applied at 18% on the construction cost.
4. Contingency provisions are 1% of the total construction cost.
5. Supervision charges are calculated at 2% of the construction cost.

6. The escalation of amounts for construction period is applied @5% per annum
7. The cost of Instrumentation and Monitoring is considered as 1% of the Civil Cost.
8. Labour Cess @1%

10.6 Assumptions: The estimate is based on following assumptions:

1. It is presumed that Four Tunnel Boring Machines shall be deployed at the work of each package. The type of machine shall be decided based on geotechnical data. The TBMs and other ancillary machines shall be new (purchased from OEM) and not refurbished.
2. It is presumed that the urban road tunnelling will increase in India and shall be prevalent at the time of COD and the conditions will be such that the machines released from the project could be used on other Indian road tunnel projects after due refurbishing. Refurbishing facilities for the TBM and other machines shall also be established in India.
3. The GNSS tolling system which is in the initial stages of adoption in India, shall be prevalent at the time of COD of the project.
4. Cost of Land Acquisition and Utility Shifting have been adopted on lump sum basis.
5. The cost of High-Speed Buses and its fare collection system etc. have been considered on lump sum basis.
6. Cost estimation is a critical component of project planning, providing essential financial insights for project execution.
7. North-South Tunnel Corridor, being a complex underground project which has several uncertainties. Some of the components are not being captured in any of the similar tenders explicitly as the industry is following the cost on a lump sum basis. The normative cost based on limited project references with limited number of components has been worked out. But the actual cost will be market driven.
8. At present, in India, there are no standard benchmark rates for unit length of urban road bored tunnels. The diameter and cross sections of the different lane configurations of road tunnels are also not standardized. Whereas for the metro tunnels, the rates per Km of twin tunnels are benchmarked by Ministry of Housing and Urban Affairs, Government of India in the year 2019, on lump sum basis and the diameter of the tunnels has also been standardized. It may be noted that the first underground tunnel project of Delhi Metro was started in 2001, and the benchmarking has been done almost two decades later after analyzing the outcome of different completed metro projects.
9. Standardization of the diameter of the tunnel paves way for the reuse of the tunnel boring machines (after due refurbishment) on the subsequent projects. In the metro projects, reusing tunnel boring is the general practice of the contractors. The reuse of TBM permits a reduction in the cost of the bored tunnel, as the cost of TBM and allied equipment forms a major part of the bored tunnel.
10. Benchmarking rates per Km of road tunnels are possible after gaining experience of the cost on several similar projects. Even after the benchmarking, the rates being captured for metro projects are in substantial variance with the benchmarking. Which gives an indication that actual market rates depend on many factors which can be accurately captured neither by the Client nor by the Consultants.
11. On the other hand, in India, urban road bored tunnel projects have started in the present decade, the examples of completed projects are very limited. However, some projects have been awarded and are in progress in Mumbai, like Coastal Road Tunnel, Orange Gate Tunnel, Thane- Borivali Tunnel, Gaimukh Tunnel. The rates of some items in this cost estimate have been referenced from these projects, although with some rationalization based on the experience of tunneling.
12. Leading OEM (M/s Herrenknecht) have been consulted, and a quotation has been obtained from them. The depreciation of the tunnelling equipment during the construction period, depending on the probability of reuse after refurbishment and requirement of same diameter of the machine, in the opinion of industry experts and contractors varies between 90% to 30%. 90% - when the machines are to be junked after the project and 30% - when the Contractor/concessionaire secures another project immediately after completion of the project where the machines of same diameter are required. Both the conditions are unlikely, and we are optimistic that the position will be somewhere in the middle

after 5 years from now, i.e., the use of bored road tunnels will increase in metropolitan cities in India for mitigating the congestion on the city roads. The standardization of the sections/ diameter of road tunnels will also be made by Indian Road Congress and Bureau of Indian Standards, later or sooner.

13. The Completion Period of the project has been decided to be around 5 years, to provide relief to the citizens of Bengaluru from acute congestion on the roads. Considering the completion period, geology of the site and the alignment, use of eight TBMs is required. However, it has been decided by the authority that the tenders will be called with a provision of eight TBMs with a depreciated value of 50%, with the consideration that in the case of exigencies a part of the tunnel project may be commissioned in 4 plus years (50 months).

14. Considering the above, we have worked out cost of the project adopting six TBMs with a depreciation of 50% in the draft DPR. After due deliberations with the Authority, an estimated cost based on the more pragmatic scenario has been decided to be adopted for call of tenders adopting eight TBMs and 50% depreciation.

10.7 Construction Time and Phasing

The project is proposed to be completed in 50 months considering methodology of construction and the time required for procurement, transportation, mobilization and initial drive of Tunnel Boring Machines (TBM). It is presumed that 4 TBMs shall be driven for each package simultaneously.

The preliminary workplan has been attached as an Annexure.

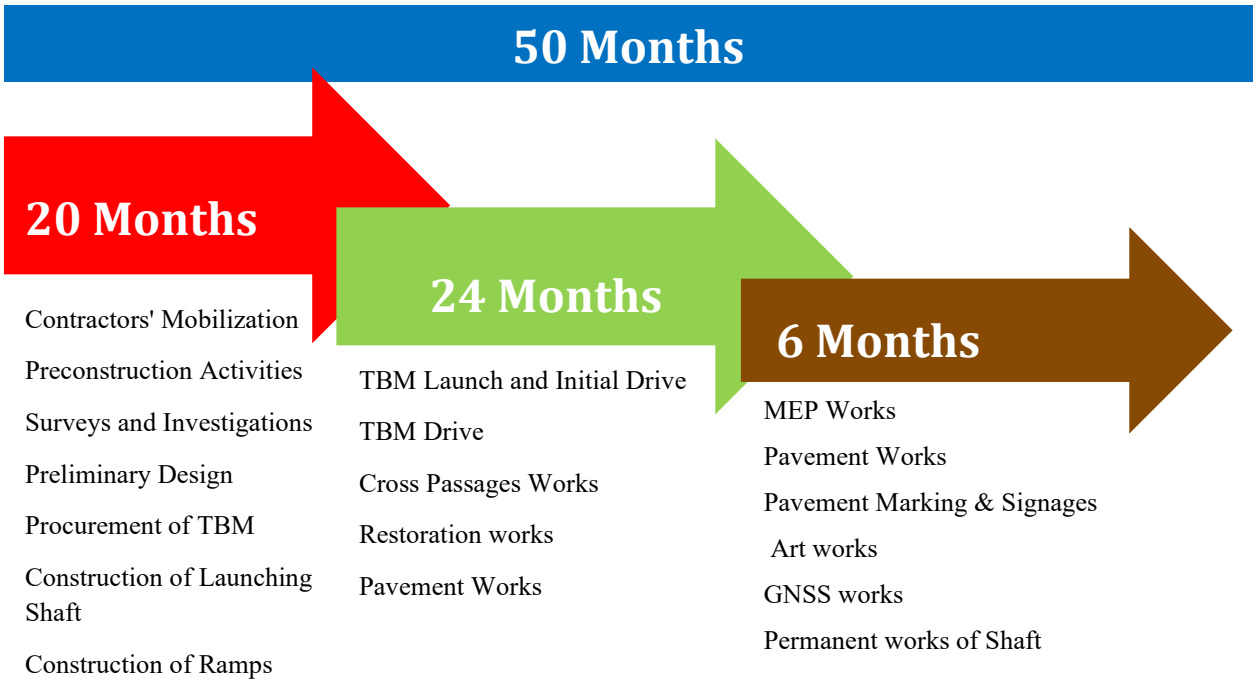


Figure 147: Phasing and Construction Time

10.8 Summary of Cost Estimate

The project cost summary is mentioned below.

Table 87: Summary of Cost for Package 1 (Km 0+000 to Km 8+748)

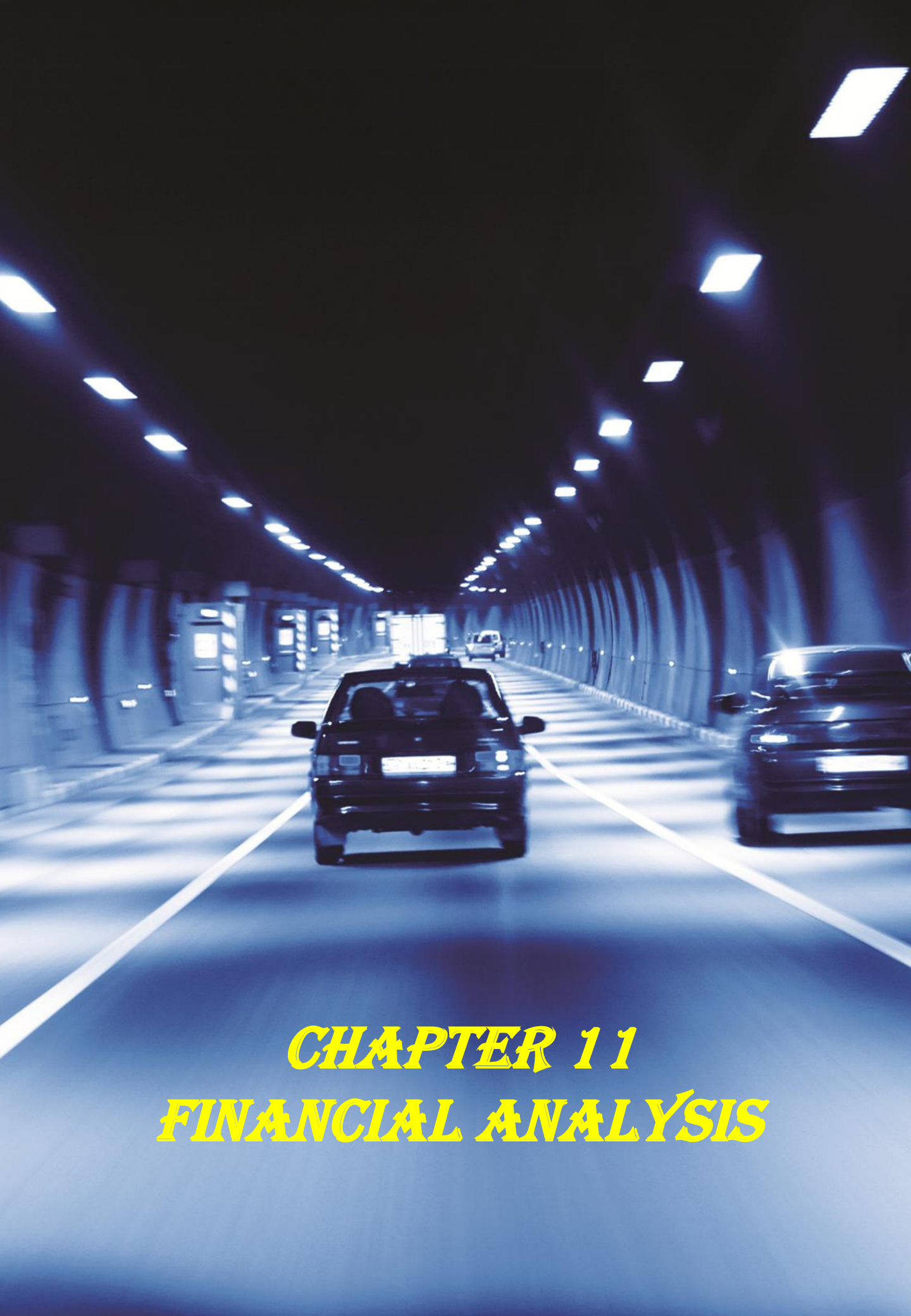
Item No.	Description	Total Amount in Rs.
BILL NO. 1	Site Clearance	60,10,749
BILL NO. 2	**Tunnel Work**	
A	Main Tunnel	
a.	Tunnelling By TBM	5,89,80,77,332
b.	Cross Passages	26,73,67,124
c.	Cut And Cover Tunnel	3,06,19,00,476

Item No.	Description	Total Amount in Rs.
d.	Open Cut (Ramps)	53,69,34,960
e.	Shafts (2 No's)	93,43,11,771
B	**Intermediate Entry/Exit**	
a.	NATM Tunnel	3,13,89,84,309
b.	Open Cut (Ramps)	1,21,87,99,719
c.	Cut And Cover Tunnel (2-lane,3-lane & Intermediate Lane)	2,82,44,08,299
C	**Sub Total Cost of Tunnel Works(A+B)**	**57,88,07,83,989**
D	Electro- Mechanical Works	3,96,70,10,106
E	I&M cost @1% of C	57,88,07,840
F	Tunnel Ventilation & Fire Fighting	1,02,85,60,940
G	Cement concrete wearing coat	30,45,37,265
H	Inter Modal Building -2 Nos	3,27,60,63,038
BILL NO. 3	Traffic Signs, Markings, Appurtenances etc.	8,89,02,666
BILL NO. 4	Reconstruction/New Construction of Structures	
a.	Aqueduct at Km 0+288, Entry Ramp-02(ORR)	52,21,373
b.	Nala Diversion at Hebbal	17,45,78,795
BILL NO. 5	**Road Restoration and Development**	
a.	Reclamation Of Existing Road in Shaft, Approach Area & Ramps (Road, Footpath, Lighting etc.)	9,24,40,759
b.	Junction Development	3,94,94,324
BILL NO. 6	**High-Capacity & High-Speed Busses with Driving and Trailing Coaches (Neo-Bus System)**	
a.	Telecommunication & Passenger Information System	5,00,00,000
b.	Fare Collection System	5,00,00,000
c.	EV Coach of Minimum 12 M Length	20,00,00,000
BILL NO. 7	Miscellaneous (Trees, Artwork in Tunnel etc.)	2,85,02,940
BILL NO. 8	GPS/GNSS-Based Tolling	3,22,00,000
B) Estimated Construction Cost Without GST		**67,80,31,14,783**
Labour Cess @ 1% Of (B)		67,80,31,148
GST @ 18% Payable on Construction Cost Only (On B)		12,20,45,60,661
C) Construction Cost Including Labour cess & GST		**80,68,57,06,592**
Contingencies @ 1% Of (B)		67,80,31,148
Planning & Designing Charges @ 1% Of (B)		67,80,31,148
Construction Supervision Charges @ 2% Of (B)		1,35,60,62,296
Maintenance For 20 Years I.E. @ 0.25% for the first 5 years, 0.35% for the next five years, 0.45% for next five years, 0.5% for the next five years (On C)		-
Escalation @ 5% Per Annum For 2nd, 3rd,4th, Year During Construction Payable to Contractor Of (C)		-
D) Total Cost Including Centages		**83,39,78,31,183**
Land Acquisition, Resettlement, Rehabilitation Cost		4,00,00,00,000
Utility Shifting Cost		75,00,00,000
E) Total Project Cost (Sum of All the Above)		**88,14,78,31,183**

Table 88: Summary of Cost for Package 2 (Km 8+748 to Km 16+745)

Item No.	Description	Total Amount in Rs.
BILL NO. 1	Site Clearance	32,37,906.40
BILL NO. 2	**Tunnel Work**	
A	Main Tunnel	

Item No.	Description	Total Amount in Rs.
a.	Tunnelling By TBM	45,46,51,66,550.23
b.	Cross Passages	24,59,05,906.74
c.	Cut And Cover Tunnel	1,32,60,10,638.63
d.	Open Cut (Ramps)	33,66,24,192.27
e.	Shafts (3 No's)	1,39,59,54,884.37
B	Intermediate Entry/Exit	
a.	NATM Tunnel	5,41,72,08,181.92
b.	Open Cut (Ramps)	1,16,02,05,284.92
c.	Cut And Cover Tunnel (2-lane,3-lane & Intermediate Lane)	3,49,56,27,989.84
C	**Sub Total Cost of Tunnel Works(A+B)**	**58,84,27,03,628.93**
D	Electro- Mechanical Works	3,13,94,74,157.47
E	I&M cost @ 1% of C	58,84,27,036.29
F	Tunnel Ventilation & Fire Fighting	1,18,65,82,932.00
G	Cement concrete wearing coat	35,44,20,402.17
H	Inter Modal Logistic Building -3 Nos	4,36,11,83,192.90
BILL NO. 3	Traffic Signs, Markings, Appurtenances etc.	9,29,45,319.73
BILL NO. 4	Reclamation Of Existing Road In Shaft, Approach Area & Ramps (Road, Footpath, Lighting etc.)	6,00,55,959.00
a.	Junction Development	3,74,62,651.45
BILL NO.5	High-Capacity & Highspeed EV Busses	
a.	Telecommunication & Passenger Information System	5,00,00,000.00
b.	Fare Collection System	5,00,00,000.00
c.	EV Coach of Minimum 12 M Length	20,00,00,000.00
BILL NO. 6	Miscellaneous (Trees, Artwork in Tunnel etc.)	2,85,17,460.00
BILL NO. 7	GPS/GNSS-Based Tolling	3,22,00,000.00
B) Estimated Construction Cost Without GST		**69,02,72,10,646.35**
Labour Cess @ 1% Of (B)		69,02,72,106.46
GST @ 18% Payable on Construction Cost Only (On B)		12,42,48,97,916.34
C) Construction Cost Including Labour cess & GST		**82,14,23,80,669.16**
Contingencies @ 1% Of (B)		69,02,72,106.46
Planning & Designing Charges @ 1% Of (B)		69,02,72,106
Construction Supervision Charges @ 2% Of (B)		1,38,05,44,212.93
Maintenance For 20 Years I.E. @ 0.25% for the first 5 years, 0.35% for the next five years, 0.45% for next five years, 0.5% for the next five years (On C)		-
Escalation @ 5% Per Annum For 2nd, 3rd,4th, & 5th Year During Construction Payable To Contractor Of (C)		-
D) Total Cost Including Centages		**4,90,34,69,095.01**
Land Acquisition, Resettlement, Rehabilitation Cost		4,00,00,00,000.00
Utility Shifting Cost		75,00,00,000.00
E) Total Project Cost (Sum of All the Above)		**89,65,34,69,095.01**



CHAPTER 11
FINANCIAL ANALYSIS

CHAPTER 11: FINANCIAL ANALYSIS

11.1 Financial Analysis

The Project Road has been studied for the financial viability to assess whether the project is attractive enough for private sector participation under the BOT model or not. The analysis ascertains the extent to which the investment by the BOT concessionaire can be recovered through toll revenue and the gap, if any, be funded through government subsidy or alternative revenue sources. This covers aspects like government grant, financing through debt and equity, loan repayment, debt servicing, taxation, depreciation, etc. The viability is evaluated in terms of the Project IRR (Financial Internal Rate of Return (FIRR) on total investment) and the Equity IRR (FIRR on equity investment), using discounted cash flow analysis. Both costs and revenues have been indexed to take account of inflation.

Target IRRs

To assess whether the project is commercially viable, the returns to investors, in terms of the pre-tax Project FIRR, post-tax Project FIRR and the Equity FIRR, were compared with the target IRRs. The returns expected by investors are a function of the value of equity issues on the Indian stock markets, interest rates on commercial loans, the risk profile of the investment and alternative investment opportunities.

11.2 Overview of implementation modes

Historically, investments in the infrastructure space, particularly in the highways/expressways etc., were being made by the Government mainly because of the large volume of resources required, long gestation period, and associated externalities. The galloping resource requirements, concern for managerial efficiency and consumer responsiveness have led in recent times to an active involvement of private sector investments.

Under PPP mechanism for road infrastructure, Government earlier offered two models viz. Build - Operate - Transfer (Toll) and Build - Operate - Transfer (Annuity). Most of the projects were awarded on these two models. In recent times, the Government has come up with a new model Hybrid Annuity Mode (HAM) and several projects are being awarded on HAM model.

PPP means an arrangement between a government or statutory entity or government owned entity on one side and a private sector entity on the other, for the provision of public assets and/or related services for public benefit, through investments being made by and/or management undertaken by the private sector entity for a specified time period. There is a substantial risk sharing with the private sector and the private sector receives performance linked payments that conform (or are benchmarked) to specified, pre-determined and measurable performance standards.

A PPP brings the public and private sectors together as partners in a contractual agreement, for a pre-defined period matched to the life of the infrastructure assets used to provide the services. The private partners (investors, contractors and operators) provide specified infrastructure services and, in return, the public sector either pays for those services or grants the private partner the right to generate revenue from the project.

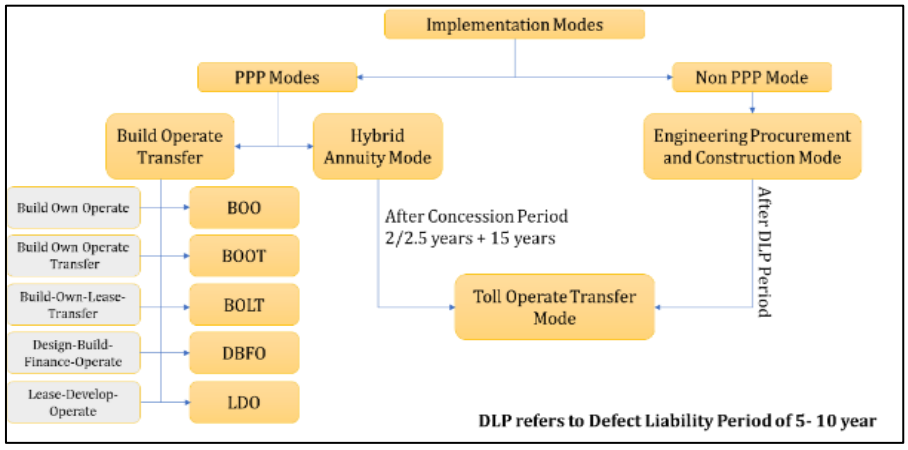


Figure 148: Implementation modes overview

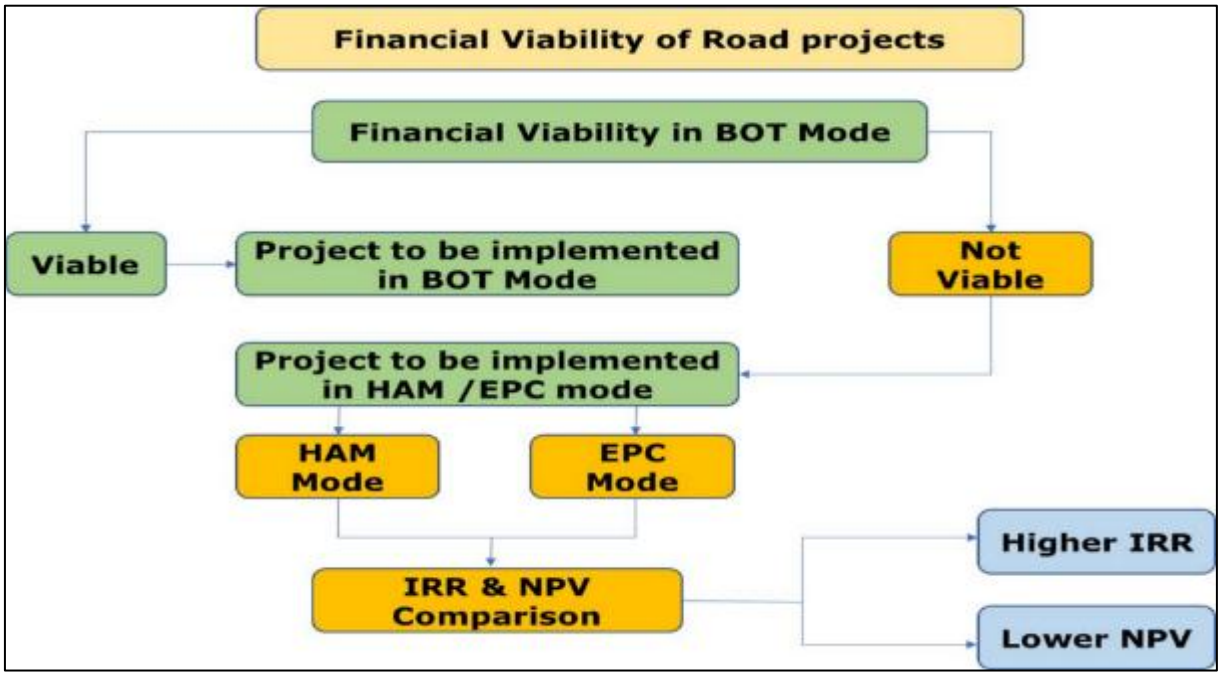


Figure 149: Flow chart of financial viability

Type of Risk → Type of Model ↓	Financing Risk	Revenue Risk or Toll collection Risk	O & M Risk
BOT Model	By Private	By Private	By Private
Annuity Model	By Private	By Govt.	By Private
BOT–VGF Model	By Govt. & Private	By Private.	By Private
EPC Model	By Govt.	By Govt.	By Govt.
HAM Model	By Govt. & Private	By Govt.	By Private

Figure 150: Comparative Analysis of Implementation Modes

Engineering Procurement & Construction Mode

- Under the EPC model, government pays private players to lay roads. The private player has no role in the road's ownership, toll collection or maintenance (it is taken care of by the government).
- The concept of Defect Liability Period in adopted for this type of projects for about 5-10 years of Operational & Maintenance.
- In this mode, there is no criteria for selection of bids, the return ratio for particular period should be greater when compared with other modes.

Hybrid Annuity Mode

- HAM's a hybrid – a mix of the EPC (engineering, procurement and construction) and BOT (build, operate, transfer)- Annuity models. HAM combines EPC (40 percent) and BOT-Annuity (60 percent).
- On behalf of the government, NHAI releases fixed grant of 40 per cent of the total bid cost. The balance 60 per cent is arranged by the developer.
- HAM arose out of a need to have a better financial mechanism for road development.
- HAM is a good trade-off, spreading the risk between developers and the Government.
- The concept of price Indexation is applicable during construction and O & M period instead of escalation.

- Price Indexation contributes to 70% of WPI component and 30% of CPI Component.
- In this mode, the Equity IRR needs to be 15% and the bid amounts are to be quoted to 15% EIRR.
- The 60% of amount is paid back in the form of Annuities for 15 Years for every half year period.
- The grant during construction period shall be disbursed in 10 instalments (each of 4%).

Build Operate Transfer

- Under the BOT model though, private players have an active role - they build, operate and maintain the road for a specified number of years before transferring the asset back to the government. Under BOT, the private player arranged all the finances for the project, while collecting toll revenue or annuity fee from the Government.
- The BOT model ran into roadblocks with private players not quite forthcoming to invest. The private player had to fully arrange for its finances be it through equity contribution or debt.
- In this mode, the Equity IRR needs to be 15% from the net cash flows.

11.3 Project section

The project section is an underground vehicular tunnel for the north-south corridor in the city of Bengaluru, starting from Hebbal Esteem Mall Junction to the Silk Board KSRP Junction. The main purpose of the proposed North south tunnel corridor is to decongest city roads, NH 44 and to provide seamless transportation facilities for the traffic towards various locations in the city of Bengaluru. The tunnel road shall reduce the travel time from about 90 minutes to 35 minutes.

11.3.1 Project Packaging

The project section is divided into two packages.

Development of Underground Vehicular Road 3-lane Twin Tunnels for the North – South Corridor of Bengaluru between Hebbal Esteem Mall junction (Km. 0+000) and Silk Board KSRP Junction (Km.16+745) along with 3-lane/2-lane entry & exit ramps on BOT (Toll) Mode including operation and maintenance.

Package -I: Hebbal (Km. 0+000) to Seshadri Road, Freedom Park (Km 8.748)

Package -II: Seshadri Road, Freedom Park (Km 8.748) to Silk Board (Km 16.745)

11.4 Capital Costs and Its Phasing

The capital cost of the Project relates to initial construction cost and land acquisition cost. Land acquisition costs have been excluded from the financial analysis, as the government has to provide land free of encumbrances to the concessionaire.

11.4.1 Base Project Cost

The total cost of the project is the cost at the time of commissioning and includes aggregate of base project cost, escalation cost, financing cost and interest during construction (IDC), Design, PMC. The Total Project Cost (TPC) is presented below Table.

Table 89: Total Project Cost Details Package 1

S. No.	Particulars	VGF %	
		30%	40%
1	Total Tunnel Length in Km.	8.748	
4	Total Civil Cost in Crore	6780.31	6780.31
5	Other costs (IDC, Escalation, Contingencies)	2159.30	1989.77
Total Project Cost in Crore		**8939.61**	**8770.08**

Table 90: Total Project Cost Details Package 2

S. No.	Particulars	VGF %	
		30%	40%
1	Total Tunnel Length in Km.	7.997	
4	Total Civil Cost in Crore	6902.72	6902.72
5	Other costs (IDC, Escalation, Contingencies)	2198.29	2025.69
Total Project Cost in Crore		**9101.01**	**8928.41**

11.4.2 Escalation Cost

The base costs have been escalated at a rate of 5 percent per annum to account for inflation and obtain the actual costs in the year of expenditure. This is in line with the long-term inflation rate generally considered for financial analysis.

11.4.3 Financing Cost on Debt

Financing cost, comprising processing fee, sponsor's contingency, etc., has been considered as per NHAI guidelines. 2% of debt amount is considered if the civil cost in up to Rs. 500 crores, 1.5% of debt amount is accounted if the civil cost is in the range of Rs. 500 crores and Rs. 1000 crores and 1% of debt amount is taken if the civil cost is more than Rs. 1000 crores.

11.4.4 Interest during Construction (IDC)

The interest during construction, which is the cost of funding incurred on the debt portion of the project, has been calculated as per SBI MCLR rate and additional 2.5% has been considered for the analysis which is in tune with the prevailing market interest rates for infrastructure projects

11.4.5 Landed Project Cost (TPC)

The total cost of the project is the cost at the time of commissioning and includes aggregate of base project cost, escalation cost, financing cost and interest during construction (IDC), Design, PMC. The TPC at the end of the construction period has been estimated and presented in above table.

11.4.6 Tax rate

Tax Rate: The tax rate adopted for this study is 25.2% (22% tax + 10% surcharge + 4% education tax) assuming that the contractor shall opt for section 15BAA.

Minimum Alternate Tax (MAT): Minimum Alternate Tax (MAT) of 0% (0% base rate +10% surcharge and 4% Education cess) has been taken into account for the total concession period, assuming that the contractor shall opt for 15BAA section.

11.5 Approach to Financial Evaluation on BOT Basis

The viability of the project depends on the working cash flows available to service the debt and equity. The viability of the project depends on the working cash flows available to service the debt and equity. This working cash flow is basically dependent upon the following: -

- Project Cost
- Traffic & Traffic Growth
- Toll Structure
- Operation and Maintenance expenses
- Interest on Debt
- Tax

11.6 Assumption for Financial Analysis

The assumptions for financial analysis are enclosed in Annexures.

11.7 Adopted Growth Rates

The average traffic growth rate concept is adopted from CMP analysis. The following are the 10-year

period growth rate considered.

Table 91: Average vehicular growth rate

Period	2027- 2037	2037 -2047	2047 - 2057
Car Growth rate	4.18%	2.68%	2.05%

11.8 Traffic Details

The tollable vehicular details from each node to node is provided in below table. The node-to-node traffic is assessed from OD Matrix, for financial viability an average traffic growth is adopted for every 10-year period. Only Cars has been allowed on the proposed tunnel route, hence only car has been considered as tollable traffic.

Based on the diversion analysis, the tollable diverted analysis from existing road to tunnel road is presented in below table.

Table 92: Tollable Vehicle Details for the year 2027-28

S. No.	From	To	CAR
From Hebbal to Silk Board			**AADT (2027-28)**
1	Hebbal (km 0.000) (Main & Service Road)	Silk Board Junction on Hosur Road	3936
		Sarjapur/ HSR layout (Ring Road)	1595
		Hosur Main Road (Wilson Garden)	2316
		Seshadri Road (Towards KR Circle)	4385
		Palace Ground (Mekhri Circle)	8249
2	ORR (km 1.300) from KR Puram	Silk Board Junction on Hosur Road	3933
		Sarjapur/ HSR layout (Ring Road)	1028
		Hosur Main Road (Wilson Garden)	6733
		Seshadri Road (Towards KR Circle)	6099
		Palace Ground (Mekhri Circle)	8051
3	Mekhri Circle (5.400)	Silk Board Junction	5274
		Sarjapur/ HSR layout (Ring Road)	2940
		Hosur Main Road (Wilson Garden)	2081
		Seshadri Road (Towards KR Circle)	14136
4	Race-Course (km 9.100) from palace rd.	Silk Board Junction	8636
		Sarjapur/ HSR layout (Ring Road)	5701
		Hosur Main Road (Wilson Garden)	10525
From Silk Board to Hebbal			**AADT (2027-28)**
1	Silk Board (km 16.693)-Hosur	Hebbal (Main & Service Rd.)	3936
		ORR (towards KR Puram) (km 1.100)	3933
		CV Raman Road (Mekhri Circle) (km 5.150)	5274
		Race Course Road (9.000)	8636
2	Sarjapur/ HSR layout (Ring Road) (km 16.386)	Hebbal (Main & Service Rd.)	1595
		ORR (towards KR Puram) (km 1.100)	1028
		CV Raman Road (Mekhri Circle)	2940
		Race Course Road (9.000)	5701
3	Jayanagar (From Ashoka Pillar) (km 11.600)	Hebbal (Main & Service Rd.)	2316
		ORR (towards KR Puram) (km 1.100)	6733

S. No.	From	To	CAR
		CV Raman Road (Mekhri Circle)	2081
		Race Course Road (9.000)	10525
4	Race Course (km 7.05) from Palace Rd.	Hebbal (Main & Service Rd.)	4385
		ORR (towards KR Puram) (km 1.100)	6099
		CV Raman Road (Mekhri Circle)	14136
5	CV Raman Road (km 4.700)	Hebbal (Main & Service Rd.)	8249
		ORR (towards KR Puram) (km 1.100)	8051

11.9 Tollable road/ structure Length Details

The tollable road/structure length as per initial designs are as follows for both options.

Table 93: Tollable road/structure length details in kms for package 1

Entry & Exit	Hebbal	ORR (Km 1.30 from KR Puram)	CV Raman Road (Mekhri Circle)	Race Course	Silk Board Junction	Sarjapur/ HSR layout (Ring Road)	Hosur Main Road (Wilson Garden)	Seshadri Road (Towards KR Circle)	Palace Road (Mekhri Circle)
Hebbal (km 0.000)	-				8.748	8.748	8.748	9.11	5.45
ORR (Km 1.30 from KR Puram)		-			8.16	8.16	8.16	7.38	4.87
Mekhri Circle (5.400)			-		3.736	3.736	3.736	3.416	
Racecourse (km 9.100) from palace rd.				-	0	0	0		
Silk Board (km 16.693)	9.27	8.00	5.44	0.00	-				
Sarjapur/ HSR layout (Ring Road) (km 16.386)	9.27	8.00	5.44	0.00		-			
Jayanagar (From Ashoka Pillar) (km 11.600)	9.27	8.00	5.44	0.00			-		
Race Course (km 7.05) from Palace Rd.	9.27	8.00	5.44					-	
CV Raman Road	7.18	5.91							-

Table 94: Tollable road/structure length details in kms for package 2

Entry & Exit	Hebbal	ORR (Km 1.30 from KR Puram)	CV Raman Road (Mekhri Circle)	Race Course	Silk Board Junction	Sarjapur/ HSR layout (Ring Road)	Hosur Main Road (Wilson Garden)	Seshadri Road (Towards KR Circle)	Palace Road (Mekhri Circle)
Hebbal (km 0.000)					7.997	8.049	4.119	0	0
ORR (Km 1.30 from KR Puram)					7.997	8.049	4.119	1.14	0.00431
Mekhri Circle (5.400)					8.395	8.447	4.517	1.14	
Race Course (km 9.100) from palace rd.					9.278	9.33	5.4		
Silk Board (km 16.693)	7.85	7.85	7.85	9.39					
Sarjapur/ HSR layout (Ring Road) (km 16.386)	8.23	8.23	8.23	9.77					
Jayanagar (From Ashoka Pillar) (km 11.600)	4.35	4.35	4.35	5.89					
Race Course (km 7.05) from Palace Rd.	1.70	1.70	0.70						
CV Raman Road	0.00	0.00							

11.10 Revenue Streams

11.10.1 Toll Rates

Toll rates are estimated based on the Gazette's published by Government of Karnataka. The base toll rates are considered from the Toll gazette PWD 06 EAP 2012 (P3), Bengaluru, Dated 07-03 -2015. As per rule 5, sub rule (1) of gazette, the base rates are increased by 3% each year without compounding with effect from 1st April 2008.

As per Sub-rule (2) of gazette the applicable base rates are revised with the effect from 1st April each year to reflect the increase in wholesale price index for the month of December of the year. The base toll rates are given in table below. For satellite based tolling system, the charges would be collected for the distance travelled in Kms.

Table 95: Toll Capping Rates

Type of vehicles	Base Rate of Fee per km in Rs
Car/Jeep/Van	0.65
LCV/Mini Bus	1.05
Bus/Truck	2.20
3 Axle trucks	2.40

Type of vehicles	Base Rate of Fee per km in Rs
MAV (4 Axle and above) Heavy Construction machinery (HCM), Earth Moving Equipment (EME)	3.45
Oversized Vehicles (7 or more axles)	4.2

11.10.2 Toll Fee

Toll revenue is the product of the forecasted traffic expected to use the project road and the appropriate toll fee for the vehicle category. Toll indexing has been carried out as per the toll policy and rounded off to nearest rupee.

- Revenue from Single Trips: Number of vehicles making single trips X Toll Fee X 365 days
- Revenue from Return Trips: Number of vehicles making Return Trips X Toll Fee X 150% X 365 days
- Revenue from Monthly Traffic Trips: Number of vehicles making Single Trip X Toll Fee X 2/3*50* 12 months.

Based on the above discussions the toll revenue has been computed for node-to-node travel length. Further the above toll rate will be adjusted by 5% per annum without compounding for the subsequent years. It is further adjusted on the basis of Wholesale Price Index as per the following formula:

- Applicable Rate of fee= Base Rate + Base Rate X {(WPI A-WPI B)/ WPI B}X 0.4
- Where WPI A = Wholesale price index for the month of December of the immediately preceding year and
- WPI B = Wholesale price index of the December month of the year

The toll rates for the subsequent years were calculated on the basis of 5% annual increase in WPI with 40% restriction. The base year for the toll revenue is considered as FY 2030-31.

The toll capping rates have been escalated with an inflation WPI rate of 5% every year. Toll rates in the 1st year of operation i.e., 2030-31 for the section including road length, structure length and bypass length is presented in the below tables.

Toll rates were calculated separately for each package.

Table 96: Toll rate in Rs. for entry & exits for single trip for the year 2030-31 for Package 1

S. No.	From	To	Length In Kms	Car
1	Hebbal (km 0.000)	Silk Board Junction	8.75	170
2	Hebbal (km 0.000)	Sarjapur/ HSR layout (Ring Road)	8.75	170
3	Hebbal (km 0.000)	Hosur Main Road (Wilson Garden)	8.75	170
4	Hebbal (km 0.000)	Seshadri Road (Towards KR Circle)	9.11	175
5	Hebbal (km 0.000)	Palace Road (Mekhri Circle)	5.45	105
6	ORR (Km 1.30 from KR Puram)	Silk Board Junction	8.16	160
7	ORR (Km 1.30 from KR Puram)	Sarjapur/ HSR layout (Ring Road)	8.16	160
8	ORR (Km 1.30 from KR Puram)	Hosur Main Road (Wilson Garden)	8.16	160
9	ORR (Km 1.30 from KR Puram)	Seshadri Road (Towards KR Circle)	7.38	145
10	ORR (Km 1.30 from KR Puram)	Palace Road (Mekhri Circle)	4.87	95
11	Mekhri Circle	Silk Board Junction	3.74	75
12	Mekhri Circle	Sarjapur/ HSR layout (Ring Road)	3.74	75
13	Mekhri Circle	Hosur Main Road (Wilson Garden)	3.74	75
14	Mekhri Circle	Seshadri Road (Towards KR Circle)	3.42	75
15	Race Course from palace rd.	Silk Board Junction	0.00	-
16	Race Course from palace rd.	Sarjapur/ HSR layout (Ring Road)	0.00	-
17	Race Course from palace rd.	Hosur Main Road (Wilson Garden)	0.00	-
18	Silk Board (km 16.693)	Hebbal	9.27	180
19	Silk Board (km 16.693)	ORR (Km 1.30 from KR Puram)	8.00	155
20	Silk Board (km 16.693)	CV Raman Road (Mekhri Circle)	5.44	105

S. No.	From	To	Length In Kms	Car
21	Silk Board (km 16.693)	Race Course	0.00	-
22	Sarjapur/ HSR layout (Ring Road) (km 16.386)	Hebbal	9.27	180
23	Sarjapur/ HSR layout (Ring Road) (km 16.386)	ORR (Km 1.30 from KR Puram)	8.00	155
24	Sarjapur/ HSR layout (Ring Road) (km 16.386)	CV Raman Road (Mekhri Circle)	5.44	105
25	Sarjapur/ HSR layout (Ring Road) (km 16.386)	Race Course	0.00	-
26	Jayanagar (From Ashoka Pillar) (km 11.600)	Hebbal	9.27	180
27	Jayanagar (From Ashoka Pillar) (km 11.600)	ORR (Km 1.30 from KR Puram)	8.00	155
28	Jayanagar (From Ashoka Pillar) (km 11.600)	CV Raman Road (Mekhri Circle)	5.44	105
29	Jayanagar (From Ashoka Pillar) (km 11.600)	Race Course	0.00	-
30	Race Course (km 7.05) from Palace Rd.	Hebbal	9.27	180
31	Race Course (km 7.05) from Palace Rd.	ORR (Km 1.30 from KR Puram)	8.00	155
32	Race Course (km 7.05) from Palace Rd.	CV Raman Road (Mekhri Circle)	5.44	105
33	CV Raman Road	Hebbal	7.18	140
34	CV Raman Road	ORR (Km 1.30 from KR Puram)	5.91	115

Table 97: Toll rate in Rs. for entry & exits for single trip for the year 2030-31 for Package 2

S. No.	From	To	Length In Kms	Car
1	Hebbal (km 0.000)	Silk Board Junction	7.997	150
2	Hebbal (km 0.000)	Sarjapur/ HSR layout (Ring Road)	8.049	150
3	Hebbal (km 0.000)	Hosur Main Road (Wilson Garden)	4.119	75
4	Hebbal (km 0.000)	Seshadri Road (Towards KR Circle)	0.000	0
5	Hebbal (km 0.000)	Palace Road (Mekhri Circle)	0.000	0
6	ORR (Km 1.30 from KR Puram)	Silk Board Junction	7.997	150
7	ORR (Km 1.30 from KR Puram)	Sarjapur/ HSR layout (Ring Road)	8.049	150
8	ORR (Km 1.30 from KR Puram)	Hosur Main Road (Wilson Garden)	4.119	75
9	ORR (Km 1.30 from KR Puram)	Seshadri Road (Towards KR Circle)	1.140	20
10	ORR (Km 1.30 from KR Puram)	Palace Road (Mekhri Circle)	0.004	0
11	Mekhri Circle	Silk Board Junction	8.395	155
12	Mekhri Circle	Sarjapur/ HSR layout (Ring Road)	8.447	155
13	Mekhri Circle	Hosur Main Road (Wilson Garden)	4.517	85
14	Mekhri Circle	Seshadri Road (Towards KR Circle)	1.140	20
15	Race Course from palace rd.	Silk Board Junction	9.278	170
16	Race Course from palace rd.	Sarjapur/ HSR layout (Ring Road)	9.330	170
17	Race Course from palace rd.	Hosur Main Road (Wilson Garden)	5.400	100
18	Silk Board (km 16.693)	Hebbal	7.847	145
19	Silk Board (km 16.693)	ORR (Km 1.30 from KR Puram)	7.847	145
20	Silk Board (km 16.693)	CV Raman Road (Mekhri Circle)	7.847	145
21	Silk Board (km 16.693)	Race Course	9.386	175
22	Sarjapur/ HSR layout (Ring Road) (km 16.386)	Hebbal	8.230	150
23	Sarjapur/ HSR layout (Ring Road) (km 16.386)	ORR (Km 1.30 from KR Puram)	8.230	150
24	Sarjapur/ HSR layout (Ring Road) (km 16.386)	CV Raman Road (Mekhri Circle)	8.230	150
25	Sarjapur/ HSR layout (Ring Road) (km 16.386)	Race Course	9.769	180
26	Jayanagar (From Ashoka Pillar) (km 11.600)	Hebbal	4.347	80
27	Jayanagar (From Ashoka Pillar) (km 11.600)	ORR (Km 1.30 from KR Puram)	4.347	80
28	Jayanagar (From Ashoka Pillar) (km 11.600)	CV Raman Road (Mekhri Circle)	4.347	80
29	Jayanagar (From Ashoka Pillar) (km 11.600)	Race Course	5.886	110
30	Race Course (km 7.05) from Palace Rd.	Hebbal	1.703	30
31	Race Course (km 7.05) from Palace Rd.	ORR (Km 1.30 from KR Puram)	1.703	30
32	Race Course (km 7.05) from Palace Rd.	CV Raman Road (Mekhri Circle)	0.703	15
33	CV Raman Road	Hebbal	0.000	0
34	CV Raman Road	ORR (Km 1.30 from KR Puram)	0.000	0

11.10.3 Other Revenues

In association with toll revenue, the development of project would generate revenue from other source, which are generated from commercial space, Advertisements, Naming Rights and leasing out space for OFC and other utilities lines in the tunnel area.

Table 98: Rental rate per Sq. ft for renting Intermodal Nodes for Package 1

S No.	Place of Intermodal change	Area (Square feet)	Area (Acres)	Rental rate per sq. ft
1	Hebbal Junction	53819.5	1.24	70
2	Palace Ground/Mekhri Circle	53819.5	1.24	70
Total Area		107639	2.48	

Source of rates: BBMP Hand book file.

Table 99: Rental rate per Sq. ft for renting Intermodal Nodes for Package 2

S No.	Place of Intermodal change	Area (Square feet)	Area (Acres)	Rental rate per sq. ft
1	Race course	53819.5	1.24	100
2	Lalbagh	53819.5	1.24	70
3	Silk Board	53819.5	1.24	50
Total Area		161458.5	3.72	

Source of rates: BBMP Hand book file.

Table 100: Naming rights for Package 1

S No.	Station	Company	Revenue (Cr.)	Duration in years	Remarks
1	Konappana Agrahara	Infosys	100	30	Naming rights, Commercial space, walkway access, Advertisement space
2	Hebbagodi	Biocon	65	30	Naming rights
3	Bommasandra	Delta	75	30	Naming rights, walkway access
4	Lakkasandra	Bosch	10	30	Walkway access

Source of rates: Metro Station Revenue

Table 101: Naming rights for Package 2

S No.	Station	Company	Revenue (Cr.)	Duration in years	Remarks
1	Konappana Agrahara	Infosys	100	30	Naming rights, Commercial space, walkway access, Advertisement space
2	Hebbagodi	Biocon	65	30	Naming rights
3	Bommasandra	Delta	75	30	Naming rights, walkway access
4	Lakkasandra	Bosch	10	30	Walkway access

Source of rates: Metro Station Revenue

The details of revenue and assumption considered for computation are enclosed in Annexure.

11.11 Proposed Sources of Finance

In general, the developer shall crystallize the sources of finance by optimizing his equity returns keeping in view the project cash flows, terms, and conditions of various financing options available. Further the market standing and financial strength of the Developer would largely determine the terms and conditions of finance offered to the Developer by various lending agencies. For the purpose of the study, following sources of finance have been taken:

- Equity: To be provided by the Developer
- Subsidy / Grant for viability of funding, to be provided by the client.
- Debt: To be arranged by the Developer / Concessionaire

11.12 Resource Mobilization Schedule

The Project construction period has been considered as 4 years 2 Months (1521 days) and development period of 8 months due to its complex nature, huge capital involved. Based on the implementation period, the project cost for each section as well as total project road as a single section.

11.13 Operations & Maintenance Cost

Routine maintenance comprises primarily of maintenance of the pavement, collection of litter, traffic management (policing), accident repairs and all ancillary works including beautification. Routine Maintenance and periodic Maintenance cost is considered as MoRT&H circular No. RW/NH-37011/02/2010/PPP (Vol.II) dated 16th November 2011 in BOT Mode.

Table 102: Routine and Periodic Maintenance cost

S. No.	Pavement Type	Routine Maintenance cost every year	Periodic Maintenance cost for every 6th year
1	Flexible	3.5 lacs per km/year	35 lacs/km
2	Rigid	4.0 lacs per km/year	-

The above said maintenance costs are escalated with 5% for 2024 prices. The operation and maintenance cost for the toll plaza includes pay roll cost of the crew, communication & security services, cost of spare parts, power consumption, computer systems etc. The annual expensed of toll plaza for O&M is considered is @ Rs. 3.75 crore/year as per 2011 circular and inflation of 5% per year has been considered.

11.14 Minimum Return Criteria

Keeping in view the present market condition, the minimum return criteria for the BOT project is considered as follows: -

- Project FIRR – Post Tax : Minimum of 13%
- Return on Equity (Equity IRR) : Minimum of 15%
- Debt Service Coverage Ratio (DSCR) : Minimum 1.0
- Net Present Value (NPV) @ 12% : Should be positive

11.15 Financial Viability

Financial viability has been carried out for concession period of 25/30 years excluding the construction period of four years and two months for the present project corridor of length with two options with the following parameters with varying the maximum grant of 40%. The basic methodology followed for estimating the financial viability of the project is to calculate the FIRR (Financial Internal Rate of Return) on the investment for the project.

The following assumptions are taken into consideration for the financial analysis: -

- Debt – Equity ratio: - 70:30
- Escalation – 5%.
- Principal Moratorium: six months

11.16 Results and Analysis

Based on the traffic study and toll rate analysis, the financial viability analysis has been carried out as per the methodology outlined in earlier sections. The objective of the viability analysis is to ascertain the existence of sustainable project returns, which shall successfully meet the expectations of its financial investors. The Returns on Investment and Returns on Equity for 30 years concession period with maximum grant of up to 40% has been estimated and the summary of results for each scenario is given in table below.

Table 103: Results in BOT Mode for following Concession period – for Package 1

Concession period	4+ Years (50 Months) + 25 years	4+ Years (50 Months) + 30 Years
Deciding factor	**With 40% Grant**	**With 40% Grant**
Project IRR	15.27%	15.64%
Equity IRR	17.79%	18.24%
DSCR	2.26	2.26
ENPV	928.00	1142.52
Remark	Viable	viable

Table 104: Results in BOT Mode for following Concession period – for Package 2

Concession period	4+ Years (50 Months) + 25 years	4+ Years (50 Months) + 30 Years
Deciding factor	**With 40% Grant**	**With 40% Grant**
Project IRR	14.36%	14.78%
Equity IRR	16.13%	16.68%
DSCR	2.09	2.09
EIRR -NPV	663.79	862.50
Remark	Viable	Viable

11.17 Sensitivity Analysis

The sensitivity analysis of the project is performed and the following scenarios are worked out.

1. Scenario I - Base Cost + Base Benefits
2. Scenario II - 15% Increase in base cost + base benefits
3. Scenario III - Base Cost +15% Decrease in base benefits
4. Scenario IV - 15% Increase in base cost +15% Decrease in base benefits

Table 105: Sensitivity analysis for 4+25 Years of concession period (for Package 1)

Scenario	Project IRR	Equity IRR	DSCR	ENPV
Scenario - I	15.27%	17.79%	2.26	928.00
Scenario - II	13.77%	15.04%	1.99	552.73
Scenario - III	13.42%	14.42%	1.93	382.11
Scenario - IV	12.02%	11.99%	1.69	Negative

Table 106: Sensitivity analysis for 4+30 Years of concession period (for Package 1)

Scenario	Project IRR	Equity IRR	DSCR	ENPV
Scenario - I	15.64%	18.24%	2.26	1142.52
Scenario - II	14.21%	15.67%	1.99	767.02
Scenario - III	13.88%	15.09%	1.93	562.32
Scenario - IV	12.55%	12.86%	1.69	178.25

Table 107: Sensitivity analysis for 4+25 Years of concession period (for Package 2)

Scenario	Project IRR	Equity IRR	DSCR	EIRR -NPV
Scenario - I	14.36%	16.13%	2.09	663.79
Scenario - II	12.91%	13.52%	1.84	276.83
Scenario - III	12.57%	12.94%	1.78	148.79
Scenario - IV	11.21%	10.63%	1.56	Negative

Table 108: Sensitivity analysis for 4+30 Years of concession period (for Package 2)

Scenario	Project IRR	Equity IRR	DSCR	EIRR -NPV
Scenario - I	14.78%	16.68%	2.09	862.50
Scenario - II	13.39%	14.26%	1.84	475.30
Scenario - III	13.08%	13.72%	1.78	315.71
Scenario - IV	11.79%	11.62%	1.56	Negative

ANNEXURE

Package 1 :Hebbal near Esteem Mall juntion (Km 0+000) to Seshadri Road (Km 8+748)			
General Assumptions - Package I			
Bid Date	**1-Mar-25**	Construction start date	**1-Nov-25**
Construction Period in days	1521	No. years of construction	4.2
Construction End date	31-Dec-29	No. of years before COD	5
COD	1-Jan-30	Type of Pavement	Rigid
First FY year in Construction	31-Mar-25	WPI- Dec 2024	155.4
First FY in O & M period	31-Mar-30	WPI on Dec before COD	609.60
No. of days in first O & M year	90	Debt Repayment start date	31-Jul-30
Debt Repayment in years	13	Debt Repayment End date	31-Jul-43
% of days in first COD	24.7%	% of days in last O & M year	75.3%
WPI growth considered (yearly)	5.0%	**Maintenance Expenses (in crores)**	
Grant during construction	40.0%	Other office Expenses for 1st O & MYear	4.97
To be Arranged By contractor/Concessionaire	60%	Insurance	7.63
Equity	30%	Electricity & patrolling expenses for 1st O & M Year	0.22
Debt	70%	**Flexible Pavement in Lakhs**	
Interest on Debt	11.60%	Routine Maintenance (Every year) for 1st Year	0.000
No. of Lanes	6	Periodic Maintenance (Every 6 th year)	0.000
Financing Cost on debt %	1.0%	**Rigid Pavement In Lakhs**	
SBI MCLR rate	9.10%	Routine Maintenance (Every year) for 1st Year	174.08
Structural Maintenance Cost per Km per Year in Cr		No. of Construction Months	50.0
Structural Maintenance Cost in Cr/Yr	2.5	Fully Access Controlled Expressway	No
Road Length		**Rigid Pavement - MCW Road**	
Flexible Pavement - MCW Road		Length of 2 lane section	0.00
Length of 2 lane section	0.00	Length of 4 lane section	0
Length of 4 lane section	0	Length of 6 lane section	8.748
Length of 6 lane section	0	**Total 4 lane Equivalent Length**	**13.12**
Total 4 lane Equivalent Length	**0.00**	**Rigid Pavement - SR Road**	
Flexible Pavement - SR Road		Length of 2 lane section	8.20
Length of 2 lane section	0	Length of 4 lane section	0
Length of 4 lane section	0	Length of 6 lane section	0
Length of 6 lane section	0	**Total 4 lane Equivalent Length**	**4.10**
Total 4 lane Equivalent Length	**0.00**	Det Repayment Years (from Start of Construction)	13
Costing Details (in Crores)			
Length of Corridor	8.748		
Total Civil Cost	6780.31		
Other costs	1989.77		
Total Project cost	8770.08	**Escalation Cost Considered During Construction**	**Yes**
Tax Assumptions			
Corporate Tax Rate			
Section 15BAA opted	Yes		
Case I		**Case II**	
Base rate	22%	Base rate	22%
Surcharge	10%	Surcharge	10%
Cess	4%	Cess	4%
Total Applicable Tax	**25.2%**	**Total Applicable Tax**	**25.2%**
MAT Tax Rate			
Case I		**Case II**	
Base rate	0.0%	Base rate	0.0%
Surcharge	10%	Surcharge	10%
Cess	4%	Cess	4%
Total Applicable Tax	**0.0%**	**Total Applicable Tax**	**0.0%**

Package 1 :Hebbal near Esteem Mall juntion (Km 0+000) to Seshadri Road (Km 8+748)							
Cost Summary (All Figures are in Crores Unless mentioned) - PK I							
A	**Bid Project Cost**	**Rs. In Crores**					
1	Civil Cost of the Project	6780.31					
2	Contingencies @ 1 % Civil Cost as per recent circular	67.80					
	Total EPC Cost	**6848.11**					
3	IE / Pre-operative Expenses @ 1% of EPC (IV)	68.48				Financing cost on debt	1.0%
4	Financing Cost on debt	36.83				IC cost	1%
5	Esclation @ 5% Per Anum	1047.03					
6	Interest During Construction	769.61					
7	**Estimated Project Cost**	**8770.08**	28.07%			CS	3508.0
						Equity	1578.61
B	**Source of Financing**	**Rs. In Crores**				Debt	3683.4
1	Total Project Cost	8770.08				**Total**	**8770.1**
2	Construction Support by Authority	3508.03	40%			Upfront Equity	0.00
3	Balance Project Cost funded by the Concessionaire	5262.05	60%				
4	Equity Contribution	1578.6	30%				
5	Debt Loan Requirement	3683.4	70%				

Package 1 :Hebbal near Esteem Mall juntion (Km 0+000) to Seshadri Road (Km 8+748)

Cash Flow Statement (In crores)-4 Years of Construction period - 25 years O& M Period - Project IRR

	VGF	40.00%					Section 15 BAA Opted			Yes	No. of O & M Years		25	D/E Ratio	2.33								
					PBDIT						FIRR						Equity IRR						
S. No.	Year	% of days	Revenue	Expenses	Net Income	Depreciation	PBIT	Interest on Debt	Profit Before Tax (PBT)	TAX	Profit After Tax (PAT)	Grant	Cash Inflows Total	Capital Expenditure	Cash Outflows Total	Net Cash flows	Debt	Total Cash Inflows	Capital Expenditure	Repayment	Total Cash Out flows	Net Cash flows	DSCR
-5	31-Mar-25		0.00		0.00		0.00		0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-4	31-Mar-26		0.00		-518.94		-518.94		-518.94			350.80	350.80	768.48	768.48	-417.67	325.89	676.69	816.36	0.00	816.36	-139.67	0.00
-3	31-Mar-27		0.00		-1262.75		-1262.75		-1262.75			1052.41	1052.41	1764.59	1764.59	-712.18	576.99	1629.40	1834.58	0.00	1834.58	-205.18	0.00
-2	31-Mar-28		0.00		-1266.21		-1266.21		-1266.21			701.61	701.61	1860.05	1860.05	-1158.44	890.75	1592.36	2016.21	0.00	2016.21	-423.85	0.00
-1	31-Mar-29		0.00		-1262.75		-1262.75		-1262.75			1052.41	1052.41	1949.77	1949.77	-897.36	918.90	1971.31	2209.96	0.00	2209.96	-238.65	0.00
0	31-Mar-30	24.7%	165.07	11.68	153.39	36.33	117.06	0.00	117.06	14.56	102.50	350.80	489.63	1620.75	1620.75	-1131.11	970.91	1460.54	1892.97	0.00	1892.97	-432.43	0.00
1	31-Mar-31	100.0%	716.53	49.73	666.79	147.34	519.46	423.17	96.29	0.00	96.29	0.00	666.79	0.00	0.00	666.79	0.00	243.62	0.00	141.67	141.67	101.95	1.18
2	31-Mar-32	100.0%	758.23	52.22	706.01	147.34	558.67	394.41	164.26	0.00	164.26	0.00	706.01	0.00	0.00	706.01	0.00	311.60	0.00	283.34	283.34	28.25	1.04
3	31-Mar-33	100.0%	813.99	54.83	759.16	147.34	611.82	361.54	250.28	0.00	250.28	0.00	759.16	0.00	0.00	759.16	0.00	397.61	0.00	283.34	283.34	114.27	1.18
4	31-Mar-34	100.0%	864.63	57.57	807.05	147.34	659.72	328.68	331.04	25.61	305.44		781.45	0.00	0.00	781.45	0.00	452.77	0.00	283.34	283.34	169.43	1.28
5	31-Mar-35	100.0%	926.20	60.45	865.74	147.34	718.41	295.81	422.60	58.13	364.47		807.62		0.00	807.62	0.00	511.81	0.00	283.34	283.34	228.47	1.39
6	31-Mar-36	100.0%	989.66	63.48	926.19	147.34	778.85	262.94	515.91	90.14	425.77		836.04		0.00	836.04	0.00	573.10	0.00	283.34	283.34	289.76	1.53
7	31-Mar-37	100.0%	1052.38	66.65	985.73	147.34	838.39	230.07	608.32	121.08	487.24		864.65		0.00	864.65	0.00	634.58	0.00	283.34	283.34	351.24	1.68
8	31-Mar-38	100.0%	1107.36	69.98	1037.38	147.34	890.04	197.21	692.83	149.26	543.57		888.12		0.00	888.12	0.00	690.91	0.00	283.34	283.34	407.57	1.85
9	31-Mar-39	100.0%	1172.24	73.48	1098.76	147.34	951.42	164.34	787.09	179.20	607.88		919.56		0.00	919.56	0.00	755.22	0.00	283.34	283.34	471.88	2.05
10	31-Mar-40	100.0%	1227.12	77.15	1149.97	147.34	1002.63	131.47	871.16	205.96	665.20		944.01		0.00	944.01	0.00	812.54	0.00	283.34	283.34	529.20	2.28
11	31-Mar-41	100.0%	1293.72	81.01	1212.71	147.34	1065.37	98.60	966.77	235.06	731.71		977.65		0.00	977.65	0.00	879.04	0.00	283.34	283.34	595.70	2.56
12	31-Mar-42	100.0%	1363.80	85.06	1278.74	147.34	1131.40	65.74	1065.67	264.48	801.18		1014.25		0.00	1014.25	0.00	948.52	0.00	283.34	283.34	665.18	2.91
13	31-Mar-43	100.0%	1425.86	89.32	1336.54	147.34	1189.20	32.87	1156.34	291.38	864.95		1045.16		0.00	1045.16	0.00	1012.29	0.00	283.34	283.34	728.95	3.31
14	31-Mar-44	100.0%	1500.94	93.78	1407.15	147.34	1259.82	4.11	1255.71	320.07	935.64		1087.09		0.00	1087.09	0.00	1082.98	0.00	141.67	141.67	941.31	7.46
15	31-Mar-45	100.0%	1580.20	98.47	1481.73	147.34	1334.39	0.00	1334.39	343.18	991.22		1138.56		0.00	1138.56	0.00	1138.56	0.00	0.00	0.00	1138.56	0.00
16	31-Mar-46	100.0%	1664.29	103.39	1560.90	147.34	1413.56	0.00	1413.56	366.07	1047.49		1194.82		0.00	1194.82	0.00	1194.82	0.00	0.00	0.00	1194.82	0.00
17	31-Mar-47	100.0%	1742.61	108.56	1634.05	147.34	1486.71	0.00	1486.71	387.16	1099.55		1246.89		0.00	1246.89	0.00	1246.89	0.00	0.00	0.00	1246.89	0.00
18	31-Mar-48	100.0%	1828.54	113.99	1714.54	147.34	1567.21	0.00	1567.21	409.83	1157.38		1304.71		0.00	1304.71	0.00	1304.71	0.00	0.00	0.00	1304.71	0.00
19	31-Mar-49	100.0%	1907.78	119.69	1788.08	147.34	1640.75	0.00	1640.75	430.51	1210.24		1357.58		0.00	1357.58	0.00	1357.58	0.00	0.00	0.00	1357.58	0.00
20	31-Mar-50	100.0%	1995.66	125.68	1869.98	147.34	1722.65	0.00	1722.65	453.07	1269.57		1416.91		0.00	1416.91	0.00	1416.91	0.00	0.00	0.00	1416.91	0.00
21	31-Mar-51	100.0%	2075.94	131.96	1943.98	147.34	1796.64	0.00	1796.64	473.45	1323.19		1470.53		0.00	1470.53	0.00	1470.53	0.00	0.00	0.00	1470.53	0.00
22	31-Mar-52	100.0%	2168.22	138.56	2029.67	147.34	1882.33	0.00	1882.33	496.60	1385.73		1533.07		0.00	1533.07	0.00	1533.07	0.00	0.00	0.00	1533.07	0.00
23	31-Mar-53	100.0%	2265.23	145.49	2119.75	147.34	1972.41	0.00	1972.41	520.69	1451.72		1599.05		0.00	1599.05	0.00	1599.05	0.00	0.00	0.00	1599.05	0.00
24	31-Mar-54	100.0%	2366.77	152.76	2214.01	147.34	2066.67	0.00	2066.67	545.70	1520.97		1668.31		0.00	1668.31	0.00	1668.31	0.00	0.00	0.00	1668.31	0.00
25	31-Mar-55	75.3%	1860.67	120.85	1739.82	111.01	1628.81	0.00	1628.81	430.06	1198.75		1309.76		0.00	1309.76	0.00	1309.76	0.00	0.00	0.00	1309.76	0.00
		Total	36833.62	2345.81	30177.16	3683.43	26493.72	2990.95	23502.78	6811.26	21002.17			Project IRR	NPV					Equity IRR	NPV	Average DSCR	
														15.27%	934.8					17.79%	928.00	2.26	

Package 1 :Hebbal near Esteem Mall juntion (Km 0+000) to Seshadri Road (Km 8+748)																								
Cash Flow Statement (In crores)-4 Years of Construction period - 30 years O& M Period - Project IRR																								
	VGF	40.00%					Section 15 BAA Opted			Yes	No. of O & M Years		30	D/E Ratio	2.33									
					PBDIT						FIRR						Equity IRR							
S. No.	Year	% of days	Revenue	Expenses	Net Income	Depreciation	PBIT	Interest on Debt	Profit Before Tax (PBT)	TAX	Profit After Tax (PAT)	Grant	Cash Inflows Total	Capital Expenditure	Cash Outflows Total	Net Cash flows	Debt	Total Cash Inflows	Capital Expenditure	Repayment	Total Cash Out flows	Net Cash flows	DSCR	
-5	31-Mar-25		0.00		0.00		0.00		0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
-4	31-Mar-26		0.00		-518.94		-518.94		-518.94			350.80	350.80	768.48	768.48	-417.67	325.89	676.69	816.36	0.00	816.36	-139.67	0.00	
-3	31-Mar-27		0.00		-1262.75		-1262.75		-1262.75			1052.41	1052.41	1764.59	1764.59	-712.18	576.99	1629.40	1834.58	0.00	1834.58	-205.18	0.00	
-2	31-Mar-28		0.00		-1266.21		-1266.21		-1266.21			701.61	701.61	1860.05	1860.05	-1158.44	890.75	1592.36	2016.21	0.00	2016.21	-423.85	0.00	
-1	31-Mar-29		0.00		-1262.75		-1262.75		-1262.75			1052.41	1052.41	1949.77	1949.77	-897.36	918.90	1971.31	2209.96	0.00	2209.96	-238.65	0.00	
0	31-Mar-30	24.7%	165.07	11.68	153.39	30.27	123.11	0.00	123.11	14.56	108.56	350.80	489.63	1620.75	1620.75	-1131.11	970.91	1460.54	1892.97	0.00	1892.97	-432.43	0.00	
1	31-Mar-31	100.0%	716.53	49.73	666.79	122.78	544.01	423.17	120.84	0.00	120.84	0.00	666.79	0.00	0.00	666.79	0.00	243.62	0.00	141.67	141.67	101.95	1.18	
2	31-Mar-32	100.0%	758.23	52.22	706.01	122.78	583.22	394.41	188.81	0.00	188.81	0.00	706.01	0.00	0.00	706.01	0.00	311.60	0.00	283.34	283.34	28.25	1.04	
3	31-Mar-33	100.0%	813.99	54.83	759.16	122.78	636.38	361.54	274.83	0.00	274.83	0.00	759.16	0.00	0.00	759.16	0.00	397.61	0.00	283.34	283.34	114.27	1.18	
4	31-Mar-34	100.0%	864.63	57.57	807.05	122.78	684.27	328.68	355.60	25.61	329.99		781.45	0.00	0.00	781.45	0.00	452.77	0.00	283.34	283.34	169.43	1.28	
5	31-Mar-35	100.0%	926.20	60.45	865.74	122.78	742.96	295.81	447.16	58.13	389.03		807.62		0.00	807.62	0.00	511.81	0.00	283.34	283.34	228.47	1.39	
6	31-Mar-36	100.0%	989.66	63.48	926.19	122.78	803.41	262.94	540.47	90.14	450.32		836.04		0.00	836.04	0.00	573.10	0.00	283.34	283.34	289.76	1.53	
7	31-Mar-37	100.0%	1052.38	66.65	985.73	122.78	862.95	230.07	632.88	121.08	511.80		864.65		0.00	864.65	0.00	634.58	0.00	283.34	283.34	351.24	1.68	
8	31-Mar-38	100.0%	1107.36	69.98	1037.38	122.78	914.60	197.21	717.39	149.26	568.13		888.12		0.00	888.12	0.00	690.91	0.00	283.34	283.34	407.57	1.85	
9	31-Mar-39	100.0%	1172.24	73.48	1098.76	122.78	975.98	164.34	811.64	179.20	632.44		919.56		0.00	919.56	0.00	755.22	0.00	283.34	283.34	471.88	2.05	
10	31-Mar-40	100.0%	1227.12	77.15	1149.97	122.78	1027.19	131.47	895.72	205.96	689.76		944.01		0.00	944.01	0.00	812.54	0.00	283.34	283.34	529.20	2.28	
11	31-Mar-41	100.0%	1293.72	81.01	1212.71	122.78	1089.92	98.60	991.32	235.06	756.26		977.65		0.00	977.65	0.00	879.04	0.00	283.34	283.34	595.70	2.56	
12	31-Mar-42	100.0%	1363.80	85.06	1278.74	122.78	1155.96	65.74	1090.22	264.48	825.74		1014.25		0.00	1014.25	0.00	948.52	0.00	283.34	283.34	665.18	2.91	
13	31-Mar-43	100.0%	1425.86	89.32	1336.54	122.78	1213.76	32.87	1180.89	291.38	889.51		1045.16		0.00	1045.16	0.00	1012.29	0.00	283.34	283.34	728.95	3.31	
14	31-Mar-44	100.0%	1500.94	93.78	1407.15	122.78	1284.37	4.11	1280.26	320.07	960.20		1087.09		0.00	1087.09	0.00	1082.98	0.00	141.67	141.67	941.31	7.46	
15	31-Mar-45	100.0%	1580.20	98.47	1481.73	122.78	1358.95	0.00	1358.95	343.18	1015.78		1138.56		0.00	1138.56	0.00	1138.56	0.00	0.00	0.00	1138.56	0.00	
16	31-Mar-46	100.0%	1664.29	103.39	1560.90	122.78	1438.12	0.00	1438.12	366.07	1072.04		1194.82		0.00	1194.82	0.00	1194.82	0.00	0.00	0.00	1194.82	0.00	
17	31-Mar-47	100.0%	1742.61	108.56	1634.05	122.78	1511.27	0.00	1511.27	387.16	1124.10		1246.89		0.00	1246.89	0.00	1246.89	0.00	0.00	0.00	1246.89	0.00	
18	31-Mar-48	100.0%	1828.54	113.99	1714.54	122.78	1591.76	0.00	1591.76	409.83	1181.93		1304.71		0.00	1304.71	0.00	1304.71	0.00	0.00	0.00	1304.71	0.00	
19	31-Mar-49	100.0%	1907.78	119.69	1788.08	122.78	1665.30	0.00	1665.30	430.51	1234.79		1357.58		0.00	1357.58	0.00	1357.58	0.00	0.00	0.00	1357.58	0.00	
20	31-Mar-50	100.0%	1995.66	125.68	1869.98	122.78	1747.20	0.00	1747.20	453.07	1294.13		1416.91		0.00	1416.91	0.00	1416.91	0.00	0.00	0.00	1416.91	0.00	
21	31-Mar-51	100.0%	2075.94	131.96	1943.98	122.78	1821.20	0.00	1821.20	473.45	1347.75		1470.53		0.00	1470.53	0.00	1470.53	0.00	0.00	0.00	1470.53	0.00	
22	31-Mar-52	100.0%	2168.22	138.56	2029.67	122.78	1906.89	0.00	1906.89	496.60	1410.29		1533.07		0.00	1533.07	0.00	1533.07	0.00	0.00	0.00	1533.07	0.00	
23	31-Mar-53	100.0%	2265.23	145.49	2119.75	122.78	1996.97	0.00	1996.97	520.69	1476.27		1599.05		0.00	1599.05	0.00	1599.05	0.00	0.00	0.00	1599.05	0.00	
24	31-Mar-54	100.0%	2366.77	152.76	2214.01	122.78	2091.22	0.00	2091.22	545.70	1545.53		1668.31		0.00	1668.31	0.00	1668.31	0.00	0.00	0.00	1668.31	0.00	
25	31-Mar-55	100.0%	2469.61	160.40	2309.21	122.78	2186.43	0.00	2186.43	570.81	1615.62		1738.40		0.00	1738.40	0.00	1738.40	0.00	0.00	0.00	1738.40	0.00	
26	31-Mar-56	100.0%	2583.66	168.42	2415.24	122.78	2292.46	0.00	2292.46	598.53	1693.92		1816.71		0.00	1816.71	0.00	1816.71	0.00	0.00	0.00	1816.71	0.00	
27	31-Mar-57	100.0%	2700.13	176.84	2523.29	122.78	2400.51	0.00	2400.51	626.66	1773.85		1896.63		0.00	1896.63	0.00	1896.63	0.00	0.00	0.00	1896.63	0.00	
28	31-Mar-58	100.0%	2818.36	185.68	2632.68	122.78	2509.90	0.00	2509.90	655.03	1854.87		1977.65		0.00	1977.65	0.00	1977.65	0.00	0.00	0.00	1977.65	0.00	
29	31-Mar-59	100.0%	2934.89	194.97	2739.93	122.78	2617.15	0.00	2617.15	682.78	1934.37		2057.15		0.00	2057.15	0.00	2057.15	0.00	0.00	0.00	2057.15	0.00	
30	31-Mar-60	75.3%	2315.42	154.24	2161.18	92.51	2068.68	0.00	2068.68	539.31	1529.37		1621.87		0.00	1621.87	0.00	1621.87	0.00	0.00	0.00	1621.87	0.00	
		Total	50795.04	3265.50	43218.88	3683.43	39535.45	2990.95	36544.50	10054.33	30800.83			Project IRR	NPV					Equity IRR	NPV	Average DSCR		
														15.64%	1149.3					18.24%	1142.52	2.26		

Package 2: Seshadri Road to Silk Board (From Km. 8.748 to Km 16.745)			
General Assumptions - Package II			
Bid Date	**1-Mar-25**	Construction start date	**1-Nov-25**
Construction Period in days	1521	No. years of construction	4.2
Construction End date	31-Dec-29	No. of years before COD	5
COD	1-Jan-30	Type of Pavement	Rigid
First FY year in Construction	31-Mar-25	WPI- Dec 2024	155.4
First FY in O & M period	31-Mar-30	WPI on Dec before COD	609.60
No. of days in first O & M year	90	Debt Repayment start date	31-Jul-30
Debt Repayment in years	13	Debt Repayment End date	31-Jul-43
% of days in first COD	24.7%	% of days in last O & M year	75.3%
WPI growth considered (yearly)	5.0%	**Maintenance Expenses (in crores)**	
Grant during construction	40.0%	Other office Expenses for 1st O & MYear	4.97
To be Arranged By contractor/Concessionaire	60%	Insurance	7.77
Equity	30%	Electricity & patrolling expenses for 1st O & M Year	0.20
Debt	70%	**Flexible Pavement in Lakhs**	
Interest on Debt	11.60%	Routine Maintenance (Every year) for 1st Year	0.000
No. of Lanes	6	Periodic Maintenance (Every 6 th year)	0.000
Financing Cost on debt %	1.0%	**Rigid Pavement In Lakhs**	
SBI MCLR rate	9.10%	Routine Maintenance (Every year) for 1st Year	162.69
Structural Maintenance Cost per Km per Year in Cr		No. of Construction Months	50.0
Structural Maintenance Cost in Cr/Yr	2.5	Fully Access Controlled Expressway	No
Road Length		**Rigid Pavement - MCW Road**	
Flexible Pavement - MCW Road		Length of 2 lane section	0.00
Length of 2 lane section	0.00	Length of 4 lane section	0
Length of 4 lane section	0	Length of 6 lane section	7.997
Length of 6 lane section	0	**Total 4 lane Equivalent Length**	**12.00**
Total 4 lane Equivalent Length	**0.00**	**Rigid Pavement - SR Road**	
Flexible Pavement - SR Road		Length of 2 lane section	8.20
Length of 2 lane section	0	Length of 4 lane section	0
Length of 4 lane section	0	Length of 6 lane section	0
Length of 6 lane section	0	**Total 4 lane Equivalent Length**	**4.10**
Total 4 lane Equivalent Length	**0.00**	Det Repayment Years (from Start of Construction)	13
Costing Details (in Crores)			
Length of Corridor	7.997		
Total Civil Cost	6902.72		
Other costs	2025.69		
Total Project cost	8928.41	**Esc Considered During Construction**	**Yes**
Tax Assumptions			
Corporate Tax Rate			
Section 15BAA opted	Yes		
Case I		**Case II**	
Base rate	22%	Base rate	22%
Surcharge	10%	Surcharge	10%
Cess	4%	Cess	4%
Total Applicable Tax	**25.2%**	**Total Applicable Tax**	**25.2%**
MAT Tax Rate			
Case I		**Case II**	
Base rate	0.0%	Base rate	0.0%
Surcharge	10%	Surcharge	10%
Cess	4%	Cess	4%
Total Applicable Tax	**0.0%**	**Total Applicable Tax**	**0.0%**

Package 2: Seshadri Road to Silk Board (From Km. 8.748 to Km 16.745)							
Cost Summary (All Figures are in Crores Unless mentioned) - PK II							
A	**Bid Project Cost**	**Rs. In Crores**					
1	Civil Cost of the Project	6902.72					
2	Contingencies @ 1 % Civil Cost as per recent circular	69.03					
	Total EPC Cost	**6971.75**					
3	IE / Pre-operative Expenses @ 1% of EPC (IV)	69.72				Financing cost on debt	1.0%
4	Financing Cost on debt	37.50				IC cost	1%
5	Esclation @ 5% Per Anum	1065.94					
6	Interest During Construction	783.51					
7	**Estimated Project Cost**	**8928.41**	28.07%			CS	3571.4
						Equity	1607.11
B	**Source of Financing**	**Rs. In Crores**				Debt	3749.9
1	Total Project Cost	8928.41				**Total**	**8928.4**
2	Construction Support by Authority	3571.36	40%			Upfront Equity	0.00
3	Balance Project Cost funded by the Concessionaire	5357.05	60%				
4	Equity Contribution	1607.1	30%				
5	Debt Loan Requirement	3749.9	70%				

Package 2: Seshadri Road to Silk Board (From Km. 8.748 to Km 16.745)

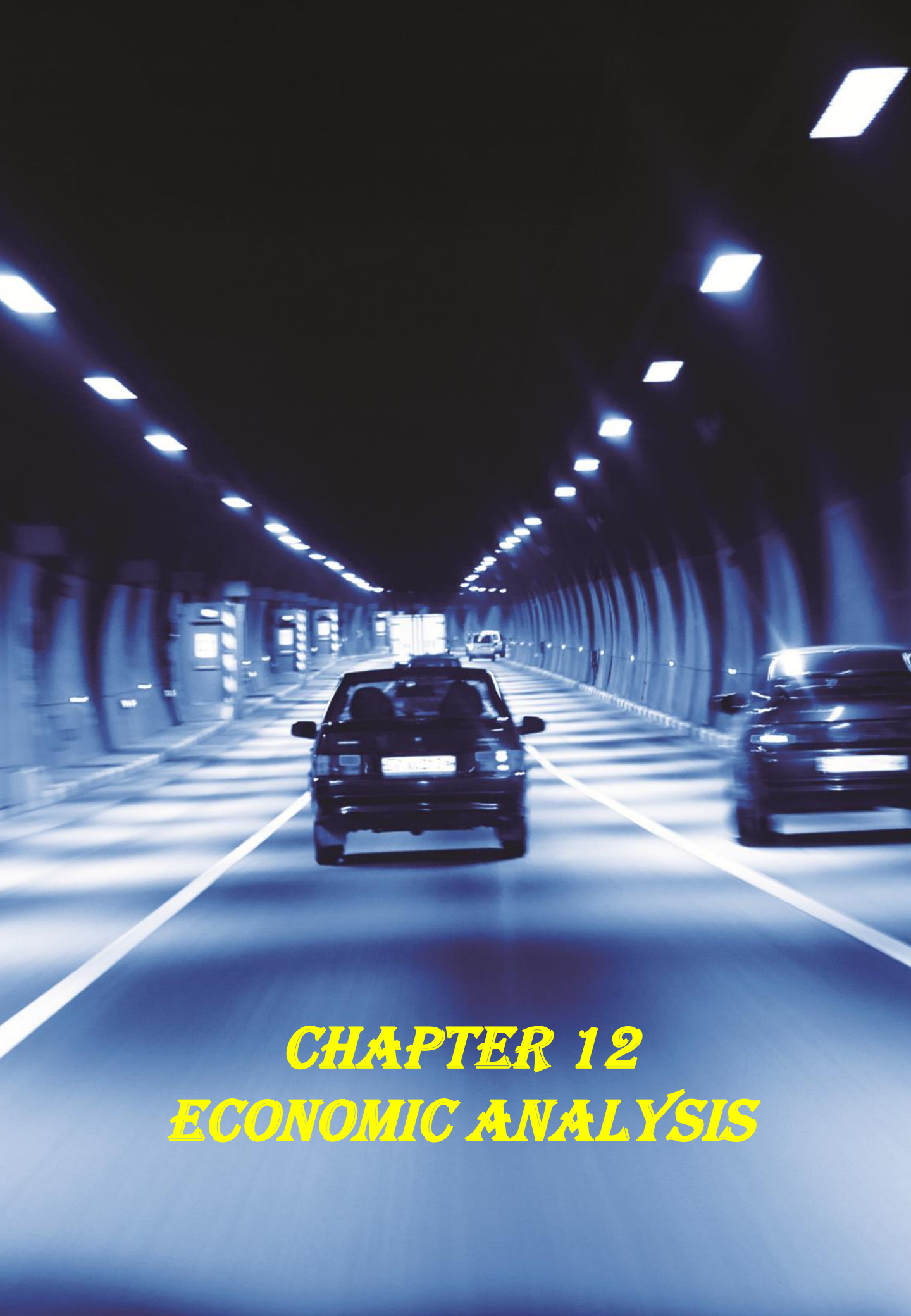
Cash Flow Statement (In crores)-4 Years of Construction period - 25 years O& M Period - Project IRR

	VGF	40.00%					Section 15 BAA Opted			Yes	No. of O & M Years		25	D/E Ratio	2.33								
					PBDIT						FIRR						Equity IRR						
S. No.	Year	% of days	Revenue	Expenses	Net Income	Depreciation	PBIT	Interest on Debt	Profit Before Tax (PBT)	TAX	Profit After Tax (PAT)	Grant	Cash Inflows Total	Capital Expenditure	Cash Outflows Total	Net Cash flows	Debt	Total Cash Inflows	Capital Expenditure	Repayment	Total Cash Out flows	Net Cash flows	DSCR
-5	31-Mar-25		0.00		0.00		0.00		0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-4	31-Mar-26		0.00		-528.31		-528.31		-528.31			357.14	357.14	782.35	782.35	-425.21	331.77	688.91	831.10	0.00	831.10	-142.19	0.00
-3	31-Mar-27		0.00		-1285.55		-1285.55		-1285.55			1071.41	1071.41	1796.45	1796.45	-725.04	587.41	1658.82	1867.70	0.00	1867.70	-208.89	0.00
-2	31-Mar-28		0.00		-1289.07		-1289.07		-1289.07			714.27	714.27	1893.63	1893.63	-1179.35	906.83	1621.10	2052.61	0.00	2052.61	-431.50	0.00
-1	31-Mar-29		0.00		-1285.55		-1285.55		-1285.55			1071.41	1071.41	1984.97	1984.97	-913.56	935.49	2006.90	2249.86	0.00	2249.86	-242.96	0.00
0	31-Mar-30	24.7%	155.49	10.99	144.51	36.99	107.52	0.00	107.52	11.89	95.63	357.14	489.76	1650.01	1650.01	-1160.25	988.43	1478.19	1927.15	0.00	1927.15	-448.96	0.00
1	31-Mar-31	100.0%	672.30	46.78	625.52	150.00	475.52	430.81	44.71	0.00	44.71	0.00	625.52	0.00	0.00	625.52	0.00	194.71	0.00	144.23	144.23	50.48	1.09
2	31-Mar-32	100.0%	717.45	49.12	668.33	150.00	518.33	401.53	116.80	0.00	116.80	0.00	668.33	0.00	0.00	668.33	0.00	266.80	0.00	288.46	288.46	-21.66	0.97
3	31-Mar-33	100.0%	766.94	51.58	715.36	150.00	565.36	368.07	197.29	0.00	197.29	0.00	715.36	0.00	0.00	715.36	0.00	347.29	0.00	288.46	288.46	58.83	1.09
4	31-Mar-34	100.0%	815.04	54.16	760.88	150.00	610.89	334.61	276.28	10.78	265.50		750.10	0.00	0.00	750.10	0.00	415.49	0.00	288.46	288.46	127.04	1.20
5	31-Mar-35	100.0%	869.72	56.86	812.85	150.00	662.85	301.15	361.71	41.93	319.77		770.92		0.00	770.92	0.00	469.77	0.00	288.46	288.46	181.31	1.31
6	31-Mar-36	100.0%	931.26	59.71	871.55	150.00	721.56	267.69	453.87	73.81	380.05		797.74		0.00	797.74	0.00	530.05	0.00	288.46	288.46	241.60	1.43
7	31-Mar-37	100.0%	981.29	62.69	918.60	150.00	768.60	234.23	534.38	101.89	432.49		816.71		0.00	816.71	0.00	582.48	0.00	288.46	288.46	294.03	1.56
8	31-Mar-38	100.0%	1033.60	65.83	967.77	150.00	817.77	200.77	617.01	129.72	487.28		838.05		0.00	838.05	0.00	637.28	0.00	288.46	288.46	348.82	1.71
9	31-Mar-39	100.0%	1090.17	69.12	1021.05	150.00	871.05	167.30	703.75	157.89	545.86		863.16		0.00	863.16	0.00	695.86	0.00	288.46	288.46	407.40	1.89
10	31-Mar-40	100.0%	1149.92	72.58	1077.34	150.00	927.34	133.84	793.50	186.17	607.33		891.17		0.00	891.17	0.00	757.32	0.00	288.46	288.46	468.87	2.11
11	31-Mar-41	100.0%	1203.16	76.20	1126.95	150.00	976.96	100.38	876.57	212.21	664.36		914.74		0.00	914.74	0.00	814.36	0.00	288.46	288.46	525.90	2.35
12	31-Mar-42	100.0%	1267.24	80.01	1187.23	150.00	1037.23	66.92	970.31	240.42	729.89		946.81		0.00	946.81	0.00	879.89	0.00	288.46	288.46	591.43	2.66
13	31-Mar-43	100.0%	1330.27	84.02	1246.26	150.00	1096.26	33.46	1062.80	267.85	794.95		978.41		0.00	978.41	0.00	944.95	0.00	288.46	288.46	656.49	3.04
14	31-Mar-44	100.0%	1397.29	88.22	1309.08	150.00	1159.08	4.18	1154.90	294.77	860.13		1014.31		0.00	1014.31	0.00	1010.13	0.00	144.23	144.23	865.90	6.83
15	31-Mar-45	100.0%	1473.08	92.63	1380.46	150.00	1230.46	0.00	1230.46	317.15	913.31		1063.31		0.00	1063.31	0.00	1063.31	0.00	0.00	0.00	1063.31	0.00
16	31-Mar-46	100.0%	1545.88	97.26	1448.62	150.00	1298.63	0.00	1298.63	337.33	961.29		1111.29		0.00	1111.29	0.00	1111.29	0.00	0.00	0.00	1111.29	0.00
17	31-Mar-47	100.0%	1621.36	102.12	1519.24	150.00	1369.25	0.00	1369.25	357.83	1011.41		1161.41		0.00	1161.41	0.00	1161.41	0.00	0.00	0.00	1161.41	0.00
18	31-Mar-48	100.0%	1695.78	107.23	1588.56	150.00	1438.56	0.00	1438.56	377.73	1060.83		1210.83		0.00	1210.83	0.00	1210.83	0.00	0.00	0.00	1210.83	0.00
19	31-Mar-49	100.0%	1771.23	112.59	1658.64	150.00	1508.64	0.00	1508.64	397.58	1111.07		1261.06		0.00	1261.06	0.00	1261.06	0.00	0.00	0.00	1261.06	0.00
20	31-Mar-50	100.0%	1842.91	118.22	1724.69	150.00	1574.69	0.00	1574.69	416.19	1158.51		1308.50		0.00	1308.50	0.00	1308.50	0.00	0.00	0.00	1308.50	0.00
21	31-Mar-51	100.0%	1929.66	124.13	1805.53	150.00	1655.53	0.00	1655.53	438.32	1217.21		1367.21		0.00	1367.21	0.00	1367.21	0.00	0.00	0.00	1367.21	0.00
22	31-Mar-52	100.0%	2014.79	130.34	1884.45	150.00	1734.45	0.00	1734.45	459.79	1274.66		1424.66		0.00	1424.66	0.00	1424.66	0.00	0.00	0.00	1424.66	0.00
23	31-Mar-53	100.0%	2105.24	136.85	1968.39	150.00	1818.39	0.00	1818.39	482.37	1336.02		1486.02		0.00	1486.02	0.00	1486.02	0.00	0.00	0.00	1486.02	0.00
24	31-Mar-54	100.0%	2198.37	143.69	2054.67	150.00	1904.67	0.00	1904.67	505.39	1399.29		1549.28		0.00	1549.28	0.00	1549.28	0.00	0.00	0.00	1549.28	0.00
25	31-Mar-55	75.3%	1726.61	113.68	1612.93	113.01	1499.92	0.00	1499.92	397.99	1101.93		1214.94		0.00	1214.94	0.00	1214.94	0.00	0.00	0.00	1214.94	0.00
		Total	34306.05	2206.59	27710.98	3749.93	23961.04	3044.94	20916.10	6217.00	19087.58			Project IRR	NPV					Equity IRR	NPV	Average DSCR	
														14.36%	670.7					16.13%	663.79	2.09	

Package 2: Seshadri Road to Silk Board (From Km. 8.748 to Km 16.745)

Cash Flow Statement (In crores)-4 Years of Construction period - 30 years O& M Period - Project IRR

	VGF	40.00%					Section 15 BAA Opted			Yes	No. of O & M Years		30	D/E Ratio	2.33								
					PBDIT						FIRR						Equity IRR						
S. No.	Year	% of days	Revenue	Expenses	Net Income	Depreciation	PBIT	Interest on Debt	Profit Before Tax (PBT)	TAX	Profit After Tax (PAT)	Grant	Cash Inflows Total	Capital Expenditure	Cash Outflows Total	Net Cash flows	Debt	Total Cash Inflows	Capital Expenditure	Repayment	Total Cash Out flows	Net Cash flows	DSCR
-5	31-Mar-25		0.00		0.00		0.00		0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-4	31-Mar-26		0.00		-528.31		-528.31		-528.31			357.14	357.14	782.35	782.35	-425.21	331.77	688.91	831.10	0.00	831.10	-142.19	0.00
-3	31-Mar-27		0.00		-1285.55		-1285.55		-1285.55			1071.41	1071.41	1796.45	1796.45	-725.04	587.41	1658.82	1867.70	0.00	1867.70	-208.89	0.00
-2	31-Mar-28		0.00		-1289.07		-1289.07		-1289.07			714.27	714.27	1893.63	1893.63	-1179.35	906.83	1621.10	2052.61	0.00	2052.61	-431.50	0.00
-1	31-Mar-29		0.00		-1285.55		-1285.55		-1285.55			1071.41	1071.41	1984.97	1984.97	-913.56	935.49	2006.90	2249.86	0.00	2249.86	-242.96	0.00
0	31-Mar-30	24.7%	155.49	10.99	144.51	30.82	113.69	0.00	113.69	11.89	101.80	357.14	489.76	1650.01	1650.01	-1160.25	988.43	1478.19	1927.15	0.00	1927.15	-448.96	0.00
1	31-Mar-31	100.0%	672.30	46.78	625.52	125.00	500.52	430.81	69.71	0.00	69.71	0.00	625.52	0.00	0.00	625.52	0.00	194.71	0.00	144.23	144.23	50.48	1.09
2	31-Mar-32	100.0%	717.45	49.12	668.33	125.00	543.33	401.53	141.80	0.00	141.80	0.00	668.33	0.00	0.00	668.33	0.00	266.80	0.00	288.46	288.46	-21.66	0.97
3	31-Mar-33	100.0%	766.94	51.58	715.36	125.00	590.36	368.07	222.29	0.00	222.29	0.00	715.36	0.00	0.00	715.36	0.00	347.29	0.00	288.46	288.46	58.83	1.09
4	31-Mar-34	100.0%	815.04	54.16	760.88	125.00	635.89	334.61	301.28	10.78	290.50		750.10	0.00	0.00	750.10	0.00	415.49	0.00	288.46	288.46	127.04	1.20
5	31-Mar-35	100.0%	869.72	56.86	812.85	125.00	687.85	301.15	386.71	41.93	344.77		770.92		0.00	770.92	0.00	469.77	0.00	288.46	288.46	181.31	1.31
6	31-Mar-36	100.0%	931.26	59.71	871.55	125.00	746.55	267.69	478.87	73.81	405.05		797.74		0.00	797.74	0.00	530.05	0.00	288.46	288.46	241.60	1.43
7	31-Mar-37	100.0%	981.29	62.69	918.60	125.00	793.60	234.23	559.38	101.89	457.48		816.71		0.00	816.71	0.00	582.48	0.00	288.46	288.46	294.03	1.56
8	31-Mar-38	100.0%	1033.60	65.83	967.77	125.00	842.77	200.77	642.01	129.72	512.28		838.05		0.00	838.05	0.00	637.28	0.00	288.46	288.46	348.82	1.71
9	31-Mar-39	100.0%	1090.17	69.12	1021.05	125.00	896.05	167.30	728.75	157.89	570.86		863.16		0.00	863.16	0.00	695.86	0.00	288.46	288.46	407.40	1.89
10	31-Mar-40	100.0%	1149.92	72.58	1077.34	125.00	952.34	133.84	818.50	186.17	632.33		891.17		0.00	891.17	0.00	757.32	0.00	288.46	288.46	468.87	2.11
11	31-Mar-41	100.0%	1203.16	76.20	1126.95	125.00	1001.96	100.38	901.57	212.21	689.36		914.74		0.00	914.74	0.00	814.36	0.00	288.46	288.46	525.90	2.35
12	31-Mar-42	100.0%	1267.24	80.01	1187.23	125.00	1062.23	66.92	995.31	240.42	754.89		946.81		0.00	946.81	0.00	879.89	0.00	288.46	288.46	591.43	2.66
13	31-Mar-43	100.0%	1330.27	84.02	1246.26	125.00	1121.26	33.46	1087.80	267.85	819.95		978.41		0.00	978.41	0.00	944.95	0.00	288.46	288.46	656.49	3.04
14	31-Mar-44	100.0%	1397.29	88.22	1309.08	125.00	1184.08	4.18	1179.90	294.77	885.13		1014.31		0.00	1014.31	0.00	1010.13	0.00	144.23	144.23	865.90	6.83
15	31-Mar-45	100.0%	1473.08	92.63	1380.46	125.00	1255.46	0.00	1255.46	317.15	938.31		1063.31		0.00	1063.31	0.00	1063.31	0.00	0.00	0.00	1063.31	0.00
16	31-Mar-46	100.0%	1545.88	97.26	1448.62	125.00	1323.63	0.00	1323.63	337.33	986.29		1111.29		0.00	1111.29	0.00	1111.29	0.00	0.00	0.00	1111.29	0.00
17	31-Mar-47	100.0%	1621.36	102.12	1519.24	125.00	1394.24	0.00	1394.24	357.83	1036.41		1161.41		0.00	1161.41	0.00	1161.41	0.00	0.00	0.00	1161.41	0.00
18	31-Mar-48	100.0%	1695.78	107.23	1588.56	125.00	1463.56	0.00	1463.56	377.73	1085.83		1210.83		0.00	1210.83	0.00	1210.83	0.00	0.00	0.00	1210.83	0.00
19	31-Mar-49	100.0%	1771.23	112.59	1658.64	125.00	1533.64	0.00	1533.64	397.58	1136.07		1261.06		0.00	1261.06	0.00	1261.06	0.00	0.00	0.00	1261.06	0.00
20	31-Mar-50	100.0%	1842.91	118.22	1724.69	125.00	1599.69	0.00	1599.69	416.19	1183.51		1308.50		0.00	1308.50	0.00	1308.50	0.00	0.00	0.00	1308.50	0.00
21	31-Mar-51	100.0%	1929.66	124.13	1805.53	125.00	1680.53	0.00	1680.53	438.32	1242.21		1367.21		0.00	1367.21	0.00	1367.21	0.00	0.00	0.00	1367.21	0.00
22	31-Mar-52	100.0%	2014.79	130.34	1884.45	125.00	1759.45	0.00	1759.45	459.79	1299.66		1424.66		0.00	1424.66	0.00	1424.66	0.00	0.00	0.00	1424.66	0.00
23	31-Mar-53	100.0%	2105.24	136.85	1968.39	125.00	1843.39	0.00	1843.39	482.37	1361.02		1486.02		0.00	1486.02	0.00	1486.02	0.00	0.00	0.00	1486.02	0.00
24	31-Mar-54	100.0%	2198.37	143.69	2054.67	125.00	1929.67	0.00	1929.67	505.39	1424.29		1549.28		0.00	1549.28	0.00	1549.28	0.00	0.00	0.00	1549.28	0.00
25	31-Mar-55	100.0%	2291.68	150.88	2140.80	125.00	2015.80	0.00	2015.80	528.24	1487.56		1612.56		0.00	1612.56	0.00	1612.56	0.00	0.00	0.00	1612.56	0.00
26	31-Mar-56	100.0%	2392.26	158.42	2233.84	125.00	2108.84	0.00	2108.84	552.71	1556.13		1681.13		0.00	1681.13	0.00	1681.13	0.00	0.00	0.00	1681.13	0.00
27	31-Mar-57	100.0%	2508.03	166.34	2341.69	125.00	2216.69	0.00	2216.69	580.80	1635.89		1760.89		0.00	1760.89	0.00	1760.89	0.00	0.00	0.00	1760.89	0.00
28	31-Mar-58	100.0%	2609.63	174.66	2434.97	125.00	2309.97	0.00	2309.97	605.14	1704.84		1829.84		0.00	1829.84	0.00	1829.84	0.00	0.00	0.00	1829.84	0.00
29	31-Mar-59	100.0%	2722.04	183.39	2538.64	125.00	2413.65	0.00	2413.65	632.00	1781.65		1906.65		0.00	1906.65	0.00	1906.65	0.00	0.00	0.00	1906.65	0.00
30	31-Mar-60	75.3%	2143.49	145.08	1998.41	94.18	1904.23	0.00	1904.23	498.26	1405.97		1500.15		0.00	1500.15	0.00	1500.15	0.00	0.00	0.00	1500.15	0.00
		Total	47246.58	3071.70	39786.40	3749.93	36036.47	3044.94	32991.52	9216.16	28163.84			Project IRR	NPV					Equity IRR	NPV	Average DSCR	
														14.78%	869.4					16.68%	862.50	2.09	



CHAPTER 12
ECONOMIC ANALYSIS

CHAPTER 12: ECONOMIC ANALYSIS

12.1 General

The proposed project designed to ease Bengaluru's notorious traffic congestions and improving the connectivity between north south corridor in the Bengaluru city. The proposed project would reduce the travel time to especially airport travellers and would be more beneficial to travellers who travels from north to south and vice versa frequently. The proposed tunnel would enhance the passenger value of time by congestion less tunnel and also would reduce the traffic burden on the existing road network.

An economic evaluation of the proposed project components was undertaken. The evaluation methodology is determined by the magnitude of the impact of the road project improvements have on the transport conditions as compared with the existing situation.

In this study, the proposed tunnel shall be used for cars. With the development of new project, the passenger time savings will improve, employment will be generated, vehicle operating costs will reduce, mileage /fuel efficiency of the project would be increased and there would be savings in Fuel and economic impact.

The results are expressed in Economic Internal Rates of Return (EIRRs) and ratios between Net Present Value (NPV) and capital costs of the proposed road improvement. NPV/capital cost ratios are used in choosing between various improvement options. The basic concept is to maximize the returns on investment.

Two alternatives were studied and the economic IRR is derived by comparing the benefits in base case and proposed case.

Base case: The vehicular users would be travelling on the existing congested route.

Proposed case: The vehicular users would be preferring to tunnel instead of existing route and some part of traffic would be diverting from existing road section.

12.1.1 Analysis Period

For Economic Internal Rate of Return calculations, a horizon period of 4 years of construction and 26 years of O & M period is considered.

12.2 Traffic parameters considered for Economic Analysis

For assessing the economic analysis of tunnel project, the traffic considered is as follows and also enclosed in the Annexure.

Table 109:Traffic data for the year 2027-28

Section	Car traffic in No's	Existing Travel Length in Kms	Length via tunnel in Kms
Hebbal -Silk Board Junction	3936	16.3	16.75
Hebbal -Sarjapur/ HSR layout (Ring Road)	1595	17.1	16.80
Hebbal -Hosur Main Road (Wilson Garden)	2316	13.4	12.87
Hebbal -Seshadri Road (Towards KR Circle)	4385	10.2	9.11
Hebbal -Palace Road (Mekhri Circle)	8249	5.1	5.45
ORR (from KR Puram Side)-Silk Board Junction	3933	17.4	16.16
ORR (from KR Puram Side)-Sarjapur/ HSR layout (Ring Road)	1028	18.2	16.21
ORR (from KR Puram Side)-Hosur Main Road (Wilson Garden)	6733	14.5	12.28
ORR (from KR Puram Side)-Seshadri Road (Towards KR Circle)	6099	11.3	8.52
ORR (from KR Puram Side)-Palace Road (Mekhri Circle)	8051	6.2	4.87
Mekhri Circle -Silk Board Junction	5274	12.8	12.13
Mekhri Circle -Sarjapur/ HSR layout (Ring Road)	2940	11.9	12.18
Mekhri Circle -Hosur Main Road (Wilson Garden)	2081	8.5	8.25
Mekhri Circle -Seshadri Road (Towards KR Circle)	14136	6.5	4.56
Race Course from palace rd.-Silk Board Junction	8636	8.7	9.28

Section	Car traffic in No's	Existing Travel Length in Kms	Length via tunnel in Kms
Race Course from palace rd.-Sarjapur/ HSR layout (Ring Road)	5701	9.5	9.33
Race Course from palace rd.-Hosur Main Road (Wilson Garden)	10525	5.7	5.40
Silk Board -Hebbal	3936	15.6	17.12
Silk Board -ORR (Km 1.30 from KR Puram)	3933	15.6	15.85
Silk Board -CV Raman Road (Mekhri Circle)	5274	12.8	13.28
Silk Board -Race Course	8636	9.4	9.39
Sarjapur/ HSR layout (Ring Road) -Hebbal	1595	16	17.50
Sarjapur/ HSR layout (Ring Road) -ORR (Km 1.30 from KR Puram)	1028	17.6	16.23
Sarjapur/ HSR layout (Ring Road) -CV Raman Road (Mekhri Circle)	2940	13.2	13.67
Sarjapur/ HSR layout (Ring Road) -Race Course	5701	10.1	9.77
Jayanagar (From Ashoka Pillar)-Hebbal	2316	14.6	13.62
Jayanagar (From Ashoka Pillar)-ORR (Km 1.30 from KR Puram)	6733	14.6	12.35
Jayanagar (From Ashoka Pillar)-CV Raman Road (Mekhri Circle)	2081	11.8	9.78
Jayanagar (From Ashoka Pillar)-Race Course	10525	7.1	5.89
Race Course from Palace Rd.-Hebbal	4385	10.1	10.98
Race Course from Palace Rd.-ORR (Km 1.30 from KR Puram)	6099	10.2	9.70
Race Course from Palace Rd.-CV Raman Road (Mekhri Circle)	14136	7.3	6.14
CV Raman Road -Hebbal	8249	6.7	7.18
CV Raman Road -ORR (Km 1.30 from KR Puram)	8051	5.9	5.91

12.3 Quantification of Economic Cost & benefits

12.3.1 Capital

To be acceptable for implementation, the proposed investments have to result in an EIRR of at least equal to the opportunity cost of capital, which is set at 12 percent1. The NPV is calculated using opportunity cost of capital as the discount rate. In terms of funding and implementation capacity, the cut-off rates of return are normally substantially higher than 12 percent.

12.3.2 Shadow Pricing and Use of Conversion Factors

All costs and benefits are valued in monetary terms and expressed in economic prices to avoid distortions in the input prices of labor, materials, equipment and foreign exchange due to market imperfections. In calculating the road agency economic costs (construction and maintenance), economic costs of construction were derived from the financial construction cost by applying a conversion factor. The various conversion factors suggested by various Ministries are as follows:

Table 110: Economic Conversion Factors

S. No.	Type	Components	Economic factor
1	Economic Cost	Capital Cost	0.85
2		Operations and Maintenance Cost	0.85
3	Economic Benefits (Factoring network effect)	Travel time Savings (VOT)	0.85
4		Vehicle Operating cost savings (VOC)	0.85
5		Employment generation	1.00
6		Emission costs	1.00
7		Reduction in fuel and Economic Impact	1.00

Source: Ministry of Housing and Urban Affairs (MoHUA) Guidelines

1 From IRC SP 30-2019

12.3.3 Benefits

The social benefits that are accrued to the society owing to implementation of Tunnel project.

a) Direct and Indirect benefits

The new infrastructure project provides substantial direct and indirect benefits to the economy. The components and steps involved in determining the direct and indirect economic benefits are:

Direct and Indirect Benefits	Network Benefits
Travel Time Savings (VOT)	Reduction in Emissions (Environmental impact)
Vehicle Operating Costs Savings (VOC)	Reduction in Fuel and Economic impact
Employment Generation	

12.3.4 Value of Time Cost

The passenger cost is calculated from Per Capita Income of Bangalore city. The value of time per minute is calculated based on the Per Capita Income of the project Influencing area. This leads to travel time savings for passengers travelling via tunnel over the existing congested roads.

Table 111: Value of time cost

Description	Details
Bangalore Per Capita Income (2022-23) in INR	760362.00
Bangalore Per Capita Income -2025 -Estimated in INR	880214.06
Average Earning Per Hr in INR	423.18
Assumed % of work trips	70%
Average Earning Per Min in INR	4.94

Source: Economic Survey of Karnataka 2023-24

12.3.5 Vehicle Operating Cost

Vehicle Operating cost (VOC) are the cost to the owner of operating a motor vehicle. Savings in vehicle operating costs of different modes arises due to decrease in the number of vehicle trips on the roads. As only cars are allowed in the tunnel section, the VOC cost for the car is considered from the guidelines given in the Manual on Economic Evaluation of Road projects in India, 2019 by the Indian Road Congress (IRC).

Table 112: Vehicle Operating cost

Vehicle Operating cost	Road type	IRI mm/Km	VOT (Rs/Km) in 2019	VOT(Rs/Km) in 2024
Car	Tunnel	2000	1.59	2.07
	Existing road	3000	2.35	3.06

12.3.6 Employment Benefits

With the development of new infrastructure project, there shall be employment generation. The employment benefits generated with the development of tunnel project is assessed based on the Asian Development Bank Guidelines.

Table 113: Employment Benefits

Description	Details	
Personnel Cost	2%	% of Project Cost
Skilled Employment Cost	20%	% of Employment Cost
Unskilled Employment Cost	80%	% of Employment Cost
Direct Employment of Skilled Workers	0.75	Factor
Direct Employment of Unskilled Workers	1	Factor
Indirect Employment Generation	1.5	Factor
Direct Employment Benefits-Operations	40%	% of Opex

Source: Asian Development Bank Guidelines

12.3.7 Network Benefits

New Infrastructure investments can influence the project influence area and generates network benefits in terms of reduction in environmental impact due to decrease in emissions and improvement in travel time reliability etc.

The components and steps involved in determining the economic benefits factoring network effects are:

Reduction in Emission

Reduction in travel length significantly contribute to pollution reduction, and these should be considered in economic analysis. The significant environmental savings come from decrease in air pollution associated with existing road traffic due to the modal split from the existing route assignment.

The reduction in emission will be calculated based on the decrease in vehicle kilometres, volume of pollutants emitted from the different modes and the cost of treatment per ton.

Table 114: Volume of pollutants emitted (gram per km) for different modes

Veh Type /Pollutant	CO	HC	NOX	PM	CO2
2 – Wheeler	1.4	0.7	0.3	0.05	28.58
Cars	1.39	0.15	0.12	0.02	139.52
Buses	3.72	0.16	6.53	0.24	787.72
Treatment Cost (Rs. /Ton)	100,000	100,000	100,000	100,000	500

Source: MoHUA Appraisal Guidelines

Reduction in Fuel and Economic impact

After the development of tunnel project, people choose to travel from existing road to tunnel and the number of vehicles on the existing road shall reduce and thus results in reduction in fuel consumption.

The benefits of fuel costs are calculated based on the mileage of vehicles and vehicle km travelled annually. The economic cost of fuel is considered in the analysis. The fuel data is collected from reliable website. The tax component in the fuel were not considered. For the economic analysis of the project, the economic price (excluding tax components)

Table 115: fuel cost and applicable taxes in Karnataka

Fuel cost	Petrol	Diesel
Economic Cost	Rs.59.32 per litre	Rs. 59.33 per litre
Assumed % of fuel type	50%	50%
Weighted average Economic Cost of Fuel	Rs.59.32 per litre	

12.3.8 Economic Cost

The construction cost of project and the investment schedule is presented below:

Table 116: Construction cost in crores and investment schedule

Description	Economic Cost
1st year of construction	3762.64
2nd year of construction	3002.64
3rd year of construction	2907.64
4th year of construction	2907.64
Total	**12580.56**

12.4 Economic Benefits

As the proposed tunnel is developed to ease the transportation to the North South corridor. The year wise economic benefits are enclosed in Annexure. All the costs are discounted at a rate of 12% as per planning commission.

Table 117: Economic Benefits

S. No.	Description	Details
1	Total Economic benefits @ 12% rate (amount in cr.)	18703
2	Net Economic Costs @ 12% rate (amount in cr.)	9710
3	Internal rate of Return	19.07%
4	Economic NPV @ 12% (amount in cr.)	8993
5	Benefit / Cost Ratio	1.926

From the above analysis the results show that the EIRR of the project road is more than the discount rate of 12%. Hence, this project shall be taken up for implementation.

Table 118: Year wise costs & benefits in Cr. – Base Scenario

Year	Economic Cost	Economic Benefits	Net benefits	Cum Cost /Benefit
2026	3,762.6	178.7	(3,583.9)	(3,583.9)
2027	3,002.6	142.6	(2,860.0)	(6,443.9)
2028	2,907.6	138.1	(2,769.5)	(9,213.5)
2029	2,907.6	138.1	(2,769.5)	(11,983.0)
2030	7.8	1,989.2	1,981.4	(10,001.6)
2031	7.8	2,171.1	2,163.3	(7,838.3)
2032	7.8	2,369.7	2,362.0	(5,476.4)
2033	7.8	2,586.8	2,579.0	(2,897.4)
2034	7.8	2,823.9	2,816.1	(81.2)
2035	7.8	3,082.9	3,075.1	2,993.9
2036	7.8	3,365.9	3,358.1	6,352.0
2037	7.8	3,675.1	3,667.3	10,019.3
2038	7.8	3,989.8	3,982.1	14,001.4
2039	7.8	3,684.6	3,676.8	17,678.2
2040	7.8	3,965.9	3,958.1	21,636.3
2041	7.8	4,268.8	4,261.0	25,897.4
2042	7.8	4,595.0	4,587.2	30,484.6
2043	7.8	4,946.3	4,938.5	35,423.1
2044	7.8	5,324.7	5,316.9	40,740.0
2045	7.8	5,732.1	5,724.3	46,464.3
2046	7.8	6,170.8	6,163.0	52,627.3
2047	7.8	6,643.2	6,635.4	59,262.8
2048	7.8	7,154.2	7,146.5	66,409.2
2049	7.8	6,722.2	6,714.4	73,123.7
2050	7.8	7,192.6	7,184.8	80,308.4
2051	7.8	7,695.9	7,688.1	87,996.6
2052	7.8	8,234.4	8,226.6	96,223.2
2053	7.8	8,810.6	8,802.9	1,05,026.1
2054	7.8	9,427.1	9,419.3	1,14,445.4
2055	7.8	10,086.6	10,078.8	1,24,524.2

12.5 Sensitivity Analysis

Sensitivity analyses were carried out to investigate the robustness of the economic viability of the project to cost over-runs and benefit reductions. The cases analysed are:

a) Cost overruns due to delay or other factors

b) Reduction in Economic Benefits

c) Combination of reduction in benefits and increase in Cost

Table 119: Sensitivity Analysis results wrt to cost and benefits

Scenario	Economic IRR	NPV @ 12%	B/C ratio
Base cost + Base Benefits	19.07%	8993.34	1.926
15% Increase in Cost + Base Benefits	17.42%	7536.89	1.675
Base cost + 15% Decrease in Benefits	17.15%	6187.89	1.637
15% Inc in cost + 15% Dec in Benefits	15.58%	4731.43	1.424

12.6 Conclusion

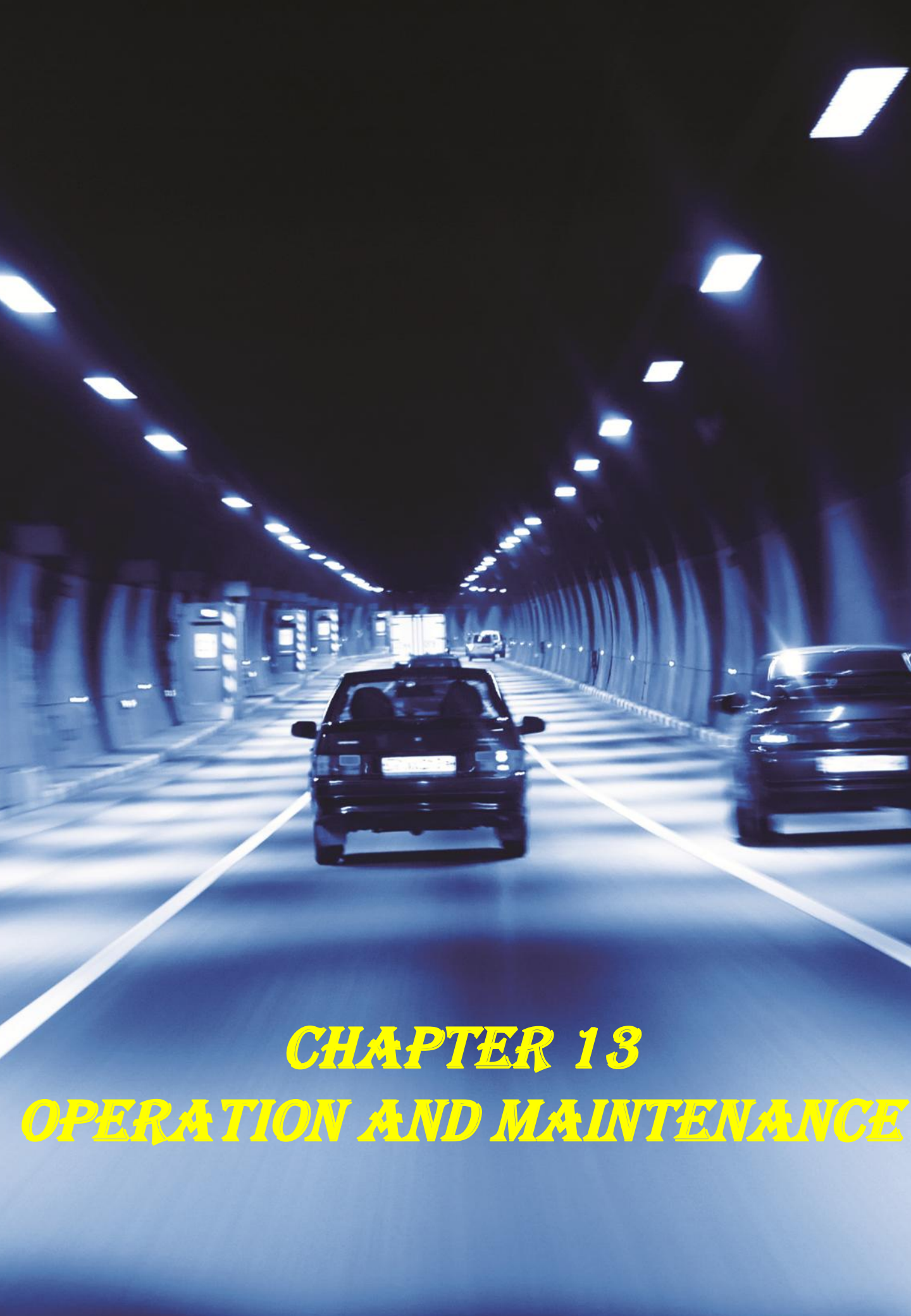
The Economic Internal Rate of Return project is more than the discount rate of 12% and NPV of economic Analysis is positive in all scenarios. Hence, this project shall be taken up for implementation.

ANNEXURE

Economic Analysis of Hebbal to Silk Board Tunnel			
Assumptions & General data for Economic Analysis			
Description	**Details**	**Description**	**Details**
Construction Start Year	2026	**Economic Conversion Factors**	
Construction period in years	4	Capital Expenditure	0.85
Construction End year	2030	Operational Expenditure	0.85
Civil Cost in Cr	13683.03	Travel Time Savings (VOT)	0.85
LA & PreConstruction Activites Cost in Cr	950	Vehicle Operating Cost (VOC) Factor	0.85
Total Economic Cost in Cr	12580.58	Routine Maintenance Cost per Km in Cr. As on COD year	0.10
Periodic Maintenance in Cr as on COD Year	0.00	WPI Dec 2024	155.4
Main Carriageway	**Length in Kms**	**Approach Lane/ Ramp**	**Length in Kms**
4 L Equivalent Length	24.15	4 L Equivalent Length	8.2
2 Lane	0	2 Lane	16.4
4 lane	0	4 lane	0
6 Lane	16.1	6 Lane	0
Total 4 Lane Length in Kms	**32.35**	Discount Rate	12%
Employment benefits	**Factor**	**Emission**	**Costs**
Personnel Cost	2%	Treatment cost/ton- Others	1,00,000.00
Skilled Employment Cost	20%	Treatment cost/ton- CO2	500.00
Unskilled Employment Cost	80%	**Existing Road Section**	
Direct Employment of Skilled Workers	0.75	Volume of Pollutant released in Gms per km - Others	1.7
Direct Employment of Unskilled Workers	1	Volume of Pollutant released in Gms per km - CO2	139.5
Indirect Employment Generation	1.5	Emission Costs Factor	1.0
Direct Employment benefits-Operations	40%	Travel Speed in Tunnel in Kmph	50
Employment benefits Factor	1.00	Assumed RF in mm/Km	5
Assumed IRI in mm/Km - After scenario	2000	WPI Base year 2019	120
Existing Lane configuration	6 Lane	Assumed IRI in mm/Km - Before scenario	3000
Average Operating Speed on Existing Road in Kmph	20	Avg Traffic Growth rate - (2027 -2037)	4.18%
Traffic Figures Year	2027	Avg Traffic Growth rate - (2037 -2047)	2.68%
WPI growth	5%	Avg Traffic Growth rate - (2047 -2057)	2.05%
Savings in Fuel and economic impact factor	1.00	Economic cost of Fuel per litre	59.3
Economy of Car in Km/ Litre - Existing Road	10	Fuel price escalation	1%
Economy of Car in Km/ Litre - Proposed Road	12	VOC Escalated year	2024
Average Occupancy per car (Persons/ Veh)	2.3	Structural Maintenance cost in Cr/Yr	5
VOC & VOT - Adopted Vehicle Type	**IRI mm/Km**	**VOC (Rs/Km) in 2019**	**VOC (Rs/Km) in 2024**
Car	2000	1.59	2.06
	3000	2.35	3.04

Economic Analysis of Hebbal to Silk Board Tunnel			
Assumptions & General data for Economic Analysis			
Section	**Car traffic in No's**	**Existing Travel Length in Kms**	**New Length in Kms**
Hebbal -Silk Board Junction	3936	16.3	16.75
Hebbal -Sarjapur/ HSR layout (Ring Road)	1595	17.1	16.80
Hebbal -Hosur Main Road (Wilson Garden)	2316	13.4	12.87
Hebbal -Seshadri Road (Towards KR Circle)	4385	10.2	9.11
Hebbal -Palace Road (Mekhri Circle)	8249	5.1	5.45
ORR (from KR Puram Side)-Silk Board Junction	3933	17.4	16.16
ORR (from KR Puram Side)-Sarjapur/ HSR layout (Ring Road)	1028	18.2	16.21
ORR (from KR Puram Side)-Hosur Main Road (Wilson Garden)	6733	14.5	12.28
ORR (from KR Puram Side)-Seshadri Road (Towards KR Circle)	6099	11.3	8.52
ORR (from KR Puram Side)-Palace Road (Mekhri Circle)	8051	6.2	4.87
Mekhri Circle -Silk Board Junction	5274	12.8	12.13
Mekhri Circle -Sarjapur/ HSR layout (Ring Road)	2940	11.9	12.18
Mekhri Circle -Hosur Main Road (Wilson Garden)	2081	8.5	8.25
Mekhri Circle -Seshadri Road (Towards KR Circle)	14136	6.5	4.56
Race Course from palace rd.-Silk Board Junction	8636	8.7	9.28
Race Course from palace rd.-Sarjapur/ HSR layout (Ring Road)	5701	9.5	9.33
Race Course from palace rd.-Hosur Main Road (Wilson Garden)	10525	5.7	5.40
Silk Board -Hebbal	3936	15.6	17.12
Silk Board -ORR (Km 1.30 from KR Puram)	3933	15.6	15.85
Silk Board -CV Raman Road (Mekhri Circle)	5274	12.8	13.28
Silk Board -Race Course	8636	9.4	9.39
Sarjapur/ HSR layout (Ring Road) -Hebbal	1595	16	17.50
Sarjapur/ HSR layout (Ring Road) -ORR (Km 1.30 from KR Puram)	1028	17.6	16.23
Sarjapur/ HSR layout (Ring Road) -CV Raman Road (Mekhri Circle)	2940	13.2	13.67
Sarjapur/ HSR layout (Ring Road) -Race Course	5701	10.1	9.77
Jayanagar (From Ashoka Pillar)-Hebbal	2316	14.6	13.62
Jayanagar (From Ashoka Pillar)-ORR (Km 1.30 from KR Puram)	6733	14.6	12.35
Jayanagar (From Ashoka Pillar)-CV Raman Road (Mekhri Circle)	2081	11.8	9.78
Jayanagar (From Ashoka Pillar)-Race Course	10525	7.1	5.89
Race Course from Palace Rd.-Hebbal	4385	10.1	10.98
Race Course from Palace Rd.-ORR (Km 1.30 from KR Puram)	6099	10.2	9.70
Race Course from Palace Rd.-CV Raman Road (Mekhri Circle)	14136	7.3	6.14
CV Raman Road -Hebbal	8249	6.7	7.18
CV Raman Road -ORR (Km 1.30 from KR Puram)	8051	5.9	5.91

Economic Analysis of Hebbal to Silk Board Tunnel (All values are in Crores)													
S. No.	Year	% of funds allocated	Cost Component			Benefit Component					EIRR	19.07%
			Ec CapEx	Ec Opex	Total Cost	Vehicle Operating Cost	Value of Time Cost	Employment Benefits	Emission Benefit	Savings in Fuel and economic impact	Total Benefits	Cost - Benefits
1	2026	25%	3762.64		**3762.6**	0.00	0.00	178.73	0.00	0.00	**178.73**	**-3583.92**
2	2027	25%	3002.64		**3002.6**	0.00	0.00	142.63	0.00	0.00	**142.63**	**-2860.02**
3	2028	25%	2907.64		**2907.6**	0.00	0.00	138.11	0.00	0.00	**138.11**	**-2769.53**
4	2029	25%	2907.64		**2907.6**	0.00	0.00	138.11	0.00	0.00	**138.11**	**-2769.53**
5	2030	100%		7.8	**7.8**	97.84	1782.22	3.11	1.73	104.28	**1989.18**	**1981.40**
6	2031	100%		7.8	**7.8**	107.03	1949.48	3.11	1.72	109.72	**2171.06**	**2163.28**
7	2032	100%		7.8	**7.8**	117.07	2132.43	3.11	1.68	115.45	**2369.74**	**2361.96**
8	2033	100%		7.8	**7.8**	128.06	2332.55	3.11	1.59	121.47	**2586.78**	**2579.00**
9	2034	100%		7.8	**7.8**	140.07	2551.46	3.11	1.43	127.81	**2823.89**	**2816.11**
10	2035	100%		7.8	**7.8**	153.22	2790.91	3.11	1.20	134.48	**3082.92**	**3075.14**
11	2036	100%		7.8	**7.8**	167.60	3052.83	3.11	0.88	141.50	**3365.91**	**3358.13**
12	2037	100%		7.8	**7.8**	183.33	3339.33	3.11	0.43	148.88	**3675.08**	**3667.30**
13	2038	100%		7.8	**7.8**	200.53	3652.71	3.11	-0.13	133.62	**3989.85**	**3982.07**
14	2039	100%		7.8	**7.8**	184.42	3359.28	3.11	-0.78	138.57	**3684.61**	**3676.83**
15	2040	100%		7.8	**7.8**	198.84	3621.81	3.11	-1.59	143.71	**3965.89**	**3958.11**
16	2041	100%		7.8	**7.8**	214.38	3904.86	3.11	-2.59	149.04	**4268.80**	**4261.02**
17	2042	100%		7.8	**7.8**	231.13	4210.03	3.11	-3.82	154.57	**4595.02**	**4587.24**
18	2043	100%		7.8	**7.8**	249.19	4539.05	3.11	-5.32	160.30	**4946.33**	**4938.55**
19	2044	100%		7.8	**7.8**	268.67	4893.78	3.11	-7.15	166.24	**5324.65**	**5316.88**
20	2045	100%		7.8	**7.8**	289.66	5276.23	3.11	-9.35	172.41	**5732.07**	**5724.29**
21	2046	100%		7.8	**7.8**	312.30	5688.58	3.11	-12.00	178.80	**6170.79**	**6163.01**
22	2047	100%		7.8	**7.8**	336.71	6133.15	3.11	-15.17	185.43	**6643.22**	**6635.44**
23	2048	100%		7.8	**7.8**	363.02	6612.46	3.11	-16.66	192.30	**7154.24**	**7146.46**
24	2049	100%		7.8	**7.8**	341.69	6223.80	3.11	-20.49	174.11	**6722.21**	**6714.44**
25	2050	100%		7.8	**7.8**	366.12	6668.90	3.11	-25.01	179.45	**7192.58**	**7184.80**
26	2051	100%		7.8	**7.8**	392.30	7145.83	3.11	-30.32	184.96	**7695.89**	**7688.11**
27	2052	100%		7.8	**7.8**	420.36	7656.87	3.11	-36.55	190.64	**8234.43**	**8226.65**
28	2053	100%		7.8	**7.8**	450.42	8204.45	3.11	-43.84	196.49	**8810.64**	**8802.86**
29	2054	100%		7.8	**7.8**	482.63	8791.20	3.11	-52.35	202.52	**9427.11**	**9419.33**
30	2055	100%		7.8	**7.8**	517.15	9419.90	3.11	-62.29	208.74	**10086.61**	**10078.83**
Total			**12581**	**202**	**12783**	**6914**	**125934**	**678**	**-335**	**4115**	**137307**	**124524**
NPV @ 12%			**9671**	**61**	**9710**	**914**	**16645**	**475**	**-15**	**684**	**18703**	**8993**



CHAPTER 13
OPERATION AND MAINTENANCE

CHAPTER 13: OPERATION AND MAINTENENCE

13.1 Operation and Maintenance of the Project

Operations and maintenance should ensure that the level of safety in tunnel is upheld by maintaining the assumed functional safety and requirements. The overall aim of operation and maintenance of a road tunnel will be to maintain a specified level of safety for the road users, with an optimum level of expenditure and without adverse environmental effect.

The maintenance shall be planned and performed in such a way that the operational assumptions made at the design stage remain validated throughout the long operational life of the road tunnel.

The Operation and Maintenance activities of the road tunnel shall be planned to achieve the following objectives:

- Safety of the road users
- Ensuring free flow of traffic
- Operational economy
- Dealing with abnormal situations

The operation and maintenance of tunnel shall be as per IRC:SP:91-2019.

The contractor shall be responsible for carrying out the operations and maintenance of the project tunnel for the entire duration of the concession period.

13.2 Operations

In order to successfully and efficiently operate and manage a road tunnels, operational tasks and the responsible body for carrying them out, need to be established in order to ensure that all actions required are handled in a consistent and safe way. The level of safety provided for tunnel users is highly dependent upon the specific characteristics of the tunnel, but it also depends strongly on operational procedures and the people who oversee the tunnel.

Some of the workforce required for the operation of tunnel.

- Tunnel manager
- Facility engineers
- Tunnel supervisor
- Tunnel operators
- Tunnel forepersons
- Tunnel mechanical specialists
- Tunnel electrical specialists
- Tunnel electronics specialists
- Safety officers
- The security officers respond to emergency situations.

The responsibility and the number of manpower should be estimated to handle the proper function of tunnel, related component functions and to tackle the emergency in case arise.

13.3 Traffic Related Functions

The supervision of traffic and operation systems for ventilation and lighting, signal systems, access control systems, which are having automatic controls. The Provision of SCADA, Supervisory and data acquisition should be in place.

The automatic control room should be maintained by trained personnel. Maintenance of smooth traffic flow and taking quick remedial measures in case of accident.

13.4 Maintenance of Tunnel

All maintenance and operational tasks carried out, both planned and unforeseen, shall be documented with the aid of appropriate registration programme for management, operation and maintenance.

Establishing procedures and practices for the inspection, documentation, for various elements of the road project. This manual will be used as part of developing a comprehensive inspection and maintenance program. The preliminary research performed indicates that a majority of tunnel owners believe there is a need to develop guidance for procedures for managing tunnel activities that could be readily implemented.

Without efficient operation and maintenance, it is not possible to guarantee the safety of road tunnel users and inadequate attention to maintenance leads to an unacceptable tunnel life/Project sustainability and also proper operation of road facilities is a major consideration in reaching the design life.

As far as possible, operations and maintenance should be carried out systematically and at appropriate intervals. The life cycle consideration of both technical equipment and construction should be taken into account when determining maintenance routines. Optimised maintenance frequency will reduce the probability for costly replacements.

13.5 Maintenance Manual

In order to ensure that maintenance is carried out systematically, a maintenance manual should be prepared such that some routines are followed by everyone involved in operation and maintenance of the project.

This should also include but not limited to the

- Maintenance of construction elements
- Maintenance of Road surface and its elements
- Maintenance of equipment
- Maintenance of technical installations

The Manual should contain precise description of service routines and the functions of individual elements, procedures for control and testing.

For each element the manual shall contain the following information.

- Description of the equipment
- Function of the equipment
- Functional specifications
- Requirements for operating standards
- Description of possible faults arising
- Description of parts to be maintained
- Service and separation procedures.

And should also include recommended procedures made by the suppliers, information from suppliers in addition, functional Control and status reports should be used.

13.5.1 Functional Control

- Is designed to ensure that the construction elements function according to the given specifications. The aim is to ensure that the components fulfil the functional safety.
- To ensure that the equipment and installations shall function as required at all times, Manual or automatic routines be specified.

An example of the functional control that is carried out for some of the construction elements includes:

- Tunnel Entry and Exit Ramps
- Cut and cover structures

- Tunnels
- Pumping stations
- Buildings for all technical equipment.
- Ventilation Shafts
- Fire and Safety Equipments

13.5.2 Status Report

Status reports for structural elements should include but not limited to the following:

- Discolouring of the surface
- Surface dampness
- Leakage points
- Cracks and Joints
- Peeling cement
- Cracks with water seepage
- Salt accumulation / efflorescence
- Rusting marks/stains

In same line, status report of the equipment should include the equipments for the various constructions and installations in the tunnel.

Systematic planning shall include one or more of the following maintenance procedures in terms of maintenance for all elements of the project viz. Bored tunnels, Cut & Cover tunnels, Ramps and all other services/Utilities.

1) Routine maintenance

Routine maintenance is defined as maintenance activities which are carried out regularly. Tasks can be performed daily, weekly, monthly, or annually. Routine maintenance typically includes regular inspections and machine, assets & equipment servicing. The primary goal is to identify problems on an ongoing basis before they result in equipment failure.

2) Preventive Maintenance

preventive maintenance occurs before a problem presents itself, which increases the longevity of assets/equipment

3) Reactive maintenance

Reactive maintenance takes place after a problem has occurred

4) Periodic Maintenance

5) Lifecycle maintenance

All operational and maintenance tasks carried out, both planned and unforeseen, should be documented with appropriate program for management, operations and maintenance.

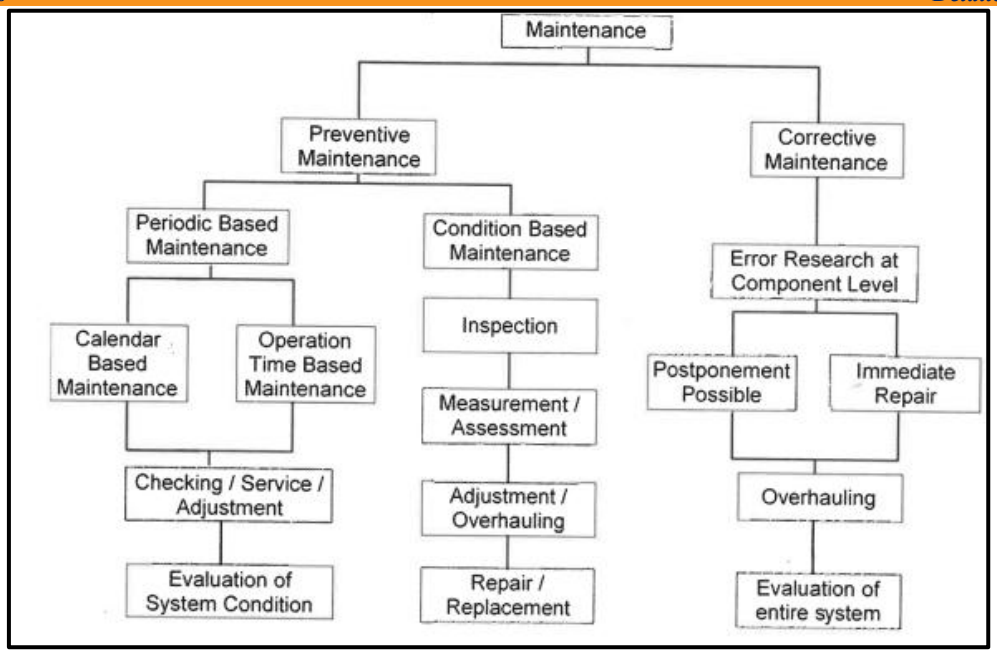


Figure 151: Maintenance As per IRC:SP:91-2019

13.6 Operation and Maintenance Activities for Tunnel

Major and Minor activities are classified as follows,

1) Inspection

2) Maintenance; tunnel structure and facilities

3) Status Reports

4) Monitoring of traffic movement, traffic accident, fire incident, etc.

5) Immediate actions when some incidents are found or reported

6) Vehicle Control (vehicles carrying hazardous materials, vehicle height, and overloaded trucks.)

13.6.1 Inspection

Inspection of a tunnel must be undertaken daily by an inspection team, and check the following:

- Facilities inside the tunnel such as lighting facility, emergency telephones, public address system, ventilation system etc. are properly functioning.
- Cleanliness of the tunnel wall, road surface, facilities, etc.
- Any cracks on concrete lining and pavement, water seepage from concrete lining, etc.
- Drainage facility (no clogging, etc.)

Table 120: Typical Inspection items for civil work components and electrical/communication

Component			Inspection Items
Civil work Component	Road Surface	Pavement	(1) Surface roughness, (2) Cracks, (3) Joint failure, (4) Heaving, (5) Pumping, (6) Local settlement
	Tunnel Portion	Tunnel	(1) Cracks, (2) Drainage, Water Flow, (3) Any deformation, (4) Slope condition
		Lining	(1) Cracks, (2) Leakage of water, (3) Free Lime, (4) Delamination, (5) Difference at a joint
		Interior Wall	(1) Damage, (2) Damages to the accessories
		Drainage	(1) Clogging, (2) Damage
		Fire Boards	(1) Damage,

Component		Inspection Items
Electrical/Mechanical/ Communication Component	Jet Fans	Abnormal noise, vibration, cable connection and voltage. Interlocking with visibility index (VI) sensors and carbon dioxide (CO) sensors.
	Lighting Facilities	Intensity of illumination. As for distribution board, checking abnormal heating, looseness and breaking of wire etc. by visual check and check with measuring instrument.
	Power Supply system and distribution equipment and backup generator	Appearance (dirt, damage), looseness, breaking of wire, oil leakage, pipe damage, abnormal noise and vibration etc. by visual check and check with measuring instrument.
	Information Collection and provision equipment	Performance, communication and appearance (dirt, damage) of each equipment. Facility/equipment which also defined as ventilation, information collection and provision should be inspected.
	Emergency Facilities	Performance and appearance (dirt, damage) of each equipment. As for signal receiving and control board, abnormal noise and heating etc. are checked by visual check etc.
	Vehicular cross passage doors	Maintenance of the doors.

Table 121: Table for Routine Maintenance

Component			Routine Maintenance Activity
Civil work Component	Road Surface	Pavement	(1) Crack sealing, (2) Joint repair, (3) repair of heaving, pumping and local settlement (4) Road surface cleaning
	Tunnel Portion	Tunnel	(1) Crack sealing, (2) Cleaning of drainage facilities, (3) Repair of Slope protection work
		Lining	(1) Lining cleaning, (2) Crack sealing, (3) Water leakage prevention, (4) Reinforcement work for the cavity at the back of lining, (5) Joint repair, (6) Delamination repair
		Interior Wall	(1) Wall Cleaning
		Drainage	(1) Drainage cleaning
		Fire Boards	(1) Cleaning of Fire Boards.
Electrical/Mechanical/ Communication Component	Jet Fans		(1) Cleaning, (2) Check the stability, (3) Replacement and overhauling of aged jet fan
	Lighting Facilities		(1) Cleaning, (2) Change a light, (3) Check the stability, (4) Replacement of lighting facility in case of luminance reduction
	All Kinds of Signboards		(1) Cleaning, (2) Change a light, (3) Check the stability, (4) Replacement of deteriorated facility
	Emergency Facilities such as Fire Hydrant, Fire Detector, Fire Extinguisher, etc.		(1) Cleaning, (2) Functioning or not, (3) Replacement of facility depending on the deterioration or the damage of the parts
	CCTV, Control System		(1) Cleaning, (2) Check the stability, (3) Functioning or not, (4) Replacement of deteriorated facility

Component		Routine Maintenance Activity
	Other Equipment such as CO Sensor, Visibility Index Sensor, Wind Velocity Sensor	(1) Cleaning, (2) Check the stability, (3) Functioning or not, (4) Replacement of deteriorated facility
	Backup Generator	(1) Cleaning filters, spark plug, nozzle, (2) Functioning or not, (2) Fuel Amount, (3) Replacement of deteriorated facility

13.6.2 Status Reports

Regular status report of various components shall be updated and recorded from time to time.

13.6.3 Monitoring and Immediate Actions

Monitoring Traffic Movement, Traffic Accident, Fire Incidents, etc., Monitoring is quite important to assure safe operation of a tunnel and to protect road users' lives.

This work must be undertaken for 24-hours a day for 365 days a year. Traffic movements are monitored through CCTV, report from a patrol group and road users. Information shall be compiled at a traffic control centre of the Tunnel Management Office, and necessary actions shall be quickly decided and informed to proper agencies and the action team.

Monitoring will be focused on the following:

- Reckless driving
- Overtaking
- Over speeding
- Stopped (stalled)/parked vehicles
- Vehicle breakdown
- Obstacles dropped from vehicles
- Accident
- Fire
- Information collected shall be properly recorded and necessary information shall be provided to road users through Variable Information Signboards and a Loudspeaker.
- Emergency actions shall be made in accordance with the instructions of the head of the monitoring team.

Information collected shall be properly recorded and necessary information shall be provided to road users through Variable Information Signboards and a Loudspeaker.

Emergency actions shall be made in accordance with the instructions of the head of the monitoring team.

Immediate Actions when some incidents are found or reported.

The head of the monitoring team shall immediately decide what to do when some incidents are found or reported from road users. He must decide whether a case must be informed to Action Team, Fire Department and/or Police.

Major incidents are as follows.

- Traffic accident
- Fire
- Vehicle Breakdown
- Obstacle dropped from vehicles
- Parked/Stopped (stalled) vehicles

13.6.4 Vehicle Control in Tunnel

The following vehicles should not be allowed to use a tunnel; thus, these vehicles should be controlled before entering a tunnel.

- Two and three wheelers (motorbikes and tricycles [Tempo]) – high probability incidence of causing traffic accident
- Vehicles carrying hazardous materials such as vehicles carrying oil or highly inflammable items– when these get an accident or a fire, it will be dangerous to people and tunnel facilities causing much disaster.
- Overloaded trucks – high risk of vehicle breakdown
- Vehicles of which height is exceeding the limit – these will damage other facilities. Height Restricting Devices must be installed at toll gates.
- Others (Mechanically defected vehicles, pedestrians and animals)

It is necessary for the BBMP to coordinate with the Transport Management, Fire Brigade and Traffic Police departments prior to tunnel opening. The subsequent actions and process should be prepared and diligently followed.

13.7 Capacity Development for the Tunnel

The staff shall be given training and safety drills for capacity development. Necessity of Capacity Development capacity for tunnel O&M must be developed prior to opening of the tunnel. Capacity development should cover various aspects in relation to tunnel O&M as follows

13.7.1 Violation of traffic rules (coordination with traffic police)

Confirm rules and regulations included in the “Road Safety Rules”, an example follows:

- Legal speed limit
- Height Limit
- Prohibition of motorbikes passing in tunnels
- Prohibition of overtaking in tunnels
- Obligation of vehicle maintenance
- Prevention of load shifting and falling objects
- Obligation of relief activities in accidents

Basically, The Management office, against violating vehicles of these traffic rules, will request related agency (traffic police) to control them (arrest, penalty, etc.), and as a part which keeps constant monitoring, will engage to ‘call attention, give instruction and remove’ to them for the delegated matters, and for the undelegated matters, will request the related agency (traffic police) to dispatch.

13.7.2 Traffic accident (coordination with traffic police)

Request the related agency (traffic police) to investigate the cause of the accident and to take legal actions. At the same time, The Management office will conduct lane regulation, close the road and remove (tow away) damaged vehicles immediately for prevention of the secondary accidents and restoration of the normal traffic. The Management office will also conduct necessary emergency repairs to restore the traffic.

13.7.3 Fire incident (coordination with Fire Department)

Confirm which powers are necessary for fire-fighting activities at a fire incident, an example follows:

Right-of-way Order to remove vehicles Rights regarding damage, etc

And coordinate with the related agency (fire department) to determine which tasks could be delegated to the Management office.

The Management office carries out fire-fighting activities within the delegated powers.

If The Management office cannot extinguish the fire within its delegated powers, it will request the fire department to dispatch.

If fire-fighting activities within the delegated powers are difficult and the arrival of the fire department may take time, consider requesting for establishing a fire department in proximity (or within the management office).

13.7.4 Vehicle control (coordination Traffic Department and Police Department)

Confirm rules and regulations included in the "Rules to Protect Road Structures", an example follows:

- Height limitations of a vehicle
- Weight limitations of a vehicle
- Width limitations of a vehicle
- Prohibition of passage of the vehicles carrying hazardous materials

The Management office will give warnings to and remove vehicles which violate these rules within its delegated powers. It will take joint actions in coordination with the related agency (traffic police) for issues outside its delegated powers.

13.7.5 Lane regulation and Road closing (coordination with traffic police)

Confirm which powers is necessary for lane regulation and road closing and will coordinate with the related agency (traffic police) to identify which actions are necessary for the management office to conduct lane regulation and road closing.

13.8 Inspection and Maintenance Work

The performance of inspection and maintenance work often depends on the five physical senses of the worker. Therefore, it is required for the worker to have advanced knowledge and experience.

For this reason, the following topics should be covered in the field of inspection and maintenance work.

- Responsibilities of the Maintenance Section and coordination with other sections.
- Inspection frequency
- What to inspect and how to record findings of inspection
- Preparation of Inspection and Maintenance Manual
- Traffic Control/Management during maintenance work

The details are as follows:

- An "Inspection Manual" will be developed which covers the following objects:
- Contents of an inspection
- Frequency of an inspection
- Criteria of an inspection
- How to record the results
- How to report the results

The manual will be distributed to workers and a training course will be held to familiarize them with the manual.

- A training course will be held to familiarize workers with usage of vehicles, measuring instruments, tools and equipment for an inspection based on their instruction manuals and through usage demonstrations of the actual machine.
- Inspection and maintenance work may be dangerous because of work on the road currently in use, in high places, related to electricity and oil, etc. For this reason, safety training will be conducted, a

check sheet will be developed, and a safety manager will be appointed. A safety manager in this context is a person who is responsible for safe work by supervising workers.

- Prior to opening, field training and an initial inspection will be held at the actual objects for inspection in order to obtain actual experience and to understand and record the initial condition of the objects.
- Some work requires joint work with other sections, such as lane regulation (coordination with Patrol Team), and confirmation of signal reception/concerted work (coordination with traffic control Centre)
- Therefore, necessary tasks for smooth work should be identified and organized.
- Documents useful for understanding details of the object should be compiled as a reference so that they could be referred to as necessary during the maintenance work

13.9 Information Leaflets

At suitable location the information leaflets as pre IRCS:SP :91-2019 should be displayed to inform user about the DO's and DON'T's.

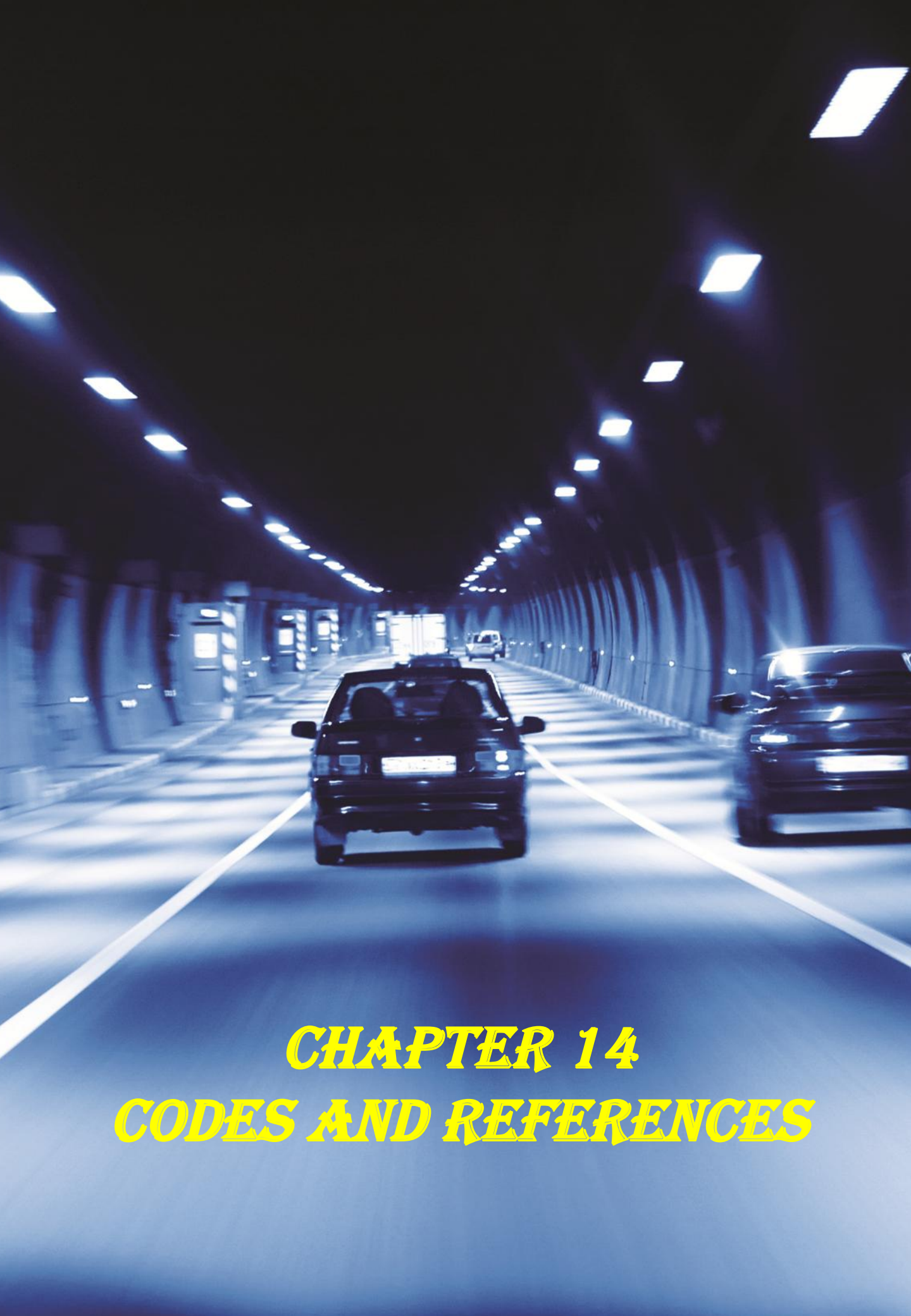
Figure 152: Information Leaflet as per IRC:SP:91-2019.

Table 8.3 Road Signages specific to Tunnel Roads

As recommended in IRC:67 following signs shall be used in Tunnels:	
Tunnel Ahead	
Dipped Headlights	
Axle Load Limit	
Height Limit Sign	
Width Limit Sign	
Load Limit	
Length Limit Sign	
Speed Limit at every 500 m, in the case of tunnels longer than 1000 m.	

Overtaking Prohibited – every 500 m in the case of tunnels longer than 1000 m.	
U-Turn Prohibited	
Vehicle Prohibition – prohibiting entry of vehicles carrying dangerous goods.	
Emergency Exit in Tunnel	
Proposed Signs	
Emergency telephone (informatory Sign)	
Fire Extinguisher (Informatory Sign)	
Lay-bys/SoS Sign	
Information on Length of the tunnel	

Figure 153: Traffic Signs as per IRC:SP:91-2019



CHAPTER 14
CODES AND REFERENCES

CHAPTER 14: CODES AND REFERENCES

Below mentions are the used and relevant codes and references for preparation of the Detailed Project Report.

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33. IS/IEC 62271: Part 102: 2003/IEC 62271-102:2003 High - Voltage switchgear and control gear: Part 102 alternating current disconnectors and earthing switches
34. IS/IEC 62271: Part 103: 2011/IEC 62271-103: 2011 High - Voltage switchgear and control gear: Part 103 switches for rated voltages above 1 kV up to and including 52 kV
35. IS/IEC 62271: Part 105: 2012/IEC 62271-105:2002(First Revision) High - Voltage switchgear and control gear: Part 105 alternating current switch - Fuse combinations for rated voltages above 1 kV up to and including 52 kV (First Revision)
36. IS/IEC 62271: Part 111: 2012/IEC 62271-111:2012 High - Voltage switchgear and control gear: Part 111 automatic circuit reclosers and fault interrupters for alternating current systems up to 38 kV
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38. IS/IEC 62271: PART 201: 2006/IEC 62271-201:2006 High - Voltage switchgear and control gear: Part 201 ac insulation - Enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
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50. IS/IEC 61439: Part 0: 2014/IEC 61439-0:2014 Low-Voltage Switchgear and Control gear Assemblies Part 0 Guidance to Specifying Assemblies
51. IS/IEC 61439: Part 1: 2011/IEC 61439-1: 2011 Low-Voltage Switchgear and Control gear Assemblies Part 1 General Rules
52. IS/IEC 61439: Part 2: 2011/IEC 61439-2: 2011 Low Voltage Switch Gear and Control gear Assemblies Part 2 Power Switch Gear and Control Gear Assemblies
53. IS/IEC 61439: Part 5: 2014/IEC 61439 - 5: 2014 Low-Voltage Switchgear and Control gear Assemblies Part 5 Assemblies for Power Distribution in Public Networks
54. IS/IEC 61439: Part 6: 2012/IEC 61439-6: 2012 Low-Voltage Switchgear and Control gear Assemblies Part 6 Busbar Trunking Systems (Busways)
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63. IS 3156 Potential transformers
64. IS 1248 Ammeter/Voltmeter
65. IS 1651 Lead Acid Battery
66. IS 722 KWH meter / KVA MDI meter
67. IS 1554 PVC insulated (heavy duty) electric cables Part I: for (part 1) working voltages up to and including 1100 volts
68. IS 1591 Glossary of terms of cables, conductors, and accessories
69. IS 1753 Aluminium conductors for insulated cables
70. IS 2982 Copper conductors' cables and cords
71. IS 2961 Recommended current ratings for cables
72. IS 5819 Recommended short circuit ratings of high voltage PVC cables
73. IS 5831 PVC insulation and sheath of electric cables
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