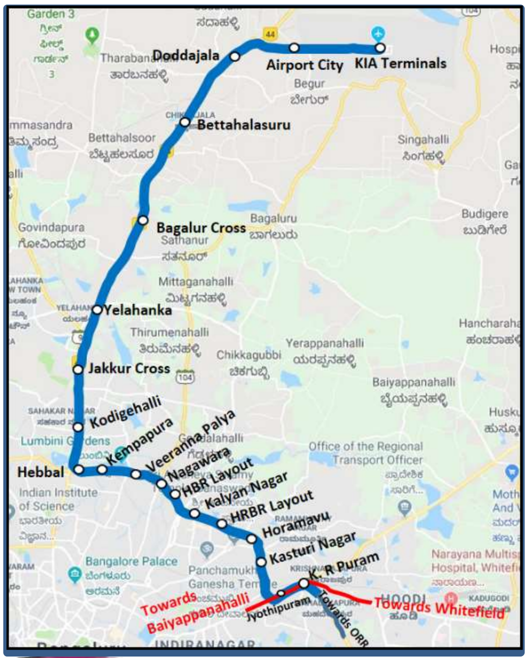
DETAILED PROJECT REPORT FOR AIRPORT METRO LINE (PHASE-2B)

FROM K R PURAM TO KEMPEGOWDA INTERNATIONAL AIRPORT



Volume 1 – Revised Detailed Report

Bangalore Metro Rail Corporation Ltd.

October 2019 (Revised)

FOREWORD

The Metro alignment between K R Puram to Airport Terminals, Bangalore via Hebbal is planned on the Outer Ring Road (ORR) and National Highway NH-44, having a route length of 38Km (36.44 Kms from Jyothipuram to KIA Terminals).

It is estimated that about half a million IT professionals are employed at Whitefield, Electronic city and along ORR from Central Silk Board from Hebbal along with various support services and indirect employment. Majority of the residents of Northern Bengaluru and Air passengers who are connected with IT hub are dependent primarily on private transport and to some extent on BMTC buses. The proposed metro corridor Phase 2B from K R Puram to KIA Terminals will serve as an effective public transport system leading to significant modal shift.

The biggest challenge, the people commuting on this corridor facing is the long time spent in travel thereby bringing down their efficiency and also affecting the overall economic efficiency. Though the Phase-1 and Phase-2 of the Metro network have been planned wherein Phase-1 is operational and Phase-2 is under construction, it is felt necessary to provide the connectivity between International Airport Terminal and Central Silk Board through K R Puram to facilitate hassle free and comfortable transport facility.

Government of Karnataka (GoK) approved implementation of the Metro Project between K R Puram to Airport for a length of 38 Kms at a cost of Rs. 10584.15 Crores based on September 2018 prices on 19.01.2019. The DPR Jan-2019 was submitted to GoI for approval of this project for part funding from Government of India (GoI). The GoI sought several clarifications in respect of the proposal for meeting the norms and requirements set out on introduction of Metro Rail Policy in August 2017.

In compliance to MoHUA observations, the cost of different components has been revised to Rs. 9934.58 Crores and brought to benchmarking levels except some additional components, which are essentially required for completion of the project. The escalation cost has been worked out as per in the MoHUA observation. The traffic forecast has been revisited based on the inputs recovered from IUT (India) and the PHPDT and Ridership estimates have been revised accordingly.

The proposed project is anchored in the Comprehensive Mobility Plan for Bengaluru city and is assessed to be most appropriate and cost-effective system for the mobility needs as per the Alternate Analysis of all possible modes.

This present report named as DPR- October 2019 is a compendium of study results carried out by BMRCL on regular interaction with other agencies working in development of Government of Karnataka whose inputs have been incorporated in finalizing this report. This report remains the sole property of BMRCL and copying it, in part or whole, without written consent is prohibited except for the sole use of Bangalore City development.

Bengaluru
October 2019

Ajay Seth
Managing Director
BMRCL

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SL No	ABBREVIATIONS	
1.	ADB	Asian Development Bank
2.	AFC	Automatic Fare Collection
3.	AFD	Agence Francaise De Development
4.	ASS	Auxiliary Sub-Stations
5.	AQI	Air Quality Index
6.	ATC	Area Traffic Control
7.	ATL	Average Trip Length
8.	ATO	Automatic Train Operation
9.	ATP	Automatic Train Protection
10.	ATS	Automatic Train Supervision
11.	ATWP	Automatic Train Wash Plant
12.	BBMP	Bruhat Bangalore Mahangara Palike
13.	BBRS	Broad Band Radio System
14.	BCC	Backup Control Centre
15.	BDA	Bangalore Development Authority
16.	BESCOM	Bangalore Electricity Supply Company
17.	BG	Broad Gauge
18.	BIAAPA	Bangalore International Airport Planning Area
19.	BIAL	Bangalore International Airport Ltd
20.	BIEC	Bangalore International Exhibition Center
21.	BMA	Bangalore Metropolitan Area
22.	BMICAPA	Bangalore Mysore Infrastructure Corridor Area Planning Authority
23.	BMR	Bangalore Metropolitan Region
24.	BMLTA	Bangalore Metropolitan Land Transport Authority
25.	BMRCL	Bangalore Metro Rail Corporation Limited
26.	BMRDA	Bangalore Metropolitan Region Development Authority
27.	BMS	Building Management System
28.	BMTC	Bangalore Metropolitan Transport Corporation
29.	BOD	Biological Oxygen Demand
30.	BPCL	Bharat Petroleum Corporation Ltd
31.	BRTS	Bus Rapid Transport System
32.	BSNL	Bharat Sanchar Nigam Ltd
33.	BUD	Bangalore Urban District
34.	BWSSB	Bangalore Water Supply and Sewerage Board
35.	c	Shear Cohesion of Soil
36.	CATC	Continuous Automatic Train Control
37.	CBI	Computer Based Interlocking
38.	CBTC	Communication Based Train Control
39.	CCTV	Closed Circuit Television
40.	CDP	Comprehensive Development Plan
41.	CGST	Central Goods and Service Tax
42.	CI	Congestion Index
43.	CMP	Comprehensive Mobility Plan
44.	CMS	Cast Manganese Steel

SL No	ABBREVIATIONS	
45.	CNG	Compressed Natural Gas
46.	CPCB	Central Pollution Control Board
47.	CR	Rock Core Recovery
48.	CRRI	Central Road Research Institute
49.	CSB	Central Silk Board
50.	CTTP	Comprehensive Traffic & Transportation Plan
51.	CTTS	Comprehensive Traffic & Transportation Study
52.	CWR	Complete Welded Rail
53.	DCC	Depot Control Centre
54.	DMC	Driving Motor Car
55.	DMI	Driver Machine Interface
56.	DMRC	Delhi Metro Rail Corporation
57.	DG	Diesel Generator
58.	DO	Dissolved Oxygen
59.	DPCS	Digital Protection Control System
60.	DPR	Detailed Project Report
61.	DRDO	Defense Research Development Organization
62.	DTG	Distance To Go
63.	DULT	Directorate of Urban Land Transport
64.	EB	Emergency Brake
65.	ED	Electro Dynamic Brake
66.	EIB	European Investment Bank
67.	E&M	Electrical & Mechanical
68.	EIRR	Economic Internal Rate of Return
69.	EIU	Environmental Impact Unit
70.	ELU	Existing Land Use
71.	EMC	Electromagnetic Compatibility
72.	EMI	Electromagnetic Interference
73.	EMP	Environment Management Plan
74.	EMV	Electro-magnetic Verification
75.	EP	Electro Pneumatic Break
76.	EPA	Environmental Protection Act
77.	ESDM	Electronics System Design & Manufacturing
78.	ESI	Environmental and Social Impact
79.	ETS	Emergency Trip System
80.	FAR	Floor Area Ratio
81.	FBR	Fare Box Revenue
82.	FIRR	Financial Internal Rate of Return
83.	FoB	Foot Over Bridges
84.	FOTS	Fiber Optic Transmission System
85.	FRLS	Fire Retardant Low Smoke
86.	FRLSOH	Fire Retardant Low Smoke Zero Halogen
87.	FSB	Full Service Brake
88.	FSI	Floor Space Index
89.	GAIL	Gas Authority of India Ltd

SL No	ABBREVIATIONS	
90.	GC	Generalized Costs
91.	GoI	Government of India
92.	GoK	Government of Karnataka
93.	GSS	Grid Sub-Station
94.	GPS	Global Positioning System
95.	HAL	Hindustan Aeronautics Ltd
96.	HBB	Home Based Business
97.	HBE	Home Based Education
98.	HBO	Home Based Other
99.	HBW	Home Base Work
100.	HPS	Higher Primary School
101.	HSD	High Speed Diesel
102.	HS	Higher Secondary
103.	HW	Hazardous Waste
104.	IBL	Inspection Bay Lines
105.	IFC	International Finance Corporation
106.	IGBT	Insulated Gate Bipolar Transistors
107.	IIM	Indian Institute of Management
108.	IISc	Indian Institute of Science
109.	IMD	Indian Meteorological Department
110.	IPT	Intermediate Public Transport
111.	IR	Indian Railway
112.	IRC	Indian Road Congress
113.	IRS	Indian Railway Specifications
114.	ISO	Indian Standards Organization
115.	ISRO	Indian Space Research Organization
116.	IT & BT	Information Technology & Bio Technology
117.	ITES	Information Technology Enabled Services
118.	ITI	Industrial Training Institute
119.	ITPL	Information Technology Park Ltd
120.	ITS	Intelligent Transport System
121.	ITRR	Intermediate Town Ring Road
122.	ISBT	Interstate Bus Terminal
123.	JICA	Japan International Co-operation Agency
124.	JnNURM	Jawaharlal Nehru National Urban Renewal Mission
125.	KIADB	Karnataka Industrial Areas Development Board
126.	KIAL	Kempegowda International Airport Ltd
127.	KEA	Karnataka Examination Authority
128.	KPTCL	Karnataka Power Transmission Corporation Ltd
129.	KRDCL	Karnataka Road Development Corporation Limited
130.	KSSIDC	Karnataka Small Scale Industries Development Corporation
131.	KSISF	Karnataka State Industrial Security Force

SL No	ABBREVIATIONS	
132.	KSPCB	Karnataka State Pollution Control Board
133.	KSRTC	Karnataka State Road Transport Corporation
134.	KTCP	Karnataka Town & Country Planning
135.	KV	Kilo Volts
136.	LAN	Local Area Network
137.	LCV	Light Commercial Vehicle
138.	Leq	Weighted Equivalent Noise Level
139.	LHS	Left Hand Side
140.	LPA	Local Planning Area
141.	LPG	Liquid Petroleum Gas
142.	LRTS	Light Rail Transit System
143.	LWR	Long Welded Rail
144.	MC	Motor Car
145.	MoEF	Ministry of Environment and Forest
146.	MoHUA	Ministry of Housing & Urban Affairs
147.	MoU	Memorandum of Understanding
148.	MPPA	Million Passengers Per Annam
149.	MRTS	Mass Rapid Transport System
150.	MS	Motor Spirit
151.	MSW	Municipal Solid Waste
152.	MVA	Mega Volt Ampere
153.	NABET	National Accreditation Board for Education and Training
154.	NAAQS	National Ambient Air Quality Standards
155.	NAL	National Aerospace Laboratories
156.	NFBR	Non Fare Box Revenue
157.	NFC	Near Field Communication
158.	NGT	National Green Tribunal
159.	NH	National Highway
160.	NHAI	National Highways Authority of India
161.	NIMHANS	National Institute of Mental Health and Neurosciences
162.	NLSIU	National Law School of India University
163.	NMS	Network Management System
164.	NMT	Non-motorized Transport
165.	NMV	Non-motorized Vehicle
166.	NOC	No Objection Certificate
167.	NUTP	National Urban Transport Policy
168.	O&M	Operation & Maintenance
169.	OMR	Old Madras Road
170.	OCC	Operation Control Centre
171.	OD	Origin Destination
172.	ORR	Outer Ring Road
173.	OVPD	Over Voltage Protection Device
174.	PAP	Project Affected Persons
175.	PBS	Public Bicycle Sharing

SL No	ABBREVIATIONS	
176.	PCU	Passenger Car Unit
177.	PD	Property Development
178.	PHPDT	Peak Hour Peak Direction Traffic
179.	PIU	Parameter Importance Unit
180.	PLU	Proposed Land Use
181.	PPP	Public Private Partnership
182.	PRR	Peripheral Ring Road
183.	PSC	Pre-stressed Concrete
184.	PSD	Platform Screen Door
185.	PT	Public Transport
186.	PWL	Pit-Wheel lathe
187.	PWM	Pulse Width Modulation
188.	P-way	Permanent Way
189.	QR Code	Quick Response Code
190.	RBL	Repair Bay Lines
191.	RDSO	Research Design & Standards Organization
192.	RHS	Right Hand Side
193.	RITES	RITES Ltd
194.	R &R	Resettlement and Rehabilitation
195.	RMP	Revised Master Plan
196.	ROB	Road Over Bridge
197.	ROW	Right of Way.
198.	RPM	Respirable Particulate Matter
199.	RQD	Rock Quality Designation
200.	RSS	Receiving Sub Station
201.	RUB	Road Under Bridge
202.	SAP	Station Accessibility Plan
203.	SBL	Stabling Bay Lines
204.	SCADA	Supervisory Control and Data Acquisition
205.	SEJ	Switch Expansion Joint
206.	SER-O	Environmental and Social Responsibility in Operations
207.	SEZ	Special Economic Zone
208.	SGST	State Goods and Service Tax
209.	SH	State Highway
210.	SHE	Safety Health and Environment
211.	SIA	Social Impact Assessment
212.	SOC	Soil Organic Carbon
213.	SOD	Schedule of Dimension
214.	SPM	Suspended Particulate Matter
215.	SPT	Standard Penetration Tests
216.	SPV	Special Purpose Vehicle
217.	SSA	Sarva Shikshana Abihiyana
218.	STRR	Satellite Town Ring Road
219.	S&T	Signaling & Telecom
220.	SWR	South Western Railway

SL No	ABBREVIATIONS	
221.	TC	Trailer Car
222.	TDR	Transfer of Development Rights
223.	TEP	Track Earthing Panel
224.	TOD	Transit Oriented Development
225.	TSS	Traction Sub Station
226.	TTMC	Traffic & Transit Management Center
227.	UG	Underground
228.	UMTA	Unified Metropolitan Transport Authority
229.	UTO	Unattended Train Operations
230.	VCF	Value Capture Financing
231.	VGF	Viability Gap Funding
232.	VOC	Vehicle Operating Cost -
233.	VOT	Value of Time
234.	WHO	World Health Organization
235.	WPR	Workforce Participation Rate
236.	Φ	Angle of Internal Friction

Executive Summary

EXECUTIVE SUMMARY

0.0 Introduction

Approval of Government of Karnataka (GoK) for implementing the Metro Project between K R Puram to Kempegowda International Airport on Outer Ring Road & NH-44 for a length of 29.062 Kms by BMRCL at a cost of Rs. 5950.02 Crores based on July 2017 prices was communicated vide G.O UDD 423 PRJ 2017 dated 19.12.2017. Following the approval, part funding from Government of India (GoI) was requested. The GoI sought several clarifications in respect of the proposal for meeting the norms and requirements set out on introduction of Metro Rail Policy in August 2017.

Accordingly, the DPR was revised as per Metro Rail Policy-2017 at September 2018 prices. The revised Detailed Project Report (DPR) of January 2019 was prepared by in-House team of BMRCL. The team has relied upon Draft Comprehensive Mobility Plan 2019 for Bengaluru City, the Draft Revised Master Plan 2031 for Bengaluru Region and various other studies undertaken for Traffic and Transportation for the city by GoK. This Report has been prepared as per Metro Rail Policy 2017 in 2 Volumes i.e., Volume 1 covering all the aspects given in Appraisal Guidelines for Metro Rail Project proposals issued by Ministry of Housing and Urban Affairs (MoHUA), GoI during September 2017 and also taking into account the latest Standards and Specifications issued by MoHUA for various Systems, Volume 2 consisting of relevant drawings and geo-technical details along the proposed corridor.

Vide G.O UDD 385 PRJ 2018, Bengaluru, dated 19.01.2019, GoK has accorded approval for implementation of the Airport Metro line from Jyothipuram to KIA Terminals as Phase 2B of the Metro project by BMRCL at a revised estimated cost of Rs. 10584.15 Crores.

Subsequently Detailed Project Reports for Bangalore Metro Phase 2A & 2B was submitted vide GoK letter No. UDD103 PRJ 2019 & UDD102 PRJ 2019 dated 28.03.2019 for consideration of Government of India.

In response to the above, after examining the Detailed Project Report MoHUA along with Institute of Urban Transport (India), have given number of observations regarding CMP, Comparative Analysis of Alternate modes, the state Government commitment to provide required support, bench marking for costing of metro rail components, cost escalation, VCF accruals, possibility of mobilizing funds from bond market, Private Participation, setting up of dedicated Urban Transport fund, security to be borne by GoK etc.

In compliance to MoHUA observations, the cost of different components has been revised and brought to the benchmarking levels except some additional components which are essentially required for completion of the project. The escalation cost has been taken as per MoHUA observation. The work on CMP has been completed and Alternative traffic analysis has been worked out. Keeping in mind MoHUA observations a fresh DPR has been prepared to avoid ambiguity with previous one at a revised estimated cost of Rs. 9934.58 Cr.

0.1 Background

Bengaluru, with a population of over 13 million in 2019 is a key engine for driving country's growth. The city is one of the fastest growing major metropolis in the country with an economic growth of 8.50 per cent and possesses world class infrastructure in housing, education & research. The Economy of Bangalore is an important part of the economy of India as a whole and contributes over 36% to the Economy of the State of Karnataka, accounting for 98% of the Software Exports of the State.

Today, Bengaluru, country's leading IT exporter has the youngest tech workers and most efficient among all global start-up hubs. Bengaluru among the 20 best start up city ecosystems in the world has emerged as the IT Start Up Capital of India with more than 30 per cent of national share. It has also been ranked 2nd in Global start-up ecosystem growth index by "Compass". It has the largest hub of semiconductor design companies, outside the Bay Area in California. Nearly 70 per cent of the country's chip designers work from Bengaluru and around 80 per cent of the sector's revenues in design are from this city alone.

Bengaluru is also known as the Garment Capital of India and has been one of the leading contributors in the growth of textile and apparel market.

Home to a large number of education and research institutions have played a major role in supporting and promoting the ecosystem. The city is also recognized as the fountainhead of global Research and Development – with Multi-National Companies having their global Research and Development Centres.

Bengaluru has been ranked as No.1 – 'Best place to live and work' by the Global HR Consultancy Mercer.

Bengaluru is identified as Global IT based city, it is uniquely connected with all the corners of the world in respect of IT business. International Airport is established at Devanahalli on the Northern part of Bengaluru which is means of transport to connect Bengaluru with all corners of the World. IT industries are concentrated on the Eastern part of Bengaluru i.e. at Electronic City, Whitefield and part of Outer Ring Road (ORR) between Central Silk Board and Hebbal. Also well planned townships, industries and other business centres distributed all along ORR between K R Puram to Hebbal and along National Highway NH-44 between Hebbal to International Airport. Hence, the route from K R Puram to International Airport along ORR and NH-44 is planned to be connected by Metro line.

BMRCL, the agency responsible for implementing and operating Metro in Bengaluru, has fully commissioned the Phase-1 Metro consisting of 42.3 Km, which includes 8.8 Km of Underground line and 40 Stations in stages from October 2011 to June 2017.

The Phase-2 of Metro for a length of 72.1 Km is under implementation, which includes extension of Phase-1 lines on all four directions and two new lines. Phase 2A is also planned to be implemented by BMRCL (an SPV incorporated for implementing the Metro projects).

0.1.1 Population and Population Density

Bangalore, officially Bengaluru, is the Capital of the Karnataka State. Bengaluru is located in the South Eastern region of the State on the Deccan Plateau and it is the third most populous city and the 5th most populous urban area in India. Bengaluru has an estimated population of 12.34 million in its urban area as of 2017, up from 8.5 million in 2011. It is now the 24th most populous city in the world and the fastest-growing Indian Metropolis behind New Delhi, growing at a whopping 47.18% from 2001 to 2011. As per the census records of 2001 and 2011, the population density values for the BMA and the BBMP have gone up from 47 to 70 and 82 to 119 PPH, respectively.

0.1.2 Transportation System in the City

- The public transport in Bengaluru is operated by Bengaluru Metropolitan Transport Corporation (BMTC). At present BMTC is operating 6,143 schedules on 2,253 routes with a fleet size of 6,677 buses and the buses cover 54,187 daily trips at an average trip length of 24.60 Km. The Bengaluru Metropolitan Transport Corporation (BMTC) buses traverse a whopping 13.33 lakh Km across the city every day.
- Apart from the bus transport system, two corridors of Metro rail are fully operational since June 2017. The North-South corridor starts at Nagasandra and ends at Yelachenahalli covering a route length of 24.2Kms. The East-West corridor starts at Baiyyappanahalli and ends at Mysore Road over a route length of 18.1 Kms. Metro currently carries 4.05 lakh commuters every day with maximum single day ridership being 4.8 lakh. The East-West line (Purple line) carries about 56% and the North-South line (Green line) carries 44% of the commuters.
- Auto rickshaws and taxis are the IPT facility available in Bengaluru. Autos are the popular form of transport. In addition, car Aggregators Ola and Uber have their extensive services in Bengaluru and are well patronised. Rent - a -mobike has emerged as a significant mode of transport in recent years.

0.1.3 Economy

The establishment and success of high technology firms in Bengaluru has led to the growth of Information Technology (IT) in India. IT firms in Bengaluru employ about 1.5 Million which is 37.5% of India's pool of 4 million IT professionals and account for the highest IT-related exports in the country. Many biggest IT-firms are located in Bengaluru which earned this southern city the name 'Silicon Valley of India'. The city also houses some major manufacturing industries like Bharat Heavy Electricals Limited, Bharat Electronics Limited and Bharat Earth Movers Limited among others. The IT majors Infosys and Wipro have their headquarters in Bengaluru.

Bengaluru, with its strong economic base, contributes about 36%[1] to Karnataka's GSDP (2016-17). Bengaluru has the highest contribution in secondary and tertiary sector's GSDP due to high concentration of major industries and infrastructure facilities. The Metropolis houses about 40% of urban population of Karnataka and has witnessed 49.4% growth in population during the decade 2001-2011, thus playing the role of a primate city in the State. In context of the State, the Population in the city of Bengaluru accounts for nearly 14.6% of the state's population concentrated in only about 0.64% of the land area.

The Economy of Bengaluru is an important part of the economy of India as a whole. State of Karnataka has an estimated GSDP of $230 billion and Bengaluru the capital of Karnataka has an estimated GDP of $83 billion. The value of IT revenue from Bengaluru is about $ 67 billion which is about 40% India IT revenue ($ 167 billion).

0.2 Alignment of the Corridor

It is estimated that about half a million IT professionals are employed at Whitefield, Electronic city and along ORR from Central Silk Board from Hebbal and with various support services and indirect employment. Majority of residents of Northern Bengaluru and Air passengers who are connected with IT hub are dependent on public/private transport along NH-44 and ORR. The proposed metro corridor Phase 2B which measures about 38Kms (36.44 Kms from Jyothipuram to KIA Terminals) serves as an alternate transport system.

The biggest challenge, these people are facing is the long time spent during transportation thereby bringing down their efficiency and also affecting the overall economic efficiency in this corridor. Though the Phase-1, Phase-2 and Phase 2A of the Metro network has been planned where in Phase-1 is operational, Phase-2 is under construction and Phase 2A is being implemented, it is very much necessary to look into providing the connectivity between International Airport and K R Puram for a length of about 38 Kms (36.44 Kms from Jyothipuram to KIA Terminals) to facilitate hassle free and comfortable movement.

[1] Economic Survey of Karnataka 2018-19

The surveys including Reconnaissance/Topographical survey, Traffic and transportation studies, Geo-tech investigations etc., were carried out along the above proposed route. The corridor proposed is from terminal station at Jyothipuram to terminal station at International Airport with a link to Baiyappanahalli Depot. The other stations being Kasturi Nagar, Horamavu, HRBR Layout, Kalyan Nagar, HBR Layout, Nagawara, Veeranna Palya, Kempapura, Hebbal, Kodigehalli, Jakkur Cross, Yelahanka, Bagalur Cross, Bettahalasuru, Doddajala, Airport City and KIA Terminals.

Route map of Airport Metro line (Phase-2B) along with Phase-1, 2 & 2A is shown in Figure 0.1.

0.3 Traffic Demand Forecast

Traffic and Transportation Study has been carried out to analyse the traffic volume and asses the variation of traffic level, composition, growth rate and forecast of the future traffic for the selected corridor.

0.3.1 Study Area

The study area includes the Bangalore Metropolitan Area (LPA area) i.e. 1294.00 Sq.km. (including part BMICAPA area – 79.14 Sq.km.) The development of Airport near Devanahalli and transport infrastructure development in the form of 6 lane access controlled road between Hebbal and Airport has triggered development around airport and near Devanahalli. To ensure planned development, BIAAPA has been established to oversee the development of the identified area. The BIAAPA study area reveals that most of the developments are in two administrative areas namely Jala Hobli and Kasba Hobli. Considering this and to account its impact on the city development part of BIAAPA area extending 227.85 sq.km has been included in the planning area.

0.3.2 Zoning System

The study area has been divided into 519 internal zones. There are 15 external zones.

0.3.3 Travel Demand Forecast

An urban transport model to replicate the Bangalore Metropolitan Area transportation system (roads, congestion delays, transit system, etc.) has been developed with a state-of-the-art software and modelling technology. This model has been used for forecasting, using altered model inputs to reflect future year scenario. By simulating roadway conditions and travel demand on those roadways, deficiencies in the system have been assessed. Potential major future network enhancements such as introduction of an MRTS or land use modifications are analysed using this tool.

The model is based on a conventional 4-stage transport model approach, which includes:

- Trip Generation - calculating the number of origins and destinations for each zone.
- Trip Distribution - attaching the origins and destinations for complete trips
- Mode Choice - determining the mode for each trip, car, Intermediate Public Transport (IPT), Public transport.
- Assignment - assigning passengers to their respective highway and transit networks.

0.3.4 Ridership Assessment for Horizon Years

The travel model generated for RMP 2031 has been used for the estimation of ridership for the proposed Metro corridor from K R Puram to Airport. This Metro line has been incorporated in the model.

0.3.4.1 Boarding and Alighting

The boarding alighting estimates for peak hour for horizon years at the Stations in the corridor is given in the **Table 0.1** below considering 5 km catchment area as envisaged in Metro policy 2017.

Table 0.1 Daily and Peak Hour Station Boarding for Phase 2B

Stations	Daily 2024		Peak 2024		Daily 2031		Peak 2031		Daily 2041		Peak 2041	
	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight
K R Puram	51,983	54,737	11,691	12,310	89,845	94,604	20,456	19,502	1,16,398	1,22,549	26,498	25,263
Kasturi Nagar	13,794	13,808	3,449	3,452	22,924	22,947	5,731	5,737	29,695	29,726	7,424	7,431
Horamavu	12,790	12,823	3,198	3,206	25,507	25,572	6,377	6,393	33,041	33,125	8,260	8,281
HRBR Layout	14,488	14,690	3,622	3,672	28,893	29,295	7,223	7,324	37,427	37,949	9,357	9,487
Kalyan Nagar	19,777	18,202	4,944	4,551	32,582	31,476	8,145	7,869	42,206	40,885	10,551	10,221
HBR Layout	17,811	17,099	4,453	3,775	40,271	38,661	10,068	9,665	52,166	50,081	13,042	12,520
Nagawara	50,470	51,489	12,618	12,872	77,165	78,723	19,291	19,681	99,959	1,01,976	24,990	25,494
Veeranna Palya	19,535	19,375	4,884	4,344	32,923	32,653	8,231	8,163	42,648	42,298	10,662	10,575
Kempapura	24,013	23,907	6,003	5,727	35,960	35,802	8,990	8,576	46,583	46,377	11,646	11,109
Hebbal	60,987	60,745	15,247	15,186	1,05,406	1,04,988	26,352	26,247	1,36,542	1,36,000	34,135	34,000
Kodigehalli	20,228	20,511	5,057	5,128	51,137	51,853	12,784	12,963	66,243	67,170	16,561	16,793
Jakkur Cross	16,699	16,499	4,175	4,125	40,345	39,862	10,086	9,966	52,263	51,637	13,066	12,909
Yelahanka	30,647	29,138	7,662	7,285	58,526	55,644	14,631	13,911	75,813	72,081	18,953	18,020
Bagalur Cross	8,382	8,540	2,095	2,135	25,145	25,619	6,286	6,405	36,688	37,379	9,172	9,345
Bettahalasuru	8,048	7,551	2,012	1,888	24,145	22,652	6,036	5,663	35,228	33,050	8,807	8,263
Doddajala	5,365	5,774	1,341	1,443	16,096	17,321	4,024	4,330	23,485	25,272	5,871	6,318
Airport City	10,842	10,230	2,711	2,558	32,527	30,691	8,132	7,673	47,458	44,780	11,864	11,195
KIA Terminals	48,113	48,629	6,113	6,171	96,225	97,259	10,392	11,724	1,40,396	1,41,903	15,162	17,106
Total	**4,33,973**	**4,33,747**			**8,35,623**	**8,35,623**			**11,14,240**	**11,14,240**		

0.3.4.2 Peak Hour Peak Direction Traffic (PHPDT)

The **Table 0.2** the PHPDT between the stations for the proposed corridor.

Table 0.2 PHPDT for Phase 2B

Station		PHPDT - 2024			PHPDT - 2031			PHPDT - 2041		
From	To	Forward	Reverse	Maximum	Forward	Reverse	Maximum	Forward	Reverse	Maximum
K R Puram	Kasturi Nagar	11,691	12,310	21,112	20,456	19,502	35,705	26,498	25,263	46,252
Kasturi Nagar	Horamavu	15,606	16,122		20,406	19,413		26,434	25,147	
Horamavu	HRBR Layout	20,270	20,472		26,628	27,685		34,494	35,863	
HRBR Layout	Kalyan Nagar	20,545	20,751		34,332	34,987		44,473	45,322	
Kalyan Nagar	HBR Layout	21,112	20,901		34,782	35,019		45,056	45,363	
HBR Layout	Nagawara	15,792	15,022		35,705	35,273		46,252	45,692	
Nagawara	Veeranna Palya	16,094	14,957		27,001	26,221		34,977	33,966	
Veeranna Palya	Kempapura	16,195	14,922		27,294	26,143		35,356	33,865	
Kempapura	Hebbal	18,425	18,242		27,592	26,100		35,742	33,810	
Hebbal	Kodigehalli	15,001	15,166		32,557	32,235		42,174	41,757	
Kodigehalli	Jakkur Cross	10,218	10,427		25,832	26,916		33,462	34,867	
Jakkur Cross	Yelahanka	9,823	10,114		19,645	20,228		25,448	26,203	
Yelahanka	Bagalur Cross	10,292	10,382		16,467	17,650		24,026	25,751	
Bagalur Cross	Bettahalasuru	9,191	9,460		17,462	17,975		25,478	26,226	
Bettahalasuru	Doddajala	7,505	7,234		14,260	13,744		20,806	20,053	
Doddajala	Airport City	6,613	6,508		12,564	11,063		18,331	16,142	
Airport City	KIA Terminals	6,171	6,113		11,724	10,392		17,106	15,162	

0.3.4.3 From the traffic study it is estimated that the daily ridership on this Metro corridor will be 4,11,636 in 2024, when the project is planned to be completed and it will rise to 8,35,623 by 2031 and to 11,14,240 by 2041. Similarly, the PHPDT will be 21,112 by 2024 which will increase to 35,705 by 2031 and to 46,252 by 2041.

0.4 Civil Engineering

The entire alignment of this line is planned to be elevated except at Yelahanka Air Force Fly zone and inside Airport area. At Yelahanka Air Force Fly zone the alignment is at grade with covered shell at Aircraft take off stretch as there is restriction for height from Air Force Authorities. Inside Airport area, the alignment switches over from elevated to at grade inside KIA Boundary. As the work on the elevated stretches of Phase-I of the project have already been completed and Phase 2 works are in progress, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc., as finalized for Phase-I and Phase-II, shall be used for KR Puram to KIA Terminals Metro line also. 17 stations are planned in Phase 2B including the terminal Stations.

0.4.1 Geometric Design

BMRCL has already implemented Phase-1 of Bangalore Metro project & now implementing Phase 2. Various design norms and parameters have been firmed up by BMRCL after detailed studies and norms followed by Metro systems in various cities. Certain modifications to the design norms have been recommended keeping in view of the Technological Advancements and specific needs of Bengaluru city.

In all,36.44 %of length falls in horizontal curves on the stretch. The radii of the curves vary from 127.50 m to 8000 m.

Details of Horizontal Curves

Total length of the stretch	: 36.44 Km (Pier ORP 658 of Phase 2A)
Number of curves	: 88
Total length of curves	: 13.245Km
% length of Curves	: 36.44%
Minimum Radius of horizontal curve	: 127.50 m

In this corridor, all Stations are located on straight alignment and on level gradient.

Vertical curves are to be provided when the change in gradient exceeds 0.4%. However, it is proposed to provide vertical curves at every change of gradient, for enhancing the comfort of the commuters.

Details of Vertical Curves

Minimum Radius	:1510 m
Maximum Gradient	:3.79%

0.4.2 Track Structure

Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus, it is imperative that the track structure selected for Metro Systems should be long lasting and should require minimum or no maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations.

Keeping the above philosophy in view two types of track structures are proposed for this corridor. The normal ballasted track is planned inside the Depot (except inside the Workshops, inspection lines and washing plant lines). The ballastless track is recommended on Viaducts as the regular cleaning and replacement of ballast at such locations will not be possible.

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

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

0.4.3 Geo Technical Investigation

The Geotechnical investigations were carried out to find out the geological strata and to arrive at the foundations. In addition, soil investigation reports for various flyovers and underpasses already conducted along this route have also been studied.

Field investigations have been carried out along the Outer Ring Road and NH-44 corridor at 16 locations with borehole exploration. The geo-technical investigation data containing bore log details is provided in **Chapter 5.**

0.4.4 Viaduct Structure

The choice of Superstructure has been made keeping in view the ease of constructability and the maximum standardization of the form-work for a wide span ranges. Accordingly, either of the following type of superstructures are considered.

i. Precast segmental box girder with post tensioning. Similar to the superstructure adopted in Phase 1 and Phase 2 of BMRCL.

ii. Precast Pre tensioned U-Girder superstructure.

0.4.4.1 Precast segmental box girder with Post Tensioning.

This essentially consists of pre-cast segmental construction with post tensioning and joints glued and is by far the most preferred technique in fast track projects. In such construction, the pre-stressing cables are placed in the conduits inside the structural concrete which are grouted with non-shrink cement slurry. The match cast joints at the interface of two segments are provided with shear keys for maintaining the correct line and level of the superstructure.

0.4.4.2 Precast Pre tensioned U-Girder superstructure.

Superstructure with single unit of U Girder for the span to accommodate one track is another method of construction of Metro structures. There will be two Girders for each span to cater for the two tracks. The U Girders are Pre tensioned, Pre cast, transported to site and erected on the spans using road cranes.

Since these units are erected as a single unit per span, the speed of construction of Superstructure becomes very fast compared to the segmental construction. Since, the Pier cap will have to accommodate two U Girders, it has to be wider and hence, is made as a precast pre-stressed unit. This feature also facilitates faster construction. However, the internal width of U Girder is generally kept as 4m and hence this type of superstructure can be adopted for spans on curves of radius only up to 300m. For spans on curves of sharper radius and for cross over spans, different superstructure such as precast I Girders with cast-in-situ deck slab have to be used.

0.4.5 Station Locations and Planning

0.4.5.1 As per the configuration of alignment, all the stations would be elevated except Airport City & KIA Terminals stations and details are as shown in **Table 0.3.**

Table 0.3 List of Stations planned on Airport line of Phase 2B Project.

Sl. No.	Name of Stations	Chainage (in m)	Inter Station Distance (in Kms)	Remarks
0.	K R Puram	17.133(Phase 2A)/ -1.294 (Phase 2B)	0.000	Elevated
1.	Kasturi Nagar	1,600.160	2.89	Elevated
2.	Horamavu	2,751.700	1.15	Elevated
3.	HRBR Layout	4,201.230	1.44	Elevated
4.	Kalyan Nagar	5,303.820	1.10	Elevated
5.	HBR Layout	6,560.920	1.25	Elevated
6.	Nagawara	7,508.790	0.94	Elevated
7.	Veeranna Palya	8,314.000	0.80	Elevated
8.	Kempapura	9,964.250	1.65	Elevated
9.	Hebbal	11,223.430	1.25	Elevated
10.	Kodigehalli	12,699.060	1.47	Elevated
11.	Jakkur Cross	14,120.040	1.42	Elevated
12.	Yelahanka	17,842.930	3.72	Elevated
13.	Bagalur Cross	20,022.280	2.17	Elevated
14.	Bettahalasuru	23,826.472	3.80	Elevated
15.	Doddajala	28,736.530	4.91	Elevated
16.	Airport City	33,705.170	4.96	At grade
17.	KIA Terminals	36,267.250	2.56	At grade

0.4.5.2 The proposed stations are either on the middle of the road or partially on the service road or off road as per details below:

a. Along ORR, elevated alignment generally passes on median of the road between K R Puram and Hebbal. The station along this stretch are generally provided above the main carriageway in the median and Entry/Exit of station are provided on either side of ORR beyond service road. Further, the alignment passes over the Right side of the NH-44 in the dedicated strip of 5mtr wide land between main carriageway and service road. The stations along National Highway are proposed over service road with Entry/Exit of station on the open land beyond the service road. The station service is extended to the other side of the National Highway by providing FOB/Subway. The proposed stations will have two side platforms and the access to the platforms is through staircases and escalators, housed in the paid area of concourse.

b. Traffic Integration facility at stations include approach roads to the stations, circulation facilities, pedestrian ways, connecting bridges for Metro and non-Metro commuters, adequate halting areas for various modes likely to come to Metro stations including feeder buses/ mini buses.
c. Connecting bridge at Concourse level has been planned for crossing the road for the use of non-Metro commuters also through unpaid areas.
d. Hebbal station is proposed with parking facilities.
e. Provision for pocket tracks and required number of cross overs are made for facilitating smooth train operations as these facilities help in easy turnaround of racks during emergency.

0.4.6 Land Requirement

As the Metro alignment has to be planned on set standards and parameters, apart from alignment, various structures like stations, parking facilities, traction sub stations, communication towers, etc. require large plots of land. The land being scarce, costly and acquisition being a complex process, the alignment is so planned that barest minimum land acquisition is involved.

Land requirement for Phase 2B Airport line is given in **Table 0.4.**

Table 0.4 Land requirement for Phase 2B.

Type of Land	Area	
	Sqm	Hectares
Private	2,08,019.00	20.80
National Highway	1,05,500.00	10.55
Total	**3,13,519.00**	**31.35**

The cost of land acquisition for the project is estimated at Rs.2171.39 Cr at the prevalent market value and as per land acquisition norms approved by the State Government.

0.5 Multimodal Integration & First and Last mile connectivity

No one mode can operate in isolation if it is to play a role in an integrated network. As each mode is suitable for different journey types, trip length, a combination of modes and complementary services is essential for seamless and effective mobility.

“The City Wide Multi-Modal Integrated Transport Plan can be defined as an approach for integration of institution, transportation & information structure for the unified transport network to provide the first mile and last mile connectivity both by private & public mode.”

To achieve Multimodal Integration, inter transit stations at Hebbal is planned. In addition to this, a Sky walk of 500m length at Horamavu is planned to connect nearest bus stop over underpass.

First and last mile connectivity can be defined as delivering connectivity from home to work and work to home with different modes of transport. The details for Multimodal Integration and first and last mile connectivity planned for this corridor are given in **Chapter 7** of this Report.

0.6 Environmental Impact Assessment/Environmental Management Plan

Ministry of Environment and Forests (MoEF), Government of India, has issued various notifications on Environmental Impact Assessment since 1994 with the latest being in 2009. According to those notifications, 32 types of projects under Schedule-I require environmental clearance from MoEF while Rail projects are exempted. The proposed project does not require Environmental Clearance as it does not create any major adverse environmental impact.

However, this report tries to identify environmental and social impacts and their mitigation measures and the details are dealt in **Chapter 14.**

The likely number of trees affected due to this line are enumerated and the number of trees affected are going to be transplanted/cut as instructed by Forest department and nourished as Compensatory Reforestation.

0.7 Train Operation Plan

Trains on the Airport metro corridor will be put to service in such a way that, from Airport Terminal to Hebbal there will be limited number of stops with high speed travel facility and from Hebbal to K.R.Puram there will be frequent train service as per travel demand analysis brought out in Chapter 3. Also since, Phase 2A line will be connected with Airport metro corridor of Phase 2B, train operation plans and train frequency of 2A corridor have been integrated for the entire corridor from Silk Board to Airport Terminal Station so that every third train starting from Silk Board will be extended to Airport Terminal station initially. The detailed train operation plan is provided in **Chapter 8.**

0.7.1 Considering the present inter station distance, sections with straight and curve alignment, dwell time at stations etc., detailed simulation was carried out and average speed of 36 Kmph is planned between KR Puram to Yelahanka and 60 kmph between Yelahanka to Airport Terminal.

0.7.2 For the purpose of planning, the Peak hour peak direction traffic (PHPDT) demands for the 2B corridor indicated in **Table 0.5**:

Table 0.5 Peak Hour Peak Direction Traffic

Corridor	YEAR		
	2024	2031	2041
KR Puram to KIA Terminals	21,112	35,705	46,252

0.7.3 Train formation

To meet the above projected traffic demand, running trains with composition of 6 Car trains has been planned with different headway.

Composition

DMC : Driving Motor Car

MC : Motor Car

TC : Trailer Car

6 Car Train Compositions : DMC - TC -MC - MC - TC – DMC

0.8 Rolling Stock

The important criteria for selection of Rolling Stock for BMRCL are mainly reliability, low energy consumption, lightweight and high efficiency leading to lower annualized cost of service. Also, the train should have high rate of acceleration and deceleration.

The proposed Rolling Stock for 2B corridor is identical in dimensions with the Rolling Stock of Phase-I to ensure interchangeability and continuity in service and compatibility of the same with Baiyappanahalli depot which has already been constructed under Phase-I. Train of 2B corridors will be maintained at Baiyappanahalli depot with suitable remodelling and additional lines (equivalent to new depot) and proposed Depot near Kempegowda International Airport (KIA). Schedule of Dimensions (SOD) of Phase-2B Metro corridor will be same as Schedule of Dimensions of Phase-I and Phase-II.

The size of the coach for 2B corridor shall be in accordance with Schedule of Dimensions (SOD) of Phase-II. Proposed Coach Dimensions are as below:

Table 0.6 Size of the Coach

Description	Length*	Width	Height
Driving Motor Car (DMC)	21.05m	2.88 m	3.8 m
Trailer car (TC)/Motor Car (MC)	20.8 m	2.88 m	3.8 m

Coaches will have longitudinal seats with seating capacity of 43 persons per coach and the exceptional dense crush capacity (AW4) of 43 seated, 273 standing thus a total of 316 passengers for a Driving Motor Car and 50 seated, 293 standing thus a total of 343 for a trailer and motor car is envisaged. Hence, it is recommended to procure Rolling Stock for Airport Link Metro corridor with maximum axle load of 15T. It is also proposed to consider the maximum design speed of train at 90 Kmph.

0.9 Power Supply System of Traction

The existing traction system in Bangalore Metro is 750 V DC third rail. Since the K R Puram – Airport line is an extension from Phase-2A, ORR Metro line, up to Kempegowda International Airport, the same traction system of 750 V DC third rail bottom current collection system is proposed to achieve the seamless integration and operational flexibility.

Incoming power supply is proposed to receive from Grid Substation of KPTCL at 66 kV and by UG cable through double feeder for each proposed RSS. Two (02) RSSs of 66/33 kV, 2x25 MVA at Yelahanka and KIAL depot along with K R Puram RSS part of Phase-2A line which is planned with a provision for 10 MVA built-in for K R Puram – Airport line will suffice the power requirement. Hence, provision for two number of RSS are made in this DPR.

The 66 kV power supply will be stepped down to 33 kV level at the above RSSs of metro authority. The 33 kV power supply drawn from the RSS will be distributed along the alignment through 33 kV ring main cable network for feeding to traction as well as auxiliary loads. These cables will be laid in dedicated ducts/hangers/brackets along the viaduct. Station auxiliary power supply is envisaged from the ASS (33/0.415 kV) located at concourse.

With only 17 passenger stations in the line, the additional TSS required are to be accommodated at especially constructed concourse below viaduct / wayside based on the land availability and Viaduct proposed and will be finalised during detailed engineering stage. Total 20 TSSs (18 mainline + 2 depot) are estimated for 2031 scenario and the precise requirement of TSSs to be determined by simulations during detailed engineering stage.

Electric power requirement for this line is likely to be 23.25 MVA approximately in year 2024, which is likely to increase to 36.69 MVA by year 2041. All the ASS & TSS of mainline are unmanned and to be SCADA compatible, to be integrated with OCC of Phase 2/2A.

0.10 Signalling and Train Control

The latest technology available in the Signalling/Train Control System is Communication Based Train Control (CBCT) System. The Phase-II lines (Line 5 &6) which is under implementation is also being provided with CBTC Signalling System. Signalling and Train Control System shall be designed to meet the required headway as that on the contiguous section of K R Puram-Silk Board line. The proposed Signalling system shall be capable of Unattended Train Operations (UTO).

The control of train operation will be done from a centralized Operation Control Centre (OCC) and will be supervised by the Traffic Controller (TC) at OCC. The OCC shall have required facilities for setting up of route and clearing of signals and other supervisory and control facilities. The Backup Control Centre (BCC) shall also be provided at suitable location geographically separated from OCC.

To cater operation requirement for Central Silk Board to Airport Link Corridor, a new Operation Control Centre (OCC) is planned with equipment and display boards of CBTC system adjacent to Baiyappanahalli Depot with a suitable connectivity to the existing OCC as the present OCC is operationally saturated.

0.11 Telecommunication and Fare Collection System

0.11.1 Telecommunication System

Telecommunication system shall cater to the needs of system traffic control, features to supplement Signalling system, operational/ maintenance and emergency communication, administrative communication, passenger information system, CCTV surveillance etc. in Metro Network. It shall also provide communication backbone for other systems such as Signalling, Power SCADA, Building Management Systems, Automatic Fare Collection (AFC) systems and administrative IT LAN.

Further, for efficient and cost effective maintenance of the Signalling & Train Control and Communication network, it is proposed to provide a network management system (NMS), which will help in diagnosing faults from a central location and attending the same with least possible delay. Adequate space for proper installation of Signalling/Train Control and Telecommunication equipment at each station shall be provided in view of regular testing and maintenance of the equipment/Systems.

0.11.2 Automatic Fare Collection System (AFC)

The proposed ticketing system shall be similar as provided for Phase-I & Phase-II i.e., of contactless smart token/card type. The AFC system shall support simultaneously ISO 14443 based type-‘A’ cards compatible with MiFare and EMV based open loop (National Common Mobility Cards, Rupay, Visa, Master Card etc.) cards. The system shall also be capable of processing and accepting NFC based fare media with the provision of mobile ticketing. The system shall have provision for QR code based mobile ticketing also.

0.12 Train Maintenance Depot

ORR corridor (Central Silk Board junction to K R Puram of length 18.36 Km) is proposed to be further extended from K R Puram to Kempegowda International Airport (KIA) via Hebbal and Yelahanka for a length of about 38Km (36.44 Kms from Jyothipuram to Airport Terminal) under Phase 2B Project of BMRCL.

Strategically, this corridor is divided in to two sections, i.e. K R Puram to Yelahanka (20.736 Km) and Yelahanka to KIA West (18.069 Km).
The length of this corridor being longer, there is a necessity to provide depot facilities at either end of the corridor to ensure seamless operation and maintenance services with a proposed headway for the line. Therefore, full-fledged depot is proposed at Airport end to be constructed in a phased manner.

There is a proposal for switch-over of Baiyappanahalli depot from E-W corridor to ORR corridor by remodelling it. While remodelling, it is also proposed to augment stabling capacity at Baiyappanahalli depot from the existing 16 lines to 42 lines to cater complete operational needs of Phase-2A & 2B corridor. Considering the augmentation plan at Baiyappanahalli, the construction of Airport depot facility is proposed in two phases. In the first Phase it is proposed to construct 12 stabling lines and a combined shed with 4 inspection lines and 2 repair lines and PWL line. In the second phase, 7 SBLs, 2 more repair lines and test track of 750 mtr length is planned to be constructed.

Traffic demand in Airport corridor is likely to increase much higher than the proposed PHPDT by the year 2041. Hence, it is imperative to ensure provision for additional 15 stabling lines for future at Airport depot to cater suitable head way in the critical sections of this corridor.

0.13 Metro-cum-Road Infrastructure

The Metro-cum-Road Infrastructure has been deleted in the current DPR to avoid complicacy in construction work owing to huge road traffic in the stretch. At grade road capacity augmentation with additional flyover loops across railway tracks at Benniganahalli is planned. ORR-Airport line (Phase 2A & 2B) and East West extension line Phase 2 will have a number of common portals that has been incorporated in the design.

0.14 Security

Provision has been made for Security arrangements to be provided during operation of the Project. The Cost and other details are available in Chapter 16 of this Report.

0.15 Cost Estimates

0.15.1 Summary of Capital Cost Estimate

The summary of revised capital cost of the project for Airport line prepared at MoHUA 2019 February prices is given in the **Table 0.7**:

Table 0.7 Summary of Cost Estimate

Sl. No.	Item	Basic Cost @ 2019 Prices
1	**2**	6
1	Alignment and Formation	1426.67
2	Station Buildings (Civil & E&M)	661.40
3	Permanent- Way	325.85
4	Traction & Power Supply	613.18
5	Signalling & Telecom	347.54
6	AFC	59.50
7	PSD	6.00
8	Utility, cable trough & Signage	281.83
9	Multi modal Integration	51.00
10	Depot (Depot at Baiyappanahalli & Near Airport)	340.00
11	Rolling Stock (SG)	1008.00
12	Security-Capital Cost	6.29
13	Road Restoration	22.00
	Total	**5149.26**
14	Land	2171.39
15	Total including Land	7320.65
16	Taxes (Excluding Land)	697.53
17	Contingencies @ 3% (Excluding land & including Taxes)	175.40
18	D & G @5% (Excluding land)	266.23
19	Price variation During construction (Except Land)	978.61
20	Interest during Construction (IDC)	496.16
21	**Grand Total including land**	**9934.58**

0.15.2 Operations and Maintenance cost:

The O&M cost for the year 2023-24 is **Rs.258.95** Crores for the new line of 38 Kms (36.44 Kms from Jyothipuram to KIA Terminals) with 17 stations, for running 6 coach train sets. Possibility of outsourcing maintenance activities for Rolling Stock, Signalling & Telecommunication, Power Supply and Traction, Station Buildings as service contracts will be explored to economise on the cost.

0.15.3 Detailed Cost estimate is given in **Chapter 16.**

0.16 Financing Plan and Financial Analysis

0.16.1 Financing Plan

The highly capital intensive Metro projects are a public utility with huge positive economic externalities but typically very low financial returns. Domestic commercial borrowings are not a viable option for financing as not only the cost of funds is on the higher side, but the tenures are also not long enough to match the long pay back periods which characterise a long gestation infrastructure project. Therefore, there is the need to explore avenues of financing with moderate rates, long tenures and a long enough initial moratorium. This requirement is fulfilled by the sovereign loans extended by Multilateral and bilateral development banks such as JICA, ADB, AFD, EIB etc. Therefore, in addition to the Equity and Subordinate Debt contribution from the Central and State Government, the Senior debt is proposed to be contracted through sovereign borrowing.

Table 0.8 Revised Funding pattern (Equity sharing model) - Phase-2B (In crores)

Sources	Amount (Rs in crore)	(% of Share)
GoI - Equity	1,139.27	11.47%
GoI - Sub-debt	174.38	1.76%
GOI Share sub total (1)	**1,313.65**	**13.22%**
GoK - Equity	1,139.27	11.47%
GoK - Sub-debt	174.38	1.76%
GoK - Sub-debt (Land Cost)	2,171.39	21.86%
Subordinate-debt (State Taxes)	348.76	3.51%
GoK Share sub total (2)	**3,833.81**	**38.59%**
Value Capture Financing (3)	**150.00**	**1.51%**
Innovative Financing (4)	**350.00**	**3.52%**
Senior Debt (Sovereign/Non Sovereign Loans) (5)	**4,287.12**	**43.15%**
Total Sources (1) to (5)	**9,934.58**	**100.00%**

0.16.2 Financing Analysis

Financial analysis is done based on estimated Capital inflows on account of equity, subordinate debt and borrowings as well contribution from innovative financing and Capital outflows are comprised of expenditure during construction and IDC. The inflows from Fare and Non fare Box revenue comprise the Revenue inflow and the revenue expenditure on operations and Operational, staff and energy cost as well as finance cost constitute the Revenue outflow.

The FIRR is derived as **6.83%** in the Most Likely scenario for estimated Ridership for a 30-year time horizon and Sensitivity Analysis has been carried out for an optimistic scenario with 10% increase in ridership and pessimistic scenario with 10% reduction in ridership coupled with a 1-year time over run and a 10% cost overrun.
(The details are in Chapter-18)

Table 0.9: Summary of Sensitivity Analysis and FIRR results

SL No	Ridership Scenarios	Pax per day	Capital Outflow including IDC (Rs in crores)	Net cash inflow (after redemption of borrowings) (Rs in crores)	FIRR	Reference
1	**Most Likely scenario**					
	Year 2024 onwards	4,09,383	(9,935)	21,695	6.83%	Annexure-18.1
	Year 2034 onwards	73,768				
2	**Optimistic scenario** (Pax 110% of Most likely scenario)					
	Year 2024 onwards	4,50,321	(9,935)	30,720	8.60%	Annexure-18.2
	Year 2034 onwards	81,145				
3	**Pessimistic Scenario** (Pax 90% of Most likely scenario with one year time overrun + CAPEX increase by 10%)					
	Year 2025 onwards	3,68,445	(10,933)	18,530	5.55%	Annexure-18.3
	Year 2035 onwards	66,391				

0.17 Economic Analysis

The benefits that the metro projects provide are more important from the government's economic and social point of view compared to the financial benefits that accrue from implementing the project. The proposed system will provide a variety of benefits to the city and society, viz. savings in fuel consumption, vehicle operating costs, travel time, reduction in road accidents and air pollution etc. These economic benefits would overweigh the financial benefits and hence assessing the same would also be of more significance.

The economic analysis for K R Puram to Airport Line has been carried out within the broad framework of EIRR (Economic Internal Rate of Return) based on Appraisal Guidelines for metro rail projects taken from website of Ministry of Housing & urban affairs.

The Economic Analysis is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the various Sensitivity Scenarios. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values computed by converting the market prices using appropriate factors. The annual streams of project costs and benefits have been compared over the entire analysis period to estimate the net cost/ benefit and to calculate the economic viability of the project in terms of EIRR. Effectively 30 years of operations from the start of services from the year 2023-24 has been considered for economic evaluation for the project.

EIRR for 30 years has been computed to be **22.11%.**

Based on the above considerations, the Economic IRR values for different scenarios are computed as follows (The details are in Chapter–19)

Table 0.10 : Sensitive Analysis

Factors	5% Change	10% Change	15% Change
Increase in Capital Cost	21.48%	20.90%	20.35%
Increase in Operation & Maintenance Cost	22.00%	21.90%	21.79%
Reduction in Ridership	21.45%	20.77%	20.08%
Reduction in Monetary Benefits (overall)	21.47%	20.70%	19.97%
Combination of Increase in Capital cost and Reduction in Monetary Benefits	20.80%	19.57%	18.39%

0.18 Implementation Strategy

0.18.1 Legal Cover for Implementing the Project

Implementation of proposed K R Puram to Airport line of Bangalore Metro Rail Project will be done under “The Metro Railways (construction of works) Act 1978” and “The Metro Railways (Operation and Maintenance) Act 2002” as amended by “The Metro Railways (Amendment) Act 2009”.

0.18.2 Implementation Schedule

The project is proposed to be implemented as Phase-2A for Bengaluru Metro in a period of 48 months from financial closure i.e. between April 2020 and December 2023. A suggested project implementation schedule is given in table below. Activity 6 i.e., commencement of piling in April 2020 will be the effective physical start of works and the Activities 1 to 5 will be the time required for approvals and preparatory works.

Table 0.11 Activities showing start date, end date & duration for implementing Phase 2B.

Activity	Description	Start	End	Duration in Months
Activity 1	Land Acquisition for Viaduct & Stations	0	12	12
Activity 2	Approval by GoK	0	3	3
Activity 3	Approval by GoI	4	6	3
Activity 4	Financial Closure by at least 50% Senior Debt	7	12	6
Activity 5	Award of civil works contract	4	12	8
Activity 6	Piling & Pile cap	15	27	12
Activity 7	Pier & Pier cap	18	30	12
Activity 8	Segment Launching	22	40	18
Activity 9	Station works	15	42	27
Activity 10	Station finishing works	35	50	15
Activity 11	Track works	35	50	15
Activity 12	System works (Traction, E & M and S&T)	30	54	24
Activity 13	Integrated Testing	54	57	3

0.19 Compliance to Metro Rail Policy 2017

The New Metro rail Policy,2017 envisages private participation as an essential requirement for either the complete provisioning of metro rail or for some unbundled components for all metro rail project proposals seeking central financial assistance. However, a private player would want to price the risk associated with the uncertain revenue streams owing to uncertainties in both projected ridership and fare materialising. This will invariably raise the cost of private investment in an already highly capital intensive project with public good characteristics leading to very unattractive returns on investment. Thus, finding private partners for construction of new Metro Rail systems through DBFOTs (Design-Build-Finance-Operate- Transfer) is rather more difficult. Therefore, BMRCL has focused on leveraging on the private resources, expertise and entrepreneurship for funding the project by way of unbundling the various activities and components.

The proposed Airport Metro line meets the objectives and norms set out in the Metro Rail Policy 2017. The proposed line seeks to provide efficient, effective sustainable mode of mass public transport for the business corridor having economic activities for 12% the country’s IT exports.

The proposed line is part of the Comprehensive Mobility Plan 2019 for Bengaluru city. It has been subjected to the alternative investment analysis for mass public transport systems, and is assessed to be the appropriate mode for the mobility needs on the corridor.

The city has a draft Transit Oriented Development Policy with some of the proposed measures already being at the stage of legal and regulatory approvals.

The state has a fully functional Directorate of Urban Land Transport. A bill for setting up Bangalore Metropolitan Land Transport Authority has been prepared and is likely to be placed before the State Legislature shortly for enactment.

0.20 Salient Aspects of the Project

0.20.1 Goals and Objectives

- The project aims to support the goals of Comprehensive Mobility Plan (CMP) for complementing economic activities and increasing the share of public transport to 70% of all motorized trips.
- It also plans to facilitate systemic changes in road usage by incentivizing efficient, equitable and sustainable mobility options through economic and regulatory measures, while discouraging inefficient and unsustainable options through imposition of cost of negative externalities.
- This project will play a key role in mitigating the mobility related binding constraints to IT eco-system in Bangalore, which accounts for 40% of revenues of IT companies in India.

0.20.2 Innovations and Piloting of New Approaches

The Project will implement the following innovations and new approaches due to the advantages of its location and alignment.

- Enhancing efficiency of usage of road as an economic asset & leveraging parking space fees to encourage use of public transport.
- Development of Inter-modal transit hubs for operational and economic integration with other modes.
- Extensive use of non-motorized transport for last mile connectivity.
- Economic integration of fare by common fare card for Metro and public bus system to complement the two important modes of public transport for the convenience of commuters.
- Augmenting road infrastructure by building Metro-cum road flyover in critical locations in the project alignment.
- Use of latest technology, modern construction practices and project monitoring through advanced IT system.

0.20.3 Innovations in Financing Leveraging

In order to reduce the dependence on borrowings, the following financing innovations are planned:

- Upfront PPP with major companies to realize about USD 70-100 million to fund capital cost.
- Land Value capture through innovative TOD measures for financing of urban infrastructure.
- Financing plan with long term and moderate cost financing from multilateral and bilateral development agencies to the extent of 45% which can be largely serviced out of revenues of BMRCL.
- It is expected to raise approximately an amount of Rs 350 crore through these arrangements and this amount would be available for project financing.

0.20.4 Private Sector Engagement (Financing, Involvement, Provision of Services)

- Innovative Financing with major companies having presence along the metro alignment giving them rights for station naming, direct access for their employees, advisement and commercial spaces for financing capital expenditure on the project and it is expected to raise approximately an amount of Rs 350 crore through these arrangements and this amount would be available for project financing.

- Back-ended PPP with BIAL during the operational phase is envisaged by transferring assets in the Airport area upon commissioning to BIAL and leasing them back to facilitate levy of user development fee on air travelers by BIAL as AERA guidelines. The revenue streams generated through transfer of this amount of Rs 800 crore would aid in debt servicing, thus mitigating the need for shadow cash support from GOK.

- Procurement of system maintenance services for Rolling Stock, Signalling & Telecom, Traction, Housekeeping and Security to be outsourced during the operational phase.

0.20.5 Value Capture Financing (VCF)

The Government of Karnataka has identified a number of instruments for Value Capture Finance through which Rs 150 crores is expected to be raised.

0.20.6 Climate Mitigation/Adaptation and Stakeholder Involvement

- The proposed project will increase the share of public transport in total intra-city passenger movements and is expected to reduce carbon dioxide emissions and resultant pollution and improve air quality of the city by shifting 0.46 million daily passengers from road to rail-based modes. The project is also expected to assist in orderly densification of the city instead of lateral growth of the urban area.
- Corridor alignments and the proposed station locations have been identified based on extensive consultation and after obtaining feedback

from key stakeholders. Involvement of public is to be mainstreamed through stakeholder consultations to minimise traffic constraints during Metro construction. To obtain support of key stakeholders towards the project, BMRCL has taken number of new initiatives e.g. slum dwellers living in acquired land are being provided with a dwelling unit irrespective of status of the slum. BMRCL compensates/ rebuilds parts of schools, hospitals, parks, religious structures, etc. affected by the project.

0.20.7 Mainstreaming of Gender

Convenient and efficient mobility option for women is expected to mitigate one of the causes of declining share of women in the workforce. The improved access to city centres, commercial hubs, airport and basic social and other services will contribute to improved job opportunity, health and education outcomes, particularly to the poor and marginalized, women and children. Dedicated special coach for women passengers in each train and reserved seats for the elderly, and persons with disabilities are some of the features planned.

0.20.8 Outcome of the Project

The project on implementation, will provide major socio-economic benefits to the society particularly in the influence zone of the corridor, such as:

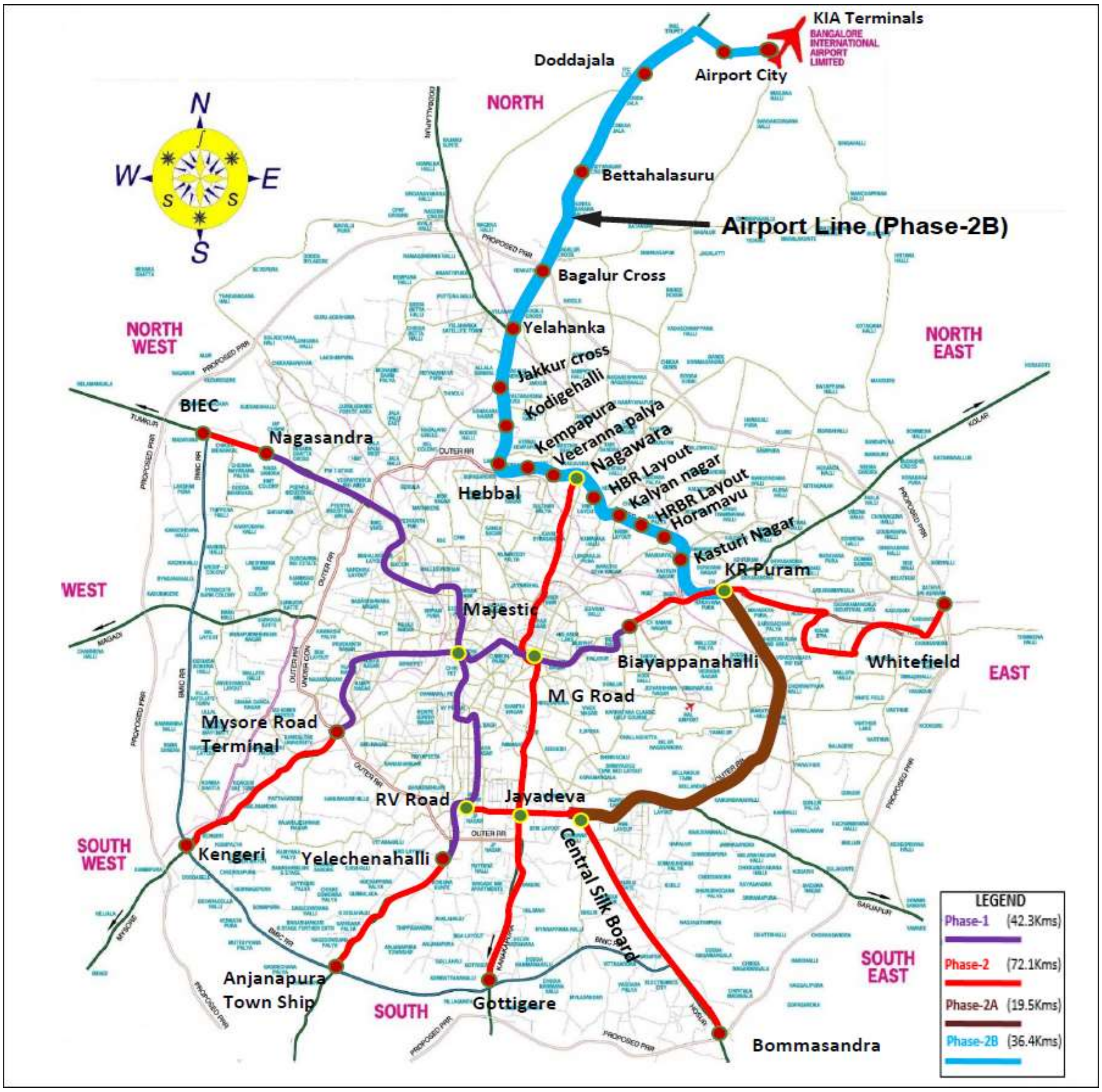
- Provide safe, reliable, affordable and environment friendly public mass transit systems for Bangalore city, which will improve mobility and benefit about 0.46 million commuters daily and support endeavour for planned urban development in Bangalore.
- Result in larger share of public transport in meeting mobility needs of the city.
- Lead to enhanced economic productivity of the city and thereby assistance for more job creation.
- Bringing the roads back to the community for social and economic development of the zone.

0.21 Recommendations

0.21.1 The analysis in this Revised Detailed Project Report (DPR) establishes not only the economic viability and desirability of this project but also brings out that construction of a Metro line on this corridor will enhance effectiveness of the Metro network. The revised cost of construction of this Metro line measuring about 38.00 Kms. (36.44 from Kms Jyothipuram to KIA Terminals Station) would be Rs. 9934.58 Crore.

0.21.2 The work of execution of this project can be entrusted to a Special Purpose Vehicle (SPV) which has the technical and managerial components to execute it. The Bangalore Metro Rail Corporation Ltd. (BMRCL) is the appropriate agency for execution of this project with their experience of Phase-1 and Phase-2 projects of BMRCL.

Figure0.1 Bangalore Metro Network Phase-1, 2, 2A & 2B.



Chapter 1

Profile of the City

CHAPTER 1

PROFILE OF THE CITY

1.1 General/Historical Background

1.1.1 Bengaluru is the capital city of the state of Karnataka. Bengaluru (previously Bendakaluru), as a city, was founded by Kempegowda. The earliest evidence for the existence of a place called Bengaluru dates back to c. 890. He marked the four corners of the city whom many treat as the architect of modern Bengaluru, built a mud fort in the city with the help of King Achutaraya. In the 19th century, Bengaluru essentially became a twin city, with the "Pete", whose residents were predominantly Kannadigas and the Cantonment created by the British. During 19th century, the Cantonment gradually expanded and acquired a distinct cultural and political salience as it was governed directly by the British and was known as the Civil and Military Station of Bengaluru. While it remained in the princely territory of Mysore, Cantonment had a large military presence and a cosmopolitan civilian population that came from outside the princely state of Mysore, including British and Anglo-Indians army officers. Bengaluru's reputation as the "Garden City of India" began in 1927 with the Silver Jubilee celebrations of the rule of Krishnaraja Wodeyar IV. Several projects such as the construction of parks, public buildings and hospitals were instituted to improve the city.

Bengaluru, with a population of over 12 million is a key engine for driving global growth. The city is one of the fastest growing major metropolis in the country with an economic growth of 10.3 per cent and possesses world class infrastructure in housing, education & research. Bengaluru is the most urbanized district with 90.94 per cent of its population residing in urban areas and contributes 35.90 percent to Gross State Domestic Product (GSDP). The district tops in contribution to secondary and tertiary sectors due to high concentration of major industries and infrastructure facilities.

Bengaluru is the heart of modern India and has been driving growth through its state of the art Industrial Hubs. It continues to be a leader in the establishment of knowledge based industries such as Information Technology, Biotechnology and Engineering, and also in the exports of Electronics, Computer Software. Make in India started as a journey for Karnataka way back in 1953, with Bosch’s (earlier Mico) manufacturing facility in Bengaluru and since then, Bengaluru, as become the hub of next-gen technologies which include Nano-tech, robotics, 3D printing, space, drone, rocket, military and aircraft technologies, as well as high-end electronics.

Today, Bengaluru, country’s leading IT exporter has the youngest tech workers and most efficient among all global start-up hubs. Bengaluru among the 20 best start up city ecosystems in the world has emerged as the IT Start Up Capital of India with more than 30 per cent of national share. It has also been ranked 2nd in Global start-up ecosystem growth index by “Compass”. It has the largest hub of semiconductor design companies, outside the Bay Area in California. Nearly 70 per cent of the country's chip designer's work from Bengaluru and around 80 per cent of the sector's revenues in design are from this city alone.

Bengaluru is also known as the Garment Capital of India and has been one of the leading contributors in the growth of textile and apparel market. It houses large manufacturing capacities across the complete manufacturing value chain viz. natural and manmade fiber production, spinning, weaving, knitting, processing, garmenting, made-ups and technical textiles. Bengaluru retains 2nd position after Delhi with most vehicles on roads and has more than 6000 plus electric vehicles.

Home to a large number of education and research institutions have played a major role in supporting and promoting the ecosystem. The vast entrepreneurial and workforce talent available in the city can be attributed to these institutes. The city is also recognized as the fountainhead of global Research and Development – with Multi-National Companies having their global Research and Development Centers here – perhaps the largest concentration of such centers anywhere in the World. United Nations has ranked Bengaluru has the 4th largest technology cluster in the world after Silicon Valley, Boston, and London. Recently, Bengaluru was also ranked as the No.1 Digital City in the World as of November 2017 and was the only city in India to be ranked 19th among world's 25 hi-tech cities ahead of Berlin, Hong Kong and Shenzhen. Bengaluru has been ranked as No.1 – 'Best place to live and work' by the Global HR Consultancy Mercer.

Bengaluru, with its strong economic base, contributes about 36%[1] to Karnataka's GSDP (2016-17). Bengaluru has the highest contribution in secondary and tertiary sector's GSDP due to high concentration of major industries and infrastructure facilities. The Metropolis houses about 40% of urban population of Karnataka and has witnessed 49.4% growth in population during the decade 2001-2011, thus playing the role of a primate city in the State. In context of the State, the Population in the city of Bengaluru accounts for nearly 14.6% of the state's population concentrated in only about 0.64% of the land area.

1.2 Location, Climate, Physical Setting & Regional Linkages.

1.2.1 Location

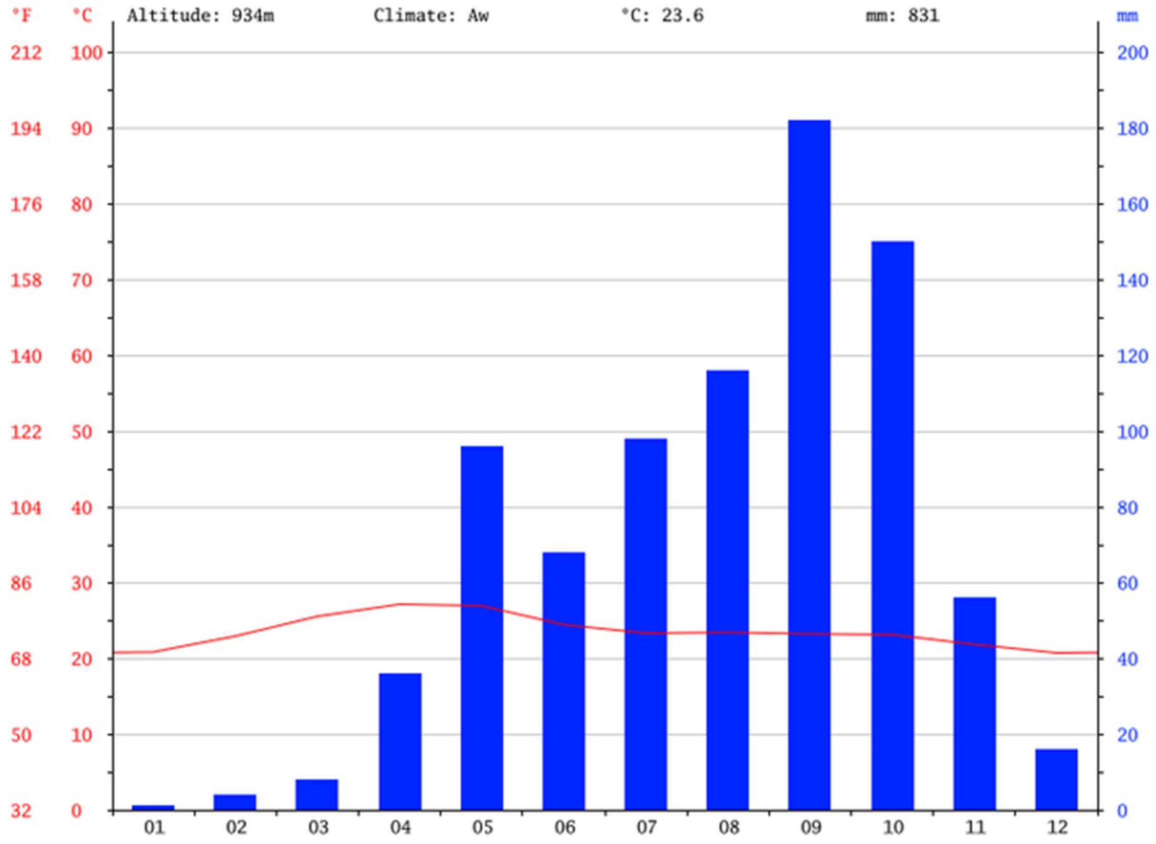
It is located in southern part of India on the Deccan Plateau. Its elevation is over 900 m (3,000 ft) above mean sea level, which is the highest for India's major cities. It is located at 12.97°N 77.56°E and covers an area of 741 km^2 (286 Sq miles) with in BBMP limits. The majority of the city of Bengaluru lies in the Bengaluru Urban district of Karnataka and the surrounding rural areas are a part of the Bengaluru Rural district.

[1] Economic Survey of Karnataka 2018-19

1.2.2 Climate

The climate of Bengaluru is tropical. The summers are much rainier than the winters in Bengaluru. This climate is considered to be tropical wet and dry or savanna climate (Aw: with the driest month having precipitation less than 60 mm (2.4 in) and less than 4% of the total annual precipitation according to the Köppen-Geiger climate classification). The temperature here averages 23.6 °C. In a year, the average rainfall is 831 mm.

Figure 1.1 Climate graph / Weather by Month in Bengaluru



Source: climate-data.org

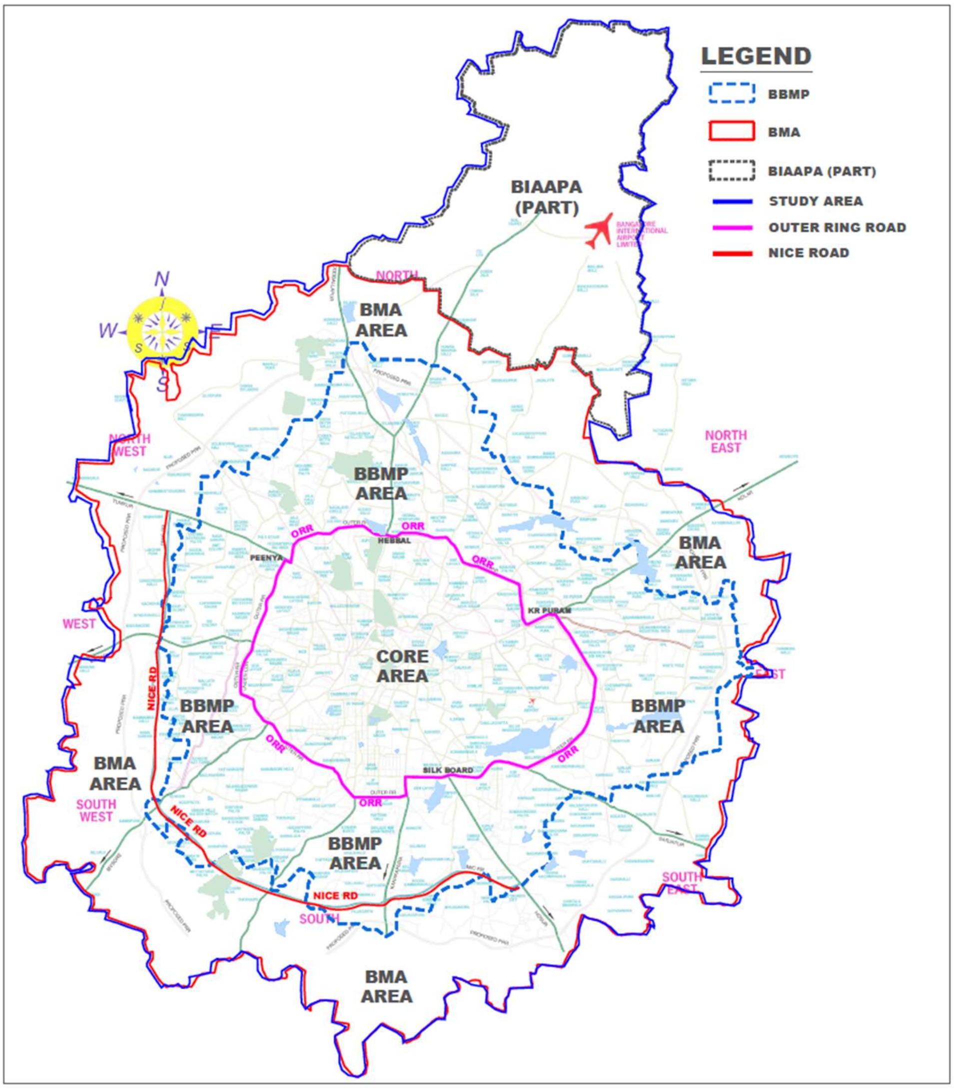
The driest month is January, with 1 mm of rain. The greatest amount of precipitation occurs in September, with an average of 182 mm. April is the warmest month of the year. The temperature in April averages 27.1 °C. The lowest average temperatures in the year occur in December, when it is around 20.7 °C. There is a difference of 181 mm of precipitation between the driest and wettest months. The variation in temperatures throughout the year is 6.4 °C.

1.2.3 Physical Setting

The study area includes the Bengaluru Metropolitan Area (LPA area) i.e. 1294.00 Sq.km. (including part BMICAPA area – 79.14 Sq.km.) The development of Airport near Devanahalli and transport infrastructure development in the form of 6 lane access controlled road between Hebbal and Airport has triggered development around airport and near Devanahalli. To ensure planned development, BIAAPA has been established to oversee the development of the identified area. The BIAAPA study area reveals that most of the developments are in two administrative areas namely Jala Hobli and Kasba Hobli. Considering this and to account its impact on the city development part of BIAAPA area extending 227.85 Sq.km has been included in the planning area for CMP.

The study area for preparation of DPR is shown in Figure 1.2.

Figure 1. 2: Study Area



1.2.4 Regional Linkages

1.2.4.1 Bengaluru is connected with major business centers of Karnataka such as, Mysore, Mangalore, Davanagere & Hubli. In turn, it is connected with major neighboring State capitals such as Mumbai, Hyderabad & Chennai. Bengaluru being known as” Silicon City” is Land of Software Development & Supply to many parts of the World. It is sharing the Software Business majorly with Hyderabad which is upcoming as second largest Software city in India. Having international Airport facility, Bengaluru business is directly connected with above said places. Hence, Metro link from Airport to the Software technology parks established at Whitefield, Electronic city etc., has become a must to meet with the rapid transport solutions towards progress of the city.

1.2.4.2 Bengaluru is connected with historic cities such as Mysore, Hampi, Bijapur etc., which is contributing towards development of tourism.

1.3 Demographic and Socio Economic Profile

1.3.1 Population Growth

Bengaluru is the most populous city in the State of Karnataka. The available census information, as extracted from population data for the unified area (BMA) for the past five decades i.e., 1971 to 2011 broadly coincides with the formation of BDA in 1976 and that the Jurisdiction of BMA has remained constant for all these years except for modifications due to administrative changes. However, the municipal boundaries/ urban agglomeration has changed every decade. In case of BBMP, present municipal boundaries have been used to arrive at historical data for BBMP.

1.3.1.1 Population in BBMP and BMA has grown rapidly as evident from **Table 1.1**, which presents the growth of population in BBMP, BMA and villages within BMA for past five decades and **Figure 1.3** presents the details of planning area.

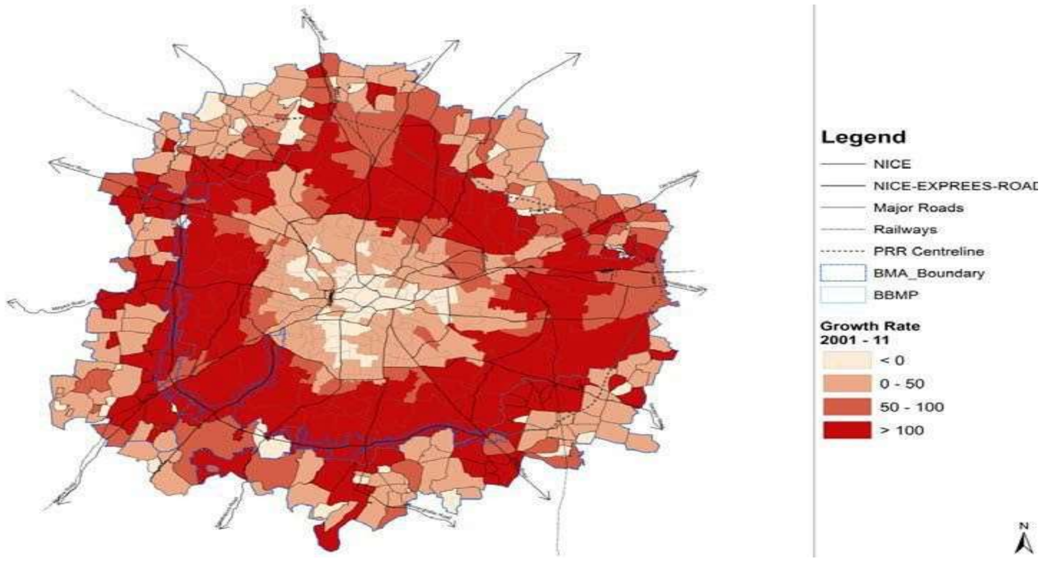
Table 1.1 Population Trends for BMA

Year	BBMP			Villages in BMA			BMA		
	Population	GR%	CAGR	Populatio	GR%	CAGR%	Population	GR%	CAGR%
1971	1897826			113879			2011705		
1981	3100811	63.4	5.03	157664	38.4	3.31	3258475	62.0	4.94
1991	4320297	39.3	3.37	209500	32.9	2.88	4529797	39.0	3.35
2001	5887853	36.3	3.14	302163	44.2	3.73	6190016	36.7	3.17
2011	8443675	43.4	3.67	600989	98.9	7.12	9044664	46.1	3.87

Note: GR- Decadal Growth Rate between two Census Years, CAGR – Compounded Annual Growth Rate
Source: Draft RMP 2031 (Table 6-1)

1.3.1.2 BBMP has consistently experienced high growth rates though there are variations between the decades. The growth rate in villages in BMA has doubled during 2001 to 2011. Due to larger influence of BBMP in the BMA, the BMA trend line is following the BBMP but is susceptible change in the pattern in future considering the large chunk of lands available for development in the surrounding villages. This requires a clear supporting policy and regulatory framework supported with measures to make the agricultural land in the BMA as productive asset for facilitating conservation of the agricultural land.

Figure 1.3 Population Growth in BMA (2001 to 2011)



Source: Draft RMP 2031 (fig 6-1)

1.3.1.3 Assessment of growth rates within BMA in the past census decade (**Figure 1.3**), indicates that growth rates in most of the wards of the city's core area (inside ORR) have been found to be in the negative, whereas a positive and a prominent growth rate is found in most of the wards belonging to the peripheral areas.

1.3.1.4 Bengaluru's population in its urban area as of 2017 is 12.34 million which is up from 8.5 million in 2011. It is now the 24th most populous city in the world and 3rd most populous city in India and the fastest-growing Indian Metropolis behind New Delhi, growing at whopping 47.18% from 2001 to 2011.

1.3.2 Population Density

Population Density is defined as the number of Persons per Hectare (PPH). As per the census records of 2001 and 2011, the population density values for the BMA and the BBMP have gone up from 47 to 70 and 82 to 119, respectively, whereas the population density in village has doubled from 5 to 10 pph. Around 23 inhabitants were added on every hectare of BMA during the 2001-11 whereas in BBMP, 37 persons have been added for every hectare during the same period. The core areas of the city have high density. while it reduces as moving away from core to the peripheral areas (**Table 1.2**). However, with close observation the percentage change in the density is at the highest with 118% for the wards located outside ORR in the BBMP followed by the villages with 99% in the 251 Villages in BMA. The core city area which has wards inside the ORR has exhibited growth of only 17% during 2001-11.

Table 1.2 Variation in Densities for different spatial units

Spatial Spread	Area in Ha	Population		Density (PPH)		Increase in Density (%)
		2001	2011	2001	2011	
Within ORR	21689	4241540	4960809	196	229	17%
Rest of the BBMP	49461	1598615	3482866	32	70	118%
BBMP	70829	5840155	8443675	82	119	45%
Villages in BMA	58571	302163	600989	5	10	99%
BMA	129400	6142318	9044664	47	70	47%

Source: Draft RMP 2031 (Table 6-2)

Figure 1.4 Population Density of BMA 2001

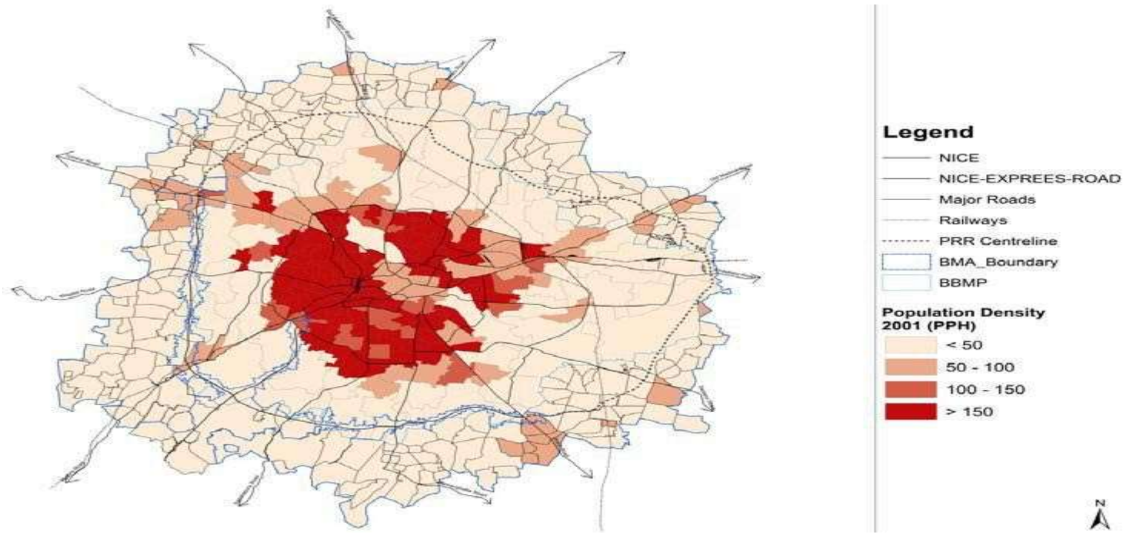
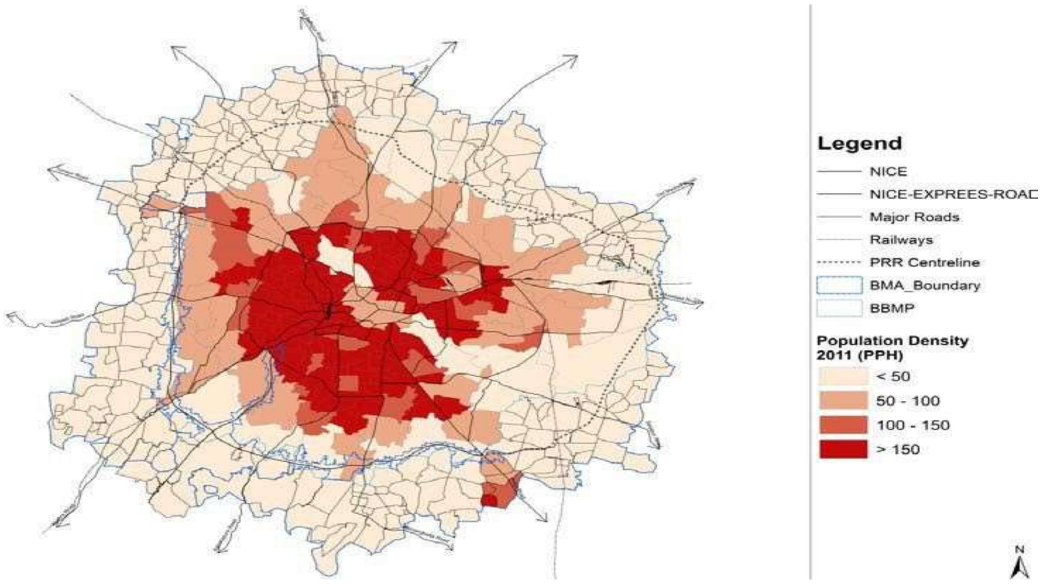


Figure 1.5 Population Density of BMA 2011



Source: Draft RMP 2031 (fig 6-4 & 6-5)

1.3.3 Migration Patterns

1.3.3.1 After Independence, Bengaluru, the State capital, saw an influx of population migrating to the city for better employment and livelihood opportunities. The total number of migrants has increased from 6,24,215 in the year 1971 to 40,27,633 in 2011, where in 47.7% of the city's population are in-migrants. With an exception of the decade 1981-1991, all the decades indicate a very high growth of in migrants, as indicated in **Table 1.3**

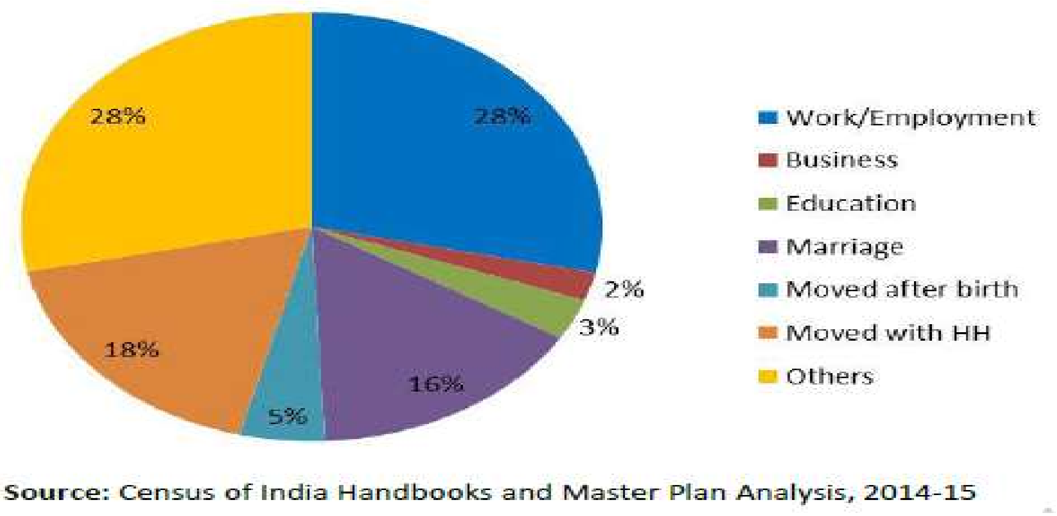
Table 1.3 Migrants in Bengaluru Urban Agglomeration

Year	Population	Natural Increase	%Share	Migrants	%Share
1971	1664208	1039993	62.49	624215	37.51
1981	2921751	1822525	62.38	1099226	37.62
1991	4137314	2952146	71.35	1185168	28.65
2001	5701446	3614727	63.40	2086719	36.6
2011 #	8443675	2742229	32.40	4027633	47.7

Source: Draft RMP 2031 (Table 6-4), # Census 2011

1.3.3.2 It is important to note here that in the migration break up, about 60% of the migrants to the Bengaluru Urban Agglomeration are from within Karnataka, while 38.7% of the migrants are from outside Karnataka. In 2001, about 28% of all the people migrated (i.e.20,86,719) to the Bengaluru Urban Agglomeration, have migrated for better work and employment opportunities. However, only 11% of them are female. The percentage of female migrants is higher among the sections that have migrated for the reasons "marriage" and "moved with households/family", being 60% and 97.2% successively. Various social and economic reasons other than for work and employment, also have contributed to the migration phenomenon as shown in **Figure 1.6**.

Figure 1.6 Reasons for Migration-2001



Source: Draft RMP 2031 (fig 6-6)

1.3.4 Spatial Patterns of Growth

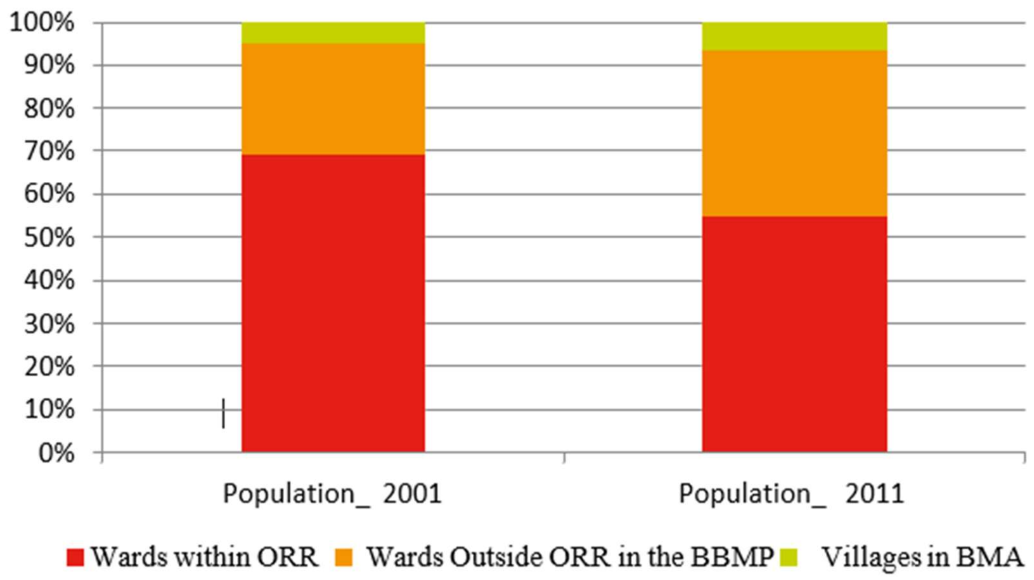
The BMA has been classified into three spatial spreads a) BBMP wards within ORR, b) BBMP wards outside ORR and up to the BBMP boundary and c) Villages in BMA to understand the spatial spread of the population. The population distribution in BMA in 2001 and 2011 is given in **Table 1.4**.

Table 1.4 Population Distribution in BMA

Spatial Spread	Population		Share of Population		Decennial Growth Rate
	2001	2011	2001	2011	
Wards within ORR	4241540	4960809	69.1	54.8	17%
Rest of BBMP	1598615	3482866	26.0	38.5	118%
Villages in BMA	302163	600989	4.9	6.6	99%
Total BMA	**6142318**	**9044664**	**100**	**100**	47%

Source: Draft RMP 2031 (Table 6-2)

Figure1.7 Population Distribution within BMA



Source: Draft RMP 2031 (fig 6-2)

1.3.5 Projection for Next 20 Years

RMP-2031 has carried out projections for the spatially constant Bengaluru Metropolitan Area based on the past trends by deploying different statistical models and component method. The models and method included are:

a. Linear Model (this assumes that Population would increase steadily in a linear pattern).
b. Quadratic Model and Cubic Models (this assumes that population would experience fluctuations in growth pattern).
c. Logistic Model (this assumes that population would reach saturation at some

point in the future).

d. Ration Method (this assumes that population would increase steadily in relation to Karnataka Urban Population).

e. Component Method (using birth and death rate and migration).

1.3.5.1 Population projections for BMA based on different methods (Statistical and Demographic) ranges from 11.8 million to 24.7 million for 2031. **Table 1.5** clearly shows that Linear Method and Component (demographic) method are predicting two extreme ends of the projections. Linear method has projected the lowest population for 2031. However, that estimate has been achieved in the year 2017 itself. The component method has projected population for higher end, which is almost 2.5 times the 2011 population for BMA. Hence, considering this population may also not be inappropriate.

Table 1.5 Observed & Projected Population Range for BMA: 1971-2031 (in '00000)

Year	Observed Population	Projected Population					
		Linear	Quadratic	Cubic	Logistic	Component	Ratio Method
1971	20.12	16.06	21.22	20.06	21.24	NA	N
1981	32.58	33.08	30.50	32.83	30.60	NA	N
1991	45.30	50.09	44.93	44.93	44.09	NA	N
2001	61.90	67.11	64.53	62.20	63.51	NA	N
2011	90.45	84.13	89.29	90.45	91.49	98.00	90.45
2016		92.64	103.60	110.52	109.81	116.26	108.20
2021		101.15	119.21	135.51	131.80	149.14	129.44
2026		109.65	136.10	166.17	158.19	192.20	157.93
2031		118.16	154.29	203.21	189.87	247.38	192.68
	R-square	0.96436	0.99540	**0.99991**	0.99376	NA	N

Explained variation/Total variation which is always b/w 0 to 1

Source: Draft RMP 2031 (Table 6-7)

1.3.5.2 Population projections by three methods, namely Logistics, Ratio and Cubic method are in the range of 19-20 million. The projection by logistic model (19 million) is ideal considering the fact that the population cannot grow forever due to its natural carrying capacity limit and instead population growth will taper off and reach saturation. However, while planning for Metropolitan region it would be appropriate to plan for higher range to account for sudden growth in the population – which cannot be predicted. Also, that the R-square among the statics method is close to accuracy for cubic method.

1.3.5.3 The Population Projection methodology and results were shared with Department of Economics and Statistics, GoK and Institute for Social and Economic Change for independent review and confirmation. Both have confirmed that the BMA population could be in the range of 19 to 20 million by 2031. Hence, it is appropriate to consider projections by Cubic method at 20.3 million for BMA by 2031.

1.4 Urban Land Use Structure / Activity Distribution

1.4.1 Existing Land Use Distribution

The Existing Land Use (ELU) is the next critical input in devising the future growth strategy of any city/town. The ELU maps show various current land uses at the specified and reasonable scale indicating residential, commercial, industrial, public & semi- public uses, recreational (parks & playgrounds), open spaces, vacant land, land under agriculture, water bodies, utilities & services facilities, circulation system, conservation areas, special areas, committed land uses, reservations and mixed land uses etc.

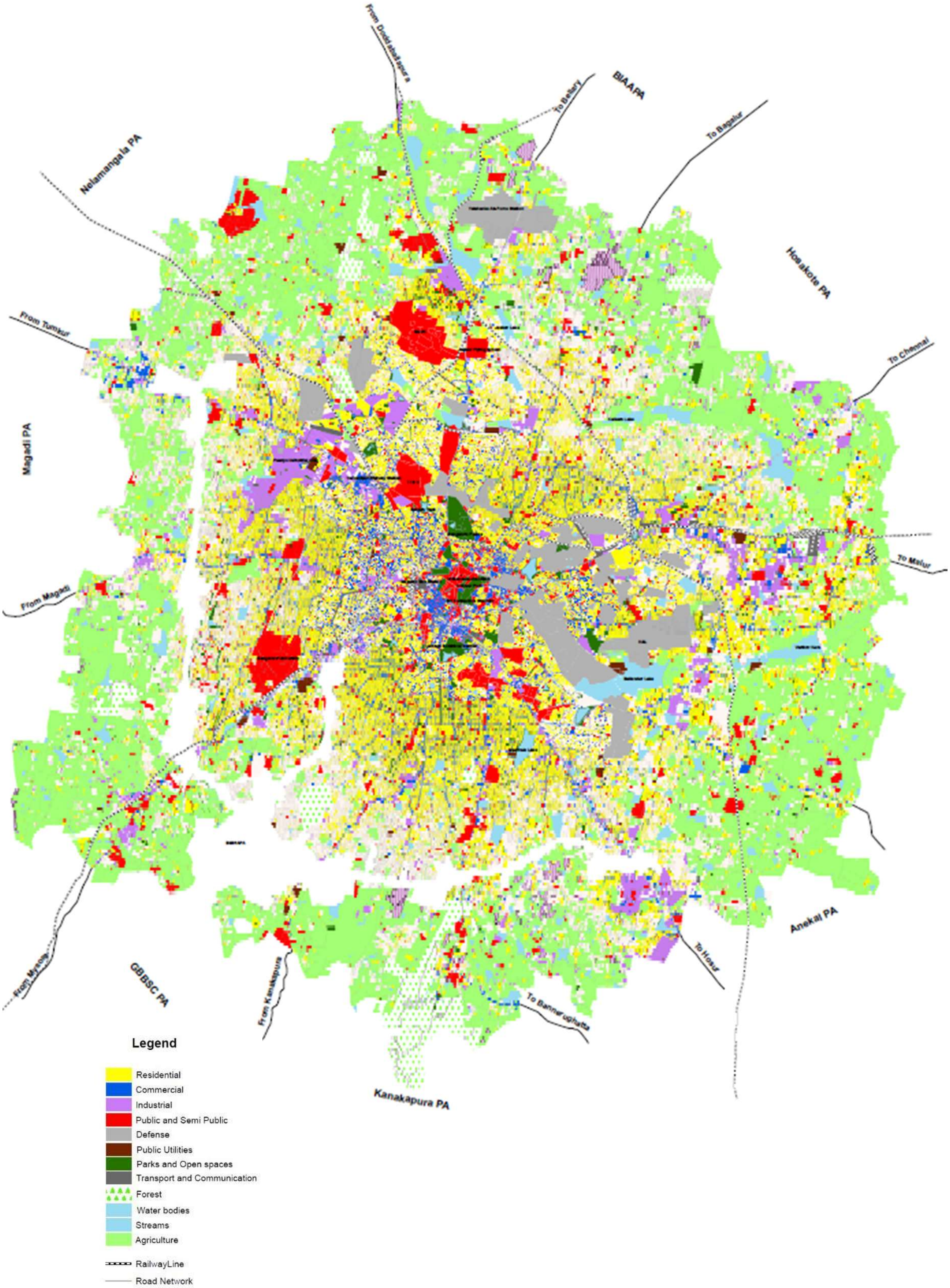
The Master Plan document (RMP-2031) has been reviewed for the existing landuse in the BDA Planning area with reference to the proposed landuse and as per RMP-2015. This analysis helps in understanding the development pattern in the city. While the shape and structure of the transport network is dependent on land use, land use itself cannot happen as planned if the transport network is not provided. In other words, land use and the network strategy must go hand in hand. The Existing Landuse Map (ELU) is presented in Figure 1.6, whereas the ELU Area Statement for LPA of BDA is given in Table 1.9.

Table 1.6: ELU Area Statement

Land Use	Existing Landuse - 2015	
	Area (Sq.km)	Share (%)
Residential	212.83	17.63%
Commercial	38.27	3.17%
Industrial	45.63	3.78%
Public & Semi-public	64.82	5.37%
Un-classified	42.32	3.51%
Public Utilities	4.86	0.4%
Parks & Open Spaces	20.67	1.71%
Transport Communication	87.85	7.28%
Vacant	305.28	25.29%
Agriculture land	300.42	24.89%
Quarry/Mining Sites	7.39	0.61%
Forest	27.53	2.28%
Water Bodies and Streams	49.1	4.07%
Total LPA of BDA	**1206.97**	**100.0%**

Source: Revised Master Plan for Bangalore - 2031 (Draft): Volume-3

Figure 1.8: Existing Land Use Map of BMA



1.4.2 Review of Zoning Regulations

1.4.2.1 The Government of Karnataka (GoK) constituted the Bengaluru Development Authority (BDA) in 1976 under separate statute, viz. the Bengaluru Development Authority Act, 1976 with the functions related to planning, development, enforcement and implementation of the schemes coming under one agency to achieve coordinated development activities of the city. Under the aegis of BDA there have been continuous efforts to plan and manage the growth of city through four Plans viz. ODP-1972, Comprehensive Development Plans (CDP) 1984, CDP 1995 and Revised Master Plan 2015 for its LPA. Currently operational Revised Master Plan (RMP) 2015 was notified by Government vide G.O. No UDD 540 BEM AA SE 2004, dated 22.06.2007 for the horizon year 2015 with the LPA area of 1219.50 Sq.km.

1.4.2.2 The LPA of BDA comprises of the major part of the Bruhat Bengaluru Mahanagara Palike (excluding area under BMICAPA) and 251 villages in the periphery of BBMP. The city has experienced an unprecedented population growth translating into varied challenges of urbanisation and urban management in general and urban land management in particular. BDA entrusted with the responsibility of preparing and revising the Master Plan as a Planning Authority for the Local Planning Area of BDA under the KTCP Act, 1961 has undertaken the revision of the RMP-2015 for the horizon period of 2031 (herein referred as RMP-2031). The area of BMA comprising of LPA of BDA and LPA of BMICAPA as per the amended boundaries admeasures 1306 Sq km. The Local Planning Area (LPA) of Bengaluru Development Authority (BDA) for RMP-2031 spreads over an area of about 1240.69 Sq km with an estimated population ranging between 18-20 million for 2031.

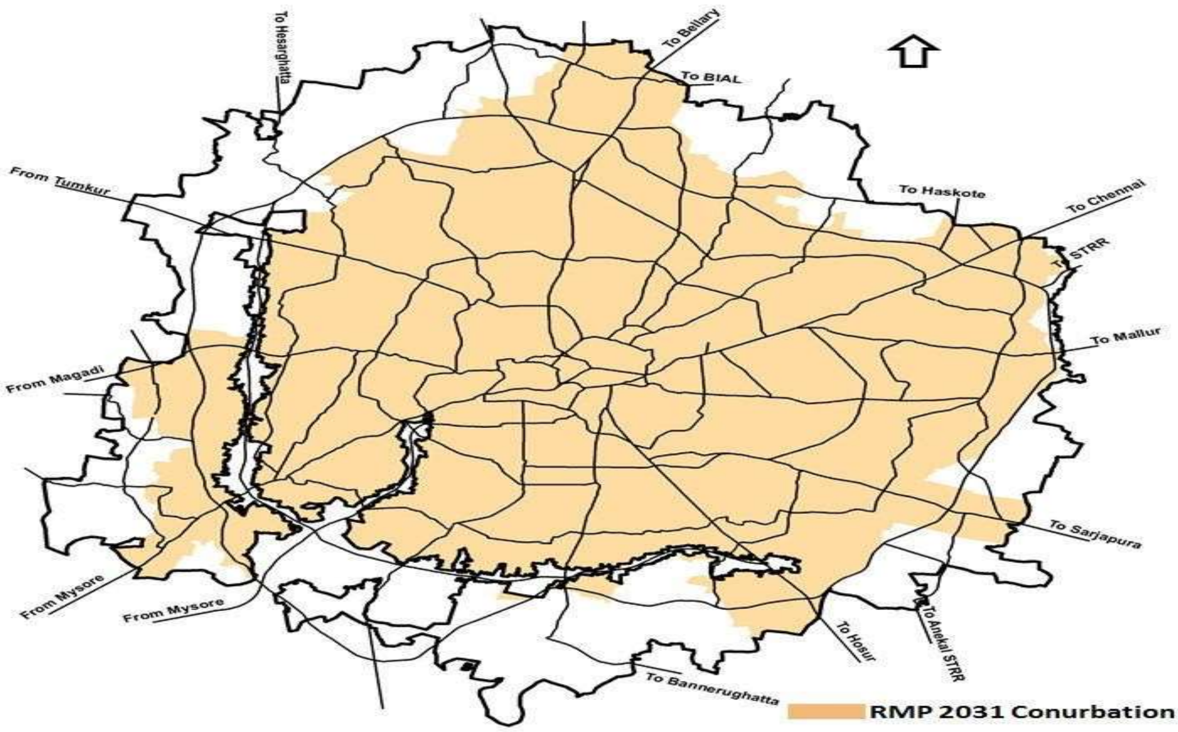
1.4.2.3 The Differential Strategy Scenario was approved by the Bengaluru Development Authority for detailing of the RMP-2031 in a Board meeting held on June 9, 2017. Summary of the directions/ decisions by the Authority are given hereunder:

a. While delineating the additional land requirements for the extension of conurbation limits of RMP 2015 for RMP 2031, the aspects related to circulation pattern, buffer zones, affordable housing and economic nodes should be considered as per the outcomes of the public consultation meetings.
b. The indicative identified economic nodes should be located near to the junctions of the major roads to the extent possible and the activities should be suitable for such locations and balance with the regional context. The proposals of the Master Plans of adjacent LPAs should be considered while formulating the proposals for RMP 2031 to achieve the balanced regional development. Separate regulations should be considered for these nodes.

1.4.2.4 Based on the decision and guidelines given by the Authority, the conurbation limits have been extended with the following considerations:

a. The Major road corridors considered for extension of conurbation considering the existing directions of growth and the capacity of the major road network, the five Special Development Zones (SDZ)/ Economic Nodes proposed are (1) SDZ Bellary Road, (2) SDZ Old Madras Road, (3) SDZ Sarjapura Road, (4) SDZ Hosur Road and (5) SDZ Mysuru Road.
b. The emergence of economic activities is highly governed as per the backward-forward linkage, However, it is a very dynamic phenomenon guided by the market demand. Considering the existing pattern of growth in these zones and in the adjoining region, SDZ Bellary Road, Hosur Road, ORR (From Central Silk board up to Hebbal) and Sarjapura Road would act as hubs of IT and other related Hi-Tech industries and supporting service sector Offices. SDZ Mysore road is envisaged as a hub for Knowledge Driven Economy. SDZ Old Madras road is envisioned to create opportunities through light and service sector industries.
c. The delineation of Special Development Zones as an extension of the conurbation limits of RMP2015 has also taken cognisance of the existing level of development in these zones in order to plan for compact high density developments as per the availability of vacant land.
d. The Special Development Zones have been envisaged as High Density Integrated Developments providing employment opportunities (Economic Nodes) supported with the necessary residential and amenity requirements. The road network in these special development zones have accordingly been proposed to accommodate the high density developments.
e. The outgrowths of the conurbation limits of RMP-2015 where the intensity of development has been observed high with regard to the economic opportunities especially along the proposed PRR alignment.

Figure 1.9 Proposed conurbation limit for RMP 2031.

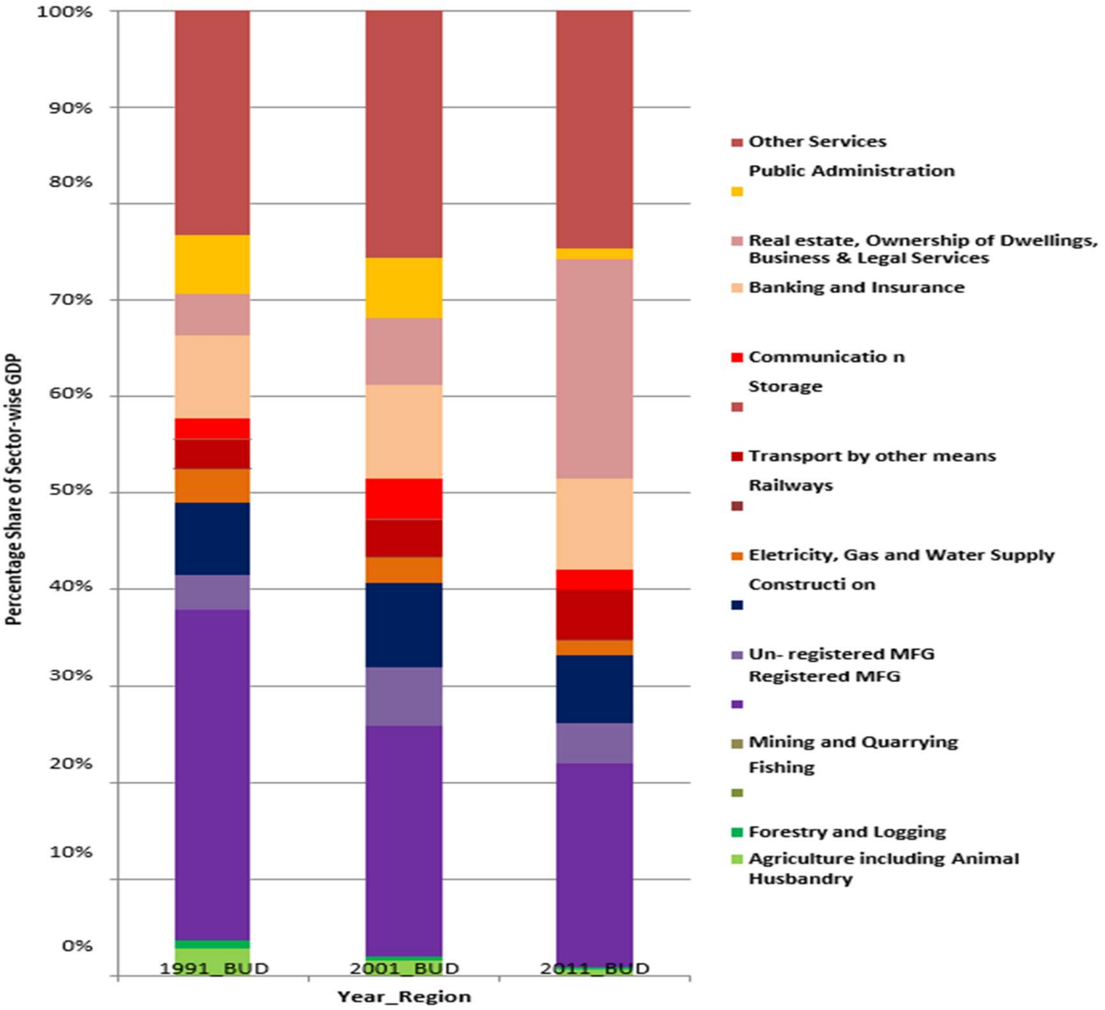


Source: Draft RMP 2031 (fig 10-1)

1.4.3 Employment Distribution by Traffic Zones

1.4.3.1 The work force participation rate has increased from 34.27% in 1991 to 44.14% in 2011. This increase in the workforce can be attributed to the growth in employment opportunities and thus in- migration and also increase in the women workforce. The growth trend of WFPR over three census years is presented in **Figure 1.10**.

Figure 1.10 Sectoral GDDP Share trends for Bengaluru Urban District (1991, 2001 and 2011)



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Source: Draft RMP 2031 (fig 7-1)

Table 1.7 Workforce Participation Rate (WPR)

Year	Bengaluru Urban District		
	Total Population	Total Workers	WFPR
1991	4839162	1658298	34.27
2001	6537124	2566914	39.27
2011	9621551	4246927	44.14

Source: Draft RMP 2031 (Table 7-2)

1.4.3.2 Employment by Sector

a. The workers residing in the area are considered as the census workers, and employment is the workers employed at given location. Workers data as per Census has been used to derive the Work Force Participation Rate and is presented in **Table 1.8 & Table 1.9**. WFPR for BMA has increased from 33.7% to 44% during 1991 to 2011 period.

Table 1.8 Workforce Participation Rate Trend BMA, BUD and BMR

WPR Area /Year	1991	2001	2011
BMA	33.7	38.9	44.0
BUD	34.0	39.5	44.3
BMR	36.5	41.2	44.9

Source: Draft RMP 2031 (Table 7-5)

Table 1.9 Existing (2016) Population, Workers and Employment in BMA and BMR

Area/Ratio	Population 2016 (in Lakh)	Workers 2016 (in Lakh)	Employment 2016 (in Lakh)
BMA	110	49	55
BMR	137	62	68
BMA:BMR Ratio	0.80	0.79	0.81

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source: Draft RMP 2031 (Table 7-6)

Note: Population and Workers data source is Census 2011. 2016 population and Workers are estimated based on the CAGR of previous decade. Employment is estimated for 2016 based on Industrial Stakeholder Meetings, Real Estate Report and various Government Reports.

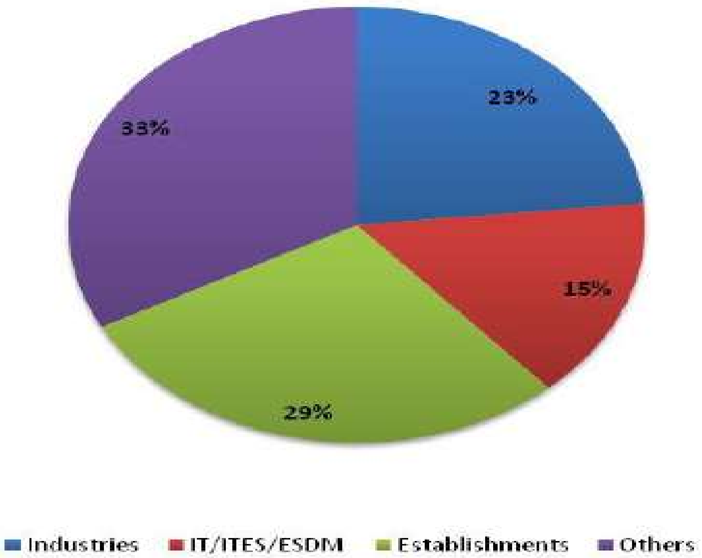
b. Data on workers for major sectors has been compiled from various sources: - Industries data from Karnataka Udyog Mitra and KSSIDC; IT/ITES data from Department of IT, BT and S&T; data on establishments from Establishment Census, Directorate of Economics and Statistics. The sectoral shares of workers are given in **Table 1.10** and **Figure 1.11** & it can be observed that industrial workers are about 23%, IT/ITES workers are 15% and workers in Establishments are 29%. The other sectors contribute about 33% of the total workers.

Table 1.10 Sectoral Share of Workers

Sectors	Employment	%Share Employment
Industries	1300067	23.45
IT/ITES/ESDM	830000	14.97
Establishments	1600323	28.86
Others including Street	1814538	32.73
Total	5544928	100.00

Source: Draft RMP 2031 (Table 7-7)

Figure 1.11 Share of Major Sectors of Employment for Bengaluru Urban District



Source: Draft RMP 2031 (fig 7-6)

c. Peenya, Whitefield, Electronic city and parts of Bommasandra and Jigani are the areas with major concentrations of industries. Old industrial areas like Rajajinagar are slowly being converted to residential/commercial and industries are being pushed out. Existing industrial base is expected to continue but new industries are not incentivized when compared to other districts of the State. Industries are expected to be setup in BMR (dependency on city's infrastructure). IT/ITES concentration is in Whitefield, ORR (From Central Silk board up to Hebbal) and Electronic city, but is also spreading in other parts of the city. Existing nodes with major employment are currently concentrated in BMA. Some of the major economic centers are Peenya Industrial Area, Petta (Core area/Trade and Commerce), Electronic City and Whitefield (IT/ITES/ESDM), Jigani (Industrial/BT). Along K R Puram- Kempegowda International Airport corridor well planned commercial and residential townships are spread. Few of them are Steel factory, Bigbazaar, Royal concorde school, Chris hospital, Florence & Florida Institute, JMJJ Hospital, Manyatha Tech Park, Esteem Mall, Columbia Asia Hospital, GKVK Campus, Jakkur Aerodrome, Kendriya Vidyalaya and ITC factory etc. As per data collected from DULT (DPR for Bengaluru BRTS, 2014 July), usage of this stretch from K R Puram- Kempegowda International Airport is 70% by private vehicles, 11% by public transport, 12% by Auto/Taxi and 7% others.

Following are the other areas with large economic activities:

i. Hoskote – KR Pruam: BPL, Bengal lamps and several other manufacturing units are spread along the NH-7 linking to the industrial area in KR Puram, which includes ITI and the Tin factory. United Motors and Heavy Equipment's Private Limited located at KIADB industrial area is one other major hi-tech engineering industry manufacturing spares of heavy earthmoving machineries. Bell Ceramics Limited, located in Chokkahalli village and the manufacturing unit of Volvo are also located in this area. The economy is product based manufacturing with a concentration of heavy engineering industries in the KIADB estate at Hoskote and textile, tobacco product. Oil refineries and silk manufacturing also dominate the economy of the area.

ii. Bidadi – Harohalli: The Toyota factory in Bidadi industrial area is the major generator of activities, encouraging more industries located in this area. The existing industrial area at Harohalli covers almost 1000 acres. The economy is product-based with manufacturing industries located in the existing Bidadi industrial area and Harohalli industrial area.

iii. Nelamangala – Peenya: The economy is product based manufacturing with textile and other small and medium scaled manufacturing industries in the Peenya industrial estate. Other products contributing to the economy are horticulture and tobacco products.

iv. Nelamangala: The economy is product based manufacturing with textiles and manufacturing – iron & steel, plastic, bio-tech, electronic and electrical and ancillary automobile in the KIADB industrial area.

v. Dodaballapur: The economy is product based dominated by the textile industry (silk weaving) and apparel parks. Other economics includes floriculture, wine industry and food processing.

vi. Devanahalli – Yelahanka: The economy is product based manufacturing and textile industry with the proposed Hardware park and Aerospace park. Airport related freight and logistics services and horticultural activities are also dominant.

vii. Jigani – Electronic City – Bommasandra – Attibele: The major attraction in the area that has caused industries to agglomerate in the region is the Electronic City in Bengaluru. Industries along the entire stretch along NH-7 from Electronic city to Attibele, and beyond, to Hosur in Tamil Nadu from this area. Attibele located at the Tamil Nadu State border, Jigani, Bommasandra, Hebbagodi, Chandapura and Sarjapura are part of the industrial area. The industrial areas of Attibele, Jigani- Bommasandra contribute to the economy of the cluster. The industries concentrating around Sarjapura town and a few scattered ones along the Sarjapura-Attible road also form a part of the industrial cluster. Adjacent areas such as Hebbagodi, Dommasandra, Chandapura (market town) and parts around Jigani and Anekal town serve as a residential base for the industrial area. This area has the internationally known multi-specialty hospital – Narayan

Hrudalaya. The economy is product based secondary manufacturing and textile industry with the KIADB industrial area. Attibele is home for most manufacturing and textile industries. Automobile giants of India – TVS Motors and Ashok Leyand are very near to this area. Attibele, Bommansandra and the Jigani-Bommsandra industrial areas consist of manufacturing industries.

viii. Ramanagara – Channapatna: The economy of the two major areas is mainly a product-based secondary sector economy with includes agro-based industry, tobacco products, toys and wooden products and enlarged segment of the workforce.

1.4.3.3 Workforce participation and employment projections

a. The workforce participation rate for BMA, as per Census, in 2011, is 43.9%, which has increased from 33.4% in 1991, indicating 5% increase in every decade. As per Census 2011, the male workforce participation is at 61.87%, whereas female work participation is 24.42%. The female participation rate has increase from 11.88% in 1991 to 24.42% in 2011, which is still lower that national (31.1%) and state average (34.4%). **Table 1.11** presents the workers by sex for past three decades.

Table 1.11 Comparison of Work Force in BMA

Sl. No	Year	Workers					
		Male	% of Male	Female	% of Female	Total	% to Total population
1	1991	1258609	52.8	255214	11.8	1513823	33.4
2	2001	1877261	57.7	533701	18.1	2410962	38.9
3	2011	2917774	61.8	1057196	24.4	3974970	43.9

Source: Draft RMP 2031 (Table 7-8)

b. The employment projections for the year 2031 have been made based on the projected population in different age groups. As per the assessment, 73.05% of male and 73.55% of the female population would fall in the age category of eligible workers (16-60). Of the eligible male and female population around 65% and 35% are projected to be workers amongst males and females. The projection of demand for jobs up to 2031 has been estimated and given in **Table 1.12**.

Table 1.12 Employment Projections for BMA

Description	2011	2021(E)	2031(E)
Total Population	9044664	13551445	20320805
Eligible Workers(16-60Group)	68.14%	70.30%	73.28%
Eligible Workers	6163034	9526666	14891086
Male Population(52%)	4715935	7046751	10566819
Female Population(48%)	4328729	6504694	9753986

Description	2011	2021(E)	2031(E)
Eligible Male Workers(%)	68.62%	70.83%	73.05%
Eligible Male Workers	3236075	4607274	7719061
Eligible Female Workers(%)	67.62%	70.58%	73.55%
Eligible Female Workers	2927087	4591013	7174057
Male Willing to Work(% of Male Workers)	61.87%	63.44%	65.00%
Male Willing to Work	2917774	4470125	6868432
Female Willing to Work(% of Female Workers)	24.42%	29.71%	35.00%
Female Willing to Work	1057196	1364054	2510920
Total Workers	3974970	5834179	9379352
Additional Jobs (over2011)	0	1859209	3545173

Source: Draft RMP 2031 (Table 7-9)

1.4.4 Activity Locations

1.4.4.1 Educational Infrastructure

Primary and Secondary Educational Infrastructure: Bengaluru has very good educational infrastructure in comparison to the rest of the state. For the purpose of administration, the education department categorises schools under various educational districts. **Table 1.13** shows the number of government and private schools across various categories in Bengaluru Urban District.

Table 1.13 Number of existing government and private institutions in each category in Bengaluru Urban District

Sl. no.	Category of Institution	Classes	No. of Govt. Institutions	No. of Pvt Institutions /Others	Total No. of Institutions
1	Primary Schools	LPS & HPS	1426	1447	2873
2	Secondary Schools	HS	172	1895	2067
3.	ITI / Polytechnics	Diploma	12	78	90
4	Degree Colleges	General	71	63	134
5	Professional Colleges and Institutes	Engineering/ Medical /Dental/Pharmacy/ Agriculture/ Law etc.,	15	196	211
	Total		**1696**	**3679**	**5375**

Source: SSA, Collegiate Edn., DTE, Kea & Google

1.4.4.2 A gap analysis study shows that most inhabited areas in BMA have access to a primary school within 1 km radius. The schools also face challenges like traffic safety and congestion during the school hours.

1.4.4.3 Higher Education Infrastructure

Bengaluru plays a role of primacy in the state of Karnataka, in the education sector. Bengaluru Metropolitan Area (BMA) has a fair share of institutes of higher education and professional institutions. Bengaluru is a hub of higher education in the country with a high number of colleges and professional institutes.

1.4.4.4 Health care Infrastructure

Accessible health infrastructure is a necessity for welfare of the residents. The city of Bengaluru has a high concentration of healthcare facilities in the BBMP area. Bengaluru serves as a tertiary healthcare centre for the surrounding region with several tertiary and referral hospitals in the city. Bengaluru has many super specialty and multispecialty facilities which also make it a healthcare tourism destination. The BBMP runs several government hospitals, maternity centres, and healthcare centres within the erstwhile BBMP areas. The rest of the BMA is served by healthcare infrastructure run by the department of health and Family Welfare. Private healthcare facilities are spread around the city. Most of the large referral and tertiary care hospitals are located within BBMP and concentrated in the core areas within the outer ring road.

1.4.4.5 There are several pockets in the peripheral areas of BMA, which are more than 5 kms away from a healthcare facility. With the increasing traffic congestion, and reducing vehicle speeds in the city, the accessibility to medical facilities has reduced even in some of the core areas in Bengaluru, especially for people living far away from healthcare centers. The access to tertiary healthcare is a major gap in the peripheral areas of BMA

1.4.4.6 Fire Stations

Fire stations are critical infrastructure that needs to be present in every planning district. An optimum distance for fire station is 10.5 sq km radius, but the frequency of fire stations need to be more in high density areas due to increase of risks. Bengaluru has 19 fire stations, mostly located in the core areas. As per the requirement of Karnataka Emergency and Fire Services Department 16 new fire stations have been incorporated in RMP 2031. In addition, RMP 2031 has identified additional fire stations and defined in Proposed Land Use map as Public and Semi-public use.

1.4.4.7 Art and Cultural Infrastructure

Bengaluru is an important center of art and culture with several prominent art schools, performance spaces and cultural hubs. Bengaluru is the capital of the Kannada cinema industry, and an important theatre and drama hub in the country. The city has several art installations, and hosts street art festivals along with formal events like art exhibitions, book fairs etc. Formal and informal spaces must be provided for art and culture to thrive city. Informal spaces include street pavements, plazas, open spaces, parks and open spaces etc. Formal spaces like art galleries, museums, performance spaces, outdoor spaces like open air theatres, cinema halls etc must be provided in all planning districts.

1.4.4.8 Markets

Markets, both formal and informal, are needed at accessible distance. While the core areas of the city have very good market facilities, such facilities must be provided in the outer areas. Each market must also have space for informal vendors and vendors who sell occasionally or seasonally. It is proposed to develop markets along with logistic hubs and in the planning districts which are devoid of markets.

1.4.4.9 Cemetery and Graveyard

Bengaluru has limited number of cemeteries and graveyards. Most of the graveyards in the city have reached the threshold. More number of graveyards is required in the city and the outer areas.

1.4.4.10 Night Shelters

RMP 2031 proposes that adequate number of night shelters be developed based across BBMP depending on the requirement by BBMP for the urban poor.

1.4.4.11 Women's Hostels

Bengaluru attracts many people from other parts of the state and the country who come here to study and work. Women, especially from poorer families find it very difficult to find a safe place to stay while they work or study in the city.

1.4.5 Land Use Plan Proposals (Master Plan and CDP strategy):

The Land Use for RMP-2031has been proposed with the following considerations:

1.4.5.1 For the purpose of detailing of RMP-2031, the entire LPA of BDA has been divided into 42 Planning Districts.

1.4.5.2 The commercial strip model including commercial axis, mutation corridor in the RMP 2031 has been relooked at and a multi-pronged strategy of planned commercial areas in the new areas of development and strip model on selected corridors/ roads of width 15 m and above has been provided based on the existing commercialization in the existing developed areas.

1.4.5.3 The economic centers/ industrial areas and the amenity areas have been spatial distributed across different Planning Districts for balancing the growth at the LPA Level.

1.4.5.4 The Development Constraints such as Air Funnel Zones, regulations related to eco-sensitive zones, quarry and mining sites, defense areas etc., have been given due cognizance while delineating the conurbation limits as well as formulating the land use proposals.

1.4.5.5 Except for the developments proposed along the five major corridors and the existing conurbation limits of RMP 2015, the agricultural belt admeasuring nearly

323 Sq.km has been retained along the periphery of the entre LPA to act as a buffer between the LPA of BDA and the developments in the adjoining LPAs.

1.4.5.6 The Proposed Land Use for RMP 2031 has considered and incorporated the planning permissions and change of land use accorded by the Authority/ Government. The Proposed Land Use of RMP2015 has been suitably amended in several zones based on the predominant existing land use and the development pattern.

1.4.5.7 The entire LPA has been divided into three planning zone i.e.

a. Planning Zone A (Ring 1+Ring 2 of the RMP 2015) comprises of the core of the City area falling within the outer ring road (erstwhile BBMP). Owing to limited availability of land and high densities, there is very little scope for further growth in this zone. This is also the zone that – owing to its high densities – is crippled by traffic congestion and environmental pollution. This zone requires strategies to stabilize the growth in this zone and interventions that discourage further commercialization in the residential areas as well as densification process.
b. Planning Zone B (Part of Ring 3 of the RMP 2015), the areas between the outer ring road and the proposed Conurbation limit of RMP-2031 form part of this zone. The infrastructure is poor in several areas in this zone, in spite of being major part falling under the jurisdiction of BBMP. Numerous lakes and water bodies present an opportunity to conserving the overall valley and tank network in the BMA. This zone is characterized by narrow roads and absence of a good network hierarchy. Improvement of infrastructure will lead to increased capacity to hold higher densities and more population in Zone B. The zone envisaged as zone of consolidation – one where development can be further encouraged through strengthened infrastructure.
c. Planning Zone C (Part of Ring 3 of the RMP 2015) is the outermost zone that extends from the conurbation limits till the boundary of the BMA. This area consists of agricultural land use and has sparse developments. RMP 2031 views this zone as a preservation zone, one where the agriculture land-use, to the extent possible, will be retained, although it requires certain additional interventions beyond zoning regulations in order to facilitate better economic utilization of the agricultural lands. This may be conceptualised as productive landscapes.

1.4.5.8 The road hierarchy has been given special attention by way of identifying major activities and the importance of the area with regard to the envisaged density patterns.

1.4.5.9 The proposed circulation pattern has been evolved on the concept of rings and radials whereby necessary missing links or widening proposals have been included to create a network comprising of 5 rings and 26 radials. The land has been earmarked for the critical junctions for easing the free flow of traffic by construction of grade separators/ flyovers. Truck terminals and ISBTs have been proposed along the major corridors and land has been accordingly allocated.

1.4.5.10 The proposals of BMRDA for regional level network including Intermediate Town Ring Road (ITRR) of Hoskote and other roads have been integrated as part of the RMP 2031 based on the ground situation and utilising the alignment of the proposed PRR with 100 m RoW under RMP 2031.

1.4.5.11 The RMP 2031 has also integrated the road network of BMICAPA.

1.4.5.12 The RMP 2031 has also taken cognizance of the road network proposed under RMP 2015 and amended several roads especially the lower hierarchy roads in the form of reduction of the proposed road widths and/ or removal of certain roads due to lack of feasibility of achieving such RoWs on ground due to high intensity of development.

1.4.5.13 RMP 2031 has identified Regional Parks/ City Level Parks in different zones utilizing the abandoned quarry sites, wherever suitable, and the areas having high intensity of streams and water bodies where NGT buffers have been integrated as part of such large open spaces.

1.4.5.14 The land for Public and Semi-public and the public utilities has been earmarked across different Planning Districts to cater to the zonal level requirements. Efforts have been made to allocate the government land parcels to the extent possible for demarcation of land for such facilities.

1.4.5.15 The Eco-sensitive zones along with their extent of regulation boundaries like Arkavati, TG Halli and Bannergatta National Park has been demarcated on the PLU Map.

1.4.5.16 RMP-2031 for the first time has classified the streams into primary, secondary and tertiary based on the Flood Modelling carried out in association with KSNMDC, GoK and earmarked on the PLU maps along with demarcation of buffers as per the orders of the Hon’ble NGT. This measure will help in keeping a close check on the encroachments in the buffer zones and also address a major issue for the city in the form of urban flooding. It will also contribute towards enhancement in the green area for the city acting as lung space. This buffer will also help in revival of the river valley system.

1.4.6.17 For Planning Zone C i.e., the Agricultural Zone, the existing Gramathan have been provided limits for the natural growth of the rural population and the area of natural expansion has been demarcated as part of the PLU Map in the respective Planning Districts.

1.4.5.18 Heritage zones/ precincts and heritage buildings have been identified and earmarked in the PLU Maps.

1.4.6.19 Proposed land use break-up for conurbation limit of RMP 2031 is given in **table 1.14.**

Table 1.14: Proposed Land Use Area Statement

Landuse Category	Area (Sq.km)	% To Total Developable Area
Residential	450.69	37.34
Commercial	27.88	2.31
Industrial	44.90	3.72
Public & Semi Public	58.66	4.86
Public & Semi Public - Defense	43.12	3.57
Public Utility	4.32	0.36
Parks / open spaces	29.71	2.46
Transport & Communication	120.77	10.01
Forest	4.71	0.39
Water Bodies and Streams	40.75	3.38
NGT Buffer	76.36	6.33
Total Developable Area	***901.87***	***74.73***
Agriculture Zone	305.05	25.27
Total	**1206.92**	**100.00**

Chapter 2

Existing Transportation System in the City

CHAPTER - 2

EXISTING TRANSPORTATION SYSTEM IN THE CITY

2.1 Introduction

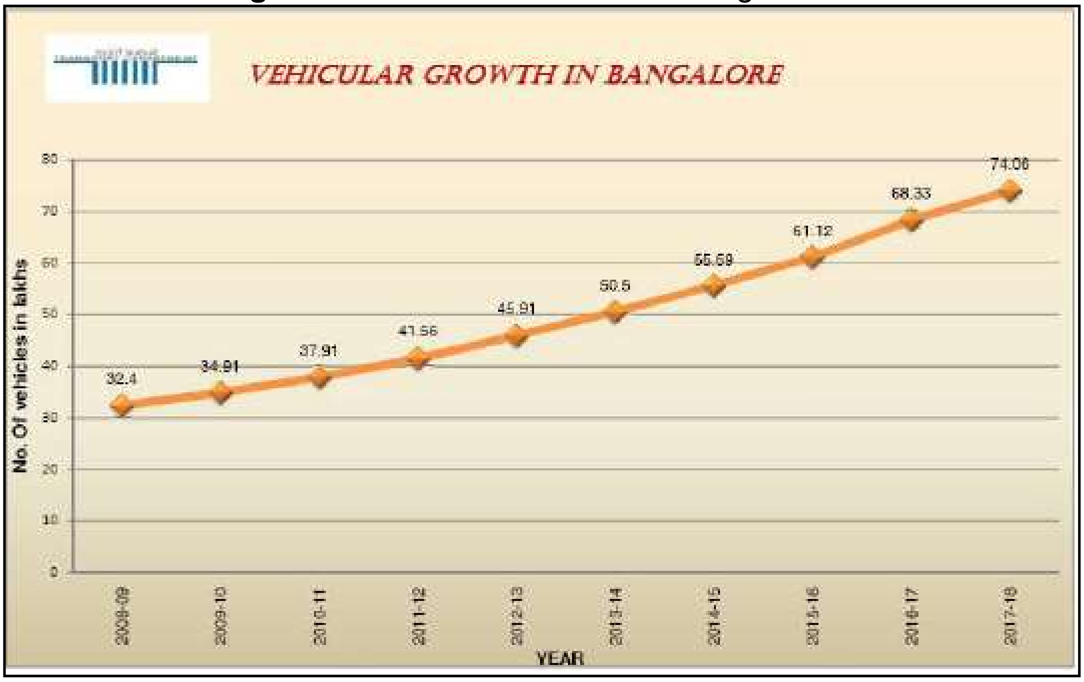
2.1.1 Bengaluru is spatially characterized by a ring-radial system of roads formed by five big axes, which converge towards the center of the city. Today, home to more than 12 million people the strained network is loaded with more than 100 lakh trips per day. Traffic in Bangalore has become a scourge and is only becoming worse. Network speeds are dropping at an alarming rate as overcapacity of its junctions and links are being reached and traffic jams have become the order of the day. Being a victim of its own success, Bangalore’s traffic infrastructure has just not been able to keep pace with the fast growing IT industry to which Bangalore is associated with.

2.2 Vehicular Growth and Composition

2.2.1 Vehicular Growth

The Bangalore Metropolitan Region has a total registered vehicular count of approximately 74 lakh vehicles, with two wheelers constituting the highest percentage of vehicular composition. Between 2008 and 2018, the number of vehicles registered in Bangalore has increased from 32.4 lakhs to 74.06 lakhs (Figure 2.1). The vehicle ownership has increased from 284 vehicles per thousand persons in 2001 to 419 vehicles per thousand persons in 2011 and further to an estimated 640 in 2018. This mean the vehicle population is increasing at much higher rate compared to rate of growth in population.

Figure 2.1: Vehicular Growth in Bangalore

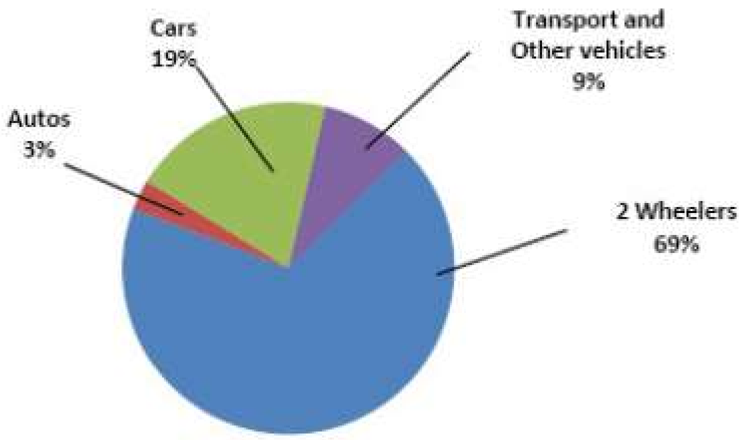


Source: Annual Report 2017-2018, Transport Dept. GoK

2.2.1 Composition of Vehicle Categories in the City

Two-wheelers dominate the vehicular composition with a share of 69% in the total registered vehicles, followed by cars and jeeps at 19%.

Figure 2.2: Composition of Registered Private Vehicles in Bangalore



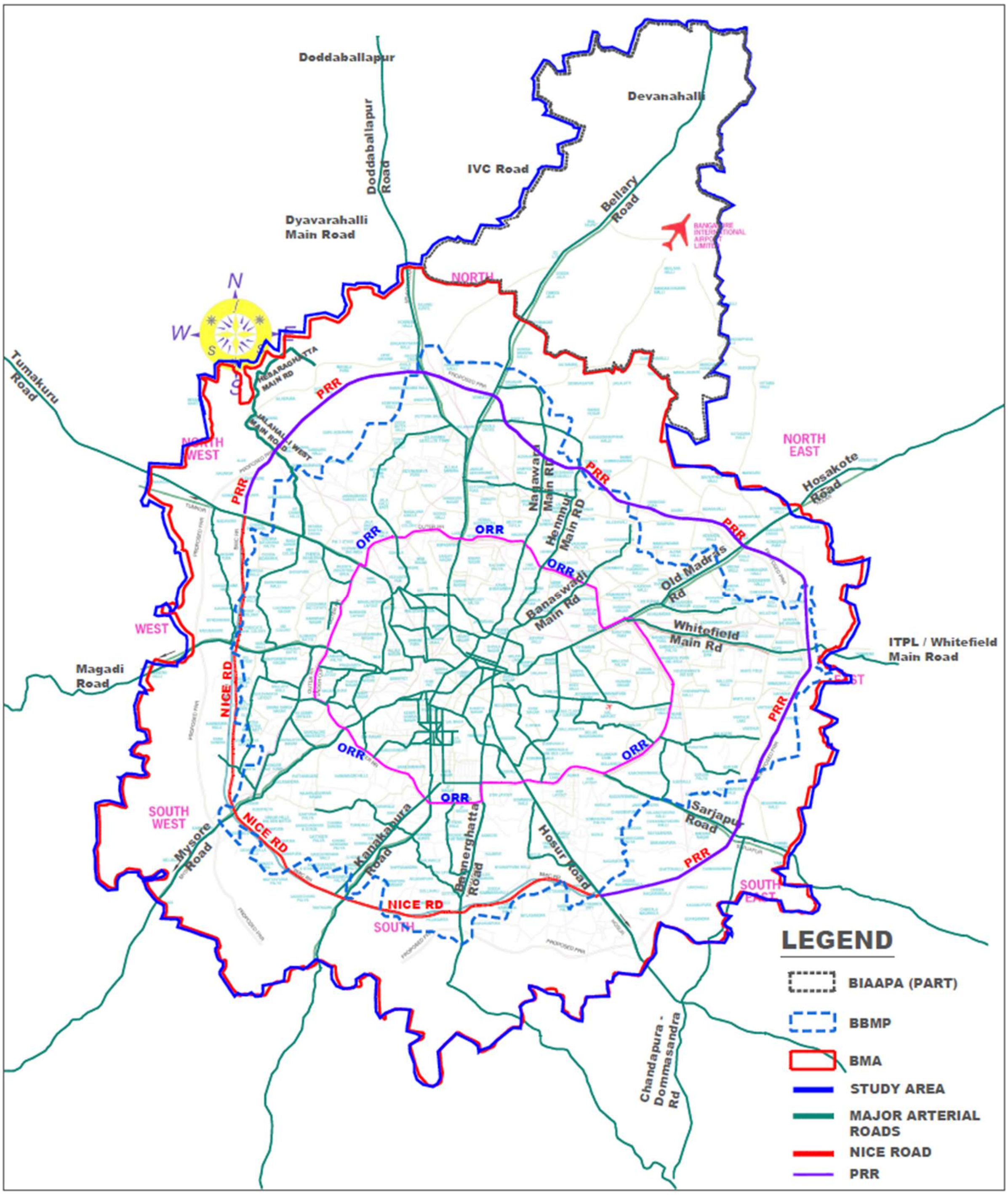
2.3 Road Network Characteristics

2.3.1 Road Network

Bangalore is endowed with a ring radial pattern of road network converging in the core area of the city. Bangalore'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 conflicts of traffic, etc. Though there is large network of roads in the city, the major road network comprised less than 20% of the total road network in the city.

The major roads in the study area are shown in Figure 2.3.

Figure 2.3: Existing Road Network Map



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

2.3.2 Road Network Inventory

The main objective of Road Inventory survey is to assess the physical characteristics and conditions of major road network in the study area, identify physical constraints and bottlenecks and to identify the potential future development.

Right of Way (ROW)

About 43% of length of roads has ROW up to 10 m and 13% have ROW between 20 to 30 m as indicated in **Table 2.1**. This indicates the limitation of widening on most of the roads.

Table 2.1: Distribution of Road Length by Right of Way

Right of way (m)	Road Length (Km)	Percentage (%)
Upto 10	1078.70	42.50
10 to 20	965.70	38.10
20 to 30	329.90	13.00
>=30	163.10	6.40
Total	**2537.40**	**100.00**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Carriageway Width

The distribution of road network as per carriageway width is presented in Table 2.2. It can be observed that about 74% of surveyed road network length has carriageway width up to 2 lane and about 20% of road network 4 lane and more.

Table 2.2: Distribution of Road Network as per Carriageway Width

Sl No.	Carraigeway	Road Length (Km)	Percentage (%)
1	Upto 2-Lane	1871.00	73.80
2	3-Lane	160.90	6.30
3	4-Lane	319.70	12.60
4	6-Lane and more	185.80	7.30
	Divided	567.30	22.40
	Undivided	1970.00	77.60
Total		**2537.40**	**100.00**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Service Roads

It is observed from **Table 2.3** that merely 5% of the road network has service lanes and rest of the network is without service lane. Thus it may be safely concluded that almost all of the primary roads in the city do not have a service road which affects their capacity adversely due to intervention from the activities on the roadside.

Table 2.3: Distribution of Road Length by Availability of Service Road

Service Road	Road Length (Km)	Percentage (%)
Present	117.60	4.60
Absent	2419.80	95.40
Total	**2537.40**	**100.00**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Key findings of the Road Inventory are as following:

- Only 22% of the road network has 4 lanes or more, however when effective width available is considered, the length is very less
- Ring Road network is weak or discontinuous at many locations.
- Parking interference has been observed at many locations in almost all major roads resulting in to reduced effective width available for traffic movement
- Bus bays are not provided on most of the major Roads

2.3.3 Bridges, RoBs, Flyovers

There are number of flyovers, grade separates, underpasses etc., in Bangalore which are constructed by BBMP, BDA, NHAI, Railway etc. The details have been given in the **Table 2.4** below:

Table 2.4 List of Flyovers and Underpass in Bengaluru

Sl. No	Location of Flyover / Under pass	Department
1	Sirsi Circle Flyover	BBMP
2	Richmond Circle Flyover	BBMP
3	ITC circle Flyover - Banasawadi main road	BBMP
4	Flyover (ROB) at Indian Petrol Bunk (Naganapalya) on Banaswadi Main Road	BBMP
5	Flyover at Lingarajpuram	BBMP
6	Grade Seperator near Anand nagar junction - Bellary road	BBMP
7	Grade Seperator near Veterinary Hospital - Bellary road	BBMP
8	Grade Seperator near Ganga nagar jn- Bellary road	BBMP
9	Underpass at Mehkri Circle	BBMP
10	Underpass at Cauvery junction	BBMP
11	Grade seperator at BDA junction	BBMP
12	Underpass at Cunningham road- Sankey road junction	BBMP
13	Underpass at Maharani college junction - Palace road	BBMP
14	Underpass at K.R.Circle	BBMP
15	RUB at Railway station near sangollirayanna junction	BBMP

Sl. No	Location of Flyover / Under pass	Department
16	Underpass at Rajajinagar entrance	BBMP
17	Underpass at malleshwaram	BBMP
18	Flyover at Yeshwanthpur junction	BBMP
19	Flyover at matthikere junction	BBMP
20	Underpass at Dr. Modi Hospital road junction on WOC road	BBMP
21	Flyover at National College near Vanivilas road	BBMP
22	Underpass at Tagore circle	BBMP
23	Underpass at Madiwala junction on Hosur road	BBMP
24	Underpass at Kadirenhalli on Outer Ring Road	BBMP
25	Underpass at Puttenahalli on Outer Ring Road	BBMP
26	Underpass at Horamavu-ORR junction on Outer Ring Road	BBMP
27	Flyover at Rani Chennanna Circle (Devegowda Petrol Bunk) on ORR	BBMP
28	Flyover at KEB junction (Petrol Bunk) on ORR	BBMP
29	Underpass at Vivekananda College on Rajkumar Road	BBMP
30	Hebbal junction Flyover (Clover leaf)	BDA
31	Flyover at Anandrao junction	BDA
32	Flyover at RMV extension	BDA
33	Underpass at Prasanna Theatre junction (Entrance to Vijayanagar) on WOC road	BDA
34	Flyover/ Underpass at dairy circle	BDA
35	Flyover/ Underpass at Jayadeva Hospital	BDA
36	Flyover at Central Silk Board	BDA
37	Flyover (Clover leaf) at Domlur - Inner ring road junction	BDA
38	Flyover at Nayandahalli on Outer Ring Road	BDA
39	Flyover at Pantarpalya on Outer Ring Road	BDA
40	Split Flyover at HSR layout - 14th main road on Outer Ring Road	BDA
41	Split Flyover at Agara on Outer Ring	BDA
42	Flyover at Sarjpaura road junction on Outer Ring Road	BDA
43	Split Flyover at Bellandur on Outer Ring Road	BDA
44	Split Flyover at Devarabisanahalli on Outer Ring Road	BDA
45	Split Flyover at Mahadevpura on Outer Ring Road	BDA
46	Split Flyover at Kalkere on Outer Ring Road	BDA
47	Split Flyover at Nagavara junction on Outer Ring Road	BDA
48	Split Underpass at Kadubisanahalli on Outer Ring Road	BDA
49	Underpass at Marathahalli on Outer Ring Road	BDA
50	Flyover at K.R. Puram Railway station on Outer Ring Road	BDA
51	Underpass at Rammurthy Nagar-ORR junction on Outer Ring Road	BDA
52	Split Underpass at Hennur cross on Outer Ring Road	BDA
53	Flyover at Bupasandra -ORR on Outer Ring Road	BDA
54	Underpass at Sanjay Nagar- ORR on Outer Ring Road	BDA
55	Underpass at BEL junction-ORR on Outer Ring Road	BDA

Sl. No	Location of Flyover / Under pass	Department
56	Flyover at Kamakshipalya junction-ORR on Outer Ring Road	BDA
57	Flyover near Teachers colony - ORR on Outer Ring Road	BDA
58	Underpass at Chandralayout junction on Outer Ring Road	BDA
59	ROB at K.R. Puram connecting Tin Factory and Kasturi Nagar on Outer Ring Road	NHAI

Source: BBMP

2.3.3 Missing Links

Review of road network in the city revealed that there are quite a few missing links, which once developed would improve connectivity in the city. Some of them are:

- Missing links within the Intermediate Ring Road which include connecting CIL Main Road and Pottery Main Road, connecting Baiyappanahalli Main Road and Pottery Main Road and augmentation of Banashankari 50 feet road that connects to BMIC Expressway.
- 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. This is a critical link as it connects areas which will further densify in the coming years.
- Peripheral Ring Road (PRR) is critical to BMA, the master plan also proposes that the PRR be extended and developed complimenting existing NICE corridor.

2.3.4 Intersections

There are an estimated 40,000 intersections in the city of which about 398 are signal controlled and approximately 600 intersections are being manually controlled during peak hours. The balance intersections are uncontrolled which is one of the reasons for congestion and unsafe crossings. While most of these controlled intersections are on major corridors of movement, it may be safe to consider, an equal number of intersections on these major roads are left uncontrolled which are causing congestion and resulted into reduced safety.

Bangalore Traffic Police have undertaken improvements at some of the intersections under BTrac program which is aimed at providing geometric improvements, standardization of signs etc. Under BTrac program, police are undertaking following:

- Minor Junction Improvement
- Intelligent Transportation Systems
- Surveillance / Enforcement cameras

- Street Furniture
- Traffic Enforcement Cameras
- Education / Awareness & capacity building

Traffic Management Center has been setup by integrating various components of road marking, signages, Enforcement Cameras, Surveillance Cameras, and Upgradation of Signals including Vehicle Actuation for effective and efficient management of traffic. As part of the ITS program, it is envisaged to install vehicle actuated, networked and adaptive traffic signals at about 440 intersections which will be monitored and controlled at Traffic Management Center, installation of traffic enforcement cameras at about 400 locations.

2.4 Major Transport Nodes

2.4.1 Railway Station

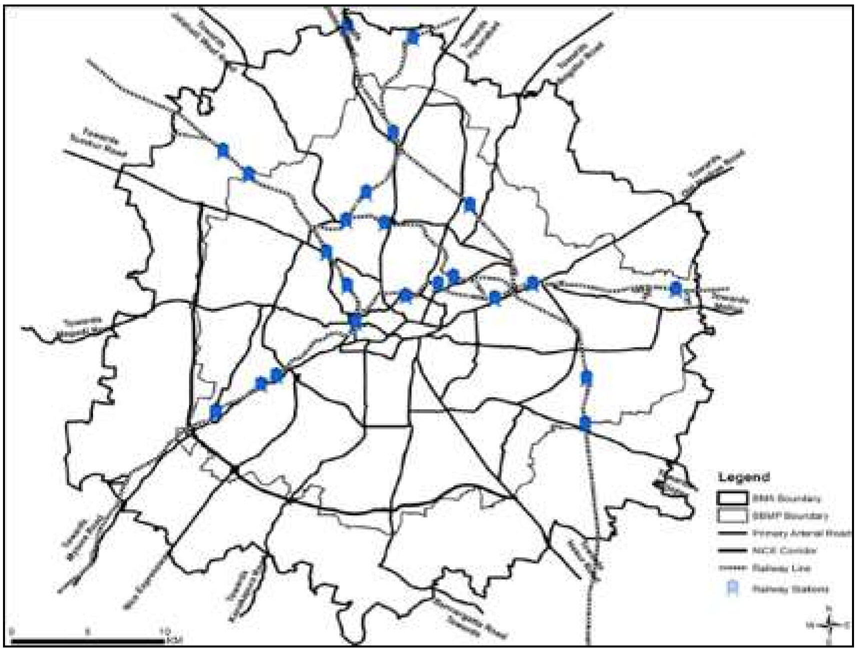
Bengaluru is an important and a major junction on the South-Western railway network. There are three major railway stations in Bengaluru - City Railway Station, Cantonment Railway Station and Yeshwantpur Railway Station. Bengaluru is served by 6 radial rail corridors.

- B.G. line from Chennai on Eastern side
- B.G. line from Mumbai-Pune on North-Western side
- B.G. line from Guntakal on the Northern side
- B.G. line from Salem / Trivandrum from Eastern side
- B.G. line from Mysore from South-West
- B.G.line from Mangalore on Western side

Though at present the rail corridors serve only intercity traffic, a small number of conventional short distance passenger trains are run in morning and evening hours to nearby (satellite) towns like Tumkur, Chikkaballapur, Bangarpet, Hosur and Mandya to serve the commuters. Its layout is conducive to convert them as “Commuter Rail System” (CRS), to provide viable commuter services to suburbs and also some nodes in the Bengaluru.

Till the beginning of 2010, no rail corridors were operated as regular intra-urban commuter corridors. However, on 6th April 2010, the Government of Karnataka in association with SWR has introduced train services from Yeshwantpur to Hosur and Yeshwantpur to Bengaluru International Airport atDevanahalli on trial basis.
The figure 2.4 presents the railway lines within BMA along with railway station.

Figure 2.4: The Railway Lines within BMA Along with Railway Station



Source: Revised master Plan for Bengaluru 2031

2.4.2 Interstate Bus Terminus (ISBT)

BMTC along with KSRTC provides the regional/ interstate connectivity from Bengaluru to other parts of the cities and vice versa. A total of six interstate bus terminals are proposed on Tumkur Road, Mysore Road, Old Madras Road, Hosur Road, Bellary Road and Magadi Road so that intercity traffic will not get mixed with the city traffic.

2.4.3 Airport

Bengaluru is well-connected to all the major destinations in India and across the globe served by Kempegowda International Airport limited which started operations from 24 May 2008. The city was earlier served by the HAL Airport. HAL Airport or Hindustan Airport an airport presently used as a business hub for general aviation, a testing facility by Hindustan Aeronautics, Limited and the Indian Armed Forces. It served as the city's domestic and international airport until 2008, and was replaced by the Kempegowda International Airport on 24 May 2008. Since the airport is located at the heart of the city, it is the preferred destination for general and business aviation. Bengaluru has two aerodromes in Yelahanka and Jakkur.

Kempegowda International Airport is located 4 kms south of Devanahalli and it is 40 kms away from the CBD (Bengaluru City Railway station). It is now the third busiest airport in India in terms of passenger traffic. The airport was designed to handle 12 million passengers per year. Since the year this airport opened in 2008, The airport handled 8.8 million passengers in its first year of operations, and 10 million in the second year. KIA handled 12.86 million passengers in 2013-14. Figure 2.5 presents the passenger and cargo handled since inception till 2018 at KIA.

Figure 2.5: Passenger & Cargo Traffic at Kempegowda International Airport (KAIL)

Source: Associations of Private Airport Operators

2.5 Pedestrian & Non- Motorized Vehicle (NMV) Facilities

The major components of non-motorized infrastructure include pedestrian and Bi cycle infrastructure.

- Pedestrian Infrastructure
- Bicycle Network
- Public Bike Sharing

Footpath is available in about of the road network, however the use is limited and affected for large parts due to encroachment, unscientific ramps/access to properties, drops, uneven surface etc. The road widening projects taken up in the city have resulted in the reduction of footpath widths inconveniencing pedestrians.

In order to improve the situation, BBMP has taken up Tender Sure works in the Central Business District incorporating wider footpaths and proper accommodation for utilities. Under this program, the city corporation is developing NMT network for the convenient and safe mobility of pedestrians and cyclists.

Public bike sharing (PBS) is operational in parts of the city and DULT is in the process of extending the public bike sharing system to the entire city. The PBS system is focused around the metro stations and the residential areas/ activity centers to help in providing last mile connectivity. As part of the program, docking/parking stations are developed and bicycles equipped with GPS are included for use by general public which can be booked through a mobile application.

In Phase 1, implementation of Parking Hubs and Cycle Tracks is proposed on MG Road, near Vidhanasoudha and in areas like Koramangala, HSR Layout, Indiranagar, Banaswadi, HRBR Layout, HBR Layout, Kacharkanahalli, etc. In all about 402 parking hubs are being taken up, each located at a spacing of 200-300m for easy accessibility for the public.

2.6 Traffic Management including Parking Management.

2.6.1 Bengaluru City has witnessed a phenomenal growth in vehicle population. As a result, many of the arterial roads and intersections are operating over the capacity (i.e., V/C is more than 1) and average journey speeds on some of the key roads in the Central Areas are lower than 10 Kmph in the peak hour. Therefore, it has become necessary to establish plans for efficient traffic management in Bengaluru. In this regard, Bengaluru City Traffic Police had envisaged the “Bengaluru Traffic Improvement Project – B-TRAC” which has been implemented in stages in the City.

The signaling system in a long stretch is not synchronized due to this the traffic after clearing and signal stops in next signal. This force the vehicle to be kept in running condition this adds to the pollution. If the signals in series is synchronized the continues traffic flow is ensured there by reducing the pollution.

2.6.2 Transport system management framework is as follows: (a) Land use development controls; (b) Primacy to Public Transport;(c) Parking controls and management; (d) Automated Control and Enforcement (ITS/ATC); (e) Entry Restriction to the Central Area; (f) Road safety plan for accident reduction. Specific components of the strategy are: (a) Central Area – Area Traffic Control System; One way systems; dedicated bye-lanes and signal priority for buses; Parking controls; creation of no-auto zones; restricted entry of traffic in to the core area (b) Core Ring Road development for unhindered movement of traffic thereby avoiding the central area (c) Corridor Traffic Control System (as in ATC) for the several radial roads (d) up gradation of Intermediate and Outer Ring Roads and development of the Peripheral Ring Road (e) Traffic Police modernization with improved communication, computerization, mobility, capacity building and automated enforcement systems.

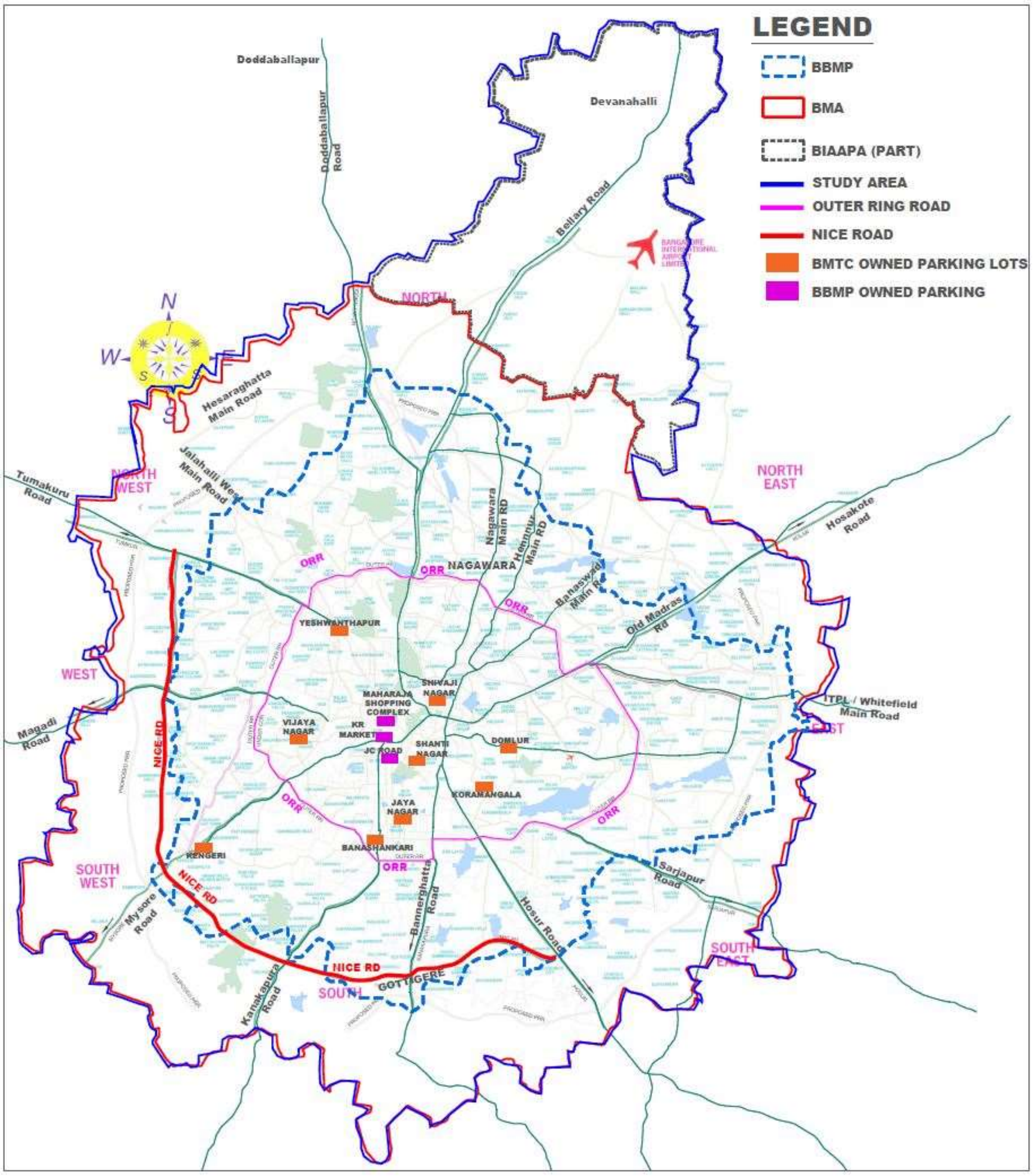
2.6.3 The various components of transport system management are as under:

a. Junction Improvements
b. Street Furniture and Road Marking Intelligent Transport System including. ATC, VMS etc for 250 intersections
c. Surveillance / monitoring and enforcement cameras etc

d. Education and Training / Others

2.6.4 Bangalore with its predominantly mixed land use, is inflicted with on-street parking. There are very few public off-street parking facilities in the city. There are about 11 public off-street parking places; of these nine were developed by BMTC and two by BBMP.

Figure2.6: BMTC and BBMP Parking Spaces in Bangalore



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Apart from these, there is one parking place developed on PPP basis adjacent to Garuda mall. Two parking complexes - one in Maharaja complex on KG road and another by BDA in Jayanagar have off-street parking spaces available for public.

In all the total capacity of off-street parking spaces available in the city for general public is about 1300 cars and 4000 two wheelers. However the numbers do not include parking spaces provided in shopping malls.

A parking policy has been developed for Bangalore which restricts total demand as one of the means to increase Public Transport Ridership.

As part of the station planning, at few metro station locations, parking is made available which is essentially serving the metro users.

With on-street parking available in almost all roads and for free, the utilization of off-street parking spaces is limited except a few.

2.7 Traffic Characteristics

2.7.1 Traffic Characteristics has been dealt in detail in **Chapter 3** of this Report.

2.8. Traffic Safety

2.8.1 The term traffic safety refers to the risk of a person being killed or seriously injured while using the traffic network as a pedestrian, cyclist or user of public or private transport.

2.8.2 The importance of traffic safety is obvious; traffic accounts for many deaths and injuries. According to the World Health Organization, road traffic injuries caused an estimated 1.26 million deaths worldwide in the year 2,000. The average rate was 20.8 per 1,00,000 people, 30.8 for males, 11.0 for females. Measures can be taken in order to reduce the number of casualties and injuries greatly.

2.8.3 Safety can be improved by reducing the chances of a driver making an error, or by designing vehicles to reduce the severity of crashes that do occur.

2.8.4 It is potentially easier to inflict damage to a situation with a low traffic safety. Therefore (and also for security issues) it is important to create preconditions for a high traffic safety situation. This can be done in two ways, firstly to create a safe road network, and secondly to use safe vehicles. The urban planner can help to create a safe road network, however, has no influence on the safety of vehicles.

2.8.5 Safety of vulnerable road users concerns safety of cyclists and pedestrians. A group of road users can be defined as 'vulnerable' in a number of ways, such as by the amount of protection in traffic (e.g. pedestrians and cyclists) or by the amount of task capability (e.g. the young and the elderly). Vulnerable road users do not usually have a protective 'shell', and also the difference in mass between the colliding opponents is often an important factor. Vulnerable road users can be spared by limiting the driving speed of motorized vehicles and separating unequal road user types as much as possible. Adapting motor vehicles (e.g. by sideunderrun-protection for trucks and collision-friendly car fronts) can lessen the injury severity of vulnerable road users. In crashes involving only vulnerable road users and no other road users, it is mainly the infrastructure that is important for the prevention and limitation of injury.

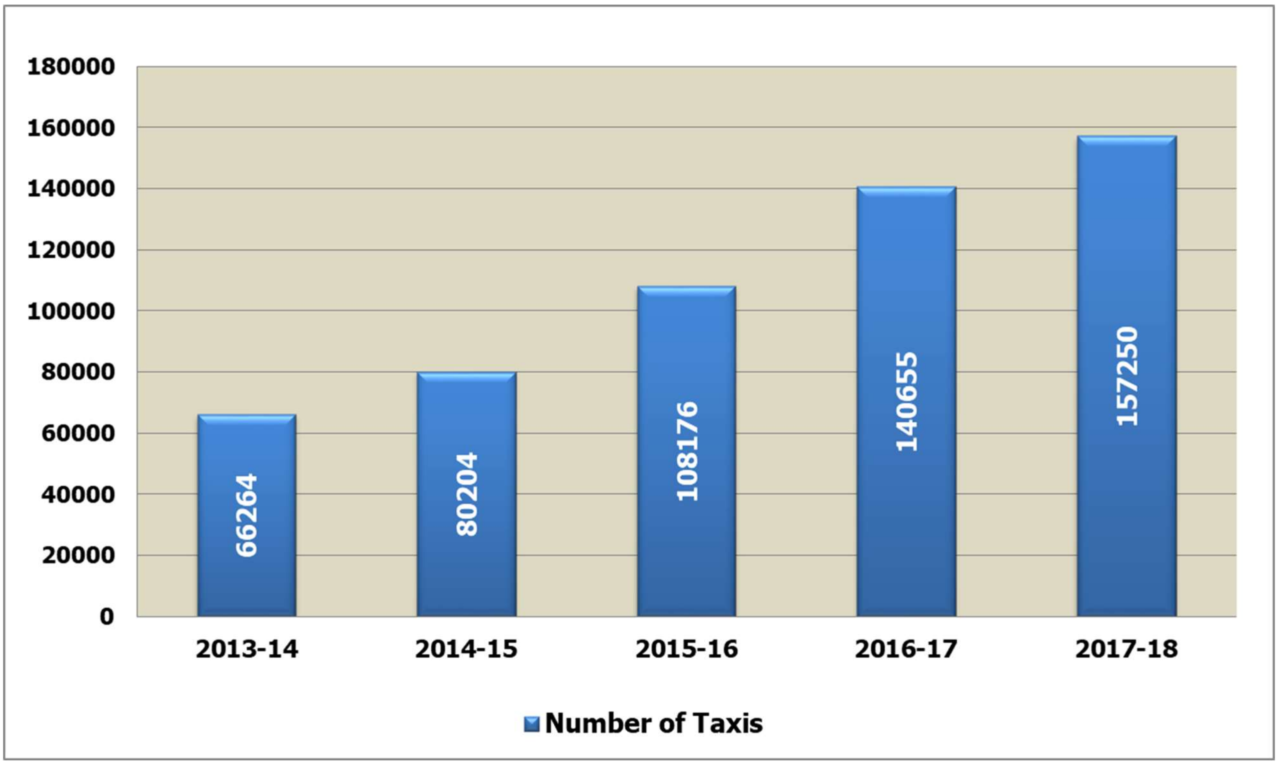
2.8.6 Other preventive measures that are often taken or recommended are wearing a helmet (cyclists), infrastructure adaptations such as pedestrian crossings, separate bicycle lanes etc. Recent developments include safety systems in cars such as collision avoidance systems, night vision and the bicycle airbag.

2.9 Intermediate Public Transport

Auto rickshaws and taxis are offering the Intermediate Public Transport facility in the city. Off-late, taxi aggregators namely Ola, Uber etc. have expanded their services and fleet considerably. Being convenient and easily available and accessible, utilization of IPT has grown considerably in the last 3-5 years.

The city has an estimated 1.57 lakh taxis as of March 2018.

Figure 2-7: Trend of Number of Taxis in Bangalore



Auto-rickshaws with their new found competitors (taxi aggregators) are generally providing the last mile connectivity near metro stations. However, there has not been any reduction in the number of vehicles in the city. Auto-rickshaws cater to a substantial 13% of total trips but constitute only 3% of total vehicular numbers.

With the availability of limited organized auto-rickshaw stands in the city areas, these are parked along the roads and near bus stops for picking up passengers there by occupying precious road space. This situation is resulting in avoidable congestion. The need for stands/ dedicated parking/waiting spaces across the city is very much there as they are an important component in the transportation system in the city.

2. 10 Public Transportation System

Primarily there are two public transport services operating in the city with BMTC offering the road based transport services and BMRCL, the rail based services. There are plans to induct commuter rail services (to be operated by Indian Railways) connecting suburban areas with major activity centers in the city which may take some more time before commuter rail services are available for public.

2.10.1 Bus Transport System in Bangalore

Bus system operated by BMTC has been the primary public transport system in Bangalore City. BMTC has established 45 depots for providing services in the city. BMTC is operating 6143 schedules (as on Aug 2018) every day. The Physical performance of BMTC is presented in Table 2.5.

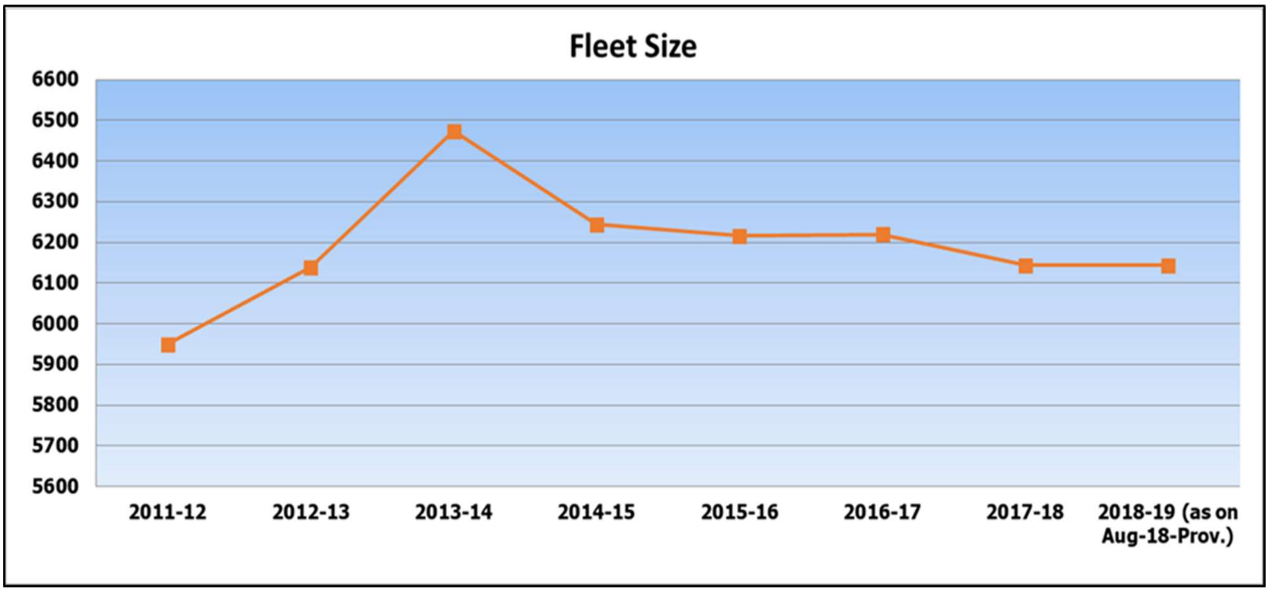
Table 2-5: BMTC Performance

Parameter	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (as on Aug-18-Prov.)
Depots	39	39	40	40	43	44	45
Fleet Operated	6139	6473	6244	6216	6219	6143	6143
Vehicles Held	6431	6775	6522	6401	6161	6677	6634
Effective Km. Per day (Lakh)	12.71	13.14	12.9	12.21	11.52	11.42	11.38
Total Service km(Lakh km)	4638.38	4795.90	4708.56	4469.82	4205.20	4164.53	-
Veh. Utilisation (Km)	221.1	218.2	214.5	208.5	206.5	203.8	202
Passengers carried per day (Lakh)	48.46	50.25	51.30	50.74	45.34	44.37	-
Passenger load factor (%)	68.5	67.2	75.8	74.2	68.8	66.8	-

Source: BMTC, Bangalore

The trend of increase in BMTC Bus Fleet Size over the years is shown in Figure 2.8.

Figure 2.8: Trend in Bus Fleet Size



BMTC buses per lakh population are presented in Table 2.6. As per the Central Institute of Road Transport (CIRT) report Bus Transport Supply Index (buses per lakh of population) must be approximately 50. Though the fleet supply is adequate the efficiency of BMTC bus service is declining over the years.

Table 2.6: BMTC Buses Per Lakh Population-Chart

Year	Population	BMTC Bus Fleet Size	Buses Per Lakh Population
2001	61.9	2658	43
2011	90.44	5949	66
2018	122.98	6143	50

As can be seen from Figure 2.8 the fleet size was increasing rapidly from 2011-12 to 2018-19. However, off late the number of buses have not kept pace with the growing population and the buses per lakh population now stands at 50. Further the bus utilization has been reducing due to the ever rising private vehicular population in city, leading to congestion affecting the overall turnaround time. This has impacted the revenue generation.

2.10.2 Metro Network

Two corridors of Metro Rail are in operation in Bangalore. One is the East-West corridor and the other is the North-South corridor. The East-West Corridor starts at Baiyappanahalli (Reach 1) and ends at Mysore Road (Reach 2). The North-South Corridor starts at Nagasandra (Reach 3) and ends at Puttenahalli (Reach 4). The total length of the Metro Rail network under operation is 42.30 Km. Extensions on East-West Corridor, North-South Corridor & two new lines Reach 5 & Reach 6 under Phase 2 (72.1km) are under implementation. Table 2.7 presents reach wise lengths for Phase 1 and Phase 2.

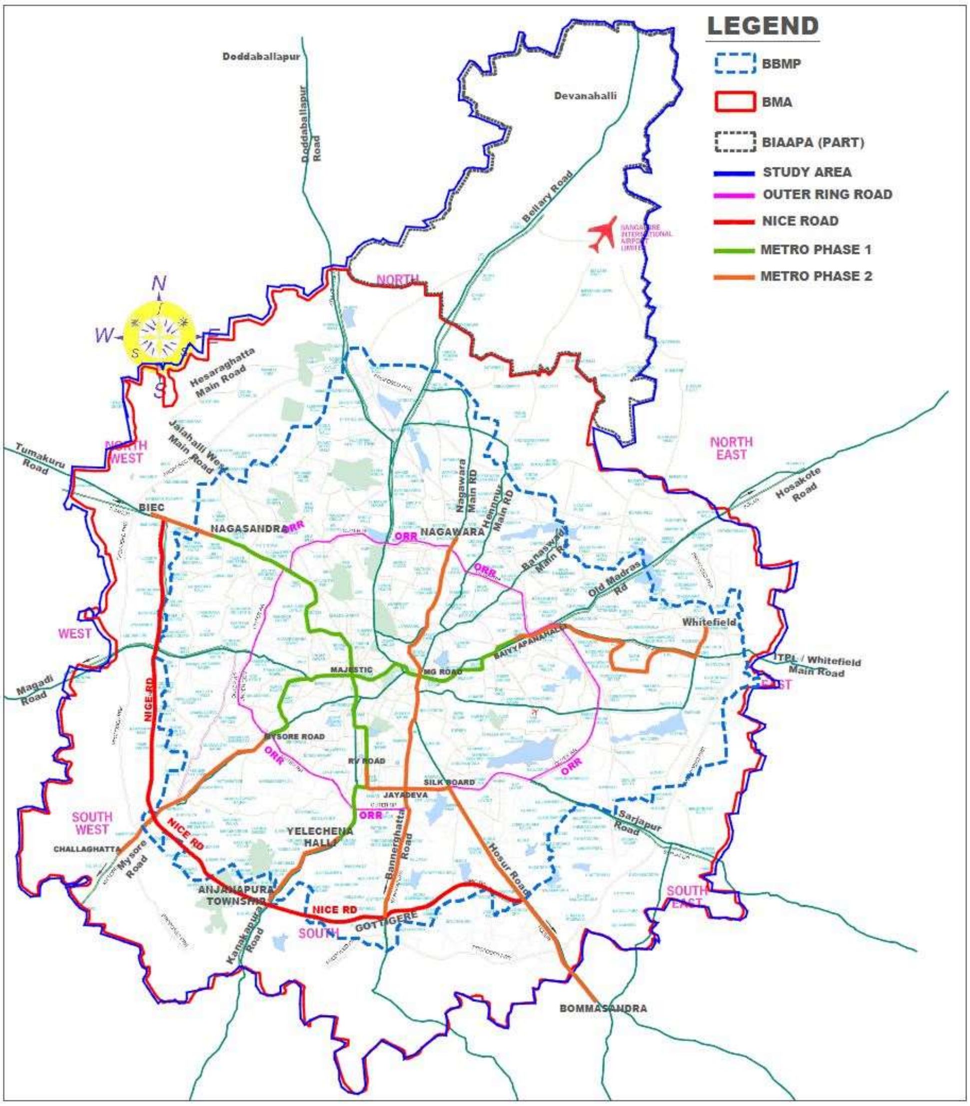
Table 2.7: Metro Corridors along with the Stretches and their Status

Sl. 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
Phase 2			
1	N-S Line Extension from Puttenahalli Cross to Anjanapura Township (R 4B)	6.29	Construction in progress
2	N-S Line Extension from Hesarghatta Cross to BIEC (R3C)	3.77	Construction in progress

Sl. No.	Corridor	Length(km)	Status
3	E-W Line Extension from Baiyappanahalli to ITPL- Whitefield (R 1A, R 1B)	15.5	Construction in progress
4	E-W Line Extension from Mysore Road Terminal to Kengeri (R2A , R2B)	6.465	Construction in progress
5	New N-S Line IIMB to Nagawara (R6)	21.25	Construction in progress
6	New E-W Line to R.V.Road to Bommasandra (R5)	18.82	Construction in progress

Average daily ridership in the two corridors under Phase 1 has registered about 4,05,000 (October, 2019). It is also to note the metro was predominantly operating with 3 car trains which were running completely packed during the peak hours. BMRCL is now introducing 6 car trains in a phased manner and this move is expected to improve the capacity, and attract increased ridership.

Figure Error! No text of specified style in document.**2-9:** Bangalore Metro Network



2.10.3 Sub-Urban Railway Network

Bangalore city has a fairly good rail network of about 62 km within the city. There are a few diesel operated passenger trains that connect to Bangalore 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 the patronage has shown 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 Bangalore is being explored and a detailed study has been made by Indian Railways to introduce a commuter rail services including identifying the improvement requirement to the railway network.

2.10.4 Institutional Framework and Responsible Agency

A good institutional frame-work is critical for effective public transport. It should address all the functions, clearly assign responsibilities and be responsive to the policy concerns of all levels of government, needs of public transport users (fares, service level, quality) and concerns of all citizens (mobility needs, air quality, traffic safety).

At present, following is the list of departments and organizations involved in urban affairs and urban transport in Bangalore.

- Urban Development Department (UDD), Government of Karnataka
- Transport Department, Government of Karnataka
- Directorate of Urban Land Transport (DULT)
- Bangalore Development Authority (BDA)
- Bruhat Bengaluru MahanagaraPalike (BBMP)
- Bangalore Metro Rail Corporation Ltd. (BMRCL)
- Karnataka Rail Infrastructure Development Corporation Ltd (K-RIDE)
- Bangalore Metropolitan Transport Corporation (BMTC)
- Karnataka State Road Transport Corporation (KSRTC)
- Traffic Police, Bangalore
- Karnataka Road Development Corporation (KRDCL)
- Public Works Department, Government of Karnataka
- National Highway Authority of India (NHAI)
- State Pollution Control Board, Bangalore

With a view to coordinate all urban transport activities in the city, there is need of an unified authority (UMTA) to be set up at the city level that acts as a planning and decision making body for all matters related to urban transport in the city.

A draft bill for constituting the UMTA for Bengaluru i.e. Bengaluru Mobility Management Authority (BMMA) has been prepared and is being finalised to provide statutory status to BMMA. BMMA shall be constituted under the Chairmanship of Chief Minister and heads of the departmental stakeholders, subject experts and representatives from civil society shall be as member. To discharge the technical and administrative functions of the authority, an Executive Committee shall be constituted comprising of the following members:

(i) Additional Chief Secretary to Government, Urban Development Department - Executive President

(ii) Principal Secretary, Transport Department - Member

(iii) ACS/Principal Secretary to Government, Finance Department - Member

(iv) Commissioner, Bruhat Bangalore Mahanagara Palike (BBMP) - Member

(v) Commissioner, Bangalore Development Authority (BDA) - Member

(vi) Commissioner, Bangalore Metropolitan Region Development Authority - Member

(vii) Managing Director, Bangalore Metro Rail Corporation Limited - Member

(viii) Managing Director, Bangalore Metropolitan Transport Corporation - Member

(ix) Director of Town and Country Planning - Member

(x) Additional Commissioner of Police (Traffic) - Member

(xi) CEO of the Authority - Member Secretary

The Commissioner of Directorate of Urban Land Transport, Government of Karnataka shall be the Chief Executive Officer of the Authority.

2.11 Past Proposals from CMP/CTTS/Transport Master Plan

Followings are the major studies conducted earlier in the city.

- Comprehensive Traffic and Transportation Plan for Bengaluru City, RITES, 2011
- Comprehensive Traffic and Transportation Study for Bengaluru Metropolitan Region, WSA, 2015
- Revision of Master Plan 2031 for Bengaluru, BDA
- Comprehensive Mobility Plan for Bengaluru

Comprehensive Traffic and Transportation Plan for Bengaluru City (2011)

The comprehensive transportation study was undertaken by KUIDFC to prepare development plan for the traffic and transportation plan for the Bengaluru City. The Vision of the CTTP was to have efficient, people friendly transport system with minimum travel time and maximum safety and comfort. Elaborate study of travel demand in the city and travel pattern has been used to develop robust multi-modal transportation system for meeting travel needs of the city's population. The major outcome of the study is identification of projects proposals for implementation to address the transportation needs for the short term, medium term and long term.

- Identification of network for the development of mass transport system covering the major corridors of movement in the City and interchange facilities with other modes of transport
- Identify network for development of medium level mass transport system such as BRT to cover the areas beyond the Mass Transit network and act as second level Public Transportation System
- Land use adjustments and densification of corridors along mass transport corridors where possible to best utilize the transportation system as catalyst for development
- Extension of commuter rail system upto the BMRDA's New Townships & beyond upto Tumkur, Hosur etc. to act as sub-urban services.
- Providing transport hubs for Interstate passenger and freight traffic near the junctions of Peripheral Ring Road with important radials such as; the National Highways and other heavily loaded roads.
- Transport integration of various modes.
- Strengthening of existing institutions dealing with various aspects of urban transport and formation of a unified transport authority for inter-agency coordination.

Comprehensive Traffic and Transportation Study for Bengaluru Metropolitan Region (2015)

The Comprehensive Traffic and Transportation Study was undertaken by BMRDA by extending the study area to areas beyond the City and included satellite towns around the City. The vision of the CTTS was to prepare transportation master plan with an aim to provide an efficient transportation system catering to the needs of population in the BMR region. The major outcome of the study is identification of projects proposals for implementation to address the needs for long term, medium term and short term.

Long Term Proposals

- Development of Multi-Modal Public Transport System

- Development of 341km of Mass transit corridors covering the major corridors of movement in the City and interchange facilities with other modes of transport
- Development of 231km of dedicated high capacity BRTS corridors to cover the areas beyond the Mass Transit network and act as second level Public Transportation System
- Development of intermodal stations for better integration
- Land use adjustments and densification of corridors along mass transport corridors where possible to best utilize the transportation system as catalyst for development
- Extension of commuter rail system upto the BMRDA's New Townships & beyond upto Tumkur, Hosur etc. to act as sub-urban services.
- Providing transport hubs for Interstate passenger and freight traffic near the junctions of Peripheral Ring Road with important radials such as; the National Highways and other heavily loaded roads.
- Transport integration of various modes.
- Strengthening of existing institutions dealing with various aspects of urban transport and formation of a unified transport authority for inter-agency coordination.
- Road Network Improvement Proposals
- Development of New Roads totaling a length of about 515km
- Development of Missing Links totaling to about 530km
- Augmentation of capacity of existing roads

Revision of Master Plan 2031

Revision of Master Plan 2031was undertaken by Bengaluru Development Authority to identify attendant issues and challenges inhibiting streamlined growth and development in the BMA and also to understand the present status of RMP 2015 plan implementation and enforcement. Simultaneously several studies and surveys were conducted to formulate the baseline scenario. This preliminary analysis facilitated demographic projections and associated demand for land, infrastructure and services for the horizon year 2031, which in turn helped in arriving at the master plan scenarios of how the city should grow.

The BDA has endeavored to revise the Master Plan for Bengaluru for 2031as a spatial-policy framework to guide the future growth of the city especially keeping the aspirations of the citizens.

RMP forBengaluru-2031 evolved 3 alternative Growth Scenarios namely:

- Containment Scenario
- Corridor Driven Scenario
- Differential Scenario

Following are the key considerations for the conceptualization of options and scenarios for the city:

- Existing Developments and Present Situation
- Regional Growth Direction
- The spatial differentiation and associated growth and development trends as noticed in the different zones of the city: a) Core Area (inside ORR or the erstwhile BMP), b) Outer
- Core (ORR to BBMP Limits) and c) Transition Area (251 Villages in the BMA)
- Population projections for the city for 2031
- In addition, the growth scenarios adopt following critical non-negotiables
  - Circulation Network (Road Network and Commuter Rail System) with focus on public transport system
  - Green network as consistent with the city's topography
  - Promotion of Public Transport
  - Provision of Affordable Housing

Following are the major transport Projects and Programmes identified by Master Plan for implementation:

- **Road Development Plan:** This includes following component:
  - Demarcation of Master Plan Roads (18m above only) on Ground
  - Upgradation/ Widening of Existing Roads
  - Development of New Links
  - Junction Improvement Programme and Development of Flyovers/ Railway Bridges
  - Preparation of Parking plans for Streets/ Areas

- **Public Transport Network Development:** This includes following component:
  - Development of Commuter Rail Service
  - Development of Metro Network
  - Development of LRT/Mono Rail/ BRTS
  - Development of Intermodal Interchanges
  - Development ISBTs
  - Development of Bus Stations/ Terminals

- **Development of Logistic Facilities:** This includes following components:
  - Demarcation of Land for Logistic Facilities
  - Development of Logistic Hubs/ Truck Terminals
  - Rejuvenation of Lakes and Streams
  - This includes following components
  - Prioritise Lakes for Rejuvenation
  - Demarcation of Lakes Extent

Comprehensive Mobility Plan for Bengaluru

The vision of the Comprehensive Mobility Plan for Bengaluru is to achieve "Efficient and Sustainable Transportation for All", with a system that serves to help fulfil the economic and social needs of residents and visitors. The strategic framework for efficient and sustainable transport has been formulated in CMP considering following strategies:

- Strategy 1: Expand reach and augment capacity of public transport systems
- Strategy 2: Improve operational efficiency of public transport systems
- Strategy 3: Promote multi-modal mobility options
- 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 measures
- Strategy 9: Promoting use of electric and cleaner fuel vehicles
- Strategy 10: Establish mechanism for planning, capacity building and accountability

The major proposals of CMP are given in Table below:

Table 2.8: CMP proposals

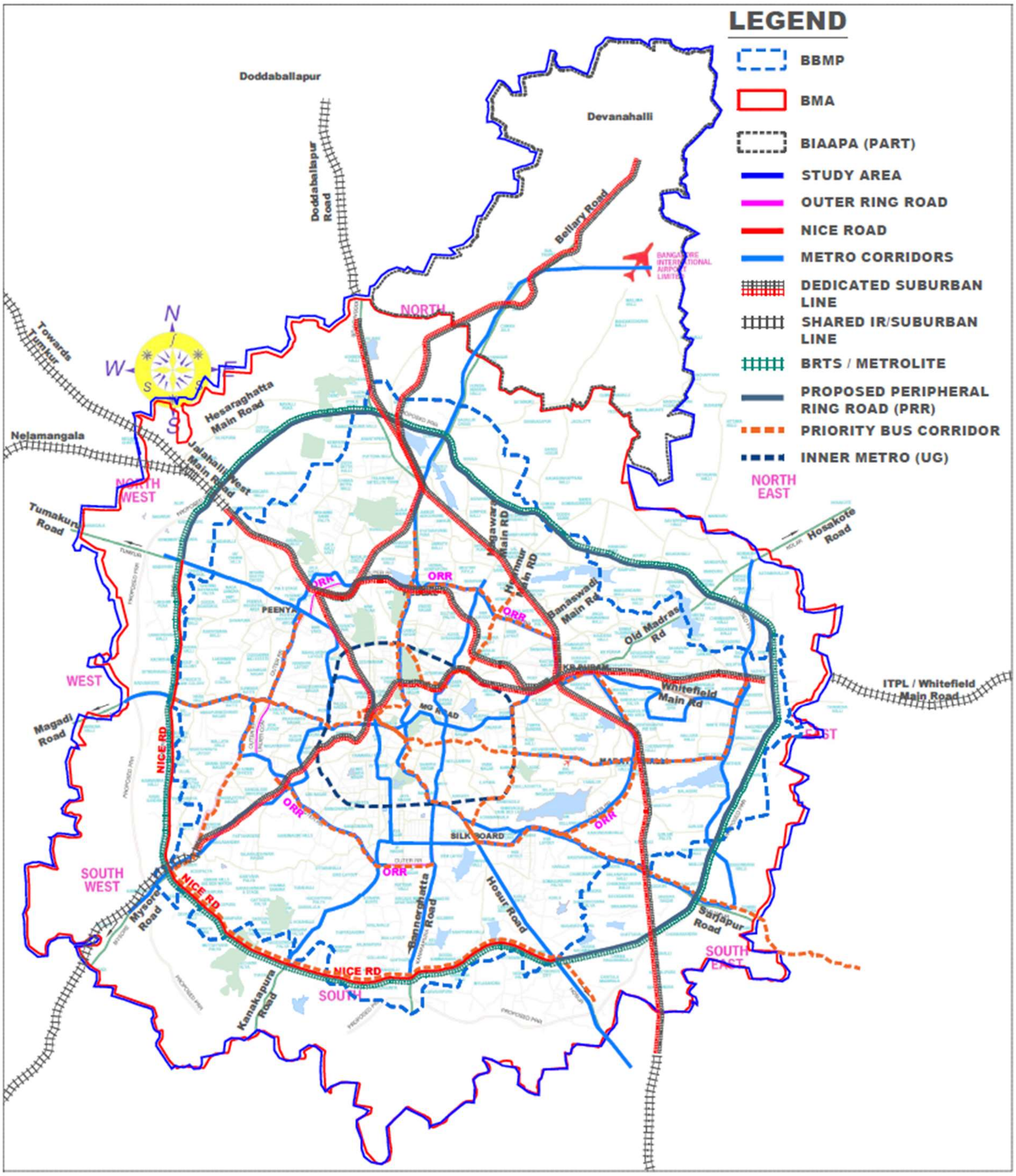
Integrated Land Use and Mobility Plan
· Transit Oriented Development
Public Transport Improvement Plan
· Bus fleet augmentation
· Bus priority corridors
· Suburban Rail on existing tracks
· BRTS/Metrolite
· Bus depots/terminals
· Metro Rail
· Dedicated Suburban Rail
Road Network Development Plan
· Junction improvements
· Foot over bridges/ walkways
· Corridor improvements
· Parking infrastructure
· Peripheral ring road
· Road widening
· Elevated corridors

Non-Motorized Transport Plan
· Public bicycle sharing
· Footpath development
· Cycle track development
· Pedestrian only streets
Multi-Modal Mobility Plan
· Elevated walkways connecting public transport stations
· Intermodal transit hubs
· Multi-modal mobility fare system
Private Transport Management Plan
· Insurance premium based on usage
· Proof of parking for vehicle ownership
· Congestion fees
Freight Movement Plan
· High-volume freight deliveries & truck movement to be restricted to night-time or off-peak hours
· Freight logistics centers
Technological Measures
· Smart signalization
· Integrated Command Control Centre
· Adoption of CNG and electric for IPT vehicles and public transport buses respectively
Travel Demand Management Plan
· Public education and awareness
· Priced parking management
Regulatory Measures
· Robust traffic management and enforcement measures
· Data-sharing standards
· Fare regulations
Governance Measures
· Build capacity for data driven decision making and integrate planning
· Operationalize BMMA
Fiscal Measures
· New vehicle & annual renewal for vehicle registration that is linked to pollution emission and fuel efficiency
· Dynamic pricing to capture and charge vehicle usage
· Institute friendlier tax environment on inputs and revenues for public transport operators

2.12 Comprehensive Mobility Plan and Proposed Metro Rail Plan

The CMP has recommended the overall public transport network of 803 km length within BMA i. e., metro, suburban rail, priority bus corridors, BRTS or Metrolite in addition to augmentation of public bus transport services. The proposed corridor KR Puram to Airport is also recommended in the CMP. The proposed public transport network as per CMP is given in Figure 2.10.

Figure 2.10: Public Transport Network



2.13 Issues and Prospects

The growing population, vehicle numbers and economic activities, have seriously aggravated the traffic problems in Bengaluru. The limited road space of Bengaluru is not able to handle the current traffic generated by the ever burgeoning population. Consequently, traffic in Bengaluru has become a scourge and is only worsening day by day. Network speeds are dropping at an alarming rate as capacity of the Junctions and links have exceeded the limits. These have contributed towards increasing traffic congestion, travel times and pollution levels.

Considering the current challenges that Bangalore is facing, which shows a unsustainable situation, a set of key priorities or principles are devised that underpin the development of the transport strategy. The strategy seeks to address the concerns of all segments of commuting population by emphasizing the pre-eminence of public transport and non-motorized modes of travel; adopting various elements of Travel Demand Management and integrating with the land use development scenarios. This is in line with the National Urban Transport Policy.

Chapter 3

Travel Characteristics & Demand Estimates

CHAPTER 3

TRAVEL CHARACTERISTICS AND DEMAND ESTIMATES

3.1 TRAFFIC AND TRANSPORTATION STUDIES

Traffic and Transportation Study analyses the traffic volume and assesses the variation of traffic level, composition, growth rate and forecasts the future traffic for a particular location or area.

3.1.1 Study Area

The study area includes the Bangalore Metropolitan Area (LPA area) i.e. 1294.00 Sq.km. (including part BMICAPA area – 79.14 Sq.km.) The development of Airport near Devanahalli and transport infrastructure development in the form of 6 lane access controlled road between Hebbal and Airport has triggered development around airport and near Devanahalli. To ensure planned development, BIAAPA has been established to oversee the development of the identified area. The BIAAPA study area reveals that most of the developments are in two administrative areas namely Jala Hobli and Kasba Hobli. Considering this and to account its impact on the city development part of BIAAPA area extending 227.85 sq.km has been included in the planning area. The study area is shown in Figure 3.1.

3.1.2 Zoning System

The study area has been divided into 519 internal zones. There are 15 external zones.

3.1.3 Land Use Surveys

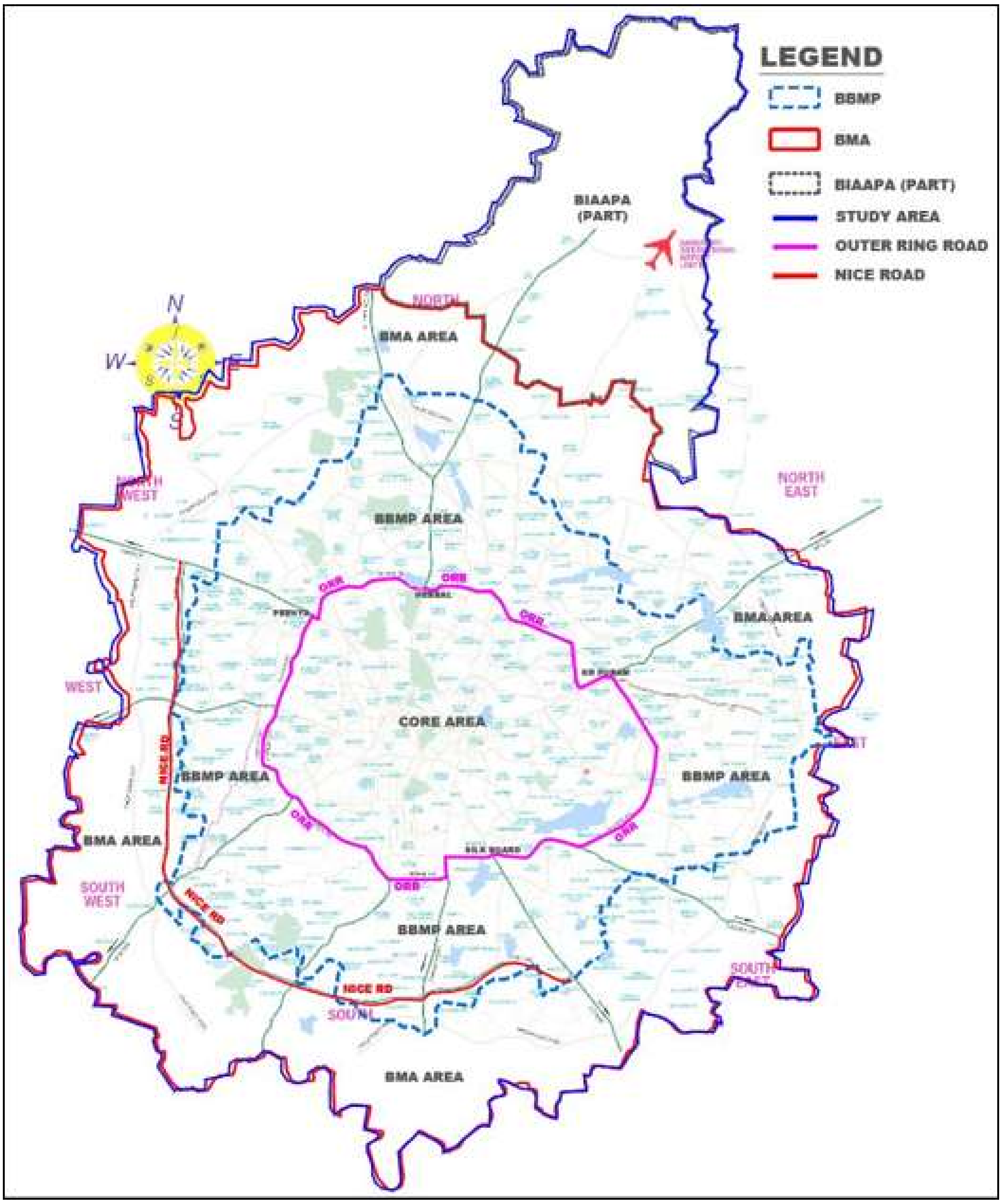
The Existing Land Use (ELU) is the next critical input in devising the future growth strategy of any city/town. The ELU maps show various current land uses at the specified and reasonable scale indicating residential, commercial, industrial, public & semi- public uses, recreational (parks & playgrounds), open spaces, vacant land, land under agriculture, water bodies, utilities & services facilities, circulation system, conservation areas, special areas, committed land uses, reservations and mixed land uses etc.

The Master Plan document (RMP-2031) has been reviewed for the existing landuse in the BDA Planning area with reference to the proposed landuse and as per RMP-2015. This analysis helps in understanding the development pattern in the city.

While the shape and structure of the transport network is dependent on land use, land use itself cannot happen as planned if the transport network is not provided. In other words, land use and the network strategy must go hand in hand.

The Existing Landuse Map (ELU) is presented in Figure 3.2, whereas the ELU Area Statement for LPA of BDA is given in Table 3.1.

Figure 3.1 Study Area



The Area allocated for transportation and communications falls very short of the requirements. The general norm is 20% but most cities achieve at least 15% and what Bangalore is bestowed with is only 7.3%. The land available for development in the core area is very limited. This area beyond the ring road will show the maximum growth in the next 5 years. The peripheral areas will be able to imbibe development beyond 2041. The green areas especially in the North East (Arkavathi) and the South East and the South (Bannerghatta) are environmentally sensitive zones and will not be available for development. The thrust in growth hence will be essentially to the north and North West. BIAPPA and the Airport zone at Devanahalli would be prime destinations for future growth.

Figure 3.2 Existing land Use Map of BMA

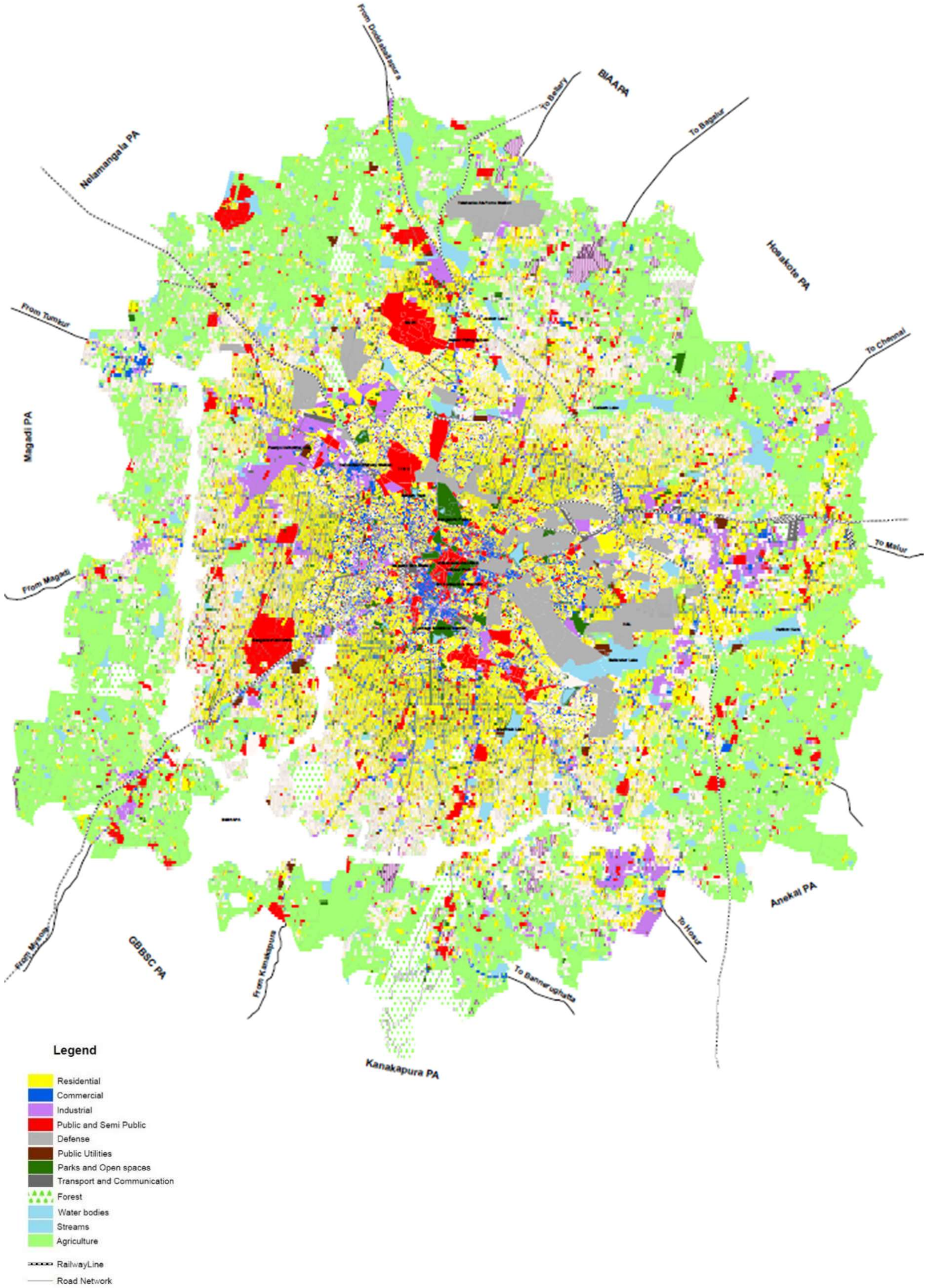


Table 3.1 ELU Area Statement

Land Use	Existing Landuse - 2015	
	Area (Sq.km)	**Share (%)**
Residential	212.83	17.63%
Commercial	38.27	3.17%
Industrial	45.63	3.78%
Public & Semi-public	64.82	5.37%
Un-classified	42.32	3.51%
Public Utilities	4.86	0.4%
Parks & Open Spaces	20.67	1.71%
Transport Communication	87.85	7.28%
Vacant	305.28	25.29%
Agriculture land	300.42	24.89%
Quarry/Mining Sites	7.39	0.61%
Forest	27.53	2.28%
Water Bodies and Streams	49.1	4.07%
Total LPA of BDA	**1206.97**	**100.0%**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

3.1.4 Traffic and Transportation Surveys

The purpose of conducting traffic surveys is to assess the traffic and transport characteristic of the study area (base line scenario) and provide inputs to developing the transport model. Focus of the surveys has been on obtaining traffic volume data on as many roads as possible (Junction data from surveillance camera were also available).

3.1.4.1 Screen Line Volume Count

Three Screen lines have been identified for the study NSW, NSE, EW, thus making a total of 45 locations and 16-hour video graphical survey has been captured for all 45 locations. Primary traffic volume counts surveys on screen lines have been conducted to collect the traffic data for the urban transport demand model validation. 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. The Peak Hour Traffic Volume at screen Line location is presented in **Table 3.2.**

It is interested to note that traffic flows are equally high on orbital roads such as the chord road and the outer ring road to some of the radial corridors. The very uniform spatial development of the city in nearly a circular growth pattern has led to this. In normal conditions this would have been an ideal situation for distribution of traffic however the size of the city unfortunately has spared none and has congested all corridors (Radials and orbital's). This argument leads to the fact that traffic jams can be caused anywhere on the network and any localised solutions like flyover may not be the solution one has to look for in Bengaluru.

Key Findings: The major road network is congested uniformly which leads to the fact that localised solutions like traffic management and unscientific flyovers may not be the solution.

Table 3.2 Peak hour Traffic volume at Screen Line Locations

Sl. No	ID	Location Name	Direction	Total	Total (PCU)	Both Direction (Vehicles)	Both Direction (PCU)
1	NSW1	Old Outer Ring Road	Towards Mysore Road	1459	1317	2734	2425
			Towards Satellite town	1275	1108		
2	NSW2	80 Feet Road (Dubasipalya Road)	Towards Mysore Rd	768	500	1129	800
			Towards Dubasipalya	361	300		
3	NSW3	Bangalore University	Towards University	904	647	3054	2084
			Towards Mysore rd	2150	1437		
4	NSW4	Outer Ring Road	Towards Mysore road	6139	4575	10129	7720
			Towards Chandra layout	3990	3145		
5	NSW5	Chord Road	Towards Vijayanagar	3348	2371	8564	5961
			Towards Mysore road	5216	3590		
6	NSW6	Hosahalli Main Road	Towards Mysore road	4880	3035	6693	4189
			Towards Chord road	1813	1154		
7	NSW7	Tank Bund Road	Towards Magadi Road	2142	1647	4905	3856
			Towards Mysore Road	2763	2209		
8	NSW8	Old Mysore Road	Towards Khodays	9071	8189	11989	10699
			Towards Okalipuram	2918	2510		
9	NSW9	Puttaswamy Road and MillCorner Road Intersection	Towards Sampige Road	3191	1877	4062	2502
			Towards5th Main Road	871	625		
10	NSW10	5th Cross Road	Towards Raj Kumar Road	5703	3796	8307	5576
			Towards Sampige Road	2604	1780		
11	NSW11	17th Cross Road (GP Rajarathnam Road)	Towards Raj Kumar Road	1487	1025	5096	3359
			Towards Canara Union Road	3609	2334		
12	NSW12	Tumkur Road	Towards Tumkur Road	4435	3663	10158	8019
			Towards Chikkabanavara	5723	4356		
13	NSW13	Outer Ring Road	Towards ORR	1840	1399	4023	3099
			Towards BELCircle	2183	1700		
14	NSW14	Jalahalli Road	Towards Gangamma Circle	1689	1180	2637	2331
			Towards Tumkur Road	948	1151		
15	NSW15	Hesaragatta Main Road	Towards Tumkur Road	897	783	1737	1472
			Towards Chikkabanavara Post	840	689		

Sl. No	ID	Location Name	Direction	Total	Total (PCU)	Both Direction (Vehicles)	Both Direction (PCU)
16	EW1	Plat form Road	Towards Seshadri Road	1923	1806	3431	3057
			Towards Malleshwaram	1508	1251		
17	EW2	SC Road	Towards Anand Rao Circle	2772	1806	4244	3128
			Towards Malleshwaram circle	1472	1322		
18	EW3	Hare Krishna Road	Towards Race Course Road	3377	2267	5060	3608
			Towards Sheshadripuram	1683	1341		
19	EW4	Sankeys Road	Towards Bellary road	6638	5145	10459	8473
			Towards Baswesvara circle	3821	3328		
20	EW5	Palace Road	Towards Cunningham Road	3503	2827	5951	4821
			Towards Bellary road	2448	1994		
21	EW6	Jayamahal Road (Cantonment Junction)	Towards Thimmaiah road	7958	5351	9905	6824
			Towards palace	1947	1473		
22	EW7	Millers Road	Towards Coles park	3112	2120	4472	3110
			Towards Jayamahal road	1360	990		
23	EW8	Tannery Road	Towards Richards town	5983	3819	7715	4958
			Towards St. Johns Church Road	1732	1139		
24	EW9	Pottery Road	Towards Clarence Road	2289	1650	2289	1650
25	EW10	Lazar Road	Towards MM road	6022	4071	7919	5388
			Towards Thomas road	1897	1317		
26	EW11	Wheeler Road Flyover	Towards Doddabanaswadi	2334	1684	5742	3906
			Towards St. John Church	3408	2222		
27	EW12	Jeevanahalli Main	Towards PSK Naidu Road	1686	1007	2458	1529
			Towards Park Road	772	522		
28	EW13	Byappanahalli Road	Towards Old Madras Road	1527	885	1952	1124
			Towards Doddabanaswadi Main road	425	239		
29	EW14	NGEF Main Road	Towards Satellite town	3293	2224	3525	2362
			Towards Old Madras Road	232	138		
30	EW15	Hoodi Main Road	Towards Hoodi	2888	1850	3468	2276
			Towards Deva	580	426		
31	EW16	Kadugodi Flyover	Towards White	1818	1594	2740	2445
			Towards Sai Baba	922	851		
32	NSE1	Yelahanka	TowardsNH-7	3113	2567	4629	3824
			Towards Yelahanka	1516	1257		
33	NSE2	NH-7	Towards Airport	3822	3456	8654	8023
			Towards Hebbal	4832	4567		
34	NSE3	Agrahara	Towards Jakkur	696	552	1401	1113
			Towards Sampige	705	561		
35	NSE4	Thanisandra Main Road	Towards ORR	1870	1454	3593	2818
			Towards K	1723	1364		
36	NSE5	Hennur-Bagalur Road	Avallahalli Main Rd	1798	1332	4001	2972
			ORR Road	2203	1640		

Sl. No	ID	Location Name	Direction	Total	Total (PCU)	Both Direction (Vehicles)	Both Direction (PCU)
37	NSE6	Hormavu-Agara Road	Hormavu road	348	278	813	629
			ORR	465	351		
38	NSE7	Hormavu Main Road	Towards Outer Ring	1772	1195	3164	2192
			towards Ramamurthy Nagar road	1392	997		
39	NSE8	Ramamurthy Nagar Main Road	Towards Outer Ring Road	3049	2199	5626	4002
			Towards Ramamurthy nagar Police Station	2577	1803		
40	NSE9	Kagdaspura Main Road	Towards Mahadevapura	1426	901	2359	1521
			Towards CV Raman nagar	933	620		
41	NSE10	ORR Dodannekundi	Towards Marathahalli	5640	4607	9316	7823
			Towards Dodannekundi	3676	3216		
42	NSE11	SGR Dental college Road	Towards Outer ring road	1323	776	2371	1473
			Towards Munnekollal main road	1048	697		
43	NSE12	Panathur Main Road	Towards outer ring road	1157	937	1816	1663
			Towards Varthur police station	659	726		
44	NSE13	Gunjur Road	Towards Sarjapur road	342	262	798	627
			Towards Gunjur Palya	456	365		
45	NSE14	Sarjapur Road	Towards Outer ring road	1322	1057	2131	1740
			Towards Ambedkar nagar	809	683		

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

3.1.4.2 Turning Volume Counts at Junctions

Classified Traffic Volume Count was carried out at 14 intersections. The peak hour PCUs observed indicate that the some of the critical junctions includes Silk board junction, Hebbal junction and Hennur junction on the ring road. The peak hour traffic volumes and 24 hours' traffic are given **Table 3.3**.

Table 3.3 Total Volume for 24 hours and peak hour on surveyed location

Sl. No.	Junction Name	Peak Hour Volume	PCUs	24-Hour Volume	PCUs	Type of Junction
		Vehicles		Vehicles		
1	Kundalahalli	6280	5656	89599	80770	4–Legged
2	Doddanakundi	8728	7032	101324	91960	5- Legged
3	Hennur Cross	16559	35852	200921	426855	5–Legged
4	Nagawara Junction	14207	11686	167711	153725	4–Legged
5	BEL Circle	10856	9195	126475	117178	4–Legged
6	Gorgunte Palya	6067	6451	104271	111723	3–Legged
7	Subhash Chandra boss Junction	9163	6899	148589	143204	4–Legged

Sl. No.	Junction Name	Peak Hour Volume	PCUs	24-Hour Volume	PCUs	Type of Junction
		Vehicles		Vehicles		
8	Sumanahalli junction	11916	9640	153735	138470	4–Legged
9	Devegowda Petrol	10415	8650	167096	139267	4–Legged
10	Sarakki	8356	6760	103590	89102	4–Legged
11	Silk Board Junction	22634	18180	323099	281521	4–Legged
12	HSR Layout 27th Main Junction	15282	12773	172375	149113	3–Legged
13	Tin Factory	15311	16919	242638	268529	4–Legged-staggered
14	Hebbal Junction	23924	18154	273755	253689	3–Legged

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

3.1.4.3 Road Inventory Survey

The main objective of Road Inventory survey is to assess the physical characteristics and conditions of major road network in the study area, identify physical constraints and bottlenecks and to identify the potential future development.

Right of Way (ROW)

About 43% of length of roads has ROW up to 10 m and 13% have ROW between 20 to 30 m as indicated in Table 3.4. This indicates the limitation of widening on most of the roads.

Table 3.4: Distribution of Road Length by Right of Way

Right Of Way (m)	Road Length (in km)	Percentage (%)
Up to 10	1078.7	42.5
10-20	965.7	38.1
20-30	329.9	13.0
>=30	163.1	6.4
Total	**2537.4**	**100.0**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Carriageway Width

The distribution of road network as per carriageway width is presented in Table 3.5. It can be observed that about 74% of surveyed road network length has carriageway width up to 2 lane and about 20% of road network 4 lane and more.

Table 3.5: Distribution of Road Network as per Carriageway Width

SL. No.	Carriageway	Road Length (Km)	Percentage (%)
1	Upto 2-Lane	1871.0	73.8
2	3 Lane	160.9	6.3
3	4-Lane	319.7	12.6
4	6- Lane and More	185.8	7.3
	Divided	567.3	22.4
	Undivided	1970.0	77.6
Total		**2537.4**	**100.0**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Service Roads

It is observed from Table 3.6 that merely 5% of the road network has service lanes and rest of the network is without service lane. Thus it may be safely concluded that almost all of the primary roads in the city do not have a service road which affects their capacity adversely due to intervention from the activities on the roadside.

Table 3.6: Distribution of Road Length by Availability of Service Road

Service Road	Road Length (in km)	Percentage (%)
Present	117.6	4.6
Absent	2419.8	95.4
Total	**2537.4**	**100.0**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Key findings of the Road Inventory are as following:

- Only 22% of the road network has 4 lanes or more, however when effective width available is considered, the length is very less
- Ring Road network is weak or discontinuous at many locations.
- Parking interference has been observed at many locations in almost all major roads resulting in to reduced effective width available for traffic movement
- Bus bays are not provided on most of the major Roads

Footpaths

Footpaths are available along about 47% of the road length as presented in Table 3.7. More than half of the road network is without footpaths.

Table 3.7: Distribution of Road Length by Availability of Footpath

Footpath	Road length (km)	Percentage (%)
Present	1183.7	46.7
One-side	41.1	1.6
Both-side	1142.6	45.0
Absent	1353.6	53.3

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

While almost 50% of the road network has foot path on one side or both sides, utility is limited to much lesser length due to encroachment by shopkeepers and parking, unevenness, damaged footpath etc.

3.1.4.4 Outer Cordon Road Side Interview

Classified traffic volume counts along with the road side interview have been carried out to assess the quantum of travel across the cordon. Origin-Destination/Road side interview survey was conducted at 13 locations to capture travel patterns. **Table 3.8** presents the Passenger Traffic at outer cordon locations.

Table 3.8 Passenger Traffic at Outer Cordon Locations

Sl. No.	OD Code	Location	Peak Hour		24-HourVolume	
			Vehicles	PCUs	Vehicles	PCUs
1	OD1	NH-7(Bangalore-Hyderabad Road)	3036	3141	53609	58618
2	OD2	SH-9(Doddaballapur Rd)	1046	1121	17926	24420
3	OD3	Hesaragatta Main Road	219	189	3839	3589
4	OD4	NH-4(Tumkur Road)	1750	2821	37680	61325
5	OD5	Magadi Road	2150	1930	41221	41276
6	OD6	Mysore Road	1917	2347	33937	45525
7	OD7	Kanakapura Road	1370	1385	22695	24676
8	OD8	Banneraghatta Main Road	685	702	11304	12037
9	OD9	NH-7(Hosur Road)	3733	4418	71374	97339
10	OD10	SH-35(Sarjapur Main Rd)	1252	1393	19094	21538
11	OD11	Channasandra Main Rd	710	875	9022	11281
12	OD12	Thanisandra Main Road	834	1174	15182	21969
13	OD13	NH-4(Old Madras Road)	1774	2719	58611	76626

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

As can be seen from the table above, the major traffic enters the city through NH7 (Hosur Road). The share of cars varies between 16% and 75% for the different locations and two wheelers vary from 8% to 59%. The percentage of trucks/ multi axle vehicles varies from 6% to 29% at various locations. Tumkur Road (NH4) has the highest percentage of goods vehicles at 29%.

The percentage share of Passenger and Goods traffic at the surveyed locations are 83 % and 17 % respectively and location wise Passenger/ Goods Traffic share for 24-hour volume and peak hour volume is presented in **Table 3.9.**

Table 3.9 Share of Passenger and Goods traffic at Outer Cordon Locations

Code	Location	24 Hour Volume				Peak Hour Volume			
		Passenger Vehicles	Goods Vehicles	Passenger (%)	Goods (%)	Passenger Vehicles	Goods Vehicles	Passenger (%)	Goods (%)
OD1	NH-7 Bangalore-Hyderabad Road)	50929	3216	94%	6%	2914	91	97%	3%
OD2	SH-9 (Doddaballapur Rd)	14342	3406	81%	19%	941	84	92%	8%
OD3	Hesaragatta Main Road	3416	230	94%	6%	208	6	97%	3%
OD4	NH-4 (Tumkur Road)	26753	10927	71%	29%	1278	525	71%	29%
OD5	Magadi Road	36275	5358	87%	13%	2043	130	94%	6%
OD6	Mysore Road	27489	6447	81%	19%	1687	231	88%	12%
OD7	Kanakapura Road	19518	3178	86%	14%	1179	192	86%	14%
OD8	Banneraghatta Main Road	9269	2147	81%	19%	528	151	78%	22%
OD9	NH-7 (Hosur Road)	54957	16417	77%	23%	3099	634	83%	17%
OD10	SH-35 (Sarjapur Main Rd)	16422	2483	87%	13%	1077	176	86%	14%
OD11	Channasandra Main Rd	7218	1713	81%	19%	625	78	89%	11%
OD12	Thanisandra Main Road	11084	4251	72%	28%	584	249	70%	30%
OD13	NH-4 (Old Madras Road)	48647	9377	84%	16%	1295	461	74%	26%
Total		**326319**	**69150**	**83%**	**17%**	**17458**	**3008**	**85%**	**15%**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

The inbound and outbound Goods Traffic volume at surveyed locations has been observed are 30,209 and 34,773 respectively. The detail table showing inbound and out bound traffic volume with types of commercial vehicles are presented in **Table 3.10** and **Table 3.11**.

Table 3.10 Daily Goods Traffic volume coming in to Bengaluru

Location Code	Location	Direction	LCV	Truck	MAV	TOTAL
OD1	NH-7(Bangalore-	In Bound	733	348	192	1273
OD2	SH-9 (Doddaballapur Rd)	In Bound	724	822	250	1796
OD3	Hesaragatta Main Road	In Bound	32	9	1	124
OD4	NH-4 (Tumkur Road)	In Bound	813	2891	782	4486
OD5	Magadi Road	In Bound	1316	1095	396	2807
OD6	Mysore Road	In Bound	545	1827	221	2593
OD7	Kanakapura Road	In Bound	481	877	140	1498
OD8	Banneraghatta Main Road	In Bound	426	402	42	870
OD9	NH-7(Hosur Road)	In Bound	2117	4264	1260	7641
OD10	SH-35(Sarjapur Main Rd)	In Bound	311	642	197	1150
OD11	Channasandra Main Rd	In Bound	77	172	9	258

Location Code	Location	Direction	LCV	Truck	MAV	TOTAL
OD12	Thanisandra Main Road	In Bound	92	515	122	729
OD13	NH-4(Old Madras Road)	In Bound	783	3794	407	4984
Total		**In Bound**	**8450**	**17740**	**4019**	**30,209**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Table 3.11 Daily Goods Traffic Volume going from Bengaluru

Location Code	Location	Direction	LCV	Truck	MAV	TOTAL
OD1	NH-7(Bengaluru-Hyderabad	Out Bound	687	593	181	1461
OD2	SH-9 (Doddaballapur Rd)	Out Bound	711	850	183	1744
OD3	Hesaragatta Main Road	Out Bound	20	94	3	117
OD4	NH-4TumkurRoad	Out Bound	392	4749	1336	6477
OD5	Magadi Road	Out Bound	990	769	240	1999
OD6	Mysore Road	Out Bound	883	2136	361	3380
OD7	Kanakapura Road	Out Bound	569	743	36	1348
OD8	Banneraghatta Main Road	Out Bound	654	390	50	1094
OD9	NH-7(Hosur Road)	Out Bound	1749	5129	1315	8193
OD10	SH-35(Sarjapur Main Rd)	Out Bound	263	441	106	810
OD11	Channasandra Main Rd	Out Bound	414	735	105	1254
OD12	Thanisandra Main Road	Out Bound	390	1730	384	2504
OD13	NH-4(Old Madras Road)	Out Bound	804	3217	371	4392
	Total	**Out Bound**	**8526**	**21576**	**4671**	**34773**

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Table 3.12 Summary of Good traffic movement

	Total Number of Goods vehicles per day	Percentage (%)
External To Internal (Inbound)	2	44%
Internal to External(Out Bound)	2	36%
External To External (By passable	1	20%
Total	**6**	

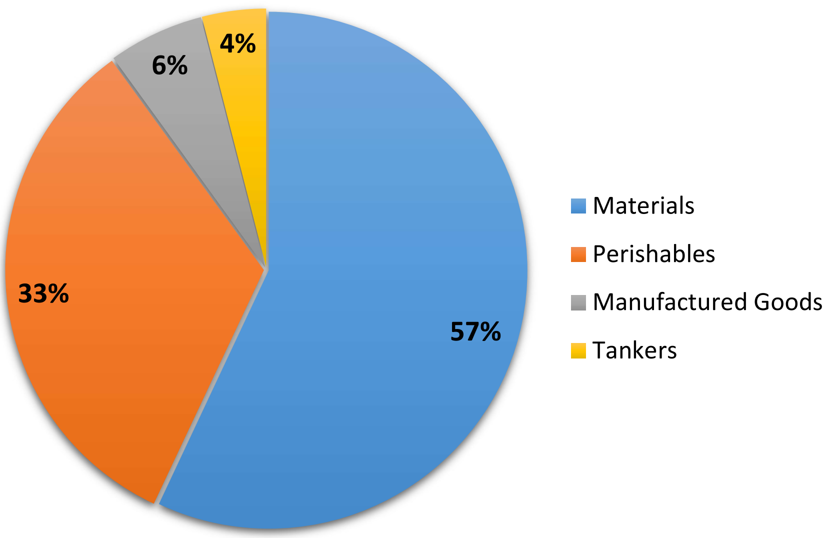
Source: Comprehensive Mobility Plan for Bengaluru (Draft)

The total goods movement observed from the outer cordon survey was 64981 out of which 44% is the inbound traffic (External to Internal movement) and 36% is out bound goods movement (Internal to External) and rest of 20% is the by passable traffic., as presented in Table 3.12, that explains almost 12000 goods movement is just through traffic, which gives the clear indication that the city requires more logistic hubs outside the city limits.

Type of Goods

The majority of the goods that the commercial vehicles carried in the study area include Industrial materials, manufactured goods, Perishables (food grains, diary product and vegetables) and Tankers as shown in **Figure 3.3**. It has been observed that maximum amount of Industrial Material carried by commercial vehicle from (OD 4) NH4 Tumkur Road followed by (OD7) Kanakpura Road and (OD 9) Hosur Road. Perishable (Food Grains/ vegetables are carried by commercial vehicles from OD 13 Old Madras Road and OD 6 Mysore Road).

Figure 3.3 Types of Goods at outer cordon points

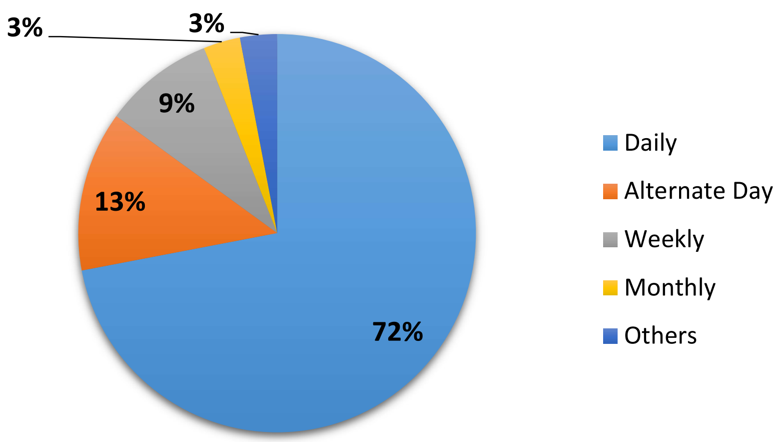


Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Trip Frequency-Passenger Vehicles

Daily trips formed majority of the trips at the outer cordons, followed by Alternate and weekly trips. The trip frequency for all locations is presented in **Figure 3.4.**

Figure 3.4 Trip frequency- Passenger Vehicle at Outer Cordon Location

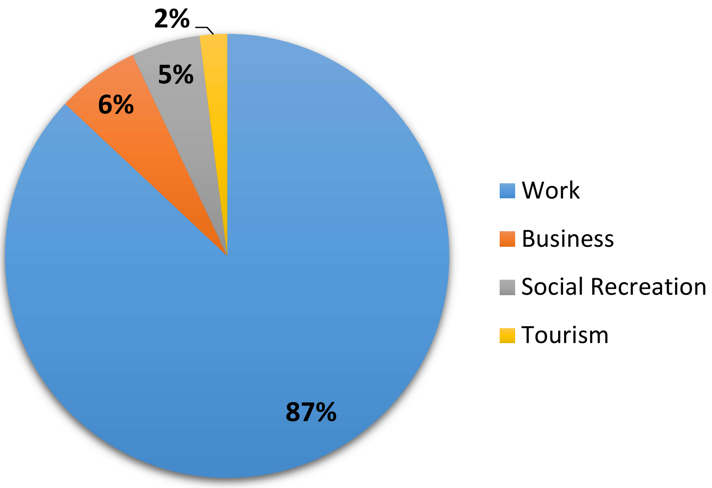


Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Trip Purpose Passenger Vehicle

Analyses on purpose of journey revealed that majority of the trips are work trips as shown in Figure 3.5. Most of work trips are originating from (OD 4) NH4 Tumkur Road, (OD 9) Hosur Road and (OD 11) Channasandara Road. Predominant business trip has been observed from (OD 12) Thanisandara Main Road, (OD 8) Bannerghatta Main Road and (OD 1) Bengaluru Hyderabad Road.

Figure 3.5 Trip purpose- passenger vehicle at outer cordon



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

3.1.4.5 Willingness to Pay/Use Survey

Household opinion survey was carried out to obtain preference of commuters about shifting to good public transport system. The respondents were asked their willingness to pay extra fare and time saving with respect to their existing mode of transport used.

Table 3.13 shows that about 91% of respondent households are willing to shift to a good public transport system where as about 9% of households want to use their existing mode of travel.

Table 3.13 Willingness to Shift to Good Public Transport System

Sl. No.	Response	No of Households (Surveyed)	Percentage (%)
1	Yes	9252	91.0
2	No	915	9.0
Total		**10167**	**100.0**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

Table 3.14 shows about 41% are willing to shift if the saving in travel time is up to 10 min. in comparison with their mode of travel. 42% of respondents show their willingness to shift to new public transport if the time saving is up to 20 min. from their existing mode of travel.

Table 3.14 Acceptable Time Savings to Shift to Good Public Transport System

Sl. No.	Time Saved	No of Respondent Households	Percentage (%)
1	up to 10 min	3835	41.45
2	up to 10 - 20 min	3892	42.07
3	up to 20 - 30 min	1525	16.48
Total		**9252**	**100.0**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

The willingness to pay extra fare for good public transport system is given in **Table 3.15**. The table indicates that about 36% respondents want the same fare for new public transport as existing bus fare and about 60% are showing their willingness to give upto 1.25 times fare for new public transport system in comparison to existing bus fare. 5% People are willing to pay more than double for good public transport system.

Table 3.15 Willingness to Pay Extra Fare in Relation to Existing Bus Fare

Sl. No	Extra Fare	No of Respondent Households	Percentage (%)
1	Same Fare	3281	35.46
2	1.25 Times	4116	44.49
3	1.5 Times	1425	15.40
4	2 Times	416	4.50
5	2.5 Times	14	0.15
Total		**9252**	**100.0**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

3.1.4.6 Bus Stop Waiting, Boarding and Alighting Survey

The bus stop passenger survey is conducted at 472 bus stops along different corridors to ascertain travel characteristics of bus passengers. The survey was administered by counting the number of passengers boarding and alighting along with O-D survey on random sampling basis by interviewing passengers. This survey was conducted at 472 bus stops within the study area for a period of 16 hours. The information included:

- Boarding/Alighting passenger volume count

- Trip purpose, travel time, travel cost etc.
- Travel frequency of passengers

Table 3.16 shows that about 65% of trips are contributed by service and business purpose and about 17% of trips are other purposes.

Table 3.16: Distribution of Bus Stop Passengers by Trip Purpose

S.N	Trip Purpose	Percentage (%)
1	Service	49.1
2	Business	15.7
3	Education	11.8
4	Social	6.0
5	Others	17.4
Total		**100.00**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

It is observed from **Table 3.17** that about 57% of total passengers spend less than 20 minutes to perform their journey.

Table 3.17: Distribution of Passengers by Travel Time

Sl.No	Travel Time (minutes)	Percentage (%)
1	<10	33.9
2	10--20	23.5
3	20-30	10.9
4	30-40	17.4
5	40-50	13.1
6	>50	1.2
Total		**100**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

It is observed from Table 3.18 that about 55% of total passengers spent Rs. 40 and more to perform their journey

Table 3.18: Distribution of Passengers by Travel Cost to reach Bus Stop

Sl.	Travel Cost (Rs)	Percentage (%)
1	<10	-
2	10--20	2.2
3	20--30	18.9
4	30--40	24.3
5	40--50	11.8
6	50--75	27.1
7	>75	15.7
Total		**100**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

3.1.4.7 Bus Occupancy Survey

The Bus occupancy varies from 71.5 to 74.5 and average occupancy is 71.5.is presented in **Table 3.19**.

Table 3.19: Bus Occupancy Survey

Location No.	Screen Line Locations	Occupancy Ratio (%)
SL_01	Mysore Road (Near-Vijaya Bank)	72.5
SL_02	Bangalore University Road_ROB	72.5
SL_03	Chord Road (Near Hampi Nagar ROB)	72.5
SL_04	Hosahahali Road (ROB)	72.5
SL_05	Tank Bund Road (Near Binny Mill) RUB	74.5
SL_06	Dhanvantri Road RUB	71.5
SL_07	S.C. Road (Near Central Electricity Authority)	71.5
SL_08	Hare Krishna Road RUB_(Near Nehru Circle)	74.5
SL_09	Sankey Road RUB (Near Windor Manohar Hotel)	71.5
SL_10	Palace Cross Road RUB (Near Maharaja Palace)	71.5
SL_11A	Jayamahal Road RUB (Near Cantt. Rly Stn)	71.5
SL_11B	Jayamahal Road RUB (Near Cantt. Rly Stn)	71.5
SL_12	Basayeshwara Main Road_RUB	71.5
SL_13	Mosque Road ROB (Near Hazisiri Ismail Sait	71.5
SL_14	Wheelers Road (ROB)	71.5
SL_15	ORR KR Puram Bridge	74.5
SL_16	K.R. Puram Bridge	74.5
SL_17	ORR Near Yashwantpur Rly Xing	71.5
SL_18	YaswantpurTumkur Road	71.5
SL_19	Mahakaviluvempu Road (Near Malleshwaram)	71.5
SL_20	Old Mysore Road RUB	72.5

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

3.1.4.8 Mode-wise Occupancy Survey at Screen lines

The average occupancy of various modes is presented in **Table 3.20.** Bus occupancy varies from 36 to 39 and average occupancy is 37.5. Average occupancy for cars, two wheelers and auto rickshaws is about 2.3, 1.5 and 1.8 respectively. The mini buses have an average occupancy of about 15.

Table 3.20: Occupancy of Fast Moving Passenger Vehicles at Screen Line Locations

Sl. No.	Survey Location Name	Average Daily Occupancy						
		Car	Jeep/ Van	Taxi	2-Whlr.	Auto	Bus	Mini Bus
SL_01	Mysore Road (Near-Vijaya Bank)	2.2	3.2	3.2	1.5	1.7	37.9	13.9
SL_02	Bangalore University Road_ROB	2.1	3.0	3.1	1.4	2.0	37.4	14.5
SL_03	Chord Road (Near Hampi Nagar ROB)	2.2	2.8	3.0	1.4	1.8	37.4	13.6

Sl. No.	Survey Location Name	Average Daily Occupancy						
		Car	Jeep/ Van	Taxi	2-Whlr.	Auto	Bus	Mini Bus
SL_04	Hosahahali Road (ROB)	2.1	3.0	3.2	1.5	1.9	37.4	14.0
SL_05	Tank Bund Road (Near Binny Mill) RUB	2.1	3.1	3.1	1.3	1.6	36.7	14.3
SL_06	Dhanvantri Road RUB	2.1	3.2	3.2	1.4	1.6	36.7	15.3
SL_07	S.C. Road (Near Central Electricity Authority) ROB	2.2	2.9	3.1	1.5	1.8	37.6	15.3
SL_08	Hare Krishna Road RUB_(Near Nehru Circle)	2.1	3.0	3.2	1.4	1.6	37.3	14.4
SL_09	Sankey Road RUB (Near Windor Manohar Hotel)	2.2	3.0	3.2	1.4	1.7	37.9	13.9
SL_10	Palace Cross Road RUB (Near Maharaja Palace)	2.2	2.9	3.2	1.6	1.8	36.9	15.3
SL_11A	Jayamahal Road RUB (Near Cantt. Rly Stn)	2.2	3.2	3.2	1.5	1.7	37.9	13.9
SL_11B	Jayamahal Road RUB (Near Cantt. Rly Stn)	2.1	3.2	3.1	1.6	2.0	37.7	14.9
SL_12	Basayeshwara Main Road_RUB	2.5	3.6	3.6	1.5	1.9	36.3	13.9
SL_13	Mosque Road ROB (Near Hazisiri Ismail Sait Masjid)	2.6	3.4	3.5	1.4	1.7	38.4	13.6
SL_14	Wheelers Road (ROB)	2.7	3.5	3.7	1.4	1.9	37.8	15.2
SL_15	ORR KR Puram Bridge	2.9	3.9	3.8	1.5	1.9	37.1	17.0
SL_16	K.R. Puram Bridge	2.6	3.7	3.9	1.5	1.8	38.6	14.8
SL_17	ORR Near Yashwantpur Rly Xing	2.7	3.6	3.7	1.4	1.7	39.4	14.9
SL_18	Yaswantpur Tumkur Road	2.5	3.6	3.5	1.5	2.0	37.9	15.1
SL_19	Mahakaviluvempu Road (Near Malleshwaram)	2.6	3.2	3.8	1.5	1.8	36.8	14.4
SL_20	Old Mysore Road RUB	2.7	2.8	3.4	1.5	1.7	37.1	14.6

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bangalore Metro, 2016, by RITES Ltd.

Total daily passenger trips at screen lines are presented in **Table 3.21**. It is observed that the passenger trips at different locations vary from 57630 trips at Jayamahal Road RUB (near Cantt. Rly. Stn) to 549462 Trips at ORR KR Puram Bridge. Locations handling more than 2 lakh trips per day are Mysore Road (near-Vijaya Bank), Dhanvantri Road RUB, Sankey Road RUB (near Windsor Manohar Hotel), ORR KR Puram Bridge, K.R. Puram Bridge, Yashwantpur Tumkur Road, Mahakaviluvempu Road (near Malleshwaram) and Old Mysore Road RUB.

Table 3.21 Daily Passenger Trips (16 Hours) at Screen Line Locations

Sl. No.	Survey Location Name	Daily Passenger Trips								Passenger Trips Modal Split %	
		Car	Car/ Van / Jeep	Taxi	2 W	Auto	Bus	Mini Bus	Total	Bus	Other Light Fast
SL_01	Mysore Road (Near-Vijaya Bank)	11402	7325	4352	24487	3892	99953	5192	**156602**	67.1	32.9
SL_02	Bangalore University Road_ROB	9329	4945	4045	17793	5108	23624	3462	**68306**	39.7	60.3
SL_03	Chord Road (Near Hampi Nagar ROB)	26241	18910	17721	66844	16085	86498	7527	**239827**	39.2	60.8
SL_04	Hosahahali Road (ROB)	21953	6472	5794	31812	28165	33893	2888	**130976**	28.1	71.9
SL_05	Tank Bund Road (Near Binny Mill) RUB	16981	6437	4675	30952	25556	47902	3511	**136014**	37.8	62.2
SL_06	Dhanvantri Road RUB	7734	5202	3838	39714	12472	146864	2035	**217860**	68.3	31.7
SL_07	S.C. Road (Near Central Electricity Authority) ROB	12168	7030	5185	30665	14566	86670	1668	**157951**	55.9	44.1
SL_08	Hare Krishna Road RUB_(Near Nehru Circle)	24042	13576	11554	53825	17974	57837	3074	**181881**	33.5	66.5
SL_09	Sankey Road RUB (Near Windor Manohar Hotel)	53516	29362	26544	60761	12174	107841	8309	**298506**	38.9	61.1
SL_10	Palace Cross Road RUB (Near Maharaja Palace)	11099	4025	3003	11673	5825	39398	2682	**77706**	54.2	45.8
SL_11 A	Jayamahal Road RUB (Near Cantt. Rly Stn)	18159	9059	9477	39017	14723	95988	5576	**191998**	52.9	47.1
SL_11 B	Jayamahal Road RUB (Near Cantt. Rly Stn)	8129	3957	3467	16162	10391	13781	1743	**57630**	26.9	73.1
SL_12	Basayeshwara Main Road_RUB	16492	8601	8907	35145	14350	9414	2228	**95137**	12.2	87.8
SL_13	Mosque Road ROB (Near Hazisiri Ismail	8436	5580	3855	20809	7891	35850	1506	**83926**	44.5	55.5

Sl. No.	Survey Location Name	Daily Passenger Trips								Passenger Trips Modal Split %	
		Car	Car/ Van / Jeep	Taxi	2 W	Auto	Bus	Mini Bus	Total	Bus	Other Light Fast
	Sait Masjid)										
SL_14	Wheelers Road (ROB)	19745	8845	6923	34504	13012	20449	2149	**105627**	21.4	78.6
SL_15	ORR KR Puram Bridge	88839	47432	49091	67492	14128	224152	58327	**549462**	51.4	48.6
SL_16	K.R. Puram Bridge	59755	32565	21321	57510	8705	98926	14619	**293400**	38.7	61.3
SL_17	ORR Near Yashwantpur Rly Xing	27040	12947	11352	21710	4780	48994	4217	**131040**	40.6	59.4
SL_18	Yaswantpur Tumkur Road	46868	35290	30931	48117	22200	119122	8039	**310567**	40.9	59.1
SL_19	Mahakaviluvempu Road (Near Malleshwaram)	31774	15758	15442	64946	32596	124622	8634	**293773**	45.4	54.6
SL_20	Old Mysore Road RUB	35901	17947	19016	45855	27591	151989	4507	**302805**	51.7	48.3

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bengaluru Metro, 2016, by RITES Ltd.

Peak hour fast moving passenger trips at screen line are presented in **Table 3.22** It is observed that the peak hour passenger trips vary from 4003 trips at Jayamahal Road RUB (Near Cantt. Rly Stn) to 51678 trips at ORR KR Puram Bridge. Locations having bus passengers trips more than 10000 in peak hour are Dhanvantri Road RUB, S.C. Road (near Central Electricity Authority) ROB, Sankey Road RUB (near Windor (Manohar Hotel), ORR KR Puram Bridge, YeshwantpurTumkur Road and Old Mysore Road RUB.

Table 3.22 Peak Hour Passenger Trips at Screen Line Locations.

Sl. No	Name of Screen-Line	Peak Hour	Peak Hour Passenger Trips							
			Car	Jeep /Van	Taxi	2-Whlr	Auto	Bus	Mini Bus	Total Trips
1	Mysore Road (Near-Vijaya Bank)	**0900-1000**	1056	362	190	2462	257	7410	364	**12101**
		1800-1900	650	470	270	2936	295	9472	574	**14667**
2	Bangalore University	**1000-1100**	1033	278	435	2608	393	2226	256	**7229**

Sl. No	Name of Screen-Line	Peak Hour	Peak Hour Passenger Trips							
			Car	Jeep /Van	Taxi	2-Whlr	Auto	Bus	Mini Bus	Total Trips
	Road_ROB	**1800-1900**	743	496	279	1312	247	2800	714	**6590**
3	Chord Road (Near Hampi Nagar ROB)	**1100-1200**	2294	1042	1841	7864	984	7770	336	**22131**
		1800-1900	2369	2152	1543	4320	1287	9120	948	**21738**
4	Hosahahali Road (ROB)	**1000-1100**	1714	555	371	2428	3646	3080	132	**11925**
		1700-1800	1583	490	414	2502	3066	2478	204	**10738**
5	Tank Bund Road (Near Binny Mill) RUB	**0900-1000**	1507	493	362	2666	3299	3880	285	**12491**
		1700-1800	1382	480	358	3167	2810	4242	238	**12677**
6	Dhanvantri Road RUB	**1100-1200**	488	326	350	4122	927	13520	48	**19781**
		1800-1900	909	563	476	4174	1503	10296	320	**18241**
7	S.C. Road (Near Central Electricity Authority) ROB	**1100-1200**	905	666	513	4413	1307	11718	256	**19778**
		1800-1900	1111	822	735	2395	934	7410	64	**13471**
8	Hare Krishna Road RUB_(Near Neru Circle)	**1000-1100**	2633	1111	1208	5155	1422	4494	224	**16246**
		1800-1900	2438	1431	1218	5265	1810	5040	336	**17540**
9	Sankey Road RUB (Near Windor Manohar Hotel)	**1000-1100**	6036	4155	3290	6696	958	12120	696	**33950**
		1800-1900	8203	2979	2910	6627	1181	10881	1316	**34099**
10	Place Cross Road RUB (Near Maharaja Place)	**0900-1000**	860	343	205	780	408	4368	225	**7189**
		1800-1900	1002	192	149	1151	400	3939	238	**7070**
11A	Jayamahal Road RUB (NearCantt. Rly Stn)	**1000-1100**	1562	606	525	2801	1382	6880	324	**14079**
		1800-1900	1258	784	589	3753	1143	7600	559	**15686**
11B	Jayamahal Road RUB (NearCantt. Rly Stn)	**1000-1100**	982	476	459	2142	907	1080	160	**6206**
		1700-1800	540	294	249	964	781	1040	136	**4003**
12	Basayeshwara Main Road_RUB	**1200-1300**	1202	662	713	2973	1336	210	108	**7204**
		1800-1900	1817	897	1000	4157	1609	840	230	**10550**
13	Mosque Road ROB (Near Hazisiri Ismail Sait Masjid)	**1000-1100**	506	449	333	1399	835	3906	128	**7556**
		1800-1900	1462	677	449	1872	600	2480	98	**7638**
14	Wheelers Road (ROB)	**1000-1100**	2381	1025	738	2393	990	1428	112	**9066**
		1800-1900	2381	844	595	3284	1281	1800	198	**10382**
15	ORR KR Puram Bridge	**1100-1200**	9835	4545	4416	6345	716	21880	2652	**50389**
		1700-1800	5923	3620	5630	7340	1348	19874	7942	**51678**
16	On K.R. Puram Bridge	**0800-0900**	4363	3087	1581	5584	624	5676	672	**21587**

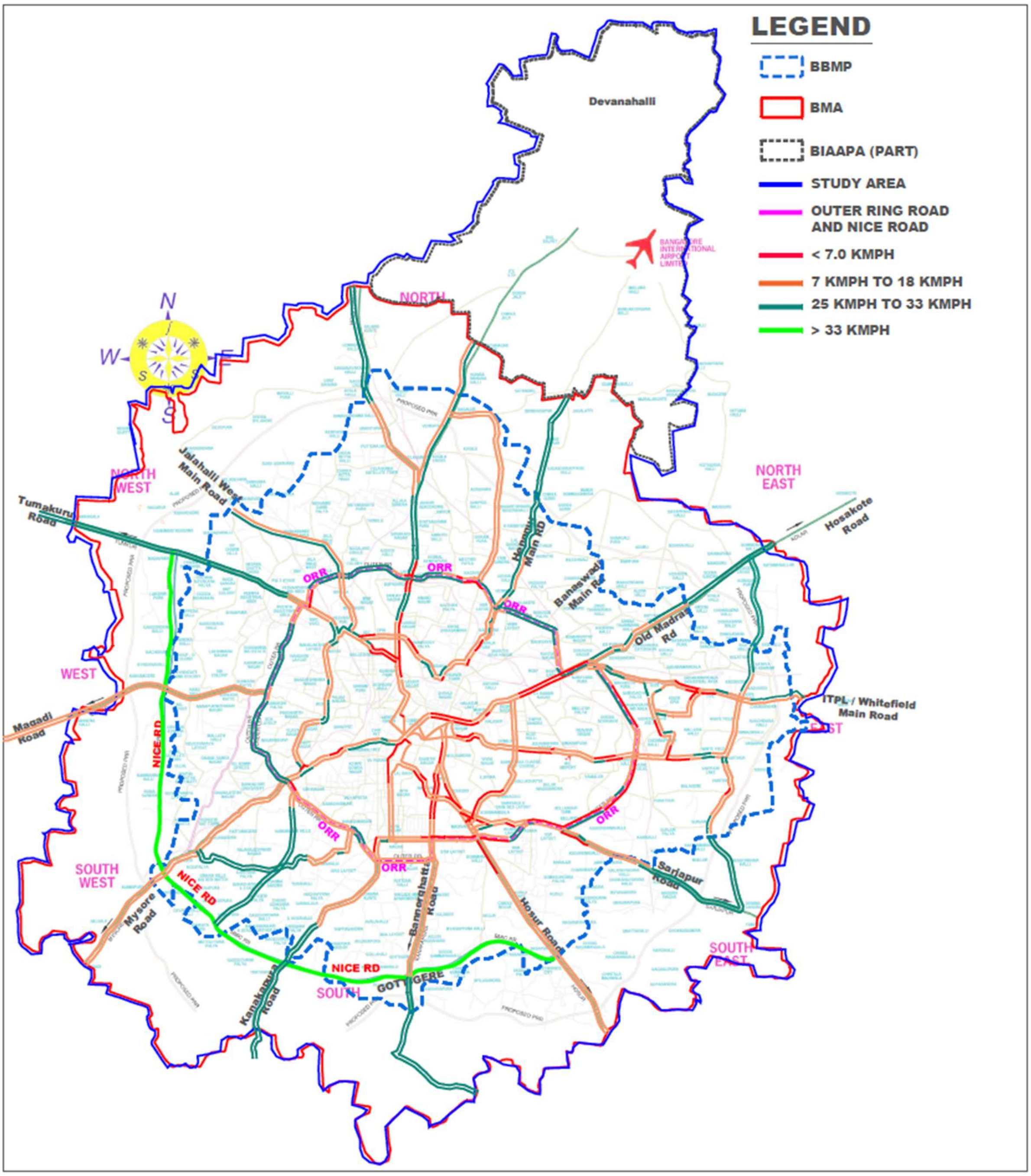
Sl. No	Name of Screen-Line	Peak Hour	Peak Hour Passenger Trips							
			Car	Jeep /Van	Taxi	2-Whlr	Auto	Bus	Mini Bus	Total Trips
		1900-2000	7028	3887	2760	4270	1046	8600	1554	**29145**
17	ORR Near Yashwantpur Rly Xing	**1000-1100**	4045	1625	743	2215	449	4186	416	**13680**
		1800-1900	2669	1656	1722	1972	223	3690	576	**12508**
18	YaswantpurTumkur Road	**1000-1100**	4094	3373	3007	6204	2495	11676	684	**31532**
		1800-1900	6060	3575	2625	5288	1705	10374	1148	**30775**
19	Mahakaviluvempu Road (Near Malleshwaram)	**1000-1100**	2458	1304	1287	4943	4479	7098	350	**21918**
		1800-1900	3528	1836	2392	5697	2904	13692	780	**30829**
20	Old Mysore Road RUB	**1000-1100**	4162	1358	2003	4472	2490	12512	192	**27189**
		1900-2000	3133	1529	1919	4049	2581	15276	448	**28934**

Source: Traffic Demand Forecast and Identification of Phase – III Corridors of Bengaluru Metro, 2016, by RITES Ltd.

3.1.4.9 Speed and Delay Survey

Floating car survey (Speed and Delay Survey) was carried out on major arterial roads. It is observed that the speeds in the city road network during peak hours are less than 11 kmph. Figure 3.6 presents the average journey speed on Primary Arterial Roads.

Figure 3.6 Average Journey Speed on Primary Arterial Roads during Peak Hour



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

3.1.4.9.1 Parking Survey

On Street parking survey

Organized market places are very limited in the city. Most of the major roads and streets have witnessed mixed landuse. This situation with no off-street parking spaces available (except for large shopping malls) resulted in part of streets turning to parking lots. This on-street parking is affecting the mobility with reduced road space available for the movement of traffic and the maneuvers of parked vehicles obstructs traffic flow often leading to congestion. There are large number of roads are marred with on-street parking. Surveys are carried out in some of the areas covering major streets/roads where on-street parking is observed.

Location- A

Most of the commercial/ shopping complexes in this location do not have required parking facilities to meet the parking demand of the visitors. It was observed that the road users parked their vehicles on Avenue road, KR market road, SJP road and S.P road. The central business district part of Bangalore, comprising Gandhinagar, Avenue Road, Chickpet, B.V.K. Iyengar Road and surrounding areas, records the highest number of business transactions but lacks adequate parking space. Two wheelers form the major component of the parked vehicles with a share of 82% followed by car 7%. From the surveys, it has been observed that the average duration of parking is found to be one hour. On street parking has reduced the capacity of roads by about 18% to 48%. High parking demand is observed on AS Char Street, BVK Iyengar road, Banappa park road, Chickpet main road, Nagarthpet road, RT Street, SJP road, SP road.

The total Parking accumulation in Location-A is 1794.7 PCE and high parking accumulation is observed on SJP road, Chickpet Main Road and BVK Iyengar Road.

Location-B

The area is predominantly a mixed land use with commercial establishments such as several corporate offices, railway station, bus stand and government establishments. Bangalore City Railway station is located across the Kempegowda Bus Station in Bangalore. It is an important hub of the South Western Railway and the Indian Railways.

Two wheelers form the major component of the parked vehicles with a share of 64% followed by car 30%. From the surveys, it has been observed that the average duration of parking is found to be one hour. On street parking has reduced the capacity of roads by about 8% to 60%.

High parking accumulation is observed on Kempegowda Road to Seshadri Road, Kalidasa Marg Road to 5th Main Road and SC road. The total Parking accumulation in Location-B is 365.45 PCE

Location-C

In Location-C, cars form the major component of the parked vehicles with a share of 50% followed by two wheelers 27%. From the surveys, it has been observed that the average duration of parking is found to be two hours. On street parking has reduced the capacity of roads by about 7% to 50%.

High parking accumulation is observed on DevrajUrs road, Link road and Ramchandra road, Race course loop road. The total Parking accumulation in Location-C is 705 PCE.

Location-D

The area is one of the oldest and most prominent areas of Bangalore. It is basically commercial area and the traffic within the zone is moderate since most of the roads are broad. Cars form the major component of the parked vehicles with a share of 45% followed by two wheelers 41%. From the surveys, it has been observed that the average duration of parking is found to be two hours.

High parking accumulation is observed on railway parallel road, race course road, 8th main road, Ali Askar road and Edward road. The total Parking accumulation in Location-D is 2259.20 PCE.

Location-E

The area is an important commercial center of Bangalore. Major traffic generators in this zone are the shopping haven Commercial Street, Russell Market Square, St Mary‟s Church, Shivajinagar Bus Terminal and educational institutions along St. John‟s Church Road. Two wheelers form the major component of the parked vehicles with a share of 65% followed by cars 22%. From the surveys, it has been observed that the average duration of parking is found to be two hours.

High parking accumulation is observed on Anna Swamy Road, Kamraj Road, Osborne Road, Thimmaiah Road, Broadway Road, Seppings Road. The total Parking accumulation in Location-E is 2934.25 PCE.

Location-F

In Location-F, two wheelers form the major component of the parked vehicles with a share of 52% followed by cars 43%. From the surveys, it has been observed that the average duration of parking is found to be two hours.

High parking accumulation is observed on MG road, Brigade road, Castle street, Lavelle road, Residency road, Church street. The total Parking accumulation in Location-F is 1243 PCE.

Location-G

In Location G, two wheelers form the major component of the parked vehicles with a share of 48% followed by car 27%. From the surveys, it has been observed that the average duration of parking is found to be one hour. On street parking has reduced the capacity of roads by about 12% to 55%.

High parking Location-G is observed on Lalbagh road, 2nd main road, Lalbagh fort road, NR road and Albert victor road. The total Parking accumulation in Location-G is 875.5 PCE.

The parking study has been carried out at some selected locations in number is 100 which covered most of the public parking areas in Bangalore City and the location wise summary of total on-Street Parking accumulation is given **Table 3.23**.

Table 3.23: Summary of on-Street Parking Accumulation

Sl.No	Location	Study Areas	Total Parking Accumulation (PCE)
1	A	Avenue road, KR market road, SJP road, S.P Road Kasturba	1794.7
2	B	Kalidasa Marg Road Anand Rao Circle, Dhavanthari Road and SC Road	365.45
3	C	Devraj Urs road, District office Road, Kalidasa Marg Road, Kasturba Road, Palace road, Nrupathuga Road etc.,	705.00
4	D	Race course road, Crescent road, Palace cross road , Millers road Cunningham road 2, Aliaskere road, jasma bhavan	2259.20
5	E	Kensington road, Annaswamy RD, Dickenson Rd, Kamaraj Rd, Veerapillai street, Gangadhar shetty Rd, Osborne Rd,	2934.25
6	F	M G road, Brigade road, Brunton road, Lavelle raod 1, Residency road, Kasturba cross road, Mallya Hospita road	1243.00
7	G	Lalbagh Road, Pampa Maha Kavi Road, Lalbagh Fort Road, NR Road, Albert Victor Road.	875.50

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Technology has also come to rescue for on-street parking management, as witnessed on brigade road, where local shop association have installed parking meters clearly marking car parking slots on the road.

Parking Fee

Parking today in Bengaluru is virtually free on most roads. The parking fee charged on most major roads in the city centre is Rs. 10 per hour. Parking is charged in most Commercial establishments/ office places and is in the range of Rs. 15 to 30 per hour which is much higher than the on-street parking fees.

Reconnaissance of Some Off Street Parking facilities in the Study Area such as Maharaja complex, Janatha Bazaar, Railway Station, Freedom Park, MS Building, Hotel Taj, Shivajinagar Bus Stand, Russel Market, Unity Building and Town Hall was carried and the following table provides the prevailing pricing for parking at these loactions. The facilities are managed by private agencies appointed by Bruhath Bangalore Mahanagara Palike (BBMP).

Table 3.24 Details of Parking fee at some Off-street Parking Areas

Sl.No.	Location	Parking Fee (Rs./hour)	
		Car	TW
	Maharaja Complex	10	3
1	Hazarath Hamid Shah	10	5
2	Janatha Bazaar	10	5
	Opposite to SukhSagar Mall	10	5
	Railway Station front side	10	3
3	M S Building	10	3
4	Cantonment railway station	10	5
	Shivajinagar bus stand	15	10
	Russel market	20	10
	Taj hotel Shivajinagar	10	5
5	Utility Building	20	10
	Shantinagar bus stand	10	5
6	Unity building	10	5

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

3.2 SOCIO-ECONOMIC CHARACTERISTICS

Household Interview Survey was carried out on a sample basis as part of the study to get the information spread over the study area. A total of 10167 households have been drawn from all the traffic zones by random sampling method. Stratification of the sample was done to cover various income groups.

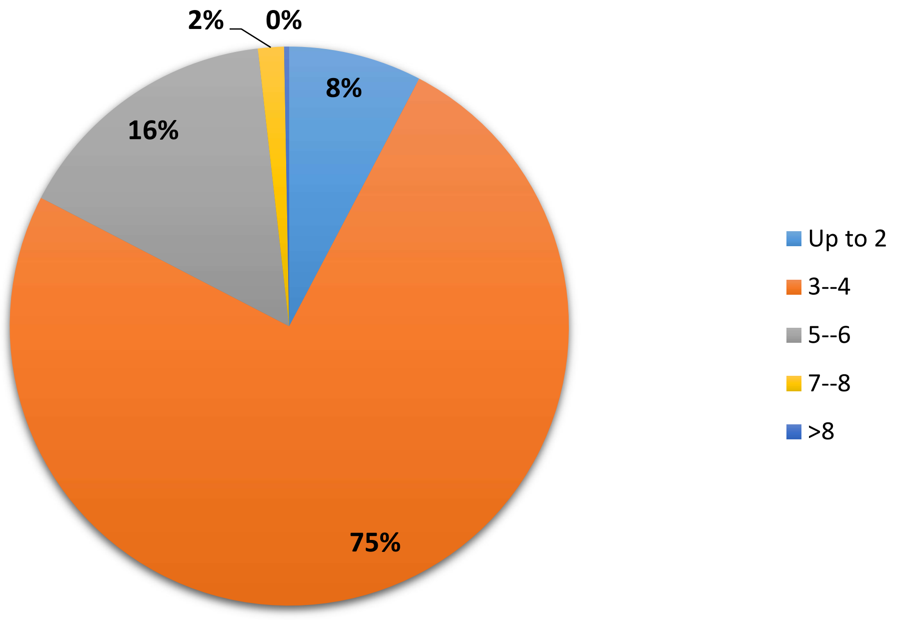
The survey format covered the socio-economic profile of the household providing details like household size, education levels, income, vehicle ownership etc. The individual trip information of the members of the household, which provides the details of the trips performed on the previous day, by the household members has also been collected.

The following outputs were derived from the analysis of the household survey.

Distribution of Household by Size

Distribution of households according to its family size is presented in Figure 3.7. The figure indicates that about 8% of the households have up to 2 members and about 16% of the households belong to the category of households which have 5-6 persons per household. Majority of households (75%) have between 3 to 4 persons per households. The average household size is 3.7 which is less than the average household size in similar sized cities in India.

Figure 3.7: Distributions of Households According to Size



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

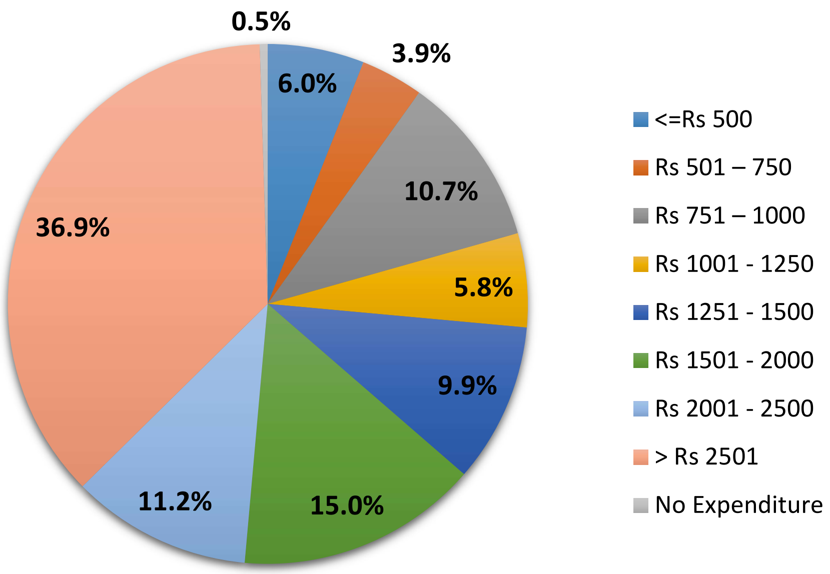
Household Income and Expenditure

It is observed that about nearly 21% of households have monthly income less or equal to Rs. 15000 and another 28% have income between Rs. 15001 – 25,000 per month. The percentage of household having monthly income more than Rs. 25,000 was observed about 51%. Average household income per month in the study area was observed to be Rs. 32374/-

Distribution of Households by Average Monthly Expenditure on Transport

The distribution of the households according to monthly expenditure on Transport is given in Figure 3.8. The figure indicates that about 21% of households spend less than or equal to Rs. 1000 per month on transport and nearly 26% have monthly expenditure on transport ranging between Rs. 1501 – 2500. Over 37% of households are having more than Rs. 2500 expenditure per month on transport. Average expenditure on transport per household is estimated as Rs 2473 per month, which is about 7.6% of average household income.

Figure 3.8: Distributions of Households According to Average Monthly Expenditure on Transport



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

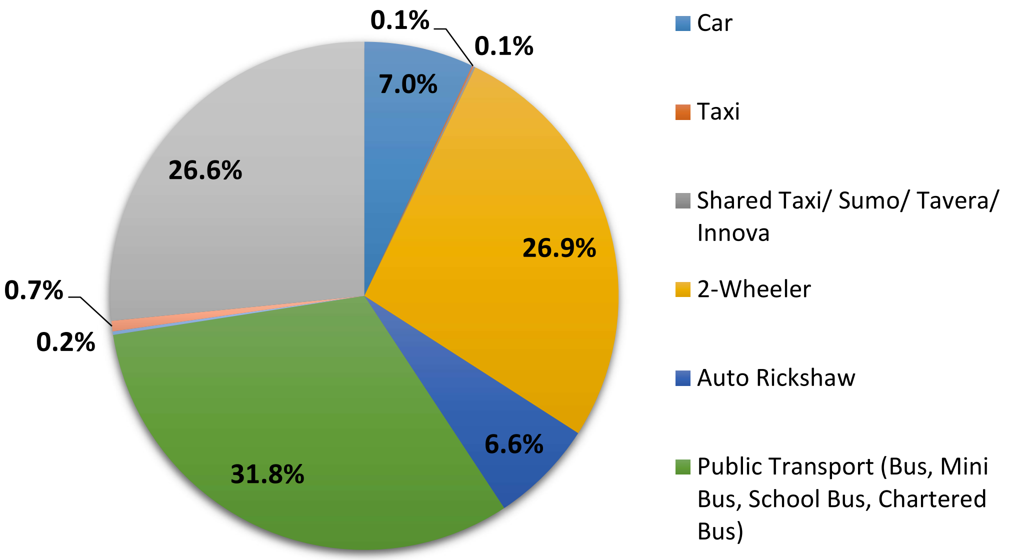
Modal Share

Distribution of trips according to mode of travel is presented in Figure 3.9. It is observed that about 26% of the trips are walk trips. However, the trips performed by 2 wheelers are about 27% and 32% trips are performed by public transport modes including bus, minibus, school bus chartered bus and metro. The trips performed by auto rickshaw are about 7%. Whereas trips performed by cars/taxi/shared taxis/sumo are about 7%. Per capita trip rate including walk is 1.24, excluding walk is 0.92 and for motorised trips is 0.91.

Table 3.25: Mode Share (including NMT trips)

Sl. No.	Mode	(%)age
1	Car	7.0%
2	Taxi	0.1%
3	Shared Taxi/ Sumo/ Tavera/ Innova	0.1%
4	2-Wheeler	26.9%
5	Auto Rickshaw	6.6%
6	Public Transport (Bus, Mini Bus, School Bus, Chartered Bus)	31.8%
7	Metro	0.2%
8	Cycle	0.7%
9	Walk	26.6%
Total		**100.0%**

Figure 3.9: Modal Split - 2015 (Including NMT Trips)

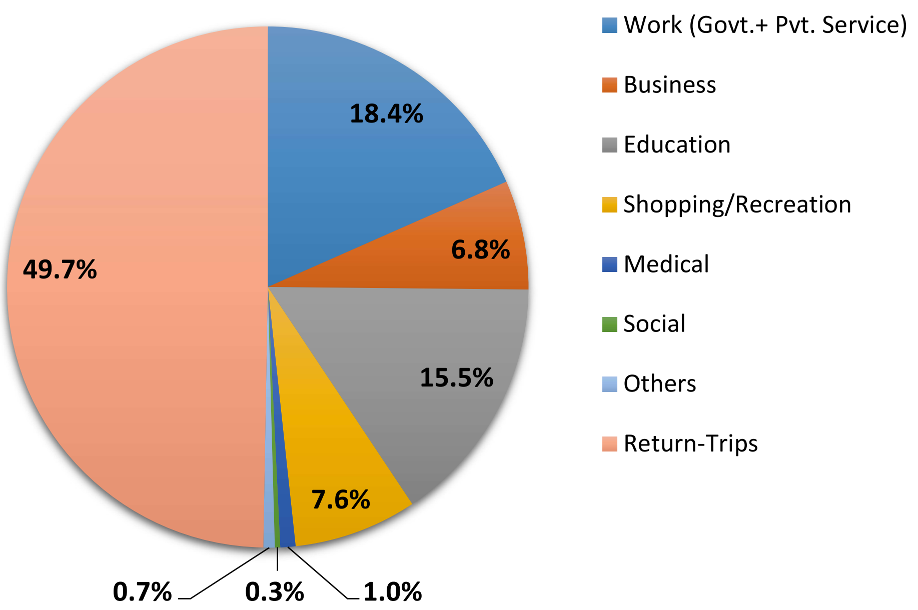


Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Purpose wise Distribution of Trips

The Figure 3.10 gives the purpose wise distribution of the trips. It is observed that about 25% of the trips are performed for work and business purpose together, where as 15% trips are education and about 10% trips which includes shopping, social, health and recreation. About 50% trips are return trips.

Figure 3.10: Purpose wise Distribution of Trips



Source: Comprehensive Mobility Plan for Bengaluru (Draft)

Mode wise Distribution of Trips by Trip Length

Average trip length by mode of travel is presented in Table 3.26. Average trip length for walk is 1.0 Km, for 2-wheeler 8.0 km, for car and taxi is 12.8 km and 13.1 km respectively and for Bus it is about 10.7 km.

Table 3.26: Mode wise Average Trip Length

Sl. No.	Mode	Average Trip Length (Km)
1	Car	12.8
2	Taxi	13.1
3	Shared Taxi	15.4
4	2- Wheelers	8.0
5	Auto	3.7
6	Bus	10.7
7	Mini Bus	10.7
8	School Bus	5.1
9	Chartered Bus	15.1
10	Cycle	2.6
11	Walk	1.0

Source: Comprehensive Mobility Plan for Bengaluru (Draft)

The City sprawl has resulted in increasing average trip length significantly.

3.3 TRAVEL DEMAND ANALYSIS

3.3.1 Modelling Approach

An urban transport model to replicate the Bengaluru Metropolitan Area transportation system (roads, congestion delays, transit system, etc.) has been developed with a state-of-the-art software and modelling technology. This model would be used for forecasting, using altered model inputs to reflect future year scenario. By simulating roadway conditions and travel demand on those roadways, deficiencies in the system would be assessed. Potential major future network enhancements such as introduction of an MRTS or land use modifications would be analysed using this tool. The model is planned is at an aggregated level and its efficacy can be established at a planning level.

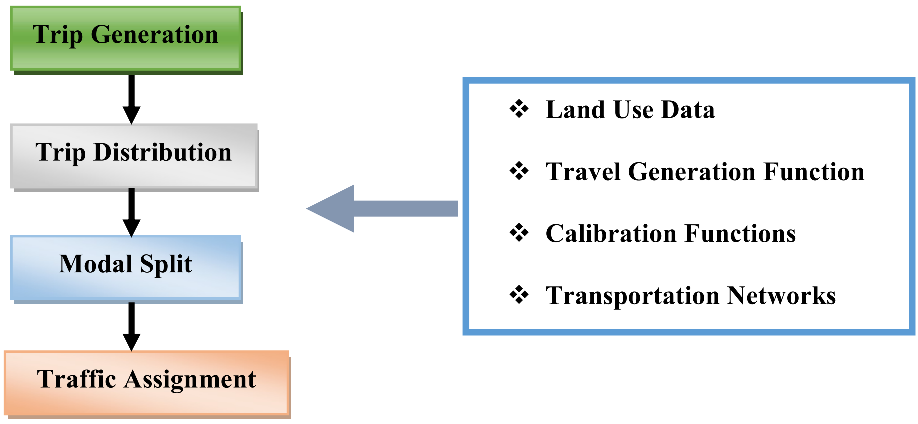
There are several software programs that are available for developing travel demand models. The Bangalore transport modal has been developed using CUBE (a state-of-the-art Travel Demand Modelling Software)

Model Structure

The model is based on a conventional 4-stage transport model approach, which includes:

- **Trip Generation** - calculating the number of origins and destinations for each zone.
- **Trip Distribution** - attaching the origins and destinations for complete trips
- **Mode Choice** - determining the mode for each trip, car, Intermediate Public Transport (IPS, Public transport).
- **Assignment** - assigning passengers to their respective highway and transit networks.

Figure3.11: Four stage modelling approach



Following steps were involved in developing the transport model

Step 1: Development of Traffic Zone System
Step 2: Development of Transport Network
Step 3: Population and Employment Distribution
Step 4: Development of OD Matrices
Step 5: Calibration and validation
Step 6: Base Year Travel Characteristics
Step 7: Forecasting Traffic

Step 1: Development of Traffic Zone System

As mentioned earlier, Transport Model has been prepared for BMR, and traffic zones have been defined based on the following parameters:

a) BBMP Ward Boundaries (for zones within BBMP)
b) Village Boundaries (for zones within BMA, but outside BBMP)
c) Proposed Land uses and Conurbation boundaries within the Local Planning Areas of BMR
d) Interstitial zones (IZs) of BMR,
e) Districts/ State for zones outside BMR

The model has 534 zones, out of which, the study area (including BMR) has been divided in to 519 internal zones. Zones within BMR includes, a) 202 Traffic zones (based on ward boundaries) within BBMP, b) 251 zones (based on village boundaries) covering rest of the area under BMA and balanced BMR area has been divided into 66 outer zones based on the urban conurbation of Local Planning Areas (LPAs). There are 15 external zones.

Step 2: Development of Transport Network

Transport network developed for the model comprises of two components,

- Highway Network for vehicles
- Transit Network for public transport system i.e. Buses, Metro etc;

Each of the networks is described in modes, zoning, network and planning period.

Step 3: Population and Employment Distribution

Using 2011 censes population and with growth rates derived from population growth of various zone from 2001 to 2011, appropriate projection for 2015 population has been computed. Employment for zones has been carefully established by allocating major employment centres to the zone system based on corroborated secondary data. In addition to mapping of employment at major employment centres, data on schools and hospital employment (collected from concerned government departments) and assumption that 30 % workforce (as per Census 2011) would work in the same zone (informal sector) have been considered for estimating employment with BMA. Whereas for BMR, existing workforce participation rate have been considered based on major employment centres.

Step 4: Development of OD Matrices

A series of processes have been used to obtain the base year OD matrices. The base year network along with Transport Model Calibration parameters taken from the earlier studies(CTTS 2008),, and the population employment distribution for 2015 converted into production and attraction trips (using earlier studies trip end equations), was used to synthesize broad level 2015 OD matrices. Mode wise trip matrices so developed were merged with freshly collected Road Side Interview data.

Step 5: Calibration and validation
Observed Validation (Passenger Vehicles)

The observed highway and public transport matrices were assigned on the network, and the assigned traffic volume was compared across screen lines. The model performs well across screen lines within a confidence range of +/-15%. The validation results are given in **Table 3.27**, **Table 3.28** and **Table 3.29** for NSW Screen Line, EW Screen Line, and NSE Screen Line respectively.

Table 3.27 Validation of Passenger Vehicles on North–South-West (NSW) Line

NSW	East Bound(EB)			West Bound(WB)		
Mode	Observed	Assigned	% Difference	Observed	Assigne d	% Difference
Car	10887	10205	6.3%	6030	5822	3.4%
Two Wheeler	12930	11920	7.8%	8649	8574	0.9%
IPT	3447	3641	5.6%	2266	2037	10.1%

Table 3.28 Validation of Passenger Vehicles on East-West (EW) Line

EW	North Bound(NB)			South Bound(SB)		
Mode	Observed	Assigned	% Difference	Observed	Assigned	% Difference
Car	10261	10740	4.7%	10631	12179	14.6%
Two Wheeler	11843	11360	4.1%	12352	14039	13.7%
IPT	3817	4030	5.6%	2890	2812	2.7%

Table 3.29 Validation of Passenger Vehicles on North-South-East (NSE) Line

NSE	East Bound(EB)			West Bound(WB)		
Mode	Observed	Assigned	%Difference	Observed	Assign ed	%Difference
Car	8576	7991	3.4%	7267	6987	3.9%
Two Wheeler`	7452	8519	14.3%	7595	8591	13.1%
IPT	978	972	0.6%	976	952	2.4%

Calibration

Trip end models were developed by relating the trip produced from and attracted to the zones with the Land use. Simple Regression equations have been calibrated. The calibrated trip end models for peak hour are presented **Table 3.30**.

Table 3.30 Generation and Attraction Model

Sub Area	Generation Model	Attraction Model
BBMP	0.0977*Population + 1587.6	0.166*Employment+2368.2
BMA	0.089*Population + 0.34	0.1364*Employment+33.12
BMR	0.0189*Population + 4.34	0.0331*Employment+56.541

Combined Mode choice cum Distribution Model: The trip distribution and model split phase is carried out by the use of a combined mode choice cum distribution function of the form:

Tijm=riGiSjAjFijm

Where,

T= number of inter zonal trips by mode m
G= Total generation trip ends by zone
A= Total attraction trip ends by zone
i= Generation Zone
j= Attraction Zone
r,s = Balancing factors (constants)
Fij= deterrence function for mode m

Fij= Km eβ ijm Ca ijm

Where,

K= Constant Factor
C=Generalized Cost
B= Calibration Constant -Exponential function
a=Calibration Constant- Power function

Double Constraints are imposed by ensuring that ensuring that

$$\sum_{jm} \mathrm{Tij} = \mathrm{Gi} \quad \text{And} \quad \sum_{im} \mathrm{Tij} = \mathrm{Ai}$$

The Calibrated parameters are given in **Table 3.31.**

Table 3.31 Deterrence Functions

Mode	K	α	β
Car	0.45	-0.04	0.012
Two-Wheeler	0.1	0.42	0.03
IPT	0.5	-0.29	0.01
Public Transport	4	-0.24	0.031

3.3.2 Summary of Base Year Travel Demand Pattern

The traffic characteristics of the study area in terms of average network speed, average trip length, volume to capacity ratio, vehicle distance travelled, total passenger hours, and are presented in **Table 3.32**.

Table 3.32: Base Year Travel Characteristics

Sl. No.	Description	Base Year (2015)	
1	**Mode Share**	**Person Trips (peak hour)**	**Percentage**
	a. Car	2,64,649	21%
	b. Two Wheelers	2,96,468	24%
	c. IPT	96,655	8%
	d. Public Transit	6,01,861	48%
	Total Trips	**12,59,633**	
2	**Average Trip Length in KM**		
	a. Car	10.2	
	b. Two Wheelers	9.8	
	c. IPT	3.7	
	d. Public Transit	12.0	
3	**Trip Rate**	0.9	
4	**Averegae Network Speed (kmph)**	12.6	
5	**Total Emissions per day**		
	a. CO2 (tones/day)	29204	
	b. HC (tones/day)	51	
	c. SPM (tones/day)	9	
	d. NOX (tones/day)	323	
	e. CO (toones/day)	198	

3.4 FUTURE TRAVEL DEMAND SCENARIO

The future travel demand would be based on several aspects including, population, and density of population, future growth directions and other planning aspects.

3.4.1 Travel Demand Forecasting

The strategic Urban Travel Demand Model developed as above has been is used to predict travel patterns and modal shares in the horizon year i.e. 2031 under the BAU transport network scenarios.

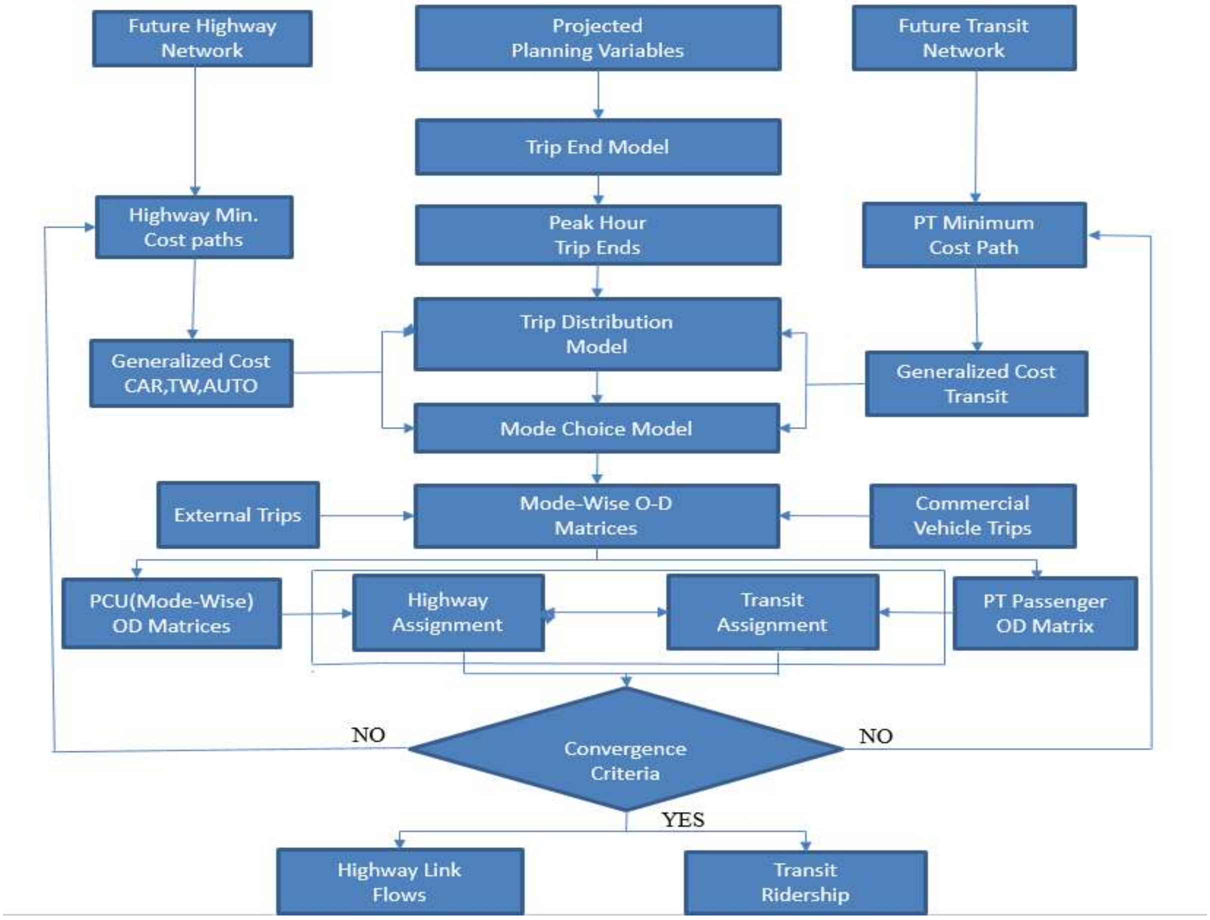
Trip End models have been used to predict the number of trips generated from and attracted to each of the zones in the study area. Projected trip ends along with the network in the future was provided as inputs to the distribution and modal split models to arrive at future trip matrices for Car, Two Wheeler, Intermediate Public Transport and Public Transport. The methodology for travel demand forecast is presented in **Figure 3.12**.

Forecast Assumptions

- Per Capita Trip Rate- will grow at 1 % in real terms
- Public Transport Fare will be in line with inflation
- Value of time will grow in line with per capita income

- Vehicle operating cost will grow at -0.7% in real terms (to take in to account technology improvement in fuel efficiency)

Figure 3.12 Methodology for forecast Model



3.4.2 Horizon Year Land Use Scenario (BAU)

It is estimated that the population forecast would reach around 20.3 million in the BMA and around 10 million would be employed in BMA.

The population projections for BMR have been attempted by considering the following measures by the Revision of Master Plan Team

- Consultants estimates for BMA under the Business-As-Usual Scenario (Component Method of Projection)
- Department of Economics and Statistics projections for different districts, taluks and urban areas in the Karnataka for 2021.
- Considering the average growth of 2001-11(actual) and 2011-21(DES, GoK Projections) to project 2031

Taking into consideration of the above the BMR population by 2031 has been estimated to be about 24 Million with BMA share of 20.3 Million (88.8%).

Spatial allocation of existing employment nodes and expected (known) upcoming employment were mapped approximately. Expected expansion in existing employment nodes were also estimated based on the area available for development or known upcoming projects. The remaining employment was allocated based on upcoming infrastructure. Refer Table 3.33 for forecasted population and employment for 2031.

Table 3.33 Forecasted Population and Employment

Sub Area	Population	Employmnet
BMA	2,03,21,000	93,79,352
BMR	36,35,561	17,31,918
Total	2,39,56,561	1,11,11,270

The decadal population growth in BMA is given in Table below:

Table 3.34: Decadal Population Growth in BMA

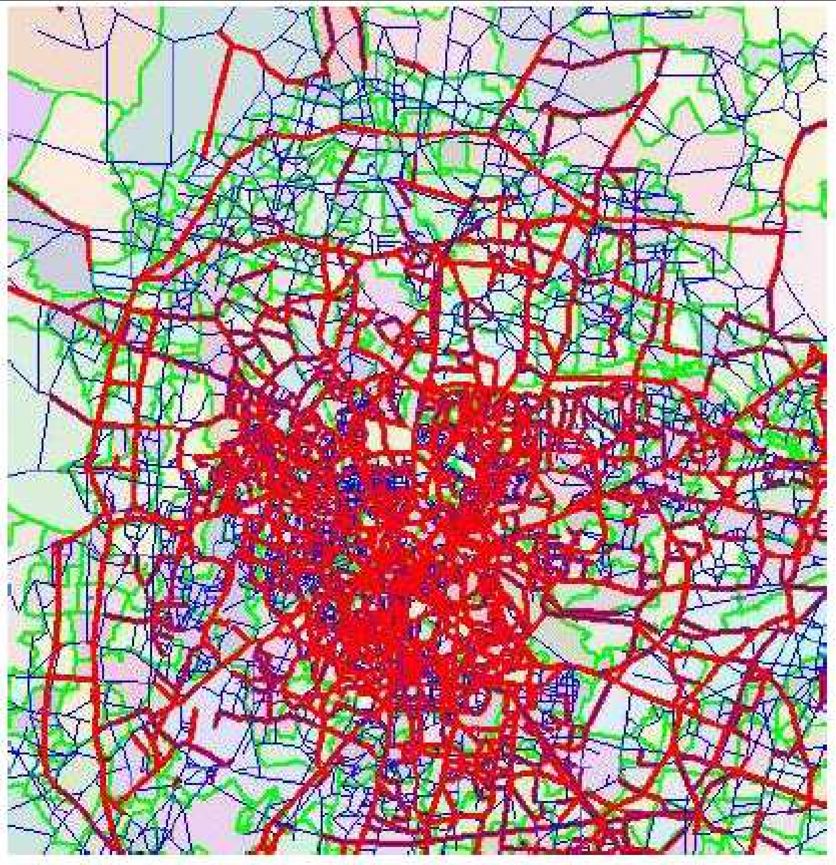
Year	Population Projection (lakhs)	Decadal Growth (%)
1971	20.06	
1981	32.83	63.66
1991	44.93	36.86
2001	62.20	38.44
2011	90.45	45.42
2021	135.51	49.82
2031	203.21	49.96
2041	257.09	26.51

3.4.3 Future Travel Demand Scenarios

The model output indicates that the road network in all major work zones in the city (Whitefield, Peenya and Electronics City), including the city Centre are highly congested and no further growth must be permitted in these areas and immediate efforts to improve the transport network to these areas are needed.

The forecasts flows on links is presented in **Figure 3.13** the volume to capacity ratios is seen to be above 1 on nearly all the links, in other words the hotspots in Bengaluru would be on every links.

Figure 3.13 V/C Ratio on All the Links (BMA) - 2031



Network congestion will also hamper bus operations significantly. It is observed in the model that the frequency will be dropped even when the numbers of buses are doubled (because of congestion). This will have an adverse effect on ridership and revenue for BMTC.

The detailed comparison on travel characteristics between Base Year and Horizon Year is presented in **Table 3.35,** in which BAU scenario, the public transport share would drop down to 36 % from present 48%.

Table 3.35: Forecast Travel Pattern

Sl. No.	Description	Base Year (2015)		Forecast Do-Nothing Year (2031)	
1	**Mode Share**	**Person Trips (peak hour)**	**Percentage**	**Person Trips (peak hour)**	**Percentage**
	a. Car	2,64,649	21%	6,89,673	30%
	b. Two Wheelers	2,96,468	24%	6,66,685	29%
	c. IPT	96,655	8%	1,14,946	5%
	d. Public Transit	6,01,861	48%	8,27,608	36%
	Total Trips	**12,59,633**		**22,98,912**	
2	**Average Trip Length in KM**				

Sl. No.	Description	Base Year (2015)	Forecast Do-Nothing Year (2031)
	a. Car	10.2	16.0
	b. Two Wheelers	9.8	16.8
	c. IPT	3.7	8.4
	d. Public Transit	12.0	13.1
3	**Trip Rate**	0.9	1.1
4	**Averegae Network Speed (kmph)**	12.6	8.4
5	**Total Emissions per day**		
	a. CO2 (tones/day)	29204	69062
	b. HC (tones/day)	51	126
	c. SPM (tones/day)	9	24
	d. NOX (tones/day)	323	768
	e. CO (tones/day)	198	464

3.5 Metro connectivity to KIA-Traffic prospects and Future Scenario of North Bengaluru and area around Bangalore International Airport

Bangalore is now witnessing a new reformation and it has started in North Bangalore region. This region is the focus of attention ever since the operation of the Kempegowda International Airport in the year 2008. It is the fastest growing region in the city and is becoming the next residential and commercial destination. Proximity to the Airport, Availability of Space, Upcoming Tech Parks, Improved Connectivity and Real Estate Development are the major factors of increasing demand in this region. The future prospects of North Bengaluru are discussed below:

3.5.1 Kempegowda International Airport (KIA) and Airport City:

As per the report of Airports Council International (ACI), KIA is the fastest growing airport in the world. KIA catered to 33.30 million passengers in 2018-19, recording a 23.80% year-on-year growth.

KIA Master Plan has been prepared to ensure land allocation for all the aeronautical use, non-aeronautical use, facilities and utilities to achieve the objective of serving 68 MMPA and One Million Tons of cargo by 2030. As per the Master Plan, the development is proposed in 3 phases for the purpose of implementation. The air traffic demand assessed is as in Table 3.36:

Table 3.36: Air Traffic Forecast (MPPA)

Terminal	Phase 1	Phase 2	Phase 3
Year	2025-26	2030-31	2033-34
Terminal 1	20.40	20.40	20.40
Terminal 2	19.60	37.35	47.85

Source: BIAL

Along with the expansion of terminal, airside and other airport facilities, airport's Non Aeronautical Development is planned to be implemented as part of next phases of overall airport development. Broadly, the proposed preliminary development mix envisages 4 separate concepts as described below:

1. **Center of Excellence**: The Center of Excellence is expected to catapult the development into a knowledge based hub with a focus on the aviation industry. Proposed thought leadership positioning would strengthen and showcase knowledge base in line with the Bangalore global brand and create a brand for the Airport city.
2. **IT-ITES SEZ**: The proposed IT-ITES SEZ will cater to the IT-ITES SEZ space demand of the occupiers. This is envisaged to provide choice to the occupiers/developers ranging from low-density campus type of development to multi-tenanted flatted development.
3. **Business District**: The Business District is visualized to house the headquarters of the corporate offices. This is envisaged as a high density development integrated with green building and energy-efficiency concept. The development is envisaged as a semi enclosed areas comprising walkways with plazas on ground connecting pedestrian walkway into the Central area.
4. **Central Area**: The Central Area is proposed to house a multi-modal hub and a parking zone. This high flux area will have maximum movement of people and visualized to have varying activities at different levels catering to both commercial activities focusing airport passengers and passenger amenities. This area will essentially have mixed development with transit at ground level and upper levels catering to retail, F&B and transit hotels to maximize revenues. The multi-modal hub is also expected to integrate proposed metro rail, internal and external transportation hubs.

The concept for the overall development is to house the high-end occupiers under aviation, precision engineering & technology sectors and the subsidiary link-up offices.

3.5.2 Connectivity

At present, the primary connectivity to KIA is through the NH-44. Traffic from the city destined to the Airport has to reach this road and then proceed towards the

KIA. NH-44 is a busy highway connecting Bengaluru to Hyderabad. The airport car park is located at ground level and can hold 2,000 vehicles. The airport is served by several taxi and rental car companies. In addition, ride-sharing companies Ola and Uber have their own pick-up zones outside the terminal. The Bangalore Metropolitan Transport Corporation (BMTC) provides bus transportation to major parts of the city through the Vayu Vajra (Kannada for "Diamond in the Air") service. It is operated using a fleet of Volvo B7RLE buses.

As the city expands towards North, the area between the city and the airport is gradually getting populated, resulting in increased traffic leading to congestion on NH-7. In future, as the numbers of travellers to KIA increase along with the general increase in the traffic of the city, NH-44 will get saturated resulting in increased congestion and unacceptable Level of Services (LoS).

Additional transport connectivity to KIA apart from the NH44 is essentially to maintain required level of service in future and to attract more travellers/business to the city, the airport being the gateway to the city. A rail based mass transit system is essential to meet this future demand to/from the airport and at the same time to keep people off the road reducing frequent augmentation of the road infrastructure. Moreover, with the large scale development by KIAL and the resultant major employment generation and entertainment facilities, the metro ridership between Yelahanka and KIAL will significantly increase in the near future

3.5.3 Traffic Demand Estimation

The passenger traffic at the airport would comprise the following;

- Airport Passengers and Meters and Greeters
- Airport Employees
- Airport City side (Sky Garden) Employees
- Airport City side (Sky Garden) visitors / customers

Airport passenger trips include the passenger trips from arrival and departure of flights and the trips made by their meters/greeters. The daily trips estimated for various categories of users of KIA for all the phases of development are shown **in Table 3.37.**

Table 3.37: Daily Trips for Various Phase of Development

Category of Users	Phase 1 (2025-26)	Phase 2 (2030-31)	Phase 3 (2033-34)
Passengers + Meeters/Greeters	1,74,646	2,19,621	2,75,547
Airport Employees	56,000	83,528	91,000
Sky Garden (W) Visitors	1,29,565	2,45,842	2,50,229
Sky Garden (W) Employees	61,493	1,11,641	1,55,505
Sky Garden (E) Visitors	1,076	20,400	37,080
Sky Garden (E) Employees	10,758	30,599	46,759
TOTAL	4,33,538	7,11,631	8,56,120

Source: KIA Report

Earlier section clearly depicts that current road system cannot sustain the traffic expected from the proposed developments in KIA. Metro connectivity to KIA is expected to be implemented by 2031 i.e. in Phase 3 of KIA development. Increased rail patronage is especially predicted for employees, visitors who would be regular travellers. Metro demand for KIA has been assessed, based on assumptions of metro's modal share in similar / comparable scenarios.

The following modal share is assumed in Phase 3 development inclusive of metro mode.

Table 3.38: Modal Share Assumptions with Metro

Modal Share	With Metro				
	Domestic Passenger	International Passenger	Employee	Sky Garden Visitor	Sky Garden Employee
Metro	30%	15%	50%	40%	53%
Car	20%	30%	5%	14%	2%
Taxi	40%	47%	5%	13%	1%
Two Wheeler	0%	0%	15%	14%	18%
Three Wheeler	0%	0%	0%	0%	0%
Bus	10%	8%	25%	18%	25%
Total	100%	100%	100%	100%	100%

Metro connectivity to KIA is expected to be implemented by 2024 at the time of completion of Phase-2B. Phase-3 of metro which is planned from Hebbal to J P Nagar and Magadi road tollgate to Peripheral Ring Road on public private participation basis, will be commissioned in 2031 and this will add up to ridership of Airport metro to a significant extent during that period and subsequently.

3.5.4 KIADB North Bangalore Hi-Tech, Hardware, Aerospace Park

Adjoining the Kempegowda International Airport, KIADB's Hi-Tech, Defence & Aerospace Park is developed in total extent of 2980.00 acres. The Industrial Area is about 9 KMs from NH-7 and it is 31 KMs from Bengaluru City. The Industrial Area is best suited for Aerospace Component Industries, IT Industries, and Defence Industries. At present, there are 60 companies in this area, Major Industries being Amada, Wipro, Tyco, Shell, Theysenkrup, Starrag India, Read-Ink Technologies etc. With metro connectivity, this area will develop further and will become major industrial hub of Bengaluru.

3.5.5 Bettahalasuru Area

Bettahalasuru is a small town in Bangalore Urban district. It is located 25 km from Majestic Bus Terminal and 16 km from Bangalore International Airport. The area is on the NH-7 which connects core city of Bengaluru and International Airport. This area is an important location as it connects to the western underdeveloped area. There are several important existing and committed development such as

- Existing Sri MVIT College with estimated population of 5,000.
- Proposed Embassy Knowledge Park, about 210 acres of high density offices, residential and commercial with estimated population of about 2 lakhs.
- Stonehill International School.
- Embassy International Riding School
- Rajankunte Township.

Thus this area would cater to about 5- 6 lakh population within next 10 years, which could as well swell to over 15-20 lakh population within next 20 years and hence this will add to metro ridership.

3.5.6 Transit Oriented Development (TOD) Policy

The policy envisages the vision of “Bengaluru becoming a public transport oriented city that is compact, people friendly, environment friendly and support economic growth while offering a good quality of life. The goals of the policy are aligned to that of the CMP with the major goals being achievement of 70% share of public transport in motorized trips and 60% of the city population living within intense TOD zone. The policy assesses that the goals may require about 600 km of mass transit corridors and development of adequate infrastructure so as to achieve the gross density ranging from 250 to 400 pph (persons per hectare) along the mass transit corridors by 2031. Beyond Bagalur cross, many real estate projects are in pipe line and will be coming up in future and with present emphasis on TOD oriented development it will give a great fillip to the ridership of Airport metro particularly from Bagalur cross to Airport. The proposed corridor will have huge impact on potential development along the corridor.

Based on above, following factors have been considered for estimation the traffic for Yelahanka to Airport Section

- The passenger traffic at KIA will be 57 million passengers for the year 2030-31. This indicates that daily passenger at KIA will be 1.51 lakhs.
- Bettahalsuru area will cater 5-6 lakh population within next 10 years.
- Population of Bagalur, Trumpet area will be grown (5% for 2031 and 4% for 2041).
- KIADB's Hi-Tech, Hardware, Aerospace Park will generate 1 lakhs employment for the year 2031.

3.6 RIDERSHIP ASSESSMENT FOR HORIZON YEARS

The traffic for Airport Line has been estimated as below **Table 3.39 and 3.40.**

Table 3.39: Daily and Peak Hour Station Boarding for Phase 2B

Stations	Daily 2024		Peak 2024		Daily 2031		Peak 2031		Daily 2041		Peak 2041	
	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight
K R Puram	51,983	54,737	11,691	12,310	89,845	94,604	20,456	19,502	1,16,398	1,22,549	26,498	25,263
Kasturi Nagar	13,794	13,808	3,449	3,452	22,924	22,947	5,731	5,737	29,695	29,726	7,424	7,431
Horamavu	12,790	12,823	3,198	3,206	25,507	25,572	6,377	6,393	33,041	33,125	8,260	8,281
HRBR Layout	14,488	14,690	3,622	3,672	28,893	29,295	7,223	7,324	37,427	37,949	9,357	9,487
Kalyan Nagar	19,777	18,202	4,944	4,551	32,582	31,476	8,145	7,869	42,206	40,885	10,551	10,221
HBR Layout	17,811	17,099	4,453	3,775	40,271	38,661	10,068	9,665	52,166	50,081	13,042	12,520
Nagawara	50,470	51,489	12,618	12,872	77,165	78,723	19,291	19,681	99,959	1,01,976	24,990	25,494
Veeranna Palya	19,535	19,375	4,884	4,344	32,923	32,653	8,231	8,163	42,648	42,298	10,662	10,575
Kempapura	24,013	23,907	6,003	5,727	35,960	35,802	8,990	8,576	46,583	46,377	11,646	11,109
Hebbal	60,987	60,745	15,247	15,186	1,05,406	1,04,988	26,352	26,247	1,36,542	1,36,000	34,135	34,000
Kodigehalli	20,228	20,511	5,057	5,128	51,137	51,853	12,784	12,963	66,243	67,170	16,561	16,793
Jakkur Cross	16,699	16,499	4,175	4,125	40,345	39,862	10,086	9,966	52,263	51,637	13,066	12,909
Yelahanka	30,647	29,138	7,662	7,285	58,526	55,644	14,631	13,911	75,813	72,081	18,953	18,020
Bagalur Cross	8,382	8,540	2,095	2,135	25,145	25,619	6,286	6,405	36,688	37,379	9,172	9,345
Bettahalasuru	8,048	7,551	2,012	1,888	24,145	22,652	6,036	5,663	35,228	33,050	8,807	8,263
Doddajala	5,365	5,774	1,341	1,443	16,096	17,321	4,024	4,330	23,485	25,272	5,871	6,318
Airport City	10,842	10,230	2,711	2,558	32,527	30,691	8,132	7,673	47,458	44,780	11,864	11,195
KIA Terminals	48,113	48,629	6,113	6,171	96,225	97,259	10,392	11,724	1,40,396	1,41,903	15,162	17,106
Total	**4,33,973**	**4,33,747**			**8,35,623**	**8,35,623**			**11,14,240**	**11,14,240**		

Peak Hour Peak Direction Traffic (PHPDT)

The **Table 3.40** shows PHPDT for the proposed corridor.

Table 3.40: PHPDT

Station		PHPDT - 2024			PHPDT - 2031			PHPDT - 2041		
From	To	Forward	Reverse	Maximum	Forward	Reverse	Maximum	Forward	Reverse	Maximum
K R Puram	Kasturi Nagar	11,691	12,310	21,112	20,456	19,502	35,705	26,498	25,263	46,252
Kasturi Nagar	Horamavu	15,606	16,122		20,406	19,413		26,434	25,147	
Horamavu	HRBR Layout	20,270	20,472		26,628	27,685		34,494	35,863	
HRBR Layout	Kalyan Nagar	20,545	20,751		34,332	34,987		44,473	45,322	
Kalyan Nagar	HBR Layout	21,112	20,901		34,782	35,019		45,056	45,363	
HBR Layout	Nagawara	15,792	15,022		35,705	35,273		46,252	45,692	
Nagawara	Veeranna Palya	16,094	14,957		27,001	26,221		34,977	33,966	
Veeranna Palya	Kempapura	16,195	14,922		27,294	26,143		35,356	33,865	
Kempapura	Hebbal	18,425	18,242		27,592	26,100		35,742	33,810	
Hebbal	Kodigehalli	15,001	15,166		32,557	32,235		42,174	41,757	
Kodigehalli	Jakkur Cross	10,218	10,427		25,832	26,916		33,462	34,867	
Jakkur Cross	Yelahanka	9,823	10,114		19,645	20,228		25,448	26,203	
Yelahanka	Bagalur Cross	10,292	10,382		16,467	17,650		24,026	25,751	
Bagalur Cross	Bettahalasuru	9,191	9,460		17,462	17,975		25,478	26,226	
Bettahalasuru	Doddajala	7,505	7,234		14,260	13,744		20,806	20,053	
Doddajala	Airport City	6,613	6,508		12,564	11,063		18,331	16,142	
Airport City	KIA Terminals	6,171	6,113		11,724	10,392		17,106	15,162	

Chapter 4

System and Technology Selection

CHAPTER 4

SYSTEM AND TECHNOLOGY SELECTION

4.1 Selection of Transit Technology

Public Transport System is an efficient user of space and energy, with reduced level of air and noise pollution. As the population of a city grows, share of public transport, road or rail-based, should increase. For a city with population of 12 million, the share of public transport should be about 75% which is at present 51%. The percentage share of public transport should progressively increase with further growth in the city population.

Whether public transport system on a corridor in the city should be road-based or rail-based will depend primarily on the traffic density during peak hours on the corridor. Experience has shown that in mixed traffic conditions, comprising slow and fast moving traffic prevailing in most of our cities, road buses can optimally carry 8,000 persons per hour per direction (PHPDT). When traffic density on a corridor exceeds 8,000 PHPDT, average speed of buses comes down, journey time increases, air pollution goes up, and commuters are put to increased level of inconvenience. Thus when on a corridor, traffic density during peak hours crosses this figure, provision of rail-based mass transport, i.e. Metro system should be considered. In any case, Metro system may become inescapable if the traffic density on a corridor reaches 15,000 PHPDT. With the growing economy and inadequate public transport services, the passengers shall shift to private modes, which is already evident from the high vehicle ownership trends in the region. This would not only aggravate the congestion on streets but also increase the pollution. Hence, it is essential to plan and provide for a Medium capacity Metro System in Bengaluru.

4.1.1 Traffic and transportation surveys like screen line volume count, turning volume count at junctions, road inventory survey etc., were carried out to assess the traffic and transport characteristic of the study area. The maximum Peak Hour Peak Direction Traffic (PHPDT) on K R Puram to Airport corridor has been assessed as 21,112 for 2024, 35,705 for 2031 and this is likely to increase to 46,252 by the year 2041. Therefore, road based public transport will not serve the purpose and there is an urgent need to introduce a Metro system in this corridor to provide fast, safe and economic and environment friendly mode for mass movement of passengers.

4.1.2 Types of Metros and their Capacity

Rail based mass transport in cities can be brought mainly under three categories: -

Table 4.1: Categories of Rail based mass transport in cities

Mode	Carrying capacity (passengers/hour) PHPDT
Light Rail Metro System (LRTS)	Up to 15,000
Medium Capacity Metro System	15,000-40,000
Heavy Capacity Metro System	40,000-60,000

Since, the number of commuters to be dealt is relatively less in Light Metro System, its trains consist of 3 Coaches (which can be increased to 6 Coaches in future) and other related infrastructure is also of a smaller size.

For medium capacity Metro systems, the train generally comprises 3 to 6 coaches with ultimate train headway of about 3 minutes. The other related infrastructure, e.g. civil works, stations, passenger-handling equipment etc. are also planned accordingly.

Heavy capacity Metro systems have to deal with large traffic densities ranging from 40,000 to 60,000 PHPDT. Accordingly, the trains have 6 to 9 coaches and other related infrastructure is also of large size. Beyond the traffic level of 60,000 PHPDT, additional parallel lines are normally planned.

4.1.3 Metrolite

MoHUA notified the standard specifications of Light Urban Rail Transit. “Metrolite” in July 2019 and it has been specifically examined if this system can be adopted for this corridor. Considering the geographical location and the present and future development of this important corridor of Bangalore City, Metrolite system will not be suitable for the following reasons:

MoHUA envisaged Metro lite as at-grade system as far as possible. For the present corridor, where the road traffic has already crossed the saturation level, provision of 8.5m exclusive corridor for an at-grade system will further cripple the transport system on this arterial road. There are several important cross roads leading to major commercial and residential conglomerations. Provision of a dedicated path on this road along this ORR will make these junctions totally unmanageable as these points are already major sources of traffic congestion. More importantly, an at-grade Metro corridor will split this well-developed part of the city into two parts on either side of this very important road. There are no roads parallel to this corridor and hence, it is not feasible even to provide one line on each road.

An elevated Metrolite will not result in significant cost reduction since the savings in Civil Engineering cost due to lower axle loads will be nominal, which will be offset by the higher cost for rolling stock as the coaches have to be imported and also the number of coaches required is higher due to lower carrying capacity. The cost of other systems will be the same to maintain close headway.

Metro lite system is to be adopted for passenger PHPDT envisaged from 2000 to 15000. However, the PHPDT is 19,573, 26,023 and 33,709 in 2024, 2031 and 2041 respectively for Phase-2A corridor. Similarly, the PHPDT expected on Phase-2B corridor is 21112, 35705 and 46252 in 2024, 2031 and 2041 respectively. Therefore, a system like Metrolite will become a serious constraint for transport on these corridors now itself, which will become a much more serious impediment in the near future.

Metro lite is planned with maximum operation speed of 60KMPH. The present corridor from Silk Board to KR Puram will further continue upto the International Airport covering a total distance of 56km. The lower operational speed of 60kmph will bring down the average train speed to about 23 KMPH and hence the travel time will increase significantly. This in turn will discourage the commuters to use public transport defeating the basic purpose of provision of the system.

In the Budget for 2018-19, GoK announced provision of Phase-3 metro network including on ORR- west which completes the metro corridor on this well-developed circular ring road. At Hebbal, where Phase-2B turns towards NH to reach KIA, seamless continuous connection is planned from ORR- East ie., Phase -2Bto the Phase-3 metro corridor on ORR-west. With this direct connectivity, the metro ridership and PHPDT on both Phase- 2A and Phase-2B will be much more than what is projected in the present Traffic demand forecast. This will make Metrolite system grossly inadequate for the traffic expected on ORR.

For the reasons mentioned above, Metrolite will not be a suitable system and will be grossly inadequate for carrying the traffic.

In view of the present and projected PHPDT on the proposed corridor of Phase-2B, medium capacity metro system will suit.

4.1.4 Advantages of a Metro system

Metro systems are superior to other modes because they provide higher carrying capacity, faster, smoother and safer travel, occupy less space, are non-polluting and energy-efficient. To summarise, a Metro system:

i. Requires 1/5th energy per passenger km compared to road-based system
ii. Causes no air pollution in the city
iii. Causes lesser noise level
iv. Occupies no road space if underground and only about 2 metres width of the road if elevated
v. Carries same amount of traffic as 5 lanes of bus traffic or 12 lanes of private motor cars (either way), if it is a light capacity system.
vi. Is more reliable, comfortable and safer than road based system
vii. Reduces journey time by anything between 50% and 75% depending on road conditions.

4.1.5 This Detailed Project Report for Metro line along the ORR and National Highway NH-44 from K R Puram to Airport Terminal is prepared in accordance with the provisions of Metro Rail Policy- 2017 and the Appraisal Guidelines for Metro Project proposal issued by MoHUA. This Report also takes into account the latest Standards and Specifications issued by MoHUA for various Systems.

4.2 Permanent Way

4.2.1 Choice of Gauge

Standard Gauge (1435mm) is invariably used for metro railways world over. During the last decade, many metros such as Cairo, Madrid, Bangkok, Manila, and Beijing etc. have been constructed in various cities of the world. All these Metros have gone in for Standard Gauge even though the national gauge for mainline railways in some of these countries was different from Standard Gauge. In India the national gauge is Broad Gauge (1676mm). The question whether Bengaluru Metro should go in for Broad Gauge or Standard Gauge has, therefore, been examined with following important parameters.

i. Metro alignments in a city have to pass through heavily built-up areas for optimal passenger utilisation and this imposes severe restrictions on the selection of curves. As in most of the cities in India no 'right of way' has been reserved for metro systems, the alignments have to follow the major arterial roads. These roads may often have sharp curves and right-angle bends. In such a situation adoption of Standard Gauge is advantageous since it permits adoption of sharper curves compared to Broad Gauge to minimise property acquisition along the alignments.

ii. In Standard Gauge 1 in 7 and 1 in 9 turn-outs, which occupy lesser length, are feasible compared to 1 in 8 ½ and 1 in 12 turn-outs required for Broad Gauge. Length of cross-overs for Standard Gauge is thus lesser than for Broad Gauge. Land requirement for depots where a large number of lines connected together in the shape of ladder is also reduced. Standard Gauge is, therefore, more suited for use in built up environment where land availability is scarce.

iii. For Standard Gauge, optimised state-of-the-art rolling stock designs are available ‘off-the-shelf’. This is not so for Broad Gauge where new designs for rolling stock have to be specially developed which entails extra time and cost.

iv. Because of the availability of a very large market, constant up-gradation of technology takes place for Standard Gauge coaches. Thus upgraded technology is available on a continued basis in case of Standard Gauge. This is not so in case of Broad Gauge.

v. For the same capacity gross weight of a metro coach is lower for Standard Gauge than for Broad Gauge. Standard Gauge rolling stock thus results in recurring saving in energy consumption during operation.

vi. Once technology for Standard Gauge coaches get absorbed and a manufacturing base for them is set up in India, there will be considerable export potential for the coaches, since almost all the countries use Standard Gauge for their metros. This is not so in case of Broad Gauge.

vii. It is some time argued that adoption of Broad Gauge for metros would enable inter-running of metro trains with Indian Railways since the latter uses Broad Gauge. Inter-running is, however, technically and / or operationally not feasible as the two systems have different:
   - Rolling Stock characteristics,
   - Signalling Systems,
   - Headways,
   - Tariffs,
   - Moving dimensions, and
   - Loading standards.

viii. Track gauge is not a technical parameter for any metro rail system. It is a planning parameter. This issue was also examined in January 2000 by the Ministry of Law and Justice who had opined that the choice of gauge is a matter which lies within the jurisdiction of the metro rail organisation entrusted with the responsibility of implementing and operating the metro systems.
Since inter-running is not feasible, choice of Gauge for a metro system should be based solely on technical and economic considerations on which Standard Gauge turns out to be superior.
In India Metros are construction in 12+ cities and are already in operation in 11 cities. Standard Gauge is being adopted for all these Metros except for Kolkata Metro and Phase 1 of Delhi Metro which adopted Broad Gauge. Delhi Metro subsequently switched to Standard Gauge for Phase 2, Phase 3 and Phase 4.

The Phase 1 of Bengaluru Metro which is operational and Phase 2 which is under implementation is adopting standard gauge and therefore the same is planned to be adopted for this corridor also.

4.2.2 Spacing of Tracks

The spacing of tracks on the Viaduct through the stations shall be 4.2m providing for the extra clearance required due to end throw/mid throw and lean on curves of radius upto 120m.In depots, the spacing to be changed beyond 4.20 m as per provisions of SOD of BMRCL 2015, for curves of radius less than 120.0 m to 100.0 m.

4.2.3 Track Structure

a. Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus, it is imperative that the track structure selected for Metro Systems should be long lasting and should require minimum or no maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. The track structure has been proposed keeping the above philosophy in view.

b. Two types of track structures are proposed for any Metro. The normal ballasted track is suitable for At-Grade (surface) portion of Main Lines and in Depot (except inside the Workshops, inspection lines and washing plant lines. The ballast-less track is recommended on Viaducts and inside tunnels as the regular cleaning and replacement of ballast at such location will not be possible. Only in case of the depot normal ballasted track is proposed for adoption.

c. From considerations of maintainability, riding comfort and also to contain vibrations and noise levels, the complete track is proposed to be joint-less and for this purpose the continuously welded track will even have to be taken through the turnouts.

d. The track will be laid with 1 in 20 canted rails including turnouts and the wheel profile of Rolling Stock should be compatible with the Rail Cant and Rail profile.

4.2.3.1 Rail Section

Keeping in view the proposed Axle load frequency of train operation, maintainability and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1,080 Head Hardened. For the Depot lines, the grade of rails may be 880 grade.

4.2.3.2 Ballastless Track on Viaduct

On the Viaduct, it is proposed to adopt plinth type ballast less track structure with RCC derailment guards integrated with the plinths. Further, it is proposed to adopt suitable fastening System with a base-plate to base-plate spacing of 70 cm on Viaducts and. The fastenings systems for ballast less track should satisfy performance criteria of fastening system for ballast less track on Metro Rails issued by Government of India, Ministry of Railways in December 2015.

4.2.3.3 Ballastless Track in Depot

a. The ballastless track in Depot may be of the following types:

i. Discretely supported on concrete/steel pedestal for inspection lines.

ii. Embedded rail type inside the Workshop.

iii. Plinth type for Washing Plant line.

iv. Normal Ballast less (as on Viaduct) for washing lines.

4.2.3.4 Buffer Stops

On main lines and Depot lines, friction buffer stops with mechanical impact absorption (non-hydraulic type) need to be provided. On elevated section the spans on which friction buffer stops are to be installed are to be designed for an additional longitudinal force of 85 T, which is likely to be transmitted in case of Rolling Stock impacting the friction Buffer Stops.

4.2.3.5 Welding

Flash Butt Welding Technique is to be used for welding of rails. Alumino-Thermic Welding is to be done only for those joints which cannot be welded by Flash Butt Welding Technique, such as joints at distressing locations and approach welds of switches & crossings. For minimizing the population of Thermit welds, mobile (rail-cum-road or portable) Flash Butt Welding Plant will have to be deployed.

4.2.3.6 Operating Environment

a. Track Structure should fulfill generally the following conditions:
   i. Standard gauge – 1,435mm.
   ii. Rail Seat inclination (slope): 1 in 20
   iii. Speed potential – 80 Kmph (max.)
   iv. Static axle load – 15 T (max.)
   v. Design rail temperature range – (-) 10 degree to (+) 70 degree Celsius
   vi. Maximum curvature and ruling gradient – As specified in SOD

4.3 Rolling Stock

4.3.1 General

Rolling stock for Reach 2B corridor of Bengaluru Metro has been selected based on the following criteria:

- Proven equipment with high reliability;
- Passenger safety features, including fire resistance;
- Energy efficiency
- Light weight equipment and coach body;
- Optimized scheduled speed;
- Aesthetically pleasing Interior and Exterior;
- Low life cycle cost; and
- Flexibility to meet increase in traffic demand.

The controlling criteria are reliability, low energy consumption, light weight and high efficiency leading to lower annualized cost of service. The coach should have high rate of acceleration and deceleration.

Since trains for Reach 2B corridor will be based at International Airport depot which will be newly constructed to meet the requirement of the Phase-2B corridor trains. However, the seamless train operation will happen in Phase-2A & 2B and considering this, trains of 2B corridor will be of the same dimensions as that of Phase-2A corridor. Hence, 2.88 m wide stainless steel light weight coaches are proposed for the Bengaluru Metro, with length of 20.8 m for trailer coach and 21.05 m for motor coach. Height of coach is 3.8 m. Train length for 6- coach train is 130.30m.

Propulsion system will be Variable Voltage Variable Frequency (VVVF) control, 3-Phase induction motor and to improve the regenerated power, it is planned to upgrade the braking characteristics of the propulsion system so that regeneration is maximum in the speed range of 60Kmph to 5 Kmph during braking.

New generation of brake control will be adopted where in case of failure of brake of one bogie/car, missing brake force will be compensated by the other bogie/car.

Rolling Stock is planned to be UTO enabled and will be suitable for GoA2 and GoA4 grade of operation

4.3.2 System Specification to be adopted for the Corridor

System specification of the Rolling stock is planned as per MoHUA guidelines. The details are given in chapter-11 (Rolling Stock).

4.4 Power Supply and Traction

4.4.1 General: The ORR line between Central Silk Board junction and KR Puram will be extended further from K R Puram to Kempegowda International Airport Limited. To achieve the seamless integration and operational flexibility, the proposed traction system in the International Airport line is also 750 V DC third rail bottom current collection system which is adopted for all the other sections of the BMRCL also. Accordingly, general approach philosophy for traction and auxiliary power system is detailed in the following paras.

4.4.1.1 Metro system requires a very high level of reliable and good quality of power supply. To ensure reliability of power supply, it is essential that the sources of supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. Therefore, it is desirable to obtain power supply at high grid voltage of 220 kV or 66 kV which is highly reliable, from stable grid sub-stations (GSS) of state electricity Authority to our receiving sub-station (RSS) and from there further transmission & distribution is done by the Metro Authority itself.
For that purpose, the high voltage power supply network along the corridor/alignment of the metro line is studied and discussion are held with the state electricity Authority regarding the feasibility of getting the reliable power supply from the two different nearest source for each RSS suiting to the load requirement. At the stage of detailed design and engineering, the 220/66 kV input

sources from GSS are suitably chosen in consultation and agreement with state electricity Authority.

4.4.1.2 The power supply received from the GSS of the state electricity Authority is fed to the receiving sub-station (RSS) of the metro through 220/66 KV cables. The size and the specification of the cable is chosen to suit the present and future load requirement and the state electricity Authority requirement also as generally the cables from GSS to RSS are maintained by state electricity Authority. Once the power is received at RSS, the 220/66 kV power supply will be stepped down to 33 kV level at the above RSSs of metro authority.

The number of the RSS is planned as per the total load requirement of the section and also to have a redundancy in the system. The system is designed is such a way that in the normal condition of operation all the RSS of that section shall be sharing the loads for the entire section i.e., feeding their designed sectional length load. However, in case of failure/interruption of entire power supply to any one of the RSS, the other RSS shall feed the load of that line also. By this arrangement a very high reliability in the power supply system required for the metro system is ensured.

Generally Conventional Air Insulated outdoor type (ASS) of 220/66 kV is proposed for RSS which is cheaper but required more land for construction. However, requirement and feasibility of GIS can also be assessed at detailed design and engineering stage in case of any land problem. RSS layout and power supply arrangement is generally of the standard design as per various national and international standards.

4.4.1.3 The 33 kV power supply drawn from the RSS will be distributed along the alignment through 33 kV ring main cable network for feeding to traction as well as auxiliary loads at the stations. The size of the cables is dependent on the load of the section which is further dependent on the number of trains, headway, alignment, gradient and auxiliary load etc. These cables will be laid in dedicated ducts/hangers/brackets along the viaduct. However, in case of total grid failure, trains will come to stop but station lighting, firefighting & some other essential services can be catered to by stand-by DG sets. Therefore, the proposed scheme is expected to ensure adequate reliability and cater to emergency situations as well.

4.4.2 Traction System

Traction sub-stations (33 kV/750 V DC) are required to be set up at the designated locations to cater the traction load which is based upon the Traction simulation, for feeding 750 V DC power supply to the third rail.

The Traction sub-stations (TSS) along with Auxiliary Sub-Stations (ASS) will be located at station building itself at concourse level inside a room. Self-cooled, cast resin dry type rectifier-transformer is proposed, which is suitable for indoor application. The traction transformer - rectifier set shall produce 750 V DC nominal output voltage with 12/24-pulse rectification so as to minimize the ripple content in the output dc voltage. From the traction sub-stations, 750 V DC cables will be laid up to third rail and return current cables will be connected to running rails.

Adequate number of cables as required to transfer of power from TSS to third rail will be provided. The capacities of transformers, cables etc. have been worked out based on the conceptual design and therefore, these capacities may be required to be fine-tuned during design stage of project implementation.

DC equipment shall be capable of giving desired performance for the designed voltage range. 33 kV cable network shall be adequately rated to transfer requisite power during normal as well as emergency situations and to meet the fault current requirement of the system. All the connected equipment of traction i.e., 33 kV switchgear, rectifier transformer, bus duct, rectifier, HSCB, negative return panel, DC cables, third rail etc., shall comply with the overload duty cycle.

A separate traction sub-station (TSS) shall be provided for depot so as to facilitate isolation of depot traction supply from mainlines in order to prevent the leakage of return currents to depot area. Tracks of Depot area shall also be isolated from mainline through insulated rail joints (IRJ). Remote operated disconnection/sectionalizing switches shall be provided to feed power from depot to mainline and vice-versa in case of failure of depot TSS and nearest mainline TSS.

The prescribed limit of highest touch potential in depot shall be as per EN 50122-1 and therefore Track Earthing Panels (TEP)/Over Voltage Protection Device (OVPD) shall be provided at suitable locations to earth the rail in case the rail potential exceeds this limit.

4.4.2.1 Third rail with bottom collection system with shroud on top and sides is proposed considering the safety. Required rated conductor rail is proposed and the manufacturing process can be co-extrusion, mechanically embossed, mechanically welded etc., which complies with the required contact resistance between aluminum & stainless steel and with proven record.

In order to avoid third rail in the maintenance areas from safety point of view, stinger is proposed in inspection bay lines of the depots similar to Bangalore Metro Phase I.

4.4.2.2 Emergency Trip System (ETS) shall be provided at platform ends, station control room and TSS in accordance with the requirements of NFPA-130. ETS can be operated by passengers and metro staff in case of emergency situations to disconnect the power supply to the train(s). Operation of ETS push button will result in tripping of relevant section of third rail in order to stop the trains in that section.

4.4.2.3 In DC traction systems, bulk of return current finds its path back to the traction sub-station via the return circuit i.e. running rails. The running rails are normally insulated to minimize leakage of currents to the track bed. However, due to leaky conditions, some current leakage takes place, which is known as ‘stray current’. The current follows the path of least resistance. Return current deviates from its intended path if the resistance of the unintended path is lower than that of intended path. The stray current may flow through the unintended path of metallic reinforcements, civil structures, public utilities etc., of the structure back to the substation. The DC stray currents cause corrosion of metallic structure where it leaves the metal. Pitting and general form of corrosion are most often encountered on DC electrified railways.

Generally, 3 types of earthing arrangements (viz. Earthed System, Floating System & Hybrid earthing System) are prevalent on metros World over for protection against stray current corrosion. Traditionally, Earthed system was used by old metros. Hybrid earthing system is being tried on experimental basis on few new metros. Floating system has been extensively used by recent metros. As per the trends World over, floating system (i.e. traction system with floating negative) is proposed which reduces the DC stray current to considerable level.

4.4.2.4 Supervisory Control And Data Acquisition System (SCADA): The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fiber provided for telecommunications will be used as communication carrier for SCADA system.

Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 66/33 kV ac switchgear, transformers, 750 V DC switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system.

OCC for International Airport line can be integrated with, Gottigere–Nagavara Line/RV Road – Bommasandra or ORR Line based on the location decided during detailed engineering stage.

4.4.3 Auxiliary Power Supply Network: The purpose of the auxiliary supply system is to fed the power for the various utilities like lighting, lifts, escalators, S&T equipment, firefighting installations & property development etc. Hence auxiliary sub-stations (ASS) are envisaged to be provided at each station. A separate ASS is required for depot. The ASS & TSS will be located at mezzanine/concourse level inside a room at station building. The auxiliary load requirements have been assessed to be about 412 kVA for elevated stations and accordingly two dry type cast resin transformers (33/0.415 kV) of 500 kVA for elevated stations (with one transformer as standby to have the redundancy) are proposed to be installed along with all the 33KV and 415 Volt switchgear and protection system.

The Depot ASSs will also be provided with 2 x 2000 kVA auxiliary transformers.

4.4.3.1 Stand by Diesel Generator (DG) Sets: In the unlikely event of simultaneous tripping of two RSSs or total grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby one DG set of adequate capacity at Elevated stations to cater the following essential services:

i. Lift operation
ii. Essential lighting at Stations on account of emergency evacuation
iii. Ventilation requirements of stations
iv. Signaling & telecommunications equipment
v. Firefighting system
vi. Signages
vii. Other emergency and essential services

Silent types of DG sets are proposed which have low noise levels.

4.4.4 **Other Building Services:** Station lighting is proposed with all LED lighting. Station emergency lighting shall have back-up from UPS and DG set as per existing norms. Each station shall have Lifts and Escalators to facilitate the movement of the passengers from ground to concourse and concourse to platform. Air conditioning for all the critical rooms like S & T, SCR and TO room is proposed. Ventilation system is proposed in ASS/TSS room.

To meet the emergencies on account of fire at station there is provision of fire detection and fire suppression system at stations as per NBC/NFPA. The main fire panel will be installed on SCR for early warning to the stall available there. The building management system will also be provided at station to monitor/control the various equipment like lifts, escalators, UPS, Air conditioning system, Pumps, Main DB, small lighting DB and lighting etc.

4 Elevators of 13 passenger capacity and 8 Escalators are estimated at each passenger station. Stations are also to be provided with latest fire detection, fire alarm and firefighting system.

Detailed System specifications of the Traction are given in detail in chapter-12 (Power supply and Traction).

4.5 Signalizing and Telecommunication System

4.5.1 Signaling and Train Control System

4.5.1.1 The Signalling & Train Control system plays a major role in Metro Railway to provide frequent, fast and safe journeys in the urban scenario. The telecommunication system serves as the communication backbone for signaling system and provides telecommunication services to meet operational and administrative requirements of rail / metro network. The Distance to Go (DTG) system provided on Purple and Green lines of Phase-I BMRCL is becoming obsolete and the latest Signalling and Train Control technology available is the Communication Based Train Control (CBTC) system. The Signaling and Train Control system shall be designed to meet the required headway. The signalling system shall also have secondary detection of trains through Axle counters/Track circuits. Radio for CBTC shall work in license free ISM band.

4.5.2 Train control requirements of the metro are planned to be achieved by adopting Continuous Automatic Train Control (CATC) based on Communication Based Train Control (CBTC) System. The train location is determined by continuous communication with Central control. The Axle counters/track circuits are installed as a fall back option and to manage non-equipped vehicle movements. CBTC system includes Automatic Train Protection (ATP) and Automatic Train Operation (ATO) sub-systems using continuous bi-directional radio communication between track side and train along with Automatic Train Supervision (ATS) sub systems. The CBTC system Provides higher traffic capacity, High reliability, better availability and less prone to failures, Reduction in cost, Quicker recoveries in case of service delays, Lesser maintenance due to Radio Communication. The CBTC system Provides high level of safety ensuring continuous safe train separation and bidirectional working. Improves capacity with safer and smoother operations. Driver will have continuous display of Target Speed and other information in his cab enabling him to optimize the speed potential of the track section. CBTC system also provides Unattended Train Operation (UTO).

4.5.3 Telecommunication System

The Telecommunication systems to be adopted for airport line shall help inefficient railway management and operation. It is essential to have a well-organized Telecommunication network covering strategic locations like OCC/BCC, stations, depots and maintenance depots, and it is equally essential to have reliable links between the strategic locations and moving trains or working staff along the railway track. The details of main sub-systems of the Telecommunication systems are detailed below:

4.5.3.1 Fiber Optic Transmission System: Ethernet based MAN/LAN based on the appropriate IEEE Ethernet standard and able to cover the entire metropolitan BMRCL areas. The entire Ethernet backbone solution shall be robust, scalable, secure, efficiently manageable and based on proven equipment and topology. The Transmission system shall use Optical Fiber Cable media and144F or 96F cable with path diversity, laid along two physically distinct routes, as the main bearer for bulk of the telecommunication network shall be provided.

4.5.3.2 Telephone Exchange: IP Based PABX system shall be used for fixed line communication between OCC and stations and between station to station for operational and administrative communication requirements. The telephone system shall be equipped with a centralized digital recording system for recording of designated telephone lines including emergency telephone lines, Emergency PAS announcements and designated radio conversations.

4.5.3.3 Train Radio System: Digital or IP Based Train radio (TETRA) system shall be provided for communication between Train Operator of moving cars, stations, maintenance personnel, depots and central control. The radio base station equipment shall be in redundant configuration.

4.5.3.4 Passenger Information Display System (PIDS): LED/LCD/TFT based boards with adequate visibility to be provided at convenient location at all stations to provide Bilingual or multilingual visual indication of the status of the running trains, and also special messages in emergencies. The viewing distance for the platform display boards for each side shall be at least 45 meters for Kannada, Hindi and English characters. The system shall be integrated with PAS and Signalling system for real time train information.

4.5.3.5 Centralized clock system**:** The system shall provide **a**ccurate display of time through a synchronization system of slave clocks driven from a master clock at the OCC and sub–master clock in station/depots. The centralized master clock shall be synchronized with GPS. This clock system shall also be used for synchronization of other systems**.**

4.5.3.6 The Passenger Announcement System(PAS): The system shall be provided to broadcast voice messages to passengers/staff at all stations and to staff in depots, and related equipment/plant rooms.PAS will cover all platform and concourse areas and will have facility of local as well as Central (OCC/BCC) Announcement.

4.5.3.7 CCTV Video Surveillance: The system shall comprise IP based CCTV cameras with Network video Recorders at stations, Centralized management, Video Analytic features and Video wall display. Redundant network video recorders (at different station) for CCTV shall be provided.

4.5.3.8 Broad Band Radio System (BBRS): The system provide a communication interface to the on board CCTV for remote monitoring of these images from OCC, DCC or the security room.

4.5.4 Automatic Fare Collection System

4.5.4.1 The AFC System shall, as a minimum, provide the facility to collect revenue, efficiently control the flow of passengers through the stations, prevent entry by unauthorized persons, minimize the use of ticketing staff, reduce fraud, provide revenue and traffic management information and provide input for future traffic planning.

4.5.4.2 In line with exiting AFC system deployed in other reaches, Bangalore Metro Automatic Fare collection (AFC) system will have three-tier architecture – Central level, Station level and Station equipment level. The system will be fully closed and gated (Automatic Gates) separating station area into paid and unpaid area. The Central Computer (CCS) shall control all the AFC equipment installed at various locations and collect usage data for generating reports/ reconciliation. Similarly, the Station Computer (SC) shall control all the AFC equipment at stations. The Ticket Office Machines (TOM) will be used for issue of single journey tickets, sale/recharge of smart cards and customer care (refund/adjustment etc.). Add Value Machines (AVMs) will be used for recharge of smart cards. Remaining Value Checking Terminal (RVCT) will be used for reading data encoded on tickets. Automatic Gates (AGs) will be provided for controlling entry and exit from the paid and unpaid areas at stations. The AGs will be operated automatically through use of tickets

4.5.4.3 Bangalore Metro AFC system uses recyclable contactless smart token (CST) for single/ return journey ticket and contactless smart card (CSC) for multiple journeys i.e. Stored Value Tickets, Trip Tickets, Staff Passes and other various ticket types.

4.5.4.4 NFC based and QR code based mobile ticketing shall be implemented.

4.5.4.5 AFC System shall also support inter-operable EMV based smart card standards (National Common Mobility Cards-NCMC) and AFC System shall be designed to be capable of accepting and processing simultaneously the existing cards/ tokens as well as NCMC cards.

Detailed System specifications of Signaling & Telecom systems are given in Chapter 9 and Automatic Fare Collection systems in Chapter 10.

Chapter 5

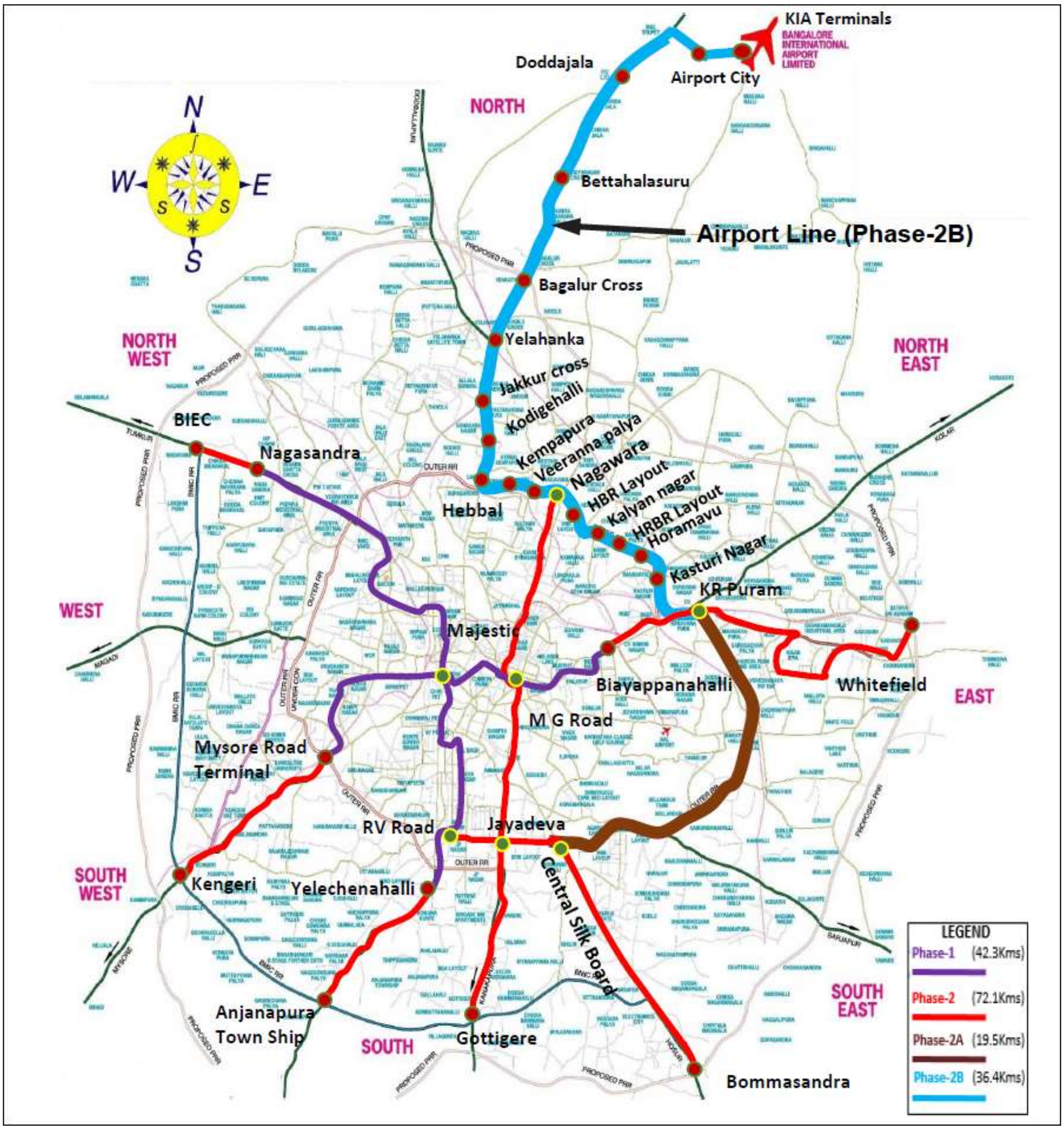
Civil Engineering - Alignment Details

CHAPTER – 5

CIVIL ENGINEERING, ALIGNMENT DETAILS

Two corridors of Metro Rail are under operation in Bengaluru. One is East-West corridor and the other is North-South corridor. The East-West Corridor starts at Baiyappanahalli (Reach 1) and ends at Mysore Road (Reach 2). The North-South Corridor starts at Nagasandra (Reach 3) and ends at Puttenahalli (Reach 4). The total length of the Metro Rail network under operation is 42.30 Km. Extensions on East-West Corridor, North-South Corridor & two new lines Reach 5 & Reach 6 under Phase 2 (72.1km) are under implementation. **Figure 5.1.1** presents the existing and proposed Metro Rail network in Bengaluru.

Figure 5.1.1 Metro Rail Network in Bengaluru



This chapter deals with alignment selection, geometrical standards for horizontal and vertical profile, Route description, Permanent way, Geotechnical investigation, Land requirements, Utility services, etc., for the proposed line from KR Puram to KIA named as Phase 2B.

5.1 Description of Alignment.

5.1.1 Description

- The proposed K R Puram to KIA Terminal line of Phase 2B having a route length of 38 Kms (36.44 Kms from Jyothipuram to KIA Terminal) will be an elevated standard gauge corridor with double line section. Alignment starts after Jyothipuram station of Phase -2 (R1- Extn) as an extended corridor of Phase-2A (Central Silk Board to Jyothipuram), then it turns right and follows Outer Ring Road (ORR) on the left side of existing flyover and joins ORR median at Kasturi Nagar. Further alignment will generally follow median of the Outer Ring Road upto Kempapura station. After Kempapura station alignment takes right turn to enter into Hebbal bus depot area where Hebbal station is located and reaches NH-44 before kodigehalli station and further continues till Trumpet on the 5 m wide strip of land reserved for high speed rail corridor between main road and service road on NH-44. Before Doddajala station alignment takes a right turn and moves parallel to Railway line for short length after crossing the railway line and takes a right turn to reach Airport road median and continues along the road median upto KIAL boundary. After KIAL Boundary the alignment takes left turn and continues off road upto KIA Terminals Station.
- A linking line starts from the existing ramp of phase-2 Reach-1 extension at Baiyappanahalli as Y junction after crossing railway line and connects the proposed Airport line at ORR after the flyover.
- Two pocket tracks of 250m (near Yelahanka station) and 200m (between Veeranapalya and Kempapura stations) length are planned for turn back, emergency stabling facilities and operational convenience.
- Seventeen elevated stations have been proposed on this line including interchange station at Nagawara.
- This line will be mainly served by proposed depot at Trumpet near Airport and by Baiyappanahalli depot in emergencies.
- Nagawara station which is located on the Airport line of Phase-2B between K R Puram & Hebbal is proposed as interchange station to Reach-6 (UG) between Gottigere- Nagawara. And stations at Hebbal, Yelahanka, Bagalur Cross station and Doddajala station are planned as future interchange stations.
- Third line takes off from Airport road median well before KIA west metro station to reach Depot which is located on the Right side of NH 44 near Trumpet toll plaza.

5.1.2 Reference point

The dead end of Phase-2A line (Pier ORP 658 near Jyothipuram station) is considered as the reference point, however 0.00 Kms for reckoning of chainage on K R Puram to KIA Terminals starts at 80mts ahead of ORP 658 towards Kasturi Nagar. The Chainage increases beyond Jyothipuram and ends at KIA Terminals.

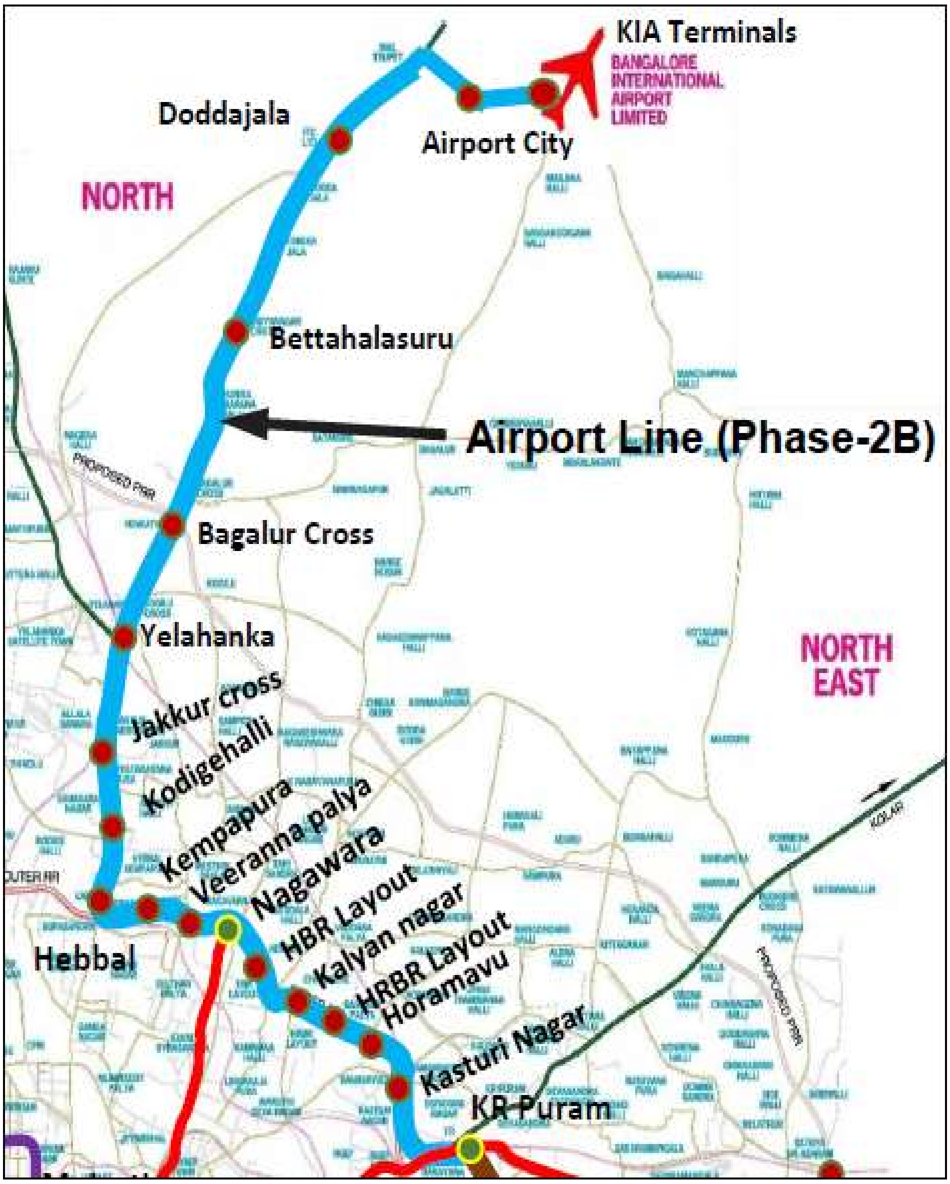
5.1.3 Designation of line

The metro line in the direction of movement from Kasturi Nagar station to KIA Terminals station is designated as ‘Up Line’ and the line from KIA Terminals station to Kasturi Nagar station is designated as ‘Down Line’.

5.1.4 Index Plan

Index Plan of the alignment from K R Puram to KIA Terminal is given in **Figure 5.1.2.**

Figure 5.1.2 Map showing K R Puram to KIA Terminals line



5.2 Analysis of the Corridor options to be elevated, underground or at grade.

The proposed corridor follows the alignment of existing Outer Ring Road (ORR) from Kasturi Nagar to Hebbal and thereafter Metro alignment follows the National Highway-44 (NH-44). The land required to locate viaduct pier is available almost for full length of the corridor. The outer ring road is 6 Lane Carriage way with service road on either side and minimum total road width is over 41m and maximum width of road is about 76m at Kalyan Nagar and 73m at HRBR Layout stretch where Median between Main road and Service road is developed as park. The minimum width of the median is about 1.5 m and even after construction of the Metro Piers on this median, the Road width will still be available, as it is existing now. An additional feature of this Corridor is that at the major Road intersections viz, HRBR layout, Nagawara and Veeranna Palya road flyovers exist as Split flyovers and three Road Under passes are available at Rammurthy Nagar, Horamavu and Hennur. The split flyovers were planned keeping in view the future Public Transport System on this Corridor. The map showing the arrangement of split flyover and metro is shown in **Figure 5.2** & **5.3**

The Piers of the Elevated Metro may be provided in the space of about 6.5-9.5m available between the two arms of the split flyover. Even at the underpasses, the Metro Piers can run at the middle.

If this Corridor is to be planned as Under Ground Metro, it will have Structural implication for passing of Under Ground below the 3 Nos of Flyovers and 3 Nos of underpasses in ORR. Apart from this, the Construction period of Under Ground Metro is longer and more Road width has to be barricaded for construction of the Under Ground Stations. Moreover, the cost of construction and operation of Under Ground Metro is much higher compared to an Elevated Metro and is preferred only where Elevated Metro is not feasible.

Construction of Metro Line At-grade between KR Puram and Hebbal (along ORR) is ruled out as two lines of Metro will occupy about 10 mtr of the road width making the remaining road grossly inadequate for the flow of traffic on this important Ring Road.

However, construction of Metro Line At-grade between Hebbal and Airport Terminal may be possible by acquiring an additional strip of 5 mtr wide land along NH-44. But acquisition of additional 5 mtr wide strip of land between Hebbal and Yelahanka is not feasible due to large scale development along the highway. However, it is feasible to consider acquisition of additional 5 mtr wide strip between Yelahanka and Trumpet Junction as there is no much development along the highway.

The cost comparison of constructing Elevated and At-grade Metro line between Yelahanka (excl) and Airport Terminal has been carried out. The length of Metro line between Yelahanka (excl) and Airport Terminal is 18.125 km having 5 Metro stations. The detailed cost comparison for Elevated alignment and at-grade alignment is shown in **Table No.5.1**.

Table No.5.1: Cost Comparison of Elevated v/s At Grade Metro for Yelahanka-Airport Terminal Section (18.125 Kms)

Sl No	Description	Unit	Elevated			At Grade		
			Qty	Rate (INR in Cr)	Amount (INR in Cr)	Qty	Rate (INR in Cr)	Amount (INR in Cr)
1	2	3	4	5	6	7	8	9
1	**Alignment and Formation**							
1.1	Elevated Viaduct including in Stations	R Km	14.53	37.00	537.43	0.00	37.00	0.00
1.2	Addl cost for 6 Special spans with composite girders.	Lumpsum			18.25			0.00
1.3	Length of Ramp to Reach at Grade.	R Km	1.00	22.36	22.36	8.50	22.36	190.06
1.4	Alignment at Grade	R Km	2.00	22.36	44.72	8.54	22.36	190.84
1.5	Alignment with Covered Shell	R Km	0.60	36.87	22.12	1.09	36.87	40.19
1.6	Compound Wall / fencing on two sides	R Km				17.08	2.39	40.82
	Sub Total (1)				**644.88**			**461.91**
2	**Station Buildings**							
2.1	Stations	Per Stn	4	26.00	104.00	4	15.00	60.00
2.2	Partially Underground Station at Airport Terminal	Per Stn	1	62.50	62.50	1	62.50	62.50
	Sub Total (2)				**166.50**			**122.50**
	Sub Total (1 + 2)				**811.38**			**584.41**
3	**Land**							
3.1	Yelahanka to KIAL Boundary (Station, Viaduct, RSS, Pocket Track, etc.,)	Sqm	55,248	-	240.34	1,21,458	-	1208.79
3.2	Depot near Airport	Sqm	91,532	-	197.22	91,532	-	197.22
3.3	NHAI Land	LS	57,210	-	108.45	57,210	-	108.45
	Sub Total (3)				**546.01**			**1514.47**
4	**Total including land (1+2+3)**				**1357.39**			**2098.88**
Note:	Above cost comparison is done only for civil structures and land component as all other cost remains same for Elevated as well as At grade alignment.							

From the above comparison, it can be seen that the At-grade alignment is costlier than Elevated alignment by about Rs. 742 crores. In spite of reduction in civil cost the At-grade alignment as a whole is costlier mainly because of the following reasons.

i) An additional land acquisition of 5 mtr wide strip along NH-44 for a length of about 11.44 km (57210 sq. mtr.) and 9000 Sq. mtr. for three At-grade stations results in to an additional cost of Rs. 968 crores.

ii) Construction of 15 grade separators (Underpass) for road and rail crossings results into an additional cost of about Rs. 200 crores.

iii) Construction of compound / security fencing on both sides of the Metro line results into an additional cost of about Rs. 41 crores.

In addition to the above the Metro Line At-grade along the road splits the city into two and number of underpasses / over bridges will have to be constructed for movement of people and vehicles from one side to other side of the Metro corridor. There will be an additional security issues due to external interferences inspite of providing compound / security fencing.

Considering all the above aspects, Elevated Metro with Elevated Stations is proposed as the most suitable option for this Corridor.

Figure 5.2 Typical Cross Section of Metro Viaduct pier at Split Flyover

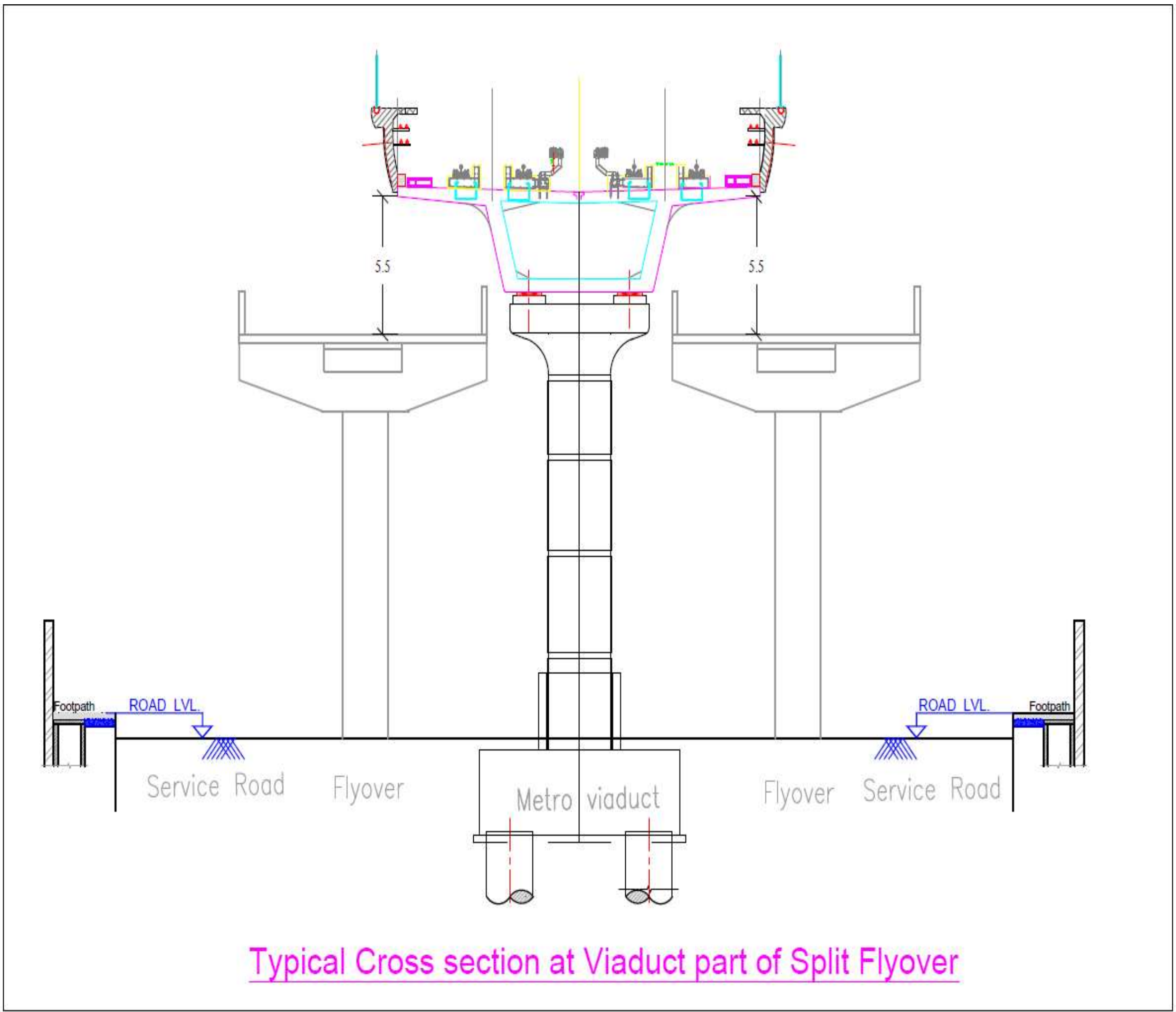
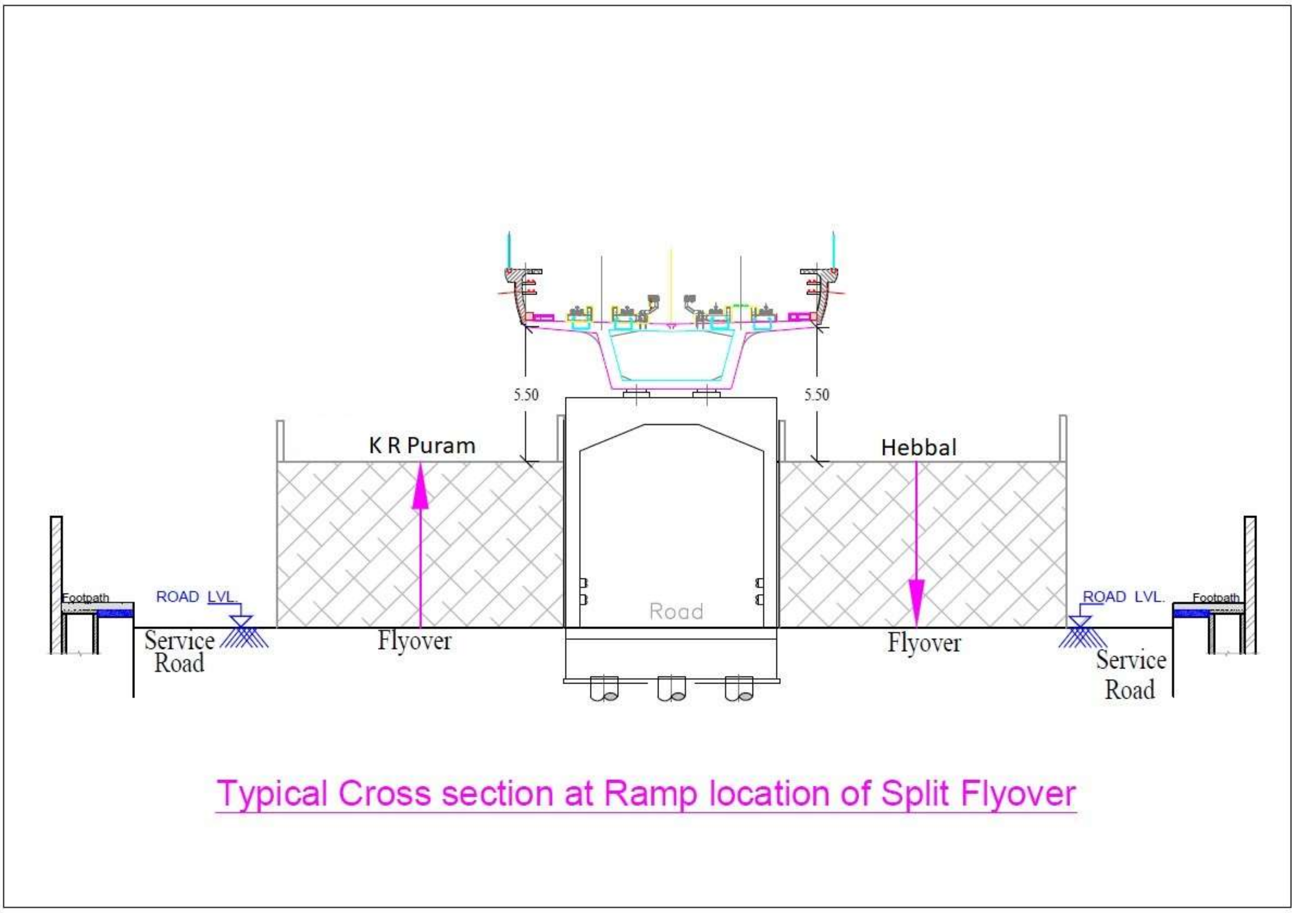


Figure 5.3 Typical Cross Section of Metro Viaduct portal at Split Flyover.



5.2.1 Viaduct Structure

5.2.1.1 Superstructure

The Superstructure is planned keeping in view the ease of construction and standardization of the form-work for a wide span ranges. Accordingly, the following type of superstructures are considered.

5.2.1.2 Comparative advantages/disadvantages of the above two types of superstructures are given below:

i. Precast segmental box girder with Post Tensioning.

This essentially consists of pre-cast segmental construction with post tensioning and joints glued and is by far the most preferred technique in fast track projects. In such construction, the pre-stressed cables are placed in the conduits inside the structural concrete which are grouted with non-shrink cement slurry. The match cast joints at the interface of two segments are provided with shear keys for maintaining the correct line and level of the superstructure.

ii. Precast Pre tensioned U-Girder superstructure.

Superstructure with single unit of U Girder for the span to accommodate one track is another method of construction of Metro structures. There will be two Girders for each span to cater for the two tracks. The U Girders are Pre tensioned, Pre cast, transported to site and erected on the spans using road cranes.

Since these units are erected as a single unit per span, the speed of construction of Superstructure becomes very fast compared to the segmental construction. Since, the Pier cap will have to accommodate two U Girders, it has to be wider and hence, is made as a precast prestressed unit. This feature also facilitates faster construction. However, the internal width of U Girder is generally kept as 4m and hence this type of superstructure can be adopted for spans on curves of radius only upto 300m. For spans on curves of sharper radius and for crossover spans, different superstructure such as precast I Girders with cast-in-situ deck slab have to be used.

5.2.1.3 The Segmental Superstructure construction has been chosen mainly due to the following advantages.

i. Segmental construction is an efficient and economical method for a large range of span lengths and types of structures. Alignment with sharp curves and variable super elevation can be easily accommodated.
ii. Segmental construction permits reduction of construction time as segments may be manufactured while substructure work proceeds, and assembled rapidly thereafter.
iii. Segmental construction protects the environment, as only space required for foundation and sub-structure is required at site. The Superstructure is manufactured at a place away from busy areas and placement of Superstructure is done with the system erected over the piers at heights.
iv. Segments are easy to stack in the casting yard/stacking yard in more than one layer, thereby saving in requirement of space.
v. It is easier to transport smaller segments by road trailers on the city roads.
vi. It is easy to incorporate last minute changes in span configuration if the site situation so warrants.
vii. Interference to the Road traffic during construction is significantly reduced.
viii. Segmental construction contributes toward aesthetically pleasing structures and good finish.
ix. The overall labour requirement is less than that for conventional methods.
x. Better quality control is possible in the casting yard.
xi. During construction, the technique shows an exceptionally high record of safety.

5.2.1.4 Sub-structure

- The Viaduct Superstructure will be supported on single cast-in-situ RCC pier.
- Circular Pier is being adopted for this corridor and the Pier Cap is provided to support the bearings under the box girders.
- To prevent the direct collision of road vehicle to Pier, a Crash barrier of 1.2m height above existing road level has been planned all around the pier. A gap of 25mm has been provided in between the crash barrier and outer face of pier to absorb the impact in case of collision by the road vehicles. The shape of

upper part of pier has been so dimensioned that a required clearance of 5.5m is always available on road side beyond vertical plane drawn on outer face of crash barrier.

- The height of the Pier has been designed in such a way that an Elevated walkway along the alignment can be provided below the Viaduct which will facilitate the commuters to directly reach the stations from important points of mass congregation such as major industries.
- The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.7m. The space between the elastomeric bearings will be utilized for placing the lifting jacks required for the replacement of elastomeric bearings during service. An outward slope of 1:200 will be provided at Pier top for the drainage due to spilling of rainwater, if any.
- The transverse spacing between bearings would be 2.60m.

5.2.1.5 Reinforcement and Pre-Stressed Steel

It is proposed to use TMT 500 grade steel as reinforcement bars conforming to IS1786, HYSD 500 grade.

For pre-stressing work, low relaxation high tensile steel strands with the configuration 19 K 15 & 12 K 15 depending on spans conforming to IS:14268 is recommended.

5.2.1.6 Typical cross section of Viaduct for segmental construction and typical section of Double U Girder Superstructure are shown in **Figures 5.4.1** & **5.4.2.**

Figure 5.4.1 Typical Cross Section of Viaduct

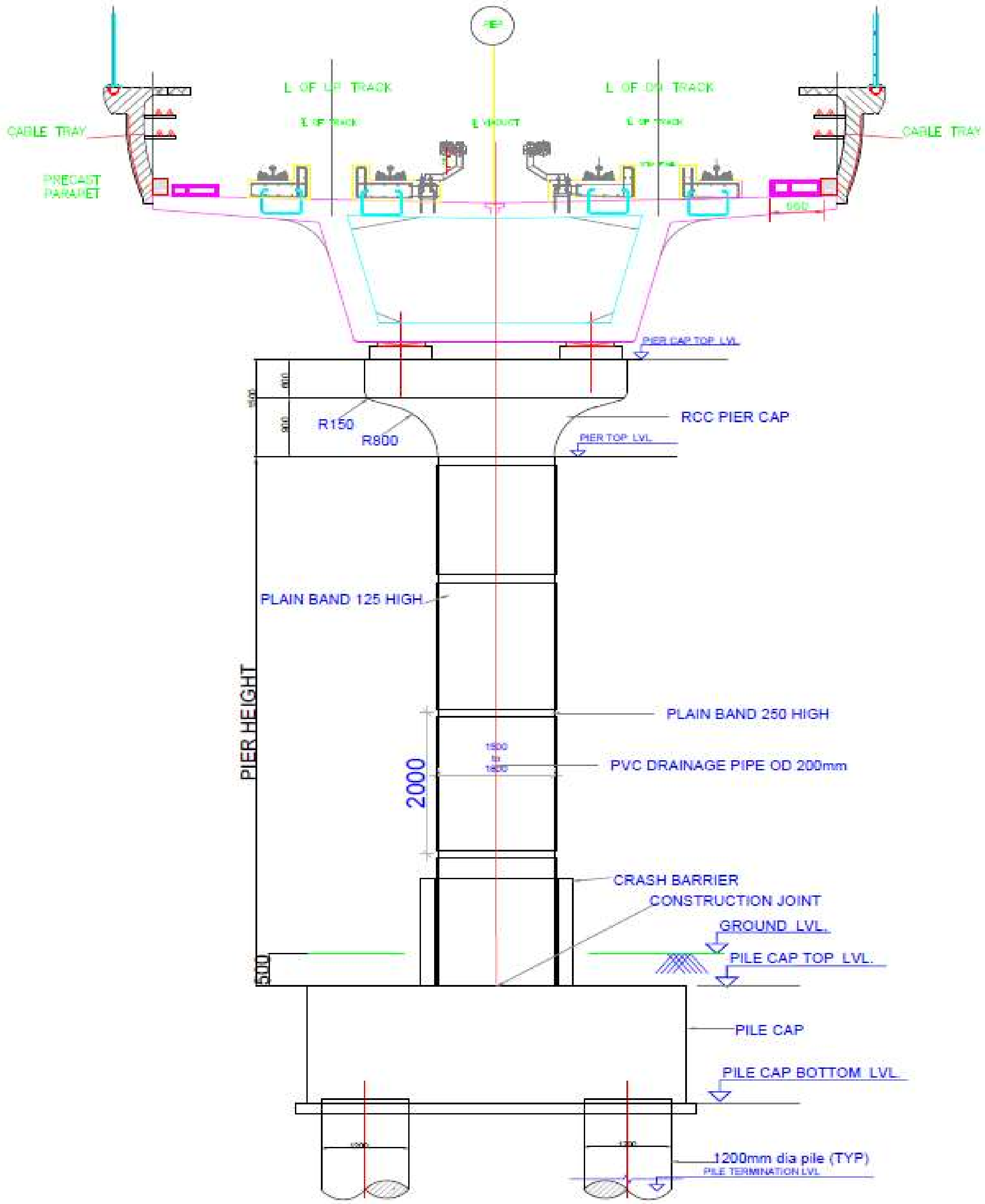
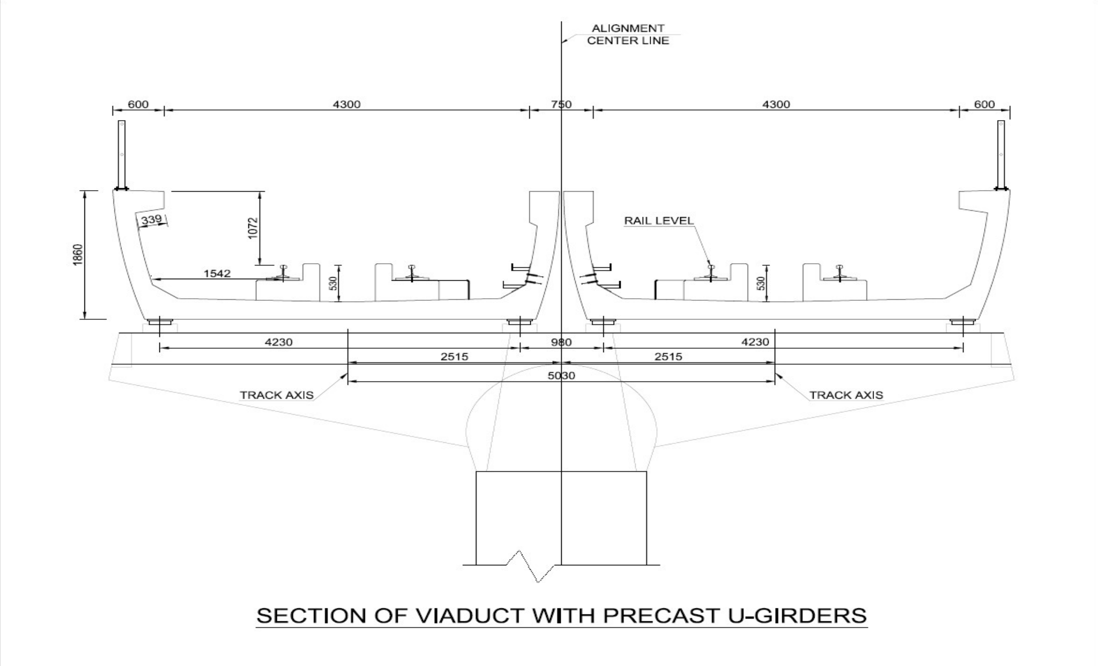


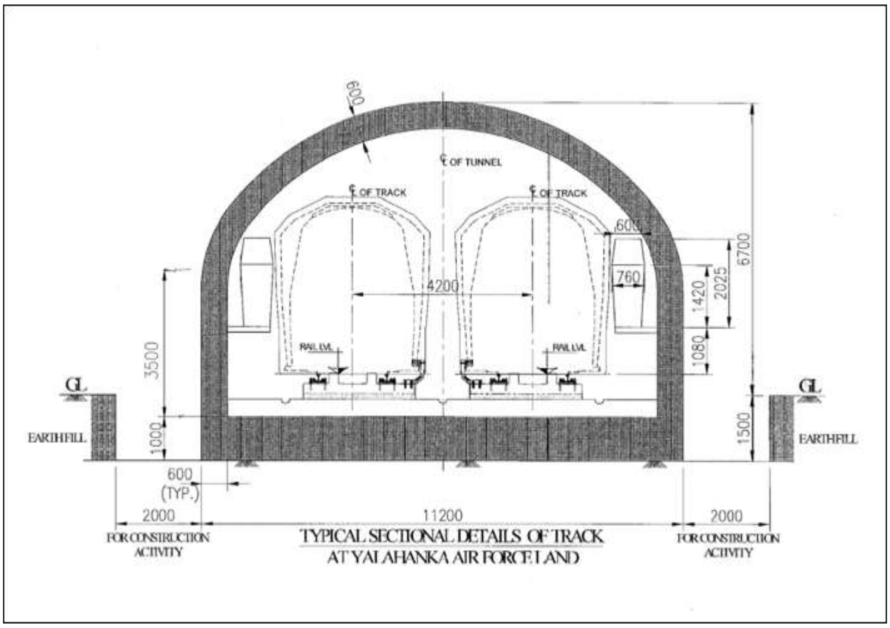
Figure 5.4.2 Typical Cross Section of the Viaduct with Double U Girder



5.2.1.7 Special Structure at Yelahanka Air force fly zone

A special structure with RCC shell as per the requirement of Yelahanka Air force authorities is proposed in the strip where alignment crossing the Yelahanka flying zone. This proposal is based on the EM Simulation report "STUDY ON THE EFFECT OF HSRL ON THE GLIDE PATH AND LOCALISER ANTENNAS OF INSTRUMENT LANDING SYSTEM" carried out by Electronics and Radar Development Establishment, DRDO, Ministry of Defense. As recommended in the section no. 9.0 of the aforementioned report, the thickness of the shell is kept as 500mm. The Typical details are shown in **Figure 5.5.**

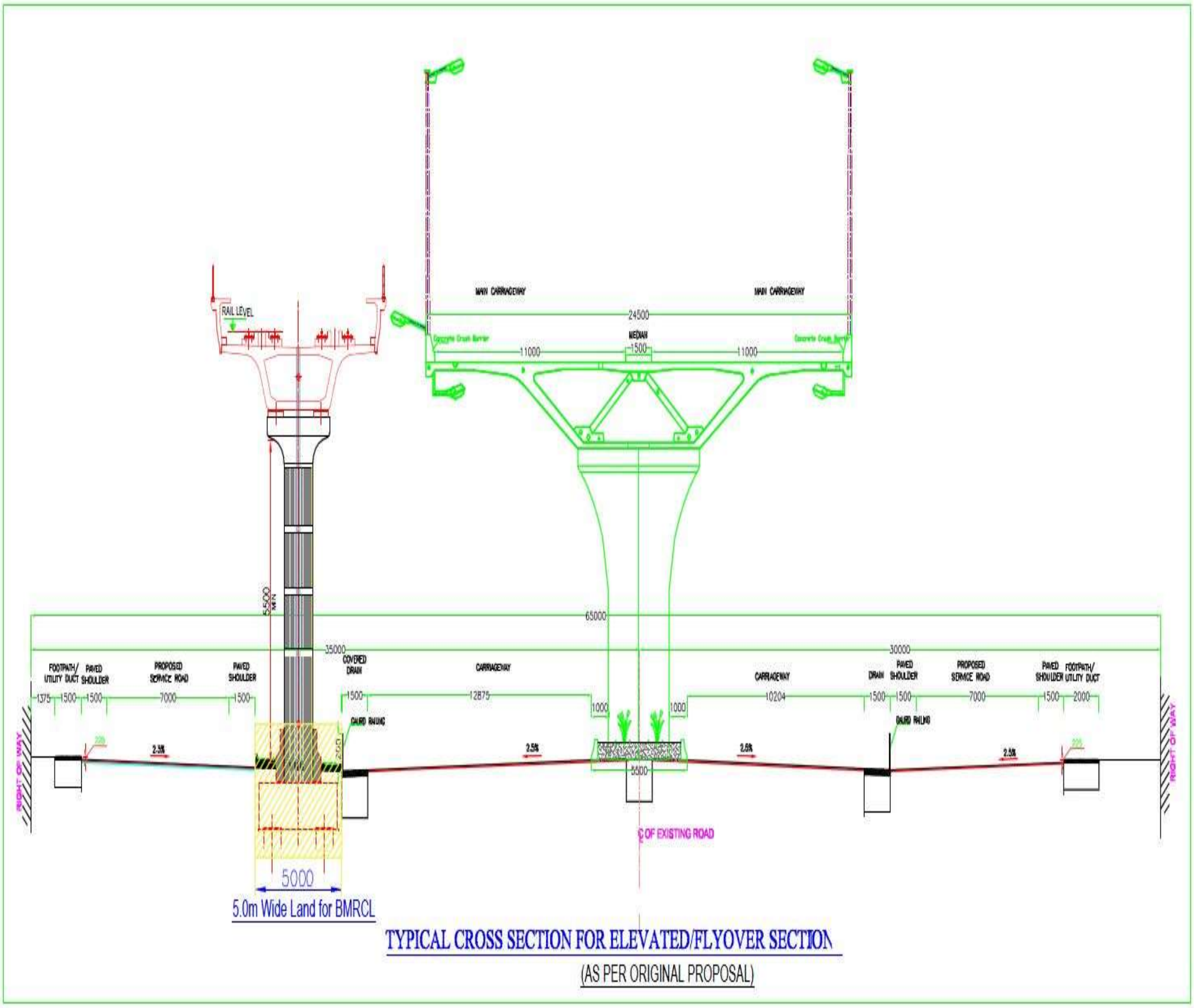
Figure 5.5 Typical details of RCC Shell at Yelahanka Air Force Fly Zone



5.2.1.8 Viaduct along existing Flyover on NH-44:

5.0 m wide strip of land earmarked for rail corridor between main road and service road along NH-44 from Hebbal till Doddajalais being used to locate the viaduct. The typical arrangement of Metro viaduct and existing NH-44 flyover is shown in **Figure 5.6**.

Figure 5.6 Viaduct Cross Section on 5.0 m wide strip along NH 44 (View from Airport side)



5.3 Geometric Design of Corridor

5.3.1 Alignment Planning and Design Norms

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

As the work on the elevated stretches of Phase 1 of the project have already been completed and Phase 2 works are in progress, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track center etc., have been finalized for Phase 1 and Phase 2 will be used for K R Puram-Airport Metro line.

5.3.2 Horizontal Alignment:

The Metro alignment will generally follow median of the Outer Ring Road from Kasthuri Nagar to Hebbal and further moves on Right side of the NH-44 in the dedicated strip of 5mtr width. The road alignment is fairly straight without sharp curves and the Metro alignment is planned with minimum radius of the horizontal curve as 127.50m. On consideration of maximum allowable Cant of 125 mm and cant deficiency of 100 mm on Metro tracks, the safe speed on curves of radii of 400 m or more is 80 km/h. On the same criteria for curves with radius of 127.5 m, speed of 46 km/h shall be permitted. The speed potential for curves of different radius is worked in **Table 5.1.** Since no curves sharper than 127.5m radius are planned, check rails are not required for any of the curves on this corridor.

The specifications for Curve radius in mid-section for Elevated Section is as below:

Preferred Radius without check rail	>190m
Minimum permissible Radius on running lines	120 m (in exceptional cases)
Minimum curve radius at stations	1000 m
Maximum permissible cant (Ca)	125
Maximum cant deficiency (Cd)	100 mm

5.3.3 Horizontal Curves

Total number of 91 horizontal curves have been proposed from Starting point near Jyothipuram to KIA Terminal station. The radii of curves varies from 127.5 m to 3000 m. The sharpest curve is 127.5 m. A statement of curves is given at **Table 5.2.**

Table 5.2 Statement of Horizontal curves in Phase-2B

Curve No.	CHAINAGES				TOTAL LENGTH OF CURVE	LENGTH OF CIRCULAR CURVE	Radius	Transition length provided	Equilibrium Cant Ce	Actual Cant Ca	Cant Deficiency Cd	Speed permitted on curve
	TS	SC	CS	ST	(m)	(m)	(m)	(m)	(mm)	(mm)	(mm)	kmph
1	60.250	110.250	262.860	312.860	252.610	152.616	**128**	50.0	195.069	100	95.069	**46**
2	454.130	504.130	526.930	576.930	122.800	22.803	**200**	50.0	198.476	100	98.476	**58**
3	816.680	856.680	880.660	920.660	103.980	23.984	**600**	40.0	125.867	65	60.867	**80**
4	920.660	960.660	982.900	1022.900	102.240	22.239	**500**	40.0	151.040	75	76.040	**80**
5	1177.370	1217.370	1244.950	1284.950	107.580	27.577	**700**	40.0	108	55	52.89	80
6	1560.940	1575.940	1671.780	1686.780	125.840	95.838	**1200**	15.0	62.933	30	32.933	**74**
7	2015.070	2030.070	2052.570	2067.570	52.500	22.508	**1600**	15.0	47.200	25	22.200	**80**
8	2168.300	2188.300	2212.770	2232.770	64.470	24.472	**1800**	20.0	41.956	20	21.956	**80**

Curve No.	CHAINAGES				TOTAL LENGTH OF CURVE	LENGTH OF CIRCULAR CURVE	Radius	Transition length provided	Equilibrium Cant Ce	Actual Cant Ca	Cant Deficiency Cd	Speed permitted on curve
	TS	SC	CS	ST	(m)	(m)	(m)	(m)	(mm)	(mm)	(mm)	kmph
9	2406.250	2456.250	2570.520	2620.520	214.270	114.276	**150**	50.0	196.667	100	96.667	**50**
10	2918.600	2933.600	2961.920	2976.920	58.320	28.320	**1200**	15.0	62.933	30	32.933	**74**
11	2976.920	2991.920	3032.210	3047.210	70.290	40.286	**1200**	15.0	62.933	30	32.933	**74**
12	3295.410	3320.410	3345.470	3370.470	75.060	25.060	**800**	25.0	94.400	45	49.400	**80**
13	3449.780	3464.780	3528.480	3543.480	93.700	63.697	**1200**	15.0	62.933	30	32.933	**74**
14	5078.540	5120.540	5146.440	5188.440	109.900	25.900	**300**	42.0	198.279	100	98.279	**68**
15	5427.880	5452.880	5474.680	5499.680	71.800	21.793	**800**	25.0	94.400	45	49.400	**80**
16	5580.800	5595.800	5830.090	5845.090	264.290	234.297	**1600**	15.0	47.200	25	22.200	**80**
17	5955.360	5995.360	6047.190	6087.190	131.830	51.831	**128**	40.0	195.069	100	95.069	**46**
18	6314.580	6324.580	6388.080	6398.080	83.500	63.502	**3000**	10.0	25.173	10	15.173	**80**
19	6398.080	6408.080	6468.590	6478.590	80.510	60.505	**3000**	10.0	25.173	10	15.173	**80**
20	6726.660	6741.660	6769.450	6784.450	57.790	27.791	**1500**	15.0	50.347	25	25.347	**80**
21	7007.440	7057.440	7147.050	7197.050	189.610	89.610	**300**	50.0	198.279	100	98.279	**71**
22	7259.160	7319.160	7349.500	7409.500	150.340	30.346	**300**	60.0	198.279	100	98.279	**71**
23	7631.920	7691.920	7805.790	7865.790	233.870	113.873	**180**	60.0	198.306	100	98.306	**55**
24	7879.460	7914.460	7948.010	7983.010	103.550	33.551	**600**	35.0	125.867	65	60.867	**80**
25	7983.010	8018.010	8050.010	8085.010	102.000	32.000	**600**	35.0	125.867	65	60.867	**80**
26	8088.400	8118.400	8137.790	8167.790	79.390	19.396	**600**	30.0	125.867	65	60.867	**75**
27	8167.790	8197.790	8221.100	8251.100	83.310	23.308	**600**	30.0	125.867	65	60.867	**75**
28	8455.100	8505.100	8543.920	8593.920	138.820	38.817	**250**	50.0	199.420	100	99.420	**65**
29	8636.260	8666.260	8753.940	8783.940	147.680	87.688	**750**	30.0	100.693	50	50.693	**80**
30	8783.940	8823.940	8856.860	8896.860	112.920	32.914	**300**	40.0	198.279	100	98.279	**65**
31	9034.150	9044.150	9070.640	9080.640	46.490	26.486	**2700**	10.0	27.970	15	12.970	**80**
32	9393.570	9408.570	9701.480	9716.480	322.910	292.906	**1200**	15.0	62.933	30	32.933	**74**
33	10081.860	10101.860	10123.900	10143.900	62.040	22.041	**1100**	20.0	68.655	35	33.655	**80**
34	10279.740	10329.740	10450.950	10500.950	221.210	121.209	**250**	50.0	199.420	100	99.420	**65**
35	10631.770	10671.770	10717.040	10757.040	125.270	45.268	**127.5**	40.0	195.834	100	95.834	**46**
36	10919.660	10959.660	11056.650	11096.650	176.990	96.994	**127.5**	40.0	195.834	100	95.834	**46**
37	11410.300	11460.300	11671.380	11721.380	311.080	211.073	**300**	50.0	198.279	100	98.279	**71**
38	11784.590	11819.590	11848.410	11883.410	98.820	28.827	**600**	35.0	125.867	65	60.867	**80**
39	12088.350	12108.350	12443.790	12463.790	375.440	335.441	**1000**	20.0	75.520	40	35.520	**80**
40	12463.790	12493.790	12597.480	12627.480	163.690	103.686	**1500**	30.0	50.347	25	25.347	**80**
41	12805.540	12830.540	12866.090	12891.090	85.550	35.552	**800**	25.0	94.400	45	49.400	**80**
42	12891.090	12916.090	12950.020	12975.020	83.930	33.927	**800**	25.0	94.400	45	49.400	**80**
43	13046.040	13076.040	13112.480	13142.480	96.440	36.436	**1200**	30.0	62.933	30	32.933	**80**
44	13499.100	13514.100	13536.130	13551.130	52.030	22.030	**2000**	15.0	37.76	20	17.760	**80**
45	13701.560	13721.560	13772.850	13792.850	91.290	51.291	**1200**	20.0	62.93	30	32.933	**80**
46	13922.980	13942.980	13998.120	14018.120	95.140	55.135	**1000**	20.0	75.52	40	35.520	**80**
47	14018.120	14038.120	14070.210	14090.210	72.090	32.089	**1000**	20.0	75.52	40	35.520	**80**

Curve No.	CHAINAGES				TOTAL LENGTH OF CURVE	LENGTH OF CIRCULAR CURVE	Radius	Transition length provided	Equilibrium Cant Ce	Actual Cant Ca	Cant Deficiency Cd	Speed permitted on curve
	TS	SC	CS	ST	(m)	(m)	(m)	(m)	(mm)	(mm)	(mm)	kmph
48	14285.560	14300.560	14375.710	14390.710	105.150	75.153	**1200**	15.0	62.93	30	32.933	**74**
49	14390.710	14405.710	14477.970	14492.970	102.260	72.264	**1200**	15.0	62.93	30	32.933	**74**
50	14511.84	14526.84	14827.82	14842.82	330.98	300.981	**2000**	14.99	37.76	20	17.760	**80**
51	15247.19	15257.19	15281.76	15291.76	44.57	24.577	**2500**	9.99	30.20	15	15.208	**80**
52	15414.53	15434.53	15662.93	15682.93	268.4	228.395	**870**	20.00	86.80	45	41.805	**72**
53	15941.99	15956.99	16000.54	16015.54	73.55	43.558	**1200**	14.99	62.93	30	32.933	**74**
54	16265.84	16275.84	16679.87	16689.87	424.03	404.039	**2000**	9.99	37.76	20	17.76	**80**
55	16856.65	16871.65	17063.89	17078.89	222.24	192.242	**1200**	14.999	62.93	30	32.933	**74**
56	17344.1	17374.1	17412.1	17442.1	98	38	**600**	30	125.86	65	60.867	**75**
57	17600.61	17625.61	17651.87	17676.87	76.26	26.263	**800**	24.99	94.40	45	49.4	**80**
58	17676.87	17701.87	17735.7	17760.7	83.83	33.833	**800**	24.99	94.40	45	49.4	**80**
59	17979.55	17997.55	18293.28	18311.28	331.73	295.729	**1100**	18.00	68.65	35	33.655	**80**
60	19872.31	19892.31	19952.32	19972.32	100.01	60.014	**1200**	19.99	62.93	30	32.933	**80**
61	20132.49	20157.49	20233.91	20258.91	126.42	76.426	**800**	24.99	94.40	45	49.4	**80**
62	20258.91	20283.91	20328.84	20353.84	94.93	44.932	**800**	24.999	94.40	45	49.4	**80**
63	21801.15	21816.15	22344.95	22359.95	558.8	528.793	**1200**	15.00	62.93	30	32.933	**74**
64	22752.9	22762.9	23005.85	23015.85	262.95	242.949	**1800**	10.00	41.95	20	21.956	**74**
65	23168.6	23193.6	23416.84	23441.84	273.24	223.238	**700**	25.00	107.88	55	52.886	**74**
66	23935.66	23947.66	24260.83	24272.83	337.17	313.171	**2600**	11.99	29.04	15	14.046	**80**
67	24498.33	24508.33	24589.65	24599.65	101.32	81.321	**2000**	9.99	37.76	20	17.76	**80**
68	24924.64	24934.64	25044.14	25054.14	129.5	109.497	**2000**	10.00	37.76	20	17.76	**80**
69	25054.14	25066.14	25226.17	25238.17	184.03	160.035	**1600**	11.99	47.20	25	22.2	**78**
70	25308.64	25338.64	25370.94	25400.94	92.3	32.306	**1200**	29.99	62.93	30	32.933	**80**
71	25613.21	25653.21	25719	25759	145.79	65.79	**500**	40	151.04	75	76.04	**80**
72	26275.15	26282.15	26307.5	26314.5	39.35	25.348	**3000**	7.001	25.17	10	15.173	**75**
73	26448.43	26458.43	26557.01	26567.01	118.58	98.574	**2100**	10.003	35.9619	20	15.962	**80**
74	26680.34	26705.34	26867.19	26892.19	211.85	161.847	**700**	25.00	107.88	55	52.886	**74**
75	26944.54	26954.54	26998.47	27008.47	63.93	43.931	**2000**	9.99	37.76	20	17.76	**80**
76	27206.02	27216.02	27240.53	27250.53	44.51	24.513	**3000**	9.99	25.17	10	15.173	**80**
77	28025.15	28035.15	28105.6	28115.6	90.45	70.453	**2000**	9.99	37.76	20	17.76	**80**
78	28192.75	28202.75	28255.71	28265.71	72.96	52.957	**1800**	10.00	41.95	20	21.956	**74**
79	28451.58	28481.58	28520.67	28550.67	99.09	39.09	**500**	30	151.04	75	76.04	**64**
80	28550.67	28580.67	28619.17	28649.17	98.5	38.497	**500**	30.00	151.04	75	76.04	**64**
81	28838.4	28873.4	28897.76	28932.76	94.36	24.361	**450**	34.99	167.82	85	82.822	**67**
82	29021.84	29056.84	29102.55	29137.55	115.71	45.711	**450**	34.99	167.82	85	82.822	**67**
83	29170	29210	29295.52	29335.52	165.52	85.524	**250**	39.99	199.42	100	99.42	**65**
84	29335.52	29375.52	29452.8	29492.8	157.28	77.279	**250**	40.00	199.42	100	99.42	**65**
85	30321.84	30351.84	30789.61	30819.61	497.77	437.766	**750**	30.00	100.69	50	50.693	**80**
86	31382.29	31447.29	31505.59	31570.59	188.3	58.294	**600**	65.00	125.86	65	60.867	**80**

Curve No.	CHAINAGES				TOTAL LENGTH OF CURVE	LENGTH OF CIRCULAR CURVE	Radius	Transition length provided	Equilibrium Cant Ce	Actual Cant Ca	Cant Deficiency Cd	Speed permitted on curve
	TS	SC	CS	ST	(m)	(m)	(m)	(m)	(mm)	(mm)	(mm)	kmph
87	31570.59	31635.59	31693.52	31758.52	187.93	57.935	**600**	64.99	125.86	65	60.867	**80**
88	32719.36	32754.36	32856.98	32891.98	172.62	102.621	**700**	34.99	107.88	55	52.886	**80**
89	32891.98	32926.98	33028.84	33063.84	171.86	101.86	**700**	35.00	107.88	55	52.886	**80**
90	35464.49	35489.49	35520.34	35545.34	80.85	30.851	**1500**	24.99	50.34	25	25.347	**80**
91	35545.34	35570.34	35601.19	35626.19	80.85	30.851	**1500**	24.99	50.34	25	25.347	**80**

Table 5.3 Abstract of Horizontal Curves in Phase-2B

Sl. No.	Radius (m)	Nos. Occurrences	Curved Length with TL (m)	% w. r. t. Total curved length
1	Upto 200	7	1257.640	9.40%
2	>200-500	15	2212.370	16.53%
3	>500-1000	28	4136.730	30.91%
4	>1000-2000	33	4983.490	37.23%
6	>2000	8	794.68	5.94%
	Total	**91**	**13384.910**	**100.00%**

5.3.4 Vertical Alignment:

Track supporting structures on elevated sections are to permit a vertical clearance of 5.50 m above road level for vehicular traffic. For meeting this requirement with the Box girder design the rail level is planned to be at least 13.5 m above the road level. Similarly, the rail level for the stations is kept as 13.5 m with footbridge (connecting bridge) under the viaduct for platform inter-change for commuters.

5.3.5 Gradients

There is no steep gradient envisaged in the alignment as the road is fairly flat and we are following the road profile. 16.30% of the alignment is on Level gradient and rest 83.70% is on different gradient. The steepest gradient on this section is 3.88% and the minimum radius of Vertical curve is kept as 1,505m. Detailed statement of vertical curves and gradients is placed in **Tables 5.4** and **5.5 (I & ii)** respectively.

Table 5.4 Statement of Vertical curves

No.	Start of Curve	End of Curve	PVI Station	PVI Elevation	Grade In	Gradient 1:X	Grade Out	Gradient 1:X	A (Grade Change)	Profile Curve Type	Profile Curve Length (m)	Curve Radius
	CH: (m)	CH: (m)	CH: (m)	(m)	%	X (m)	%	X (m)				(m)
1			312.860	916.073			-1.71%	-58.480				
2	602.330	637.671	620.000	910.812	-1.71%	-58.480	0.63%	158.730	2.34%	Sag	35.341	1510
3	1081.810	1147.591	1114.700	913.918	0.63%	158.730	3.43%	29.155	2.80%	Sag	65.781	2350
4	1490.177	1541.924	1516.050	927.680	3.43%	29.155	0.00%	Level	3.43%	Crest	51.747	1510
5	1730.504	1764.036	1747.270	927.680	0.00%	Level	1.68%	59.524	1.68%	Sag	33.532	2000
6	2081.514	2133.727	2107.620	933.723	1.68%	59.524	-1.78%	-56.180	3.46%	Crest	52.213	1510
7	2321.568	2395.512	2358.540	929.253	-1.78%	-56.180	3.12%	32.051	4.90%	Sag	73.944	1510
8	2637.436	2684.484	2660.960	938.680	3.12%	32.051	0.00%	Level	3.12%	Crest	47.048	1510
9	2867.808	2905.152	2886.480	938.680	0.00%	Level	-2.47%	-40.486	2.47%	Crest	37.344	1510
10	3574.543	3602.137	3588.340	921.317	-2.47%	-40.486	-0.75%	-133.333	1.73%	Sag	27.594	1600
11	3810.800	3842.160	3826.480	919.535	-0.75%	-133.333	-2.83%	-35.336	2.08%	Crest	31.360	1510
12	4090.179	4132.841	4111.510	911.479	-2.83%	-35.336	0.00%	Level	2.83%	Sag	42.662	1510
13	4347.368	4385.593	4366.480	911.479	0.00%	Level	-2.39%	-41.841	2.39%	Crest	38.225	1600
14	4593.346	4659.615	4626.480	905.265	-2.39%	-41.841	2.00%	50.000	4.39%	Sag	66.269	1510
15	4871.502	4901.458	4886.480	910.465	2.00%	50.000	3.50%	28.571	1.50%	Sag	29.956	2000
16	5192.795	5245.606	5219.200	922.109	3.50%	28.571	0.00%	Level	3.50%	Crest	52.811	1510
17	5506.528	5533.772	5520.150	922.109	0.00%	Level	-0.54%	-185.185	0.54%	Crest	27.244	5000
18	5868.661	5904.300	5886.480	920.112	-0.54%	-185.185	-2.91%	-34.364	2.36%	Crest	35.639	1510
19	6416.007	6459.874	6437.940	904.085	-2.91%	-34.364	0.00%	Level	2.91%	Sag	43.867	1510
20	6668.668	6710.692	6689.680	904.085	0.00%	Level	-2.78%	-35.971	2.78%	Crest	42.024	1510
21	6926.349	6981.552	6953.950	896.728	-2.78%	-35.971	0.87%	114.943	3.66%	Sag	55.203	1510
22	7434.269	7460.452	7447.360	901.034	0.87%	114.943	0.00%	Level	0.87%	Crest	26.183	3000
23	7726.380	7742.521	7734.450	901.034	0.00%	Level	0.65%	153.846	0.65%	Sag	16.141	2500
24	8198.192	8220.789	8209.490	904.101	0.65%	153.846	0.00%	Level	0.65%	Crest	22.597	3500
25	8423.490	8444.290	8433.890	904.101	0.00%	Level	1.38%	72.464	1.38%	Sag	20.800	1510
26	8690.438	8734.022	8712.230	907.936	1.38%	72.464	-1.51%	-66.225	2.89%	Crest	43.584	1510
27	8997.064	9015.896	9006.480	903.495	-1.51%	-66.225	-0.26%	-384.615	1.25%	Sag	18.832	1510
28	9524.013	9552.327	9538.170	902.104	-0.26%	-384.615	0.55%	181.818	0.81%	Sag	28.314	3500
29	9845.560	9872.921	9859.240	903.861	0.55%	181.818	0.00%	Level	0.55%	Crest	27.361	5000
30	10105.265	10121.555	10113.410	903.861	0.00%	Level	-0.47%	-212.766	0.47%	Crest	16.290	3500
31	10578.067	10616.293	10597.180	901.609	-0.47%	-212.766	1.06%	94.340	1.53%	Sag	38.226	2500
32	10791.635	10833.386	10812.510	903.899	1.06%	94.340	-0.33%	-303.030	1.39%	Crest	41.751	3000
33	11138.311	11159.409	11148.860	902.796	-0.33%	-303.030	0.00%	Level	0.32%	Sag	21.098	6500
34	11337.880	11387.840	11362.860	902.788	0.00%	Level	3.31%	30.211	3.31%	Sag	49.960	1510

No.	Start of Curve	End of Curve	PVI Station	PVI Elevation	Grade In	Gradient 1:X	Grade Out	Gradient 1:X	A (Grade Change)	Profile Curve Type	Profile Curve Length (m)	Curve Radius
	CH: (m)	CH: (m)	CH: (m)	(m)	%	X (m)	%	X (m)				(m)
35	12223.333	12287.487	12255.410	932.304	3.31%	30.211	-0.94%	-106.383	4.25%	Crest	64.154	1510
36	12533.592	12560.009	12546.800	929.555	-0.94%	-106.383	0.00%	Level	0.94%	Sag	26.417	2800
37	12832.601	12865.700	12849.150	929.555	0.00%	Level	-2.19%	-45.662	2.19%	Crest	33.099	1510
38	13318.963	13402.838	13360.900	918.335	-2.19%	-45.662	3.36%	29.762	5.56%	Sag	83.875	1510
39	13945.946	13996.554	13971.250	938.870	3.36%	29.762	0.00%	Level	3.36%	Crest	50.608	1505
40	14323.096	14347.264	14335.180	938.870	0.00%	Level	-0.40%	-250.000	0.40%	Crest	24.168	6000
41	15175.139	15219.062	15197.100	935.399	-0.40%	-250.000	-2.40%	-41.667	2.00%	Crest	43.923	2200
42	16412.605	16507.396	16460.000	909.024	-2.40%	-41.667	3.88%	25.773	6.28%	Sag	94.791	1510
43	16617.469	16676.031	16646.750	916.272	3.88%	25.773	0.00%	Level	3.88%	Crest	58.562	1510
44	16783.168	16804.092	16793.630	916.272	0.00%	Level	-0.23%	-434.783	0.23%	Crest	20.924	9000
45	17276.975	17306.445	17291.710	915.114	-0.23%	-434.783	-1.71%	-58.480	1.47%	Crest	29.47	2000
46	17706.352	17733.648	17720.000	907.806	-1.71%	-58.480	0.00%	Level	1.71%	Sag	27.296	1600
47	17946.376	17973.624	17960.000	907.806	0.00%	Level	0.97%	103.093	0.97%	Sag	27.248	2800
48	18399.319	18440.681	18420.000	912.283	0.97%	103.093	3.56%	28.090	2.59%	Sag	41.362	1600
49	18646.384	18673.617	18660.000	920.828	3.56%	28.090	2.20%	45.455	1.36%	Crest	27.233	2000
50	19061.906	19098.094	19080.000	930.056	2.20%	45.455	0.39%	256.410	1.81%	Crest	36.188	2000
51	19821.294	19844.526	19832.910	932.972	0.39%	256.410	0.00%	Level	0.39%	Crest	23.232	6000
52	20102.029	20124.712	20113.370	932.972	0.00%	Level	0.38%	263.158	0.38%	Sag	22.683	6000
53	20677.697	20722.303	20700.000	935.189	0.38%	263.158	2.61%	38.314	2.23%	Sag	44.606	2000
54	20944.051	21015.949	20980.000	942.495	2.61%	38.314	-2.15%	-46.512	4.76%	Crest	71.898	1510
55	22207.889	22285.271	22246.580	915.218	-2.15%	-46.512	2.97%	33.670	5.13%	Sag	77.382	1510
56	22921.845	22958.155	22940.000	935.832	2.97%	33.670	0.57%	175.439	2.41%	Crest	36.31	1510
57	23745.313	23774.687	23760.000	940.481	0.57%	175.439	-0.41%	-243.902	0.98%	Crest	29.374	3000
58	24626.594	24653.406	24640.000	936.854	-0.41%	-243.902	-1.75%	-57.143	1.34%	Crest	26.812	2000
59	25239.070	25280.930	25260.000	925.984	-1.75%	-57.143	1.02%	98.039	2.77%	Sag	41.86	1510
60	25779.500	25820.500	25800.000	931.489	1.02%	98.039	-1.70%	-58.824	2.72%	Crest	41	1510
61	26966.993	26993.007	26980.000	911.475	-1.70%	-58.824	-0.66%	-151.515	1.04%	Sag	26.014	2500
62	27295.576	27344.425	27320.000	909.247	-0.66%	-151.515	1.79%	55.866	2.44%	Sag	48.849	2000
63	28114.270	28189.910	28152.090	924.120	1.79%	55.866	3.30%	30.303	1.51%	Sag	75.64	5000
64	28575.303	28624.958	28600.130	938.912	3.30%	30.303	0.01%	10000.000	3.29%	Crest	49.655	1510
65	29496.954	29553.726	29525.340	939.019	0.01%	10000.000	-3.75%	-26.667	3.76%	Crest	56.772	1510
66	29743.148	29817.233	29780.190	929.460	-3.75%	-26.667	1.16%	86.207	4.91%	Sag	74.085	1510
67	30713.905	30776.555	30745.230	940.636	1.16%	86.207	-2.99%	-33.445	4.15%	Crest	62.65	1510
68	31081.054	31128.546	31104.800	929.877	-2.99%	-33.445	0.15%	666.667	3.15%	Sag	47.492	1510
69	31793.808	31837.112	31815.460	930.972	0.15%	666.667	-2.01%	-49.751	2.17%	Crest	43.304	2000

No.	Start of Curve	End of Curve	PVI Station	PVI Elevation	Grade In	Gradient 1:X	Grade Out	Gradient 1:X	A (Grade Change)	Profile Curve Type	Profile Curve Length (m)	Curve Radius
	CH: (m)	CH: (m)	CH: (m)	(m)	%	X (m)	%	X (m)				(m)
70	32194.695	32215.786	32205.240	923.132	-2.01%	-49.751	-2.97%	-33.670	0.96%	Crest	21.091	2200
71	32562.713	32607.567	32585.140	911.845	-2.97%	-33.670	0.00%	Level	2.97%	Sag	44.854	1510
72	34019.379	34055.321	34037.350	911.855	0.00%	Level	-2.38%	-42.017	2.38%	Crest	35.942	1510
73	34455.244	34476.377	34465.810	901.657	-2.38%	-42.017	-1.53%	-65.359	0.85%	Sag	21.133	2500
74	34800.022	34838.339	34819.180	896.235	-1.53%	-65.359	1.00%	100.000	2.54%	Sag	38.317	1510
75	35191.651	35258.809	35225.230	900.309	1.00%	100.000	-3.45%	-28.986	4.45%	Crest	67.158	1510
76	35399.876	35451.884	35425.880	893.394	-3.45%	-28.986	0.00%	Level	3.45%	Sag	52.008	1510
77	36417.950	36417.950	36417.950	893.394	0.00%	Level						

Table 5.5 Statement of Gradients

No.	Chainage From	Chainage To	Length (m)	Gradient	Rise/Fall
1	0	637.671	637.671	-1.71%	Fall
2	637.671	1147.591	509.92	0.63%	Rise
3	1147.591	1541.924	394.333	3.43%	Rise
4	1541.924	1764.036	222.112	0.00%	Level
5	1764.036	2133.727	369.691	1.68%	Rise
6	2133.727	2395.512	261.785	-1.78%	Fall
7	2395.512	2684.484	288.972	3.12%	Rise
8	2684.484	2905.152	220.668	0.00%	Level
9	2905.152	3602.137	696.985	-2.47%	Fall
10	3602.137	3842.16	240.023	-0.75%	Fall
11	3842.16	4132.841	290.681	-2.83%	Fall
12	4132.841	4385.593	252.752	0.00%	Level
13	4385.593	4659.615	274.022	-2.39%	Fall
14	4659.615	4901.458	241.843	2.00%	Rise
15	4901.458	5245.606	344.148	3.50%	Rise
16	5245.606	5533.772	288.166	0.00%	Level
17	5533.772	5904.3	370.528	-0.54%	Fall
18	5904.3	6459.874	555.574	-2.91%	Fall
19	6459.874	6710.692	250.818	0.00%	Level
20	6710.692	6981.552	270.86	-2.78%	Fall
21	6981.552	7460.452	478.9	0.87%	Rise
22	7460.452	7742.521	282.069	0.00%	Level
23	7742.521	8220.789	478.268	0.65%	Rise
24	8220.789	8444.29	223.501	0.00%	Level
25	8444.29	8734.022	289.732	1.38%	Rise
26	8734.022	9015.896	281.874	-1.51%	Fall
27	9015.896	9552.327	536.431	-0.26%	Fall
28	9552.327	9872.921	320.594	0.55%	Rise

No.	Chainage From	Chainage To	Length (m)	Gradient	Rise/Fall
29	9872.921	10121.555	248.634	0.00%	Level
30	10121.555	10616.293	494.738	-0.47%	Fall
31	10616.293	10833.386	217.093	1.06%	Rise
32	10833.386	11159.409	326.023	-0.33%	Fall
33	11159.409	11387.84	228.431	0.00%	Level
34	11387.84	12287.487	899.647	3.31%	Rise
35	12287.487	12560.009	272.522	-0.94%	Fall
36	12560.009	12865.7	305.691	0.00%	Level
37	12865.7	13402.838	537.138	-2.19%	Fall
38	13402.838	13996.554	593.716	3.36%	Rise
39	13996.554	14347.264	350.71	0.00%	Level
40	14347.264	15219.062	871.798	-0.40%	Fall
41	15219.062	16507.396	1288.334	-2.40%	Fall
42	16507.396	16676.031	168.635	3.88%	Rise
43	16676.031	16804.092	128.061	0.00%	Level
44	16804.092	17306.445	502.353	-0.23%	Fall
45	17306.445	17733.648	427.203	-1.71%	Fall
46	17733.648	17973.624	239.976	0.00%	Level
47	17973.624	18440.681	467.057	0.97%	Rise
48	18440.681	18673.617	232.936	3.56%	Rise
49	18673.617	19098.094	424.477	2.20%	Rise
50	19098.094	19844.526	746.432	0.39%	Rise
51	19844.526	20124.712	280.186	0.00%	Level
52	20124.712	20722.303	597.591	0.38%	Rise
53	20722.303	21015.949	293.646	2.61%	Rise
54	21015.949	22285.271	1269.322	-2.15%	Fall
55	22285.271	22958.155	672.884	2.97%	Rise
56	22958.155	23774.687	816.532	0.57%	Rise
57	23774.687	24653.406	878.719	-0.41%	Fall
58	24653.406	25280.93	627.524	-1.75%	Fall
59	25280.93	25820.5	539.57	1.02%	Rise
60	25820.5	26993.007	1172.507	-1.70%	Fall
61	26993.007	27344.425	351.418	-0.66%	Fall
62	27344.425	28189.91	845.485	1.79%	Rise
63	28189.91	28624.958	435.048	3.30%	Rise
64	28624.958	29553.726	928.768	0.01%	Rise
65	29553.726	29817.233	263.507	-3.75%	Fall
66	29817.233	30776.555	959.322	1.16%	Rise
67	30776.555	31128.546	351.991	-2.99%	Fall
68	31128.546	31837.112	708.566	0.15%	Rise
69	31837.112	32215.786	378.674	-2.01%	Fall
70	32215.786	32607.567	391.781	-2.97%	Fall
71	32607.567	34055.321	1447.754	0.00%	Level

No.	Chainage From	Chainage To	Length (m)	Gradient	Rise/Fall
72	34055.321	34476.377	421.056	-2.38%	Fall
73	34476.377	34838.339	361.962	-1.53%	Fall
74	34838.339	35258.809	420.47	1.00%	Rise
75	35258.809	35451.884	193.075	-3.45%	Fall
76	35451.884	36417.95	966.066	0.00%	Level

Table 5.6 Abstract of Gradients

Sl. No.	Description	Nos. Occurrences	Length (m)	% w. r. t. Total Alignment length
1	Level	16	5935.595	16.30%
2	> 0% to = 1%	21	11317.651	31.08%
3	> 1% to = 2%	14	7233.262	19.86%
4	> 2% to = 3%	15	8117.425	22.29%
5	> 3% to = 4%	10	3814.07	10.47%
	Total	**77**	**36418.00**	**100.00%**

5.3.6 Design Speed

The maximum sectional speed will be 80 km/h. However, the applied Cant, and length of transition will be decided in relation to normal speeds at various locations, as determined by simulation studies of alignment, vertical profile and Station locations. This is with the objective of keeping down the wear on rails on curves to the minimum. The permitted speed on different curves are worked out and indicated in **Table 5.2**.

5.3.7 Permanent Way

5.3.7.1 Spacing of Tracks

The spacing of tracks on the Viaduct through the stations shall be 4.2m providing for the extra clearance required due to end throw/mid throw and lean on curves of radius upto 120m.In depots, the spacing to be changed beyond 4.20 m as per provisions of SOD of BMRCL 2015, for curves of radius less than 120.0 m to 100.0 m.

5.3.7.2 Track Structure

a. Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus, it is imperative that the track structure selected for Metro Systems should be long lasting and should require minimum or no maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. The track structure has been proposed keeping the above philosophy in view.

b. Two types of track structures are proposed for any Metro. The normal ballasted track is suitable for At-Grade (surface) portion of Main Lines and in Depot (except inside the Workshops, inspection lines and washing plant lines. The ballast-less track is recommended on Viaducts and inside tunnels as the regular cleaning and replacement of ballast at such location will not be possible. Only in case of the depot normal ballasted track is proposed for adoption.

c. From considerations of maintainability, riding comfort and also to contain vibrations and noise levels, the complete track is proposed to be joint-less and for this purpose the continuously welded track will even have to be taken through the turnouts.

d. The track will be laid with 1 in 20 canted rails including turnouts and the wheel profile of Rolling Stock should be compatible with the Rail Cant and Rail profile.

5.3.7.3 Rail Section

Keeping in view the proposed Axle load frequency of train operation, maintainability and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1,080 Head Hardened. For the Depot lines, the grade of rails may be 880 grade.

5.3.7.4 Ballastless Track on Viaduct

On the Viaduct, it is proposed to adopt plinth type ballast less track structure with RCC derailment guards integrated with the plinths. Further, it is proposed to adopt suitable fastening System with a base-plate to base-plate spacing of 70 cm on Viaducts and. The fastenings systems for ballast less track should satisfy performance criteria of fastening system for ballast less track on Metro Rails issued by Government of India, Ministry of Railways in December 2015.

5.3.7.5 Ballastless Track in Depot

a. The ballastless track in Depot may be of the following types:

   i. Discretely supported on concrete/steel pedestal for inspection lines.
   ii. Embedded rail type inside the Workshop.
   iii. Plinth type for Washing Plant line.
   iv. Normal Ballast less (as on Viaduct) for washing lines.

5.3.7.6 Buffer Stops

On main lines and Depot lines, friction buffer stops with mechanical impact absorption (non-hydraulic type) need to be provided. On elevated section the spans on which friction buffer stops are to be installed are to be designed for an additional longitudinal force of 85 T, which is likely to be transmitted in case of Rolling Stock impacting the friction Buffer Stops.

5.3.7.7 Welding

Flash Butt Welding Technique is to be used for welding of rails. Alumino-Thermic Welding is to be done only for those joints which cannot be welded by Flash Butt Welding Technique, such as joints at distressing locations and approach welds of switches & crossings. For minimizing the population of Thermit welds, mobile (rail-cum-road or portable) Flash Butt Welding Plant will have to be deployed.

5.3.7.8 Operating Environment

a. Track Structure should fulfill generally the following conditions:
   - Standard gauge – 1,435mm.
   - Rail Seat inclination (slope): 1 in 20
   - Speed potential – 80 Kmph (max.)
   - Static axle load – 15 T (max.)
   - Design rail temperature range – (-) 10 degree to (+) 70 degree Celsius
   - Maximum curvature and ruling gradient – As specified in SOD

5.3.8 Track Structure

5.3.8.1 General: The track structure should fulfill the following requirements:

i. The track structure should confirm to / satisfy Schedule of Dimension requirement and other maintenance instructions of Metro systems.

ii. Ride comfort and running safety of track vehicle dynamics should be satisfied.

iii. The track structure should be designed with long welded / continuously welded rail on main line track in case of ballasted as well as ballastless track.

iv. The horizontal alignment shall consist of a series of straights joined to circular curves generally with transition curves. Curvature and Cant shall be calculated based on the train speed for each train type on the section. Compound and reverse curves are acceptable, provided they are connected by an adequate transition curve.

v. The vertical alignment should be designed to achieve a smooth profile line with gradual changes. Changes in the profile should be connected by vertical curves, which shall be as generous in length as the location allows. Vertical curves including its transition shall not be located at stations within the length of platform. A vertical curve within the length of transition and turnouts is also not desirable. Vertical curve radius is constrained by the need to limit the vertical acceleration for passenger ride comfort.

5.3.8.2 The technical standards for Track structure deals with the following components

i. Rail and Welding
ii. Sleeper and Fastening for ballasted track

iii. Track slab for ballastless track
iv. Fastening system for ballastless track
v. Insulated glued joint
vi. Turnout, scissors crossover
vii. Switch Expansion Joints
viii. Gradients

5.3.8.3 Rails and Rail Welding

a. Rails

For Main Line Track: The rail used on main line shall be 60E1 (UIC 60), 1080 grade Head Hardened. It is essential to have preventive rail grinding arrangements in case 60E1 (UIC 60), 1080 HH rails are used.

For Depot lines

The rail used on depot lines can be non-head hardened and shall be 60E1 (UIC 60), 880 grade.

Specification

The rail shall be class ‘A’ rails as per IRS-T-12-2009 specification with latest amendments. However, any suitable length of rail more than 13m considered appropriate by Metro on consideration of transportation and handling can be adopted, provided the rails are ultimately welded into long welded rails. The rail shall be manufactured and tested in accordance with IRS-T-12-2009 (with latest amendment). The chosen manufacturers shall be required to submit their inspection and test plan for approval by Metro Railway as per IRS-T-12-2009. Metro Railways will ensure that the inspection and test plan approved by them strictly conforms to the requirement of IRS specifications.

b. Welding of Rail

The welding of rails should conform to Indian Railway Specifications and technical instructions issued from time to time. The present instructions are contained in following documents:

- Alumino Thermit Welding
  Indian Railway Standard specifications for Alumino Thermit Welding of Rails (IRS/T-19 with latest amendments)

  Manual for Fusion Welding of Rails by the Alumino-Thermic Process: Revised - 2012 with latest amendments.

- Flash Butt Welding:
  Manual for Flash Butt Welding of Rails, January 2012 with latest amendments.

Special emphasis has been given by Metro for provisions of these instructions regarding procurement, execution of works and areas requiring prior approval / standardization by RDSO.

c. Ultrasonic Testing of Rail and Welds
The rails and welds shall be ultrasonically tested in field as per requirement of concerned specification / manual / instructions. The testing shall be ensured as per provisions of "Manual for Ultrasonic Testing of Rail and Welds – Revised 2012" with latest amendments. The provisions of "IRS specification for Ultrasonic testing of Rails / Welds (Provisional), Revised 2012" shall also be followed.

5.3.8.4 Sleeper and fastening for Ballasted Track

a. Sleepers

Standard Gauge
PSC sleeper for standard gauge has been designed by BMRCL duly following the principal guidelines of Indian Railway.

Fastening System
The elastic fastening system prevalent on Indian Railways shall be used duly ensuring the inspection protocol for fastening components laid down for IR.

In case of use of elastic fastening other than in use on IR, prior approval shall be obtained from Railways.

5.3.8.5 Track Slab for Ballastless Track

a. Track shall be laid on cast in situ / precast reinforced plinth or slab, herein referred to as the 'track slab'. The track slab shall be designed as plinth beam or slab type ballast less track structure with derailment guards. It shall accommodate the base plates of the fastening system. In general, track slab (including sleeper, if any) on which the fastening and rail are to be fitted shall perform the following functions:
   i. Resist the track forces. (Static and dynamic).
   ii. Have adequate edge distance of concrete beyond the anchor bolts to provide resistance against edge failure.
   iii. Provide a level base for uniform transmission of track / rail forces.
   iv. Have geometrical accuracy and enable installation of track to the tolerances laid down.
   v. Ensure drainage.
   vi. Resist Weathering
   vii. Be construction friendly, maintainable and quickly repairable in the event of a derailment. The 'Repair and Maintenance Methods' shall be detailed in a Manual to be prepared and made available.

viii. Ensure provision for electrical continuity between consecutive plinths / slabs by an appropriate design.

ix. Plinth beam or slab of ballastless track should be suitable for Viaduct or tunnel / Underground structure.

x. Proper design of expansion joints suitable for joints of Viaduct structure.

xi. Design should be suitable for curves as per SOD of Metro system.

xii. Design of subgrade / embankment for slab should be furnished to ensure durability and functional stability in service.

xiii. Design should be suitable and incorporate provision of utilities e.g. cable, wires, ducts, water channels, etc.

b. The detailed design calculations of track slab along with detailed structural drawings as approved by Metro authorities shall be furnished for record.

5.3.8.6 Check Rail / Restraining Rail

Check Rails / Restraining Rails should be provided on curves on main line where radius is 190m or less on Standard gauge. The clearance of check rail / restraining rails shall be suitably decided after requisite studies. The detailed design calculations / studies in this regard shall be furnished for record. Check Rails / Restraining Rails shall not be mandatory for curves in depots, yards and non-passenger lines where speed is not more than 25 Kmph. However, decision in this regard will be taken by BMRCL based on layout and maintenance requirement.

5.3.8.7 Derailment Guards

The derailment guard should be provided inside / outside of running rail on Viaduct as well as in tunnel having multiple tracks and at grade section locations specified by the Metro Railway. In tunnels, the derailment guard should be preferably be provided inside the track, so that it permits less way of coach towards tunnel wall in case of derailment.

Derailment guard shall be designed such that in case of derailment:

i. The wheels of a derailed vehicle under crush load, moving at maximum speed are retained on the Viaduct or tunnel.

ii. Damage to track and supporting structures is minimum.

The detailed design calculations of derailment guards along with detailed structural drawings shall be furnished for record.

5.3.8.8 Glued insulated Rail Joint

Normally glued joint should be avoided. Wherever inescapable, G3(L) type of glued insulated rail joint shall be used as per RDSO drawing no. T-5843. The glued joints shall be manufactured and tested in accordance with RDSO's 'Manual for Glued Insulated Rail Joints-1998' with all amendments.

5.3.8.9 Turnouts, Scissors Crossover

a. Standard of Turnout:

- On main lines, the turnouts and diamond crossing shall be of the following standards:

  Standard Gauge
  1 in 9 type or flatter turnout (desirable)
  1 in 7 type turnout (minimum)
  Scissors cross-over of 1 in 9 / 1 in 7 type consisting of 4 turnouts and 1 diamond crossing

- On depot and other non-running lines, the turnouts and diamond crossing shall be of the following standards:

  Standard Gauge
  1 in 7 type or flatter turnout
  Scissors crossover of 1 in 7 type consisting of 4 turnouts and 1 diamond crossing
  1 in 7 derailing switches / 1 in 7 type symmetrical split turnout

b. The Metro railway decides to use sharper angle layout, they should establish the adequacy of the speed potential of the turnout for the purpose for which it is used and the negotiability of the turn out by the rolling stock with a safety margin. The requirement for turnouts as specified in the following clauses shall include switch devices, crossings and associated check and lead rails as appropriate.

   i. Turnouts (switches, lead, crossing and associated closure & check rails) shall be suitable for installation on PSC sleepers for ballasted track or concrete slab for ballastless track.
   ii. Turnouts shall be manufactured to allow for installation of continuously welded track.
   iii. Turnout shall be compatible with proposed rolling stock and its operational characteristics.
   iv. The assembly must ensure continuous electrical contact with the train and all the points shall be operated by electric motors.
   v. The CMS crossing to be used on mainline shall be subjected to explosive hardening.
   vi. All turnouts shall be laid with cant with a rail slope as that of main line towards center of track.
   vii. All turnouts and their components shall be designed to minimize electrical leakage from running rails to the ground.
   viii. Scissor crossover should be designed for Track centers not infringing SOD.

c. Type and Geometry of Turnout

Detailed design of all turnouts, scissors, and crossover should comply the following geometrical parameters.

Standard Gauge

1 in 9 turnouts
The design shall be tangential with a switch angle not exceeding $0^0$20’00”. It is desirable that the radius of lead rail of turnout is not less than 300m. Lead curve of 190m radius may be laid as an exception. All clearances shall be in accordance with relevant provisions of SOD.

1 in 7 turnouts
The design shall be tangential with a switch angle not exceeding $0^0$20’00”. It is desirable that the radius of lead rail of turnout is not less than 190m. Lead curve of 140m radius may be laid as an exception. All clearances shall be in accordance with relevant provisions of SOD.

d. Scissors Crossover
The basic geometry of the turnouts of scissors crossover shall be same as that of corresponding ordinary turnouts as mentioned above.

e. Operating requirement of turnout, scissor crossover:

- Track layout design shall permit trains to operate at maximum capability wherever possible. Turnouts and crossover shall be selected such that they do not form a restriction to the operating speed on main line. Switches and crossings shall not be located on transition curves or vertical curves. Turn backs and CBTC systems shall be designed for the operational frequency of 2 minutes to accommodate any upride in the demand.
- Speed: The turnout shall be designed for the speed on mainline side equal to the speed as on mainline track. The minimum speed potential of the various turnouts and scissors crossover on the turnout side should be as follows

Standard Gauge

- 1 in 9 type turnout with 300 m radius (speed potential of 45Kmph)
- 1 in 7 / 1 in 9 type turnout with 190 m radius (speed potential of 35Kmph)
- 1 in 7 type turnout with 140m radius (speed potential of 25 Kmph)
- Scissors crossover 1 in 9 type with 300 m radius (speed potential of 45 Kmph)
- Scissors crossover 1 in 9/1 in 7 type with 190 m radius (speed potential of 35 Kmph)
- Scissors crossover 1 in 7 type with 140 m radius (speed potential of 25 Kmph)

- 1 in 7 type symmetrical spilt turnout (speed potential of 45 Kmph)

f. Technical Specifications

i. General

- All the points shall be capable of being operated by electric motors in accordance with the signaling specification.
- The top surfaces of PSC sleeper / RCC slab supporting rail seat of turnout and scissors crossover shall be flat without any Can't / slope.
- The track form of the turnout shall have uniform resilience as that of the adjoining track form.
- The fixation of turnouts, scissor cross-over on track slab shall be through base plates / bearing plates.

ii. Rails

The rails used in turnouts shall be 1080 grade Head Hardened, However, rails used in turnouts on depot and other non-running lines may be of 880 grade.

The rails used for manufacturing of turnouts shall satisfy the following conditions:

- The rails shall be manufactured and tested in accordance with IRS/T-12-2009 with latest amendment.
- The section of rails shall be 60E1 (UIC60) for stock, lead and 60E1 A1 (ZU1-60)/60E1 A4 for switch rail.
- The rails shall qualify as Class 'A' rails as per IRS/T-12-2009.
- The rails shall be with ends un-drilled.
- The rails shall be of grade 1080HH and be suitable for being welded by alumnio-thermic or flash butt welding technique.

iii. Switches

- Each switch device shall consist of two stock rails, one left hand one right hand and two switch rails, one left hand one right hand.
- The switch rail shall be one piece with no weld or joint within the switch rail length.
- The end of the asymmetrical switch rail shall be forged to 60E1 (UIC60) rail profile with minimum length of 500mm. The forged switch rail end shall be suitable for welding or installation of insulated rail joint.

- Slide chairs in the switch portion shall be coated with an appropriate special coating, so as to reduce the point operating force and to eliminate the requirement of lubrication of sliding surfaces during service.
- Switches shall provide suitable flange way clearance between the stock rail and the switch rail with the switch rail in open position (minimum 60mm). The 1 in 12 and 1 in 9 (with radius of 300 mts) and flatter turnouts shall be provided with second drive or other suitable arrangement to ensure minimum gap of 60mm at JOH as well as proper housing of switch rail with stock rail up to JoH. 1 in 8.5, 1 in 9 turnouts (with radius of 190m) and 1 in 7 and sharper turnouts may not be provided with second drive arrangement, however minimum gap of 60mm at JOH as well as proper housing of switch rail with stock rail up to JoH should be ensured. The normal opening of switch at toe of switch shall be kept as 160mm.
- The switch manufacturer shall include provision for all holes required to main drive machines, stretcher bars and detection equipment to suit the requirements of the signaling and switch operating system duly chamfered to avoid stress concentration at the edge of the holes.
- The switches shall be designed with an anti-creep device at the heel of switch to withstand thermal forces of the CWR track.
- The switches and all slide chairs shall be same for ballasted and ballastless turnouts.

iv. Crossings

- All crossings shall be Cast Manganese Steel (CMS) crossings with weldable rails of minimum 1.2m length undrilled for welding into the overall turnout.
- The CMS crossings shall be manufactured from Austenitic Manganese Steel as per UIC 866.
- All CMS crossings shall have welded leg extensions of 60E1 (UIC60) rails. This shall be achieved by flash butt welding of buffer transition rail piece of suitable thickness to CMS crossings and rail leg extension.
- All CMS crossings on main line shall have a minimum initial hardness of 340 BHN.
- All CMS crossings and their welded leg extensions for all scissor crossover shall be suitably dimensioned so as to eliminate the necessity of providing small cut rail pieces for the purpose of inter-connection. However, the need for providing insulated glued joints from signaling requirement point of view shall be taken care of in the design, if required.

- The provision of rail Cant shall be taken care of on the tope surface of the CMS crossing and the bottom surface of all CMS crossing shall be flat.

v. Check Rails

- The check rail section shall be 33C1 (UIC33) or similar without any direct connection with running rails.
- Check rails shall have the facility for the adjustment of check rail clearances up to 10mm over and above the initial designed clearance.
- Each check rail end shall be flared by machining to have minimum clearance of 62mm at end.
- The check rail connections in turnouts shall be through specially designed bearing plates / brackets.
- All the check rails shall be higher by 25mm above running rails. The lengths and positions of the check rail in diamond crossings shall provide safety and be compatible with the overall track layout.

vi. Sleeper for Turnouts, Scissor Crossover (Ballasted Track)

- Sleeper shall be of pre-stressed concrete, mono-block, suitable for installation in track both with and without signaling circuits and with and without electrification.
- Sleepers shall be designed to provide a minimum service life of fifty years under nominal axle load as that of main line for the Metro system. Rail seat pads and rail clip etc., shall be designed to provide a minimum service life of 15 years.
- The sleeper base surface shall be rough cast while the top and side surface shall be smooth to prevent retention of moisture and foreign materials.
- Sleepers must be suitable for installation by track laying machines and sleeper insertion equipment of a type used for isolated sleeper laying.
- The sleeper must be able to transfer all the relevant track forces generated by train operations and the forces of rail expansion and contraction to the ballast.

Design requirements for PSC sleepers

A. The sleepers should satisfy the following design requirement:
Design Parameters
Rail sleeper fastening – Elastic resilient type.
Spacing of sleepers – 600mm (max) for main line and 650 mm (max) for Depots and other non-running lines, except at few locations such as near point machine locations where it may be varied to meet the design requirements.

i. Ballast cushion – 300mm for mainline and 250mm for Depots and sidings.
ii. Ballast profile suitable for LWR/CWR.
iii. Specifications and Drawings (with latest amendment)
iv. Special cement – IRS T 40 1985
v. HTS wire plain and strand – BIS – 1785 (Pt-1) 1983 and BIS 6006.
vi. Polyethylene dowels – Provisional 1997 Drg. No. RDSO 3002 Alt-3
vii. IRS Specification for turnout sleeper T-45 1996
viii. IRS Bridge Code 1982
ix. Code of Practice for Pre-Stressed concrete IS-1343

B. The design should satisfy the following additional requirements: -
The connections of the slide chairs and bearing plates/special bearing plates/brackets shall be designed for easy installation and maintenance. All the fittings shall be suitably designed to ensure full compatibility and also to ensure interchangeability of slide chairs between ballasted and ballastless turnouts.

For attaining suitable Cant of the rail, as provided on mainline, (excluding crossing and switch portion), suitably designed pads of appropriate material shall be provided between rail pad & PSC sleeper. Also fastening system should be designed to get the desired Toe Load.

The detailed design of Monoblock PSC sleepers for the turnouts along with structural drawings shall be checked and approved by Metro Railways.

5.3.8.10 Switch Expansion Joint

- The SEJ for ballasted track shall be laid on PSC sleepers whereas the SEJs for ballastless track, if required, shall be laid on reinforced concrete slab.
- The rail section for all SEJs shall be UIC 60, 1080 HH grade as per IRS-T-12-2009.
- The SEJ for ballasted track shall be designed for a maximum gap of 80mm.
- The SEJ for ballastless track should be designed for the maximum gap required as per design.
- The ballasted SEJ shall be as per RDSO drawing T-6902 & T-6922
- The ballasted SEJ for BG shall be laid with PSC sleepers as per RDSO drawing T-4149. For Standard Gauge, PSC sleeper shall be designed such that SEJ to RDSO drawing along with its bearing plates / chairs may be accommodated for installation of SEJ.
- Sleepers used for SEJs shall be flat and Cant will be provided through CI chair.
- The SEJ shall be suitable for two-way directional traffic.

5.3.8.11 Gradients

a. The maximum grade (compensated for curvature) shall be 4%.

Note:

i. There will be no change of gradient in transition portion of curves.
ii. The gradient will be compensated for curvature at the rate of 0.04% per degree of curve.

b. Maximum permissible gradient on turnouts

On Ballasted Track 0.25%
On Ballastless Track 2.5%

Note:

i. There shall be no change of grade on and within 15m of any turnout on ballastless track. Similarly, there shall be no change of grade on and within 30 meters of any turnout on ballasted track.
ii. In case of turnouts on gradient, there shall be no horizontal curve on and within 15 meters of any turnout on ballastless track and 30 meters of any turnout on ballasted track.

c. Track Gradient in Platform

Maximum	1 in 400
Desirable	level

Note: There shall be no change of gradient in platform track.

5.3.8.12 Noise and Vibration

Metro system shall be designed to ensure that noise emitted is well within the prescribed limits for the particular area.

5.3.9 General Alignment Drawing

The General Alignment Drawing of Phase 2B on Airport line is enclosed as **Annexure-1** of **Volume 2**.

5.4 Identification of Existing Services and Utilities

The proposed alignment of KR Puram to Airport is traversing along the Outer Ring Road. Number of sub-surface, surface and overhead utility services viz. sewers, water supply lines, storm water drains, telephone cables, GAIL gas pipe line, overhead electrical transmission lines, electric poles, traffic signals, Skywalks etc. are existing along the proposed alignment. These utility services are essential and have to be maintained in working order during different stages of construction by temporary / permanent diversions or by supporting in position. The underground services such as Water supply, Sanitary, Gas pipe line etc with reference to the proposed alignment have been identified and details of existing utility services along the proposed alignment have been collected from the concerned authorities i.e., BWSSB, BBMP, BSNL, BESCOM, KPTCL and GAIL.

5.4.1 Shifting of Utilities

A detailed survey of overhead and underground utilities pertaining to BWSSB, BBMP, BSNL, BESCOM, KPTCL, GAIL and private telecom operators is carried out for the corridor. Above ground, the main utility to be shifted will be telephone cables, OHT lines, electric poles, traffic signals etc.

Underground utilities, particularly communication cables and water mains, sewer lines and Gas lines are identified. To exactly locate these utilities, trial trenches will have to be dug, during which disruptions to the existing traffic flow is caused.

To the extent possible, the alignment is planned in such a way that there is minimum diversion of utilities. Only a lump sum provision for utility diversions has been made in the estimate.

While planning for diversion of underground utility services e.g. sewer lines, water pipe lines, cables, Gas pipe line etc., during construction of Metro alignment, the following guidelines have been adopted:

a. Utility services have to be kept operational during the entire construction period and after completion of project. All proposals should therefore, ensure their uninterrupted functioning.
b. The elevated Viaduct does not pose any serious difficulty in negotiating the underground utility services, especially those running across the alignment. In such situation, the spanning arrangement of the Viaduct may be suitably adjusted to ensure that no foundation need be constructed at the location, where utility is crossing the proposed Metro alignment. In case of utility services running along the alignment either below or at very close distance, the layout of piles in the foundations is to be suitably modified such that the utility service is either encased within the foundation piles or remains clear of them. The proposed alignments along the corridor is mainly elevated and running mostly along the central verge of the road except at few locations while negotiating existing/proposed flyovers, curves and other obligatory points etc.
c. The sewer / drainage lines generally exist away from main carriageway. However, in certain stretches, these might have come near the central verge or under main carriageway, as a result of subsequent road widening. The sewer / drainage lines and water mains running across the alignment and getting affected by the normal location of column foundations are proposed to be taken care of by relocating column supports of Viaduct by change in span length or by suitably adjusting the layout of pile foundation. Where, this is not feasible, these utilities lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines.
d. If GAIL gas pipe line is encountered during execution of Metro works, re arrangement of spans will be resorted to.

5.5 Geotechnical Investigations

5.5.1 Introduction

Bengaluru is situated at an elevation of 900 m above Mean Sea Level on a gently sloping rolling topography, sloping gently from North to South. Terrain wise, the western portion of the district is covered by a chain of small-disconnected hillocks. Northern, Eastern and Central parts of the district is having undulating topography.

Geology wise, Bengaluru district shows dominant presence of 'Archean' crystalline formation comprising Peninsular Gneissic complex with small patch of hornblende schist in the northern part and intrusive closepet granites all along the western part of the district. These Gneissic complexes are in the age of 2.6 to 3.0 billion Years. They are essentially Granodioritic and Granitic formed due to several thermal-tectonic movements with large influx of Sialic materials representing remobilized parts of an older crust with abundant additions of granitic materials. These Gneissic complexes act as basement for belt of Schists, largely basaltic and characterized by Gold mineralization which is noticed in nearby Kolar. Small stretch comprising unconsolidated sediments are also noticed in Channapatna and Devanahalli. The soil overburden generally is dominated by Silty sand /residual silt and shows presence of clay as a nominal interstitial binder. Overburden in upper layers is generally in loose /medium compact condition especially in areas with high water table.

The overburden thickness is variable and is reflective of typical differential weathering that has occurred over a prolonged period. This is followed by completely weathered and highly weathered rock. Bengaluru falls under Zone II of Seismic Zoning Map as per IS: 1893 (Part I) – 2002.

The geotechnical investigations were carried out by M/s. Beureau veritas, Bengaluru, in addition, soil investigation reports for various flyovers and underpasses already conducted on the route were also studied.

The main purpose of the Geotechnical Investigations undertaken is to have an in-sight into the geological conditions along the proposed corridor of K R Puram KIA Terminal line of Phase 2B, so as to arrive at the type of foundations to be adopted for elevated corridors.

5.5.2 Field Investigation

Field investigation has been carried out along the Airport line at 16 locations by borehole exploration up to a maximum depth of 30.0 m. If rock was encountered drilling was carried up to a depth of 3 m in intact hard rock. Boreholes were generally located near Station areas.

Boreholes exploration was carried out by rotary drilling method using heavy duty rotary drilling rigs. Drilling in soil was carried out by MS soil cutters having suitable cutting edges. In soft/weathered rock, where strata are very dense, advancement of borehole was done by Tungsten Carbide (TC) bits of Nx size. In moderately weathered and hard rock, core drilling was progressed using Nx size Diamond bits with double tube core barrel.

Standard Penetration Tests (SPT) were carried out in the boreholes as per IS 2131 at regular intervals of generally at 1.5 m depth. Undisturbed soil samples were collected by using thin walled steel tubes of 150 mm diameter, 450 mm long as per IS 2132, in cohesive soil strata. Both DS and UDS samples were sealed and labelled properly and brought to the laboratory for further testing. Rock cores were collected from core barrel after the completion of each drill run and marked with borehole numbers and sequential core piece numbers. Rock Core Recovery (CR) and Rock Quality Designation (RQD) have been recorded for each drill run. The rock core samples were stored in wooden core boxes and brought to laboratory for further testing.

Groundwater was encountered in only one borehole (BH – 19) during the field investigation. No long-term monitoring of ground water was carried out. Thus, the ground water conditions established is applicable for the time of investigation only. The ground water condition is subjected to climatic changes and any changes in the surrounding area. Reconfirmation of groundwater level is recommended prior to any work relating to the ground water regime.

The details of stratification, SPT values, Ground Water Table etc., are indicated in the Sub-Soil Profiles in **Sl.No-4** of **Volume 2**.

5.5.3 Laboratory Testing

The following laboratory tests were conducted on soil, water and rock samples collected from the boreholes.

a. Tests on soil samples:
   - Grain size analysis - Sieve and Hydrometer Analysis
   - Atterberg's Limits - Liquid & Plastic Limit
   - Natural Moisture Content
   - Bulk and Dry Density
   - Consolidation Test
   - Shear Strength - Triaxial/Direct Shear test
   - Lab Permeability Test
   - Specific Gravity

b. Tests on Rock samples:
   - Specific Gravity, Density, Water Absorption and Porosity of rock
   - Hardness
   - Uni-axial compressive strength
   - Point Load Index strength
   - Modulus of Elasticity
   - Abrasion test
   - Shear strength

c. Chemical Tests on Soil and Water Samples:
   - pH
   - Chloride
   - Sulphates
   - Organic matte

5.5.4 General Stratification:

a. General stratification as obtained from the field and laboratory investigation shows typical residual formation, which is characteristic feature in this region. The top layer generally consists of filled up soil followed by greyish brown/Yellowish silty Sand with clay or clayey Sand/Silt in medium dense layer. This layer is underlain by dense to very dense brownish/greyish to yellowish completely weathered rock, this layer represents the “Transition layer” from soil to highly weathered rock. This is followed by highly weathered rock made up of weathering varying from moderate to high underlain by more compact hard rock.

b. The rock stratum was encountered in most of the boreholes except few boreholes, where as soft rock is in the form of very dense silty SAND and hard rock in the form of fine grained fresh to Slightly and at places Moderately Weathered strong rock was encountered up to the investigation depth.

5.5.5 Analysis of Results

The stratification encountered along the proposed routes mostly consists of medium dense to dense silty sand or sandy silt, clayey sand and sandy clay at shallow depths. This layer is followed by medium dense to dense silty sand or sandy silt, which is moderately plastic in nature. This layer is underlain by very dense silty sand (Soft Rock), weathered rock and hard rock layer in sequence.

Ground water accumulation in bore holes was measured during and after completion of drilling activities. The ranges of depth of water table encountered at particular sections are mentioned in bore logs. The profile of water table at individual borehole can be found in stratigraphy drawing. However, it should be noted that water table is susceptible to large variation due to seasonal and annual changes and hence requires monitoring by installing piezometers.

No field or laboratory testing has been carried out on any of the filled up materials identified on borehole logs.

The moisture content at all locations varies from 10% to 28%. The mean moisture content observed at all locations in the stretch is around 16%. The summary of the natural moisture content is tabulated in tables.

The liquid limit at all locations varies from 25% to 56%. The mean liquid limit observed at all location in the stretch is around 40%. The summary of the liquid limit is tabulated in tables.

The plastic limit at all locations varies from 16% to 32%. The mean plastic limit observed at all location in the stretch is around 24%. The summary of the plastic limit is tabulated in tables.

Index properties of soil such as grain size distribution and liquid limit, plastic limit values indicated that plasticity characteristics of soil is low to moderate. The average value of plasticity index was 14%. The fine friction predominantly consists of silt and non-expansive in nature. The summary of the plasticity index of soil is tabulated in tables.

In the present study SPT value firms for basic for identifying the nature of sub structure. The profile of SPT N value versus depth for each location along the alignment is shown in figure.

The general trend of SPT values with depth is tabulated in tables.

Triaxial test and direct shear results indicate that in general the average values of cohesive strength of soil is ranging from 0.06 to 0.14 kg/cm^2 and angle of internal friction is ranging from 20 to 25 degrees.

Chemical Analysis of soil and water samples reveals that pH, chloride and sulphates are within the permissible limits. It can be noted from the index properties that density values of rock specimen are ranging from 2.64 g/cc to 2.86 g/cc and water absorption of the test specimen shows a range of 0.08% to 1.59%.

The porosity value along the complete stretch varies from 0.7% to 2.4%. High values of porosity are observed in respective locations.

Uniaxial compressive strength results indicate that the values are ranging from 144 kg/cm^2 to 1446 kg/cm^2. The strength values are mainly dependent on interlocking, bonding and Cementing of individual mineral and rock grains. These features are developed during formation stages of rock and could be the reason for wide variation in strength results. Relatively lower values of compressive strength were observed in between the locations.

Similarly, density of rock was analyzed against unconfined compressive strength values. It was observed that a proper trend could not be established between unconfined compressive strength and unit weight of rock as the variation in density values is very small.

It is seen from the index properties that specific gravity of rock varies from 2.56 to 2.89, Modulus of Elasticity (E) values of rock varies from 10 GPa to 90 GPa.

5.5.5.1 Recommendations (As suggested by M/s Bureau Veritas based on soil exploration conducted along the alignment at field).

After examining the subsurface condition, coring, SPT results, its relative density and other engineering properties, the following options are suggested for foundation design of the Proposed Work.

5.5.5.1.1 Deep foundations (Pile Foundations):

The safe load carrying capacity of piles and likely termination depths at each borehole location for cast in-situ bored piles for different pile diameters are given in **Table 5.7**. A factor of safety of 2.5 is considered in the calculations.

Table 5.7 Termination Depth of Pile

Sl. No.	BH No	Termination depth of pile (m)	Foundation strata
1	BH-13	16.0	Hard Rock
2	BH-14	16.0	2m socket length in weathered rock N>100
3	BH-15	15.0	3m socket length in Soft Rock (Very dense Silty SAND) N>100
4	BH-16	18.0	3m socket length in Soft Rock (Very dense Silty SAND) N>100
5	BH-17	23.0	5m socket length in Soft Rock (Very dense Silty SAND) N>100
6	BH-18	14.5	1m socket length in Hard Rock
7	BH-19	22.0	2m socket length in weathered rock N>100
8	BH-20	18.0	3m socket length in highly weathered N>100
9	BH-21	19.0	3m socket length in Soft Rock (Very dense Silty SAND) N>100
10	BH-22	15.0	3m socket length in Soft Rock (Very dense Silty SAND) N>100
11	BH-23	8.0	2m socket length in weathered rock Weathered Rock
12	BH-24	13.0	3m socket length in Soft Rock (Very dense Silty SAND) N>100
13	BH-26	16.0	2m socket length in weathered rock Weathered Rock
14	BH-27	17.0	1m socket length in Hard Rock
15	BH-28	7.0	2m socket length in weathered rock Weathered Rock

Note: rock head at BH 23, 26 and 28 is encountered at shallow levels, it is advised to confirm the same by confirmatory boreholes till rock head.

The piles of 1000mm & 1200mm are considered as required by M/s BMRCL. The safe load carrying capacity of piles in this case is generally governed by structural capacity of pile. The recommended safe load on piles considering piles with M25 concrete are as follows.

Table 5.8 Safe Load

Pile dia (mm)	Recommended Safe Load (Tonnes)
1000	400
1200	600

Since the above pile bearing capacities are arrived based on Empirical formulae and hence it is suggested to verify the pile bearing capacities by conducting the pile load tests on test piles.
In addition, different piling contractors offer different design and capacity of piles based on method of installation. It is suggested that the exact pile design with their corresponding capacities offered may be obtained from specialist piling contractors.

5.5.5.1.2 Socketing for Pile foundations

Depending on rock type at pile termination, the following depth of socketing is recommended as per IS 14593:1998.

Table 5.9 Socketing Depth of Pile

Stratum at socket level	Depth of socketing (D = Pile diameter)
Soft rock	2.5 D
Hard Rock	1 D

5.5.5.1.3 Shallow Foundation: (BH – 25):

Shallow foundations are recommended wherever the hard strata (Soft rock/weathered rock/Hard rock) are encountered with in 4.0m depth below ground level. Based on field and laboratory test results, an allowable bearing pressure of 50 T/sqm is recommended. At locations where the foundation rests on intact hard rock, an allowable bearing pressure of 100 T/m2 is recommended.

Table 5.10 Safe Bearing Pressure for Shallow Foundations

Sl No.	Depth of foundation (m)	Net allowable bearing pressure (T/M2)	Width of Footing (m)
		BH - 25	
1	1.50	50	4.0
2	2.0	100	

5.6 Land Acquisition with Ownership Details

5.6.1 As the Metro alignment has to be planned on set standards and parameters, apart from alignment, various structures like stations, parking facilities, traction sub stations, communication towers, etc. require large plots of land. The land being scarce, costly and acquisition being complex process, the alignment is so planned that barest minimum land acquisition is involved. Land is mainly required for;

- Metro Structure (including Route Alignment), Station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities etc.,
- Receiving/Traction Sub-stations.

5.6.2 Break-up of Land Requirement

The total land requirement for Viaduct, Stations and Electrical works on this line is 2,94,471 Sqm of which 1,05,500 Sqm is NHAI Land and 2,07,871 Sqm is Private Land. The details of Land proposed to be acquired for this corridor is shown in **Table 5.11.**

The alignment drawing along with Land plan is enclosed as **Sl.No-1 and Sl.No-3** in **Volume 2** respectively.

Table 5.11 Land Proposed to be acquired for Phase 2B Airport line

Sl No	Viaduct (Elevated) From	Viaduct (Elevated) To	Station	Unit	Private Land area	Remarks
1	Jyothipuram to Kasturi Nagar including Link line to Baiyappanahalli			Sqm	8,577	Viaduct
2	Road widening for viaduct before Kasturi Nagar Station by the side of Benniganahalli flyover			Sqm	4,308	Road widening
3			Kasturi Nagar	Sqm	1,973	Station
4			Horamavu	Sqm	2,223	Station
5			HRBR Layout	Sqm	2,223	Station
6			Kalyan Nagar	Sqm	2,223	Station
7			HBR Layout	Sqm	1,614	Station
8			Nagawara	Sqm	79	Station
9			Veeranna Palya	Sqm	2,469	Station & Viaduct
10	Veeranna Palya	Kempapura		Sqm	163	Viaduct
11			Kempapura	Sqm	1,935	Station
12			Hebbal	Sqm	18,724	Station, Viaduct & Parking
13			Kodigehalli	Sqm	3,342	Station & Viaduct
14			Jakkur Cross	Sqm	3,368	Station & Viaduct
15			Yelahanka	Sqm	8,020	Station, Viaduct & RSS
16			Bagalur Cross	Sqm	7,216	Station & Viaduct
17			Bettahalasuru	Sqm	2,663	Station & Viaduct
18			Doddajala	Sqm	4,943	Station & Viaduct
19	Doddajala	BIAL Boundary	Part-A	Sqm	7,347	Viaduct
			Part-B	Sqm	33,079	Viaduct & Depot entry

Sl No	Viaduct (Elevated)		Station	Unit	Private Land area	Remarks
	From	To				
20			**Sub Total**		**1,16,486**	
21	Depot near Airport (Private land-22.62 Acres)			Sqm	91,532	Depot
22			**Sub Total**		**2,08,019**	
23	5 m wide strip along NH 44 from Hebbal to Doddajala			Sqm	1,05,500	
24			**Total Land**		**3,13,519**	

Note:

1) Land for Viaduct in Jakkur Flying school is not considered as same is being acquired by NHAI.
2) Land for Viaduct, Covered shell & Ramps in Airforce area is not considered as same is being acquired by NHAI.
3) Land within KIAL boundary is not considered as same is to be provided by KIAL.
4) The land will be acquired as per provisions of the Karnataka Industrial Area Development Act 1966.

Chapter 6

Station Planning

CHAPTER 6

STATION PLANNING

6.1 Station Planning

The location of the Stations is planned with the following considerations:

a. The Stations are planned close to the Commercial and Residential establishments to facilitate the commuters and increase the ridership.

b. The Stations are planned close to important Cross roads for ease of commuters from these Roads to reach the stations. This will also make operation of feeder services more convenient.

c. To reduce the cost of land acquisition and to make it less cumbersome, the stations are generally planned in vacant Lands and preferably in Government Lands wherever possible.

6.1.1 Locations of the Stations planned and the interstation distances from KR Puram to KIA Terminals alignment covering 36.44 kms are detailed in the **Table 6.1.**

Table 6.1 List of Stations of Phase 2B

Sl.No	Name of Stations	Chainage (in m)	Inter Station Distance (in Kms)	Remarks
0	K R Puram	17.133(Phase 2A)/ -1.294 (Phase 2B)	0.000	Elevated
1.	Kasturi Nagar	1,600.160	2.89	Elevated
2.	Horamavu	2,751.700	1.15	Elevated
3.	HRBR Layout	4,201.230	1.44	Elevated
4.	Kalyan Nagar	5,303.820	1.10	Elevated
5.	HBR Layout	6,560.920	1.25	Elevated
6.	Nagawara	7,508.790	0.94	Elevated
7.	Veeranna Palya	8,314.000	0.80	Elevated
8.	Kempapura	9,964.250	1.65	Elevated
9.	Hebbal	11,223.430	1.25	Elevated
10.	Kodigehalli	12,699.060	1.47	Elevated
11.	Jakkur Cross	14,120.040	1.42	Elevated
12.	Yelahanka	17,842.930	3.72	Elevated
13.	Bagalur Cross	20,022.280	2.17	Elevated
14.	Bettahalasuru	23,826.472	3.80	Elevated
15.	Doddajala	28,736.530	4.91	Elevated
16.	Airport City	33,705.170	4.96	At grade
17.	KIA Terminals	36,267.250	2.56	At grade

6.1.2 The average interstation distance in this line between Jyothipuram and Hebbal is around 1.0 Km. However, in exceptional cases the interstation distance varies depending on the development and catchment of ridership. The interstation distance is less than 1 Km between HBR station and Nagawara station due to the presence of Manyata Tech Park and other software companies who are main beneficiaries.

The interstation distance is more than 1.4 Kms between the following Stations:

The interstation distance between Horamavu and HRBR Layout has been kept as 1.44 Kms depending on the nearest available flyover at interchange location for pickup and drop facilities.

Further, the interstation distance mentioned in Table below is kept as more than 1.4 Kms considering less catchment of ridership on this stretch as the area is sparsely populated. Also, it is proposed to provide the metro service from Airport to Hebbal as High speed rail with limited stops. In the civil design, provisions are being incorporated for additional stations in future.

Table 6.2 Interstation distance more than 1.4 Kms

Station		Distance in Kms
From	**To**	
Veeranna Palya	Kempapura	1.62
Hebbal	Kodigehalli	1.47
Kodigehalli	Jakkur Cross	1.42
Jakkur Cross	Yelahanka	3.72
Yelahanka	Bagalur Cross	2.17
Bagalur Cross	Bettahalasuru	3.80
Bettahalasuru	Doddajala	4.91
Doddajala	Airport City	4.96
Airport City	KIA Terminals	2.56

6.1.3 As per the configuration of alignment, all the stations would be elevated except 2 stations i.e. Airport City, KIA Terminals Stations are inside Airport boundary. Horamavu, HRBR Layout, Kalyan Nagar, HBR Layout, Nagawara and Kempapura stations are planned on the center of the road and Kasturi Nagar, Veeranna Palya, Hebbal, Kodigehalli, Jakkur Cross, Yelahanka, Bagalur Cross and Doddajala stations are partially on service road. Further, Kasturi Nagar station if proposed in original location, it will be established partiality on service road.

a. On the middle of the road –Kasturi Nagar, Horamavu, HRBR Layout, Kalyan Nagar, HBR Layout, Nagawara, & Kempapura.

b. Partially on the service road/Off road – Kasturi Nagar, Veeranna Palya, Hebbal, Kodigehalli, Jakkur Cross, Yelahanka, Bagalur Cross and Doddajala.
c. Within the KIAL boundary at grade– Airport City and KIA Terminals station.

6.2 The special features of each Station and their details

6.2.1 Interchange stations

a. Nagawara Station

This is the 6th elevated Station on Airport the line which is proposed as interchange station for R6 (UG) line between Gottigere –Nagawara and Airport Link Metro line. The station is proposed to be constructed over the ORR and is linked with Nagawara station of R6 (UG) line at termination location with necessary foot over bridges.

b. Kempapura Station

This is the 8th elevated station on the Airport line also proposed as interchange station with future extension towards Gorguntepalya. This station is proposed on the BMTC depot land available next to BDA flyover network. This station is proposed with Foot over Bridges connecting all the parts of the BDA flyover network where passenger alighting locations are identified.

c. Yelahanka Station

Yelahanka station is 12th elevated station on the Airport line which is proposed as elevated off road station which will serve as inter change station to the future line of Doddaballapur. The station is planned on the right side of the National Highway next to the service road. The Station access from the other side of the National Highway is through a FOB.

d. Bagalur Cross Station

This station is 13th elevated station on the Airport line. It is proposed as elevated station proposed to be designed as Interchange station to link with PRR Metro line in future and is located off the service road on the National Highway. The access from the other side of the road is through Subway.

e. Doddajala Station

This is the 15th elevated station on the Airport line. This elevated station has been proposed on the service road of the National Highway which will serve as interchange station to the future metro line of Devanahalli. The access from the other side of the road is through Subway. This station is planned as future Interchange for the alignment taking off to Devanahalli.

6.2.2. Intermediate Stations

a. **Kasturi Nagar Station:**

This is the 1st elevated station on the Airport line center of ORR. This station will be linked with the existing Channasandra Railway Station
including connecting the neighboring dwelling area with foot over bridge next to eastern service road. This station structure is designed as cantilever station.

b. **Horamavu Station:**

This is the 2nd elevated station on the Airport line along Ring road after the alignment takes left turn towards Hebbal. This station is situated on the median of the ORR connected with entry/exit structures on either side of the main road beyond available service road. This station structure is designed as cantilever station.

c. **HRBR Layout Station**:

This is the 3rd elevated station on the Airport line along median of the ring road. It is connected with entry/exit structure on either side of the ORR. The median between main road and service road is sufficient wide, where the operational rooms of the said station can be arranged.

d. **Kalyan Nagar Station:**

This is the 4th elevated station on the Airport line proposed on the median of the road. The entry/exit of the said station is proposed on either side the ORR beyond service road where BMTC bus depot land is available on the East side of alignment. The median between main road and service road is sufficiently wide, so that operation rooms can be arranged on this land.

e. **HBR layout Station:**

This is the 5th elevated station on the Airport line proposed on the median of the ORR similar to that of the HRBR Layout Station. The entry/exit structure is situated on either side of the service road. One of the entry/exit is proposed on the BDA park land i.e., on the East side of alignment.

f. **Veeranna Palya Station:**

This is the 7th elevated station on the Airport Line along median of the ORR. It is provided with entry/exit structures on either side of the station beyond service road.

g. **Hebbal Station:**

This is the 9th elevated station on the Airport Line along median of the ORR. It is provided with entry/exit structures on either side of the station beyond service road.

h. Kodigehalli Station:

This station is 10th elevated station situated on the Airport line along National Highway. The said station is typical off road cantilever station with entry exit structure on one side. The entry exit structure is also proposed to be off road for this station. Ancillary structures required for operational activities have been housed in the land available on the RHS of the alignment.

i. Jakkur Cross Station:

This station is 11th elevated station on the Airport line along National Highway. The said station is typical off road cantilever station with entry exit structure on one side. The entry exit structure is also proposed to be off road for this station. Ancillary structures required for operational activities have been housed in the land available on the RHS of the alignment.

j. Bettahalasuru Station

This station is 14th elevated station on the Airport line along National Highway. The said station is typical off road cantilever station with entry exit structure on one side. The entry exit structure is also proposed to be off road for this station. Ancillary structures required for operational activities have been housed in the land available on the RHS of the alignment.

k. Airport City Station

This station is proposed as elevated station within KIA boundary (16th station on airport line). The commuters can approach the station from south of the road where the commercial activities are being planned by KIAL for which entry/exit structures and connecting bridges are proposed. Ancillary Structures required for operational activities have been proposed in adjacent area.

l. KIA Terminals Station

The KIA Terminal Station is partially underground Station inside the KIA Land (17th station the Airport line). It is planned as per the requirement of Bangalore International Airport limited. The station is planned as Portal station with all the commuter and ancillary facility at one level i.e., platform level. The access is through skywalks from the pedestrian plaza at Terminal 1, Terminal 2, and Hotel of T1. This station is proposed to be integrated with the Multi-Level Car Parking for airport functionality. However, structurally suitable isolation will be provided for the BMRCL structure.

The general planning, design criteria and facilities inside the metro stations of Airport will be similar to that of the regular station in addition to the requirement of KIAL.

6.3 Multimodal Transport Integration

Along this corridor Hebbal is identified for major hub of Multi modal integration as this is proposed to be the interchange stations of Metro lines. Apart from this bus bays are being proposed at all metro stations adjacent to service Road for BMTC buses and feeder services to ensure the multimodal integration. An additional area of 211 Sqm is being exclusively acquired for the same purpose. Since this Road is in addition to the existing service Road of ORR, this area will effectively function as Multimodal traffic integration point without causing to the usual traffic on the road.

6.4 Road Crossing Facility for Non-commuters.

Currently there is Skywalk available at proposed Kasturi Nagar, HRBR Layout, Kalyan Nagar, HBR layout, Veeranna Palya and Kodigehalli for Pedestrians to cross the busy Road. This Sky walk needs to be dismantled during Metro Construction and re-erected after completion of the Metro Works, as this causes hindrance to the metro construction. However, in all proposed metro stations, non-commuters will also be able to cross the road, similar to the way they do on skywalks. In view of this facility, the metro stations will also serve as skywalks for pedestrian crossings which are an added facility for road users.

6.5 Station Facilities

6.5.1 Salient features of a Typical Station are as follows:

- The length of the platform is kept as 135 m for operation of 6 car trains and the width of the platform varies from 4.0 m to 7.20 m.
- The station can be divided into public and non-public areas (those areas where access is restricted). The public areas can be further subdivided into paid and unpaid areas.
- The platform level has adequate circulating area for passengers for normal operating conditions and also for recognized abnormal scenario or any emergency.
- The platform level at elevated stations is determined by a critical clearance of 5.50 meter under the concourse above the road and allowing 3.0 m clearance for the concourse below the cross girder. This makes Rail level in an elevated Station about 14.50 meters above the ground level.
- The concourse contains automatic fare collection system in a manner that it divides the concourse into two distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. Frisking is planned as concourse level before passing through AFC gates. On passing through the ticket gates, the passengers enter the 'paid area’, which includes access to the platforms.
- The arrangement of the concourse is assessed on individual Station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be

achieved by the station supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators.

- The AFC gates however are located at the Concourse level in the Entry/Exit buildings at the Stations where full length Concourse is not provided.
- Sufficient space for queuing and regulating passenger flow is allowed at the Ticketing gates, Ticket Vending Machines and AFC gates.
- Station entrances are located with particular reference to passenger catchment points.
- Office accommodation, Operational areas and Plant rooms spaces is provided in the non-public areas at each station.
- An appropriate area of 600.0 Sqm is being proposed as property development at each metro station.

6.5.2 Stairs, Escalators and Lifts for Normal and Emergency Operations are planned at all stations on each side of the station, two escalators and one staircase of 3.6 m width is provided from ground to concourse. Two staircases of 3.0m width and two escalators are provided to each platform from concourse. These stairs and escalators together provide an escape capacity adequate to evacuate passengers in emergency from platforms in conformity to the provisions of NBC-2016.

The evacuation time for egress of passengers has been checked as per norms.

a. The elevated alignment generally passes above median of the road and the station is also proposed above the road with entries planned beyond the existing service road. The proposed stations will have two side platforms and the access to the platforms is through staircases and escalators, housed in the paid area of concourse. In addition, Elevators are provided to cater to Senior citizens and Differently abled commuters.
b. Ticket / token counters, Ticket Vending Machines and information display system have been proposed in the unpaid area of concourse.
c. Automatic Fare Collection machines have been proposed between paid & unpaid concourse. The commuter after purchasing ticket / token enters into the paid concourse.
d. A conflict free circulation system is proposed for commuters and operational staff.
e. Public Conveniences in the form of toilets have also been proposed in the paid area at the Stations.
f. Connecting bridge at Concourse level has been planned for crossing the road for the use of Metro commuters and General public.
g. Each metro station has been proposed for property development area of 600 Sqm.
h. Bus bays for BMTC buses are being proposed close to station for multimodal transport integration and to ensure last mile connectivity for commuters.

6.6 Property Development at Stations

An average area of 600.0 Sqm of property development is ensured in each station. The property development area is usually proposed in the unpaid area of concourse floor.

6.7 Architectural Finishes

Light weight and sleek steel structures have been envisaged for roof of stations with part translucent fabric sheeting for ambient day lighting within the stations. Granite floor, stainless steel and balustrade etc., have been proposed for aesthetic reasons and for ease of maintenance. The structural system proposed is modern, sleek and aesthetically appealing and cost effective. The Station roof is designed for provision of Solar panels on Top, to source green energy for major part of the station electrical power requirements.

6.8 Passenger Facilities

The proposed station will have the following facilities for the information of the passenger:

a. Passenger Information Display System
b. Public Address System
c. Clocks
d. Signage
e. A connecting bridge is planned below the viaduct connecting the two platforms on either side to permit commuters to interchange platform.

6.9 Accessibility for differently abled.

Minimum four elevators have been proposed in each Station for elderly and physically challenged persons from Ground to Concourse and Concourse to the Platforms. Entry to the Station will have a ramp as per the norm for ease of movement of differently abled persons. Exclusive toilets having special facilities for the use of differently abled persons are also provided in Station. There will be a special dedicated path with tactile flooring for visually impaired persons.

6.10 Parking in stations

No specific parking space is planned at the stations to promote use of public transport by the commuters. However, a part of the space at ground level is earmarked for development of bicycle/scooter sharing facility as a means of Last Mile Connectivity. Further, a parking lot is proposed at Hebbal station for which land acquisition need to be initiated.

6.11 Drawings

Concept plans of Stations are enclosed as **Sl. No-2** in **Volume 2.**

Chapter 7

Intermodal Integration

CHAPTER 7

INTERMODAL INTEGRATION

7.1 Intermodal Integration with Existing Modes

Namma Metro, Bengaluru's Metro Rail system, is the city's most significant investment to-date in providing a life line for the city's constrained and congested road ways. The high capacity Mass Transit mode offers two trunk routes- Purple line (Baiyyappanahalli- Mysore Road) and Green line (Nagasandra – Puttenahalli) in Phase 1 and two more routes along with extension to Purple and Green line in Phase 2. Phase 1 of Namma Metro covering a distance of 42.3 Km on Purple and Green lines in 4 Reaches has started complete service from June 2017.

With respect to maximizing public benefits of transit, how will the end user reach the Metro Station from his/her origin and how safe will the journey as a pedestrian, a cyclist and aged or a disabled individual be to these stations? At the institutional level, who will be responsible for ensuring the coordination between the various stakeholders? What should be the role of BBMP, BDA, BMRCL and other Governmental agencies, the private sectors and the citizens to ensure the goal for ensuring accessibility for all.

As a response to proactively address these concerns, the State of Karnataka 's Directorate of Urban Land Transport (DULT) has commissioned for the preparation of Station Accessibility Plans (SAP) for 11 Namma Metro stations along the Green line (Nagasandra- Puttenahalli) Metro Corridor. The primary objectives of the SAP project include:

- Ensuring seamless connectivity between the Metro stations, to and from the Metro stations, and between multiple modes of transportation.
- Prioritizing Non- Motorized Transportation (NMT) as the primary mode for completing trips within a 10-minute walking distance from the Metro Stations.
- Identifying opportunities to preserve and enhance the tangible and intangible assets with in the area surrounding the stations through appropriate development controls.
- Creating catalyst projects based on the station area's existing character and infrastructure capacities to support higher density and intensity uses, where feasible.
- Providing technical support for planning at the local level i.e., often a challenge for Governmental agencies.

The urban growth exerts immense pressure on urban transport system. Urban mobility is not limited to the development of transport infrastructure, use of emerging technologies & green fuels, traffic management, applications of intelligent systems, etc. but also demands better average traffic speed, less operation costs, maximum utilization of public transport, less congestion and accidents on road, easy & safe movement of pedestrian, etc. However, Urban Local Bodies (ULBs) always try to deliver smooth and easy flow by connecting various modes of transport - individual or groups, single or collective, private or public, exclusive lanes or shared lanes, etc. in order to meet the needs of the commuters in their daily activities.

Transport is a critical element of urban system. In present scenario, mega / million plus cities generate more travel demands which is not fully met by either motorized or non-motorized modes. Hence, mass rapid transit system is required as effective means of providing for better, advanced, efficient and quality transit services. However, the efficiency and effective MRTS depends on availability of various modes at city and regional level, location & design of nodes, pedestrian flow at transfer station, etc. Similarly, network structure, line density, stop density, frequency of services, bus routes, etc. enhance connectivity and accessibility. Finally, it evolves Multi Modal Transport System (MMTS) which involves the coordinated use of different modes and their proper integration to decongest road, reduce journey time, enhance environment and increase running speed.

7.1.1 Multi Modal Integration

Multi Modal Integration relates to a seamless connectivity for different combination of modes i.e. vehicle modes (bus, metro, car, etc.) or service modes (private/public) between which the traveller or the commuter has to make without any transfer.

The Ministry of Urban Development, Govt. of India (2006) formulated National Urban Transport Policy, 2006 with the broad objective to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to jobs, education, recreation and such other needs within cities. One of the methods to achieve such objectives is to “enabling the establishment of quality focused multi modal public transport systems that are well integrated, providing seamless travel across modes”.

Figure 7.1 Coordinated integration

A coordinated integration of different modes brings about reduced congestion on the road, greater convenience and seamless connectivity for the commuters and cost effectiveness.

7.1.2 **Physical Integration** plays a major role between integrating modes, the close and ease of access at mode interchanges can enhance public transport services significantly. This not only includes the physical connections between public transport modes but also refers to the connectivity of public transport modes and areas surrounding the stations and stops. As every trip begins and ends on foot, walking should be appropriately integrated as one of the transport modes to the public transport systems. In this term, interchanges between transport modes are where the most barriers exist. Therefore, the main aim in this case is to minimize the obstacles related to the transfers. Walkways should be carefully designed to facilitate the transfer of passengers from one mode to another. Facilitating of transferring between modes by reducing the walking distances and providing well-designed ramps and stairs can guarantee ease and safety of transfers amongst modes.

A fundamental element of a seamless public transport journey is the need to reduce the costs associated with interchanges. These costs can affect the demand for public transport in terms of the influences that interchanges have on waiting time, transferring time between vehicles, the attendant risks and inconvenience. Some studies have highlighted that the desirability of interchanges is influenced by interchange attributes, including personal security and travel information.

With the introduction of Namma Metro in Bangalore, integration with the bus based system has become an important element where the commuters can commute through seamless connectivity within the modes to reach to their destinations.

7.1.3 **Need for Integration**

7.1.3.1 The physical integration of the public transport services has become very essential to provide a seamless connectivity for the commuters to move from one mode to another mode without any difficulties. It is necessary to ensure consistency through physical integration.

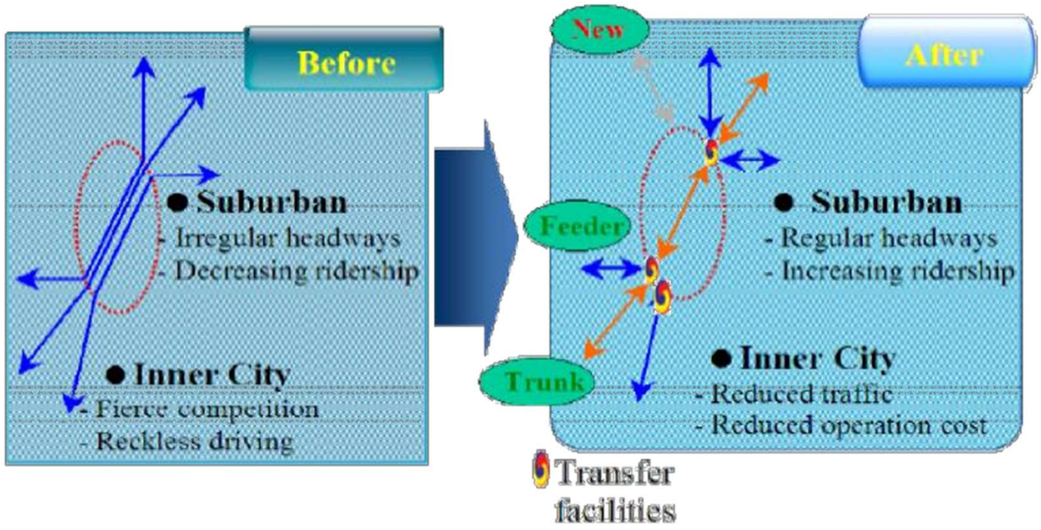
The concept of integration is to enable easy transfer among diverse transport modes such as train, airplane, ship, subway, bus, taxi, bike, walk, and automobiles. Public transport integration is therefore necessary for passengers from the origin areas through different public transport modes to reach to their destinations. A network of convenient and comfortable interchange transfer zone facilities must be located readily and conveniently at accessible locations across different modes which ensures that passengers can interchange within a short walking distance without any difficulties. The close and ease of access at mode interchanges can enhance public transport services significantly. This not only includes the physical connections between public transport modes but also refers to the connectivity of public transport modes and areas surrounding the stations and stops.

As every trip begins and ends on foot, walking should be appropriately integrated as one of the transport modes to the public transport systems. In this term, interchanges between transport modes are where the most barriers exist. Therefore, the main aim in this case is to minimize the obstacles related to the transfers. Walkways should be carefully designed to facilitate the transfer of passengers from one mode to another. Facilitating of transferring between modes by reducing the walking distances and providing well-designed ramps and stairs can guarantee ease and safety of transfers amongst modes.

A fundamental element of a seamless public transport journey is the need to reduce the costs associated with interchanges. These costs can affect the demand for public transport in terms of the influences that interchanges have on waiting time, transferring time between vehicles, the attendant risks and inconvenience.

Pedestrian facilities should be connected with an efficient transport network for the movement of people should be developed. In order to make the best use of a public transport system, safer and more convenient pedestrian linkages from across the various public transport modes should be developed. The purpose is to improve pedestrian's environment and facilities to shorten their walking distance to main transport point as indicated in **Figure 7.2**.

Figure 7.2 Improvement of Pedestrian's Environment and Facilities



7.1.3.2 Attributes of a Good Pedestrian Facility

Some common attributes of good pedestrian facility are described below:

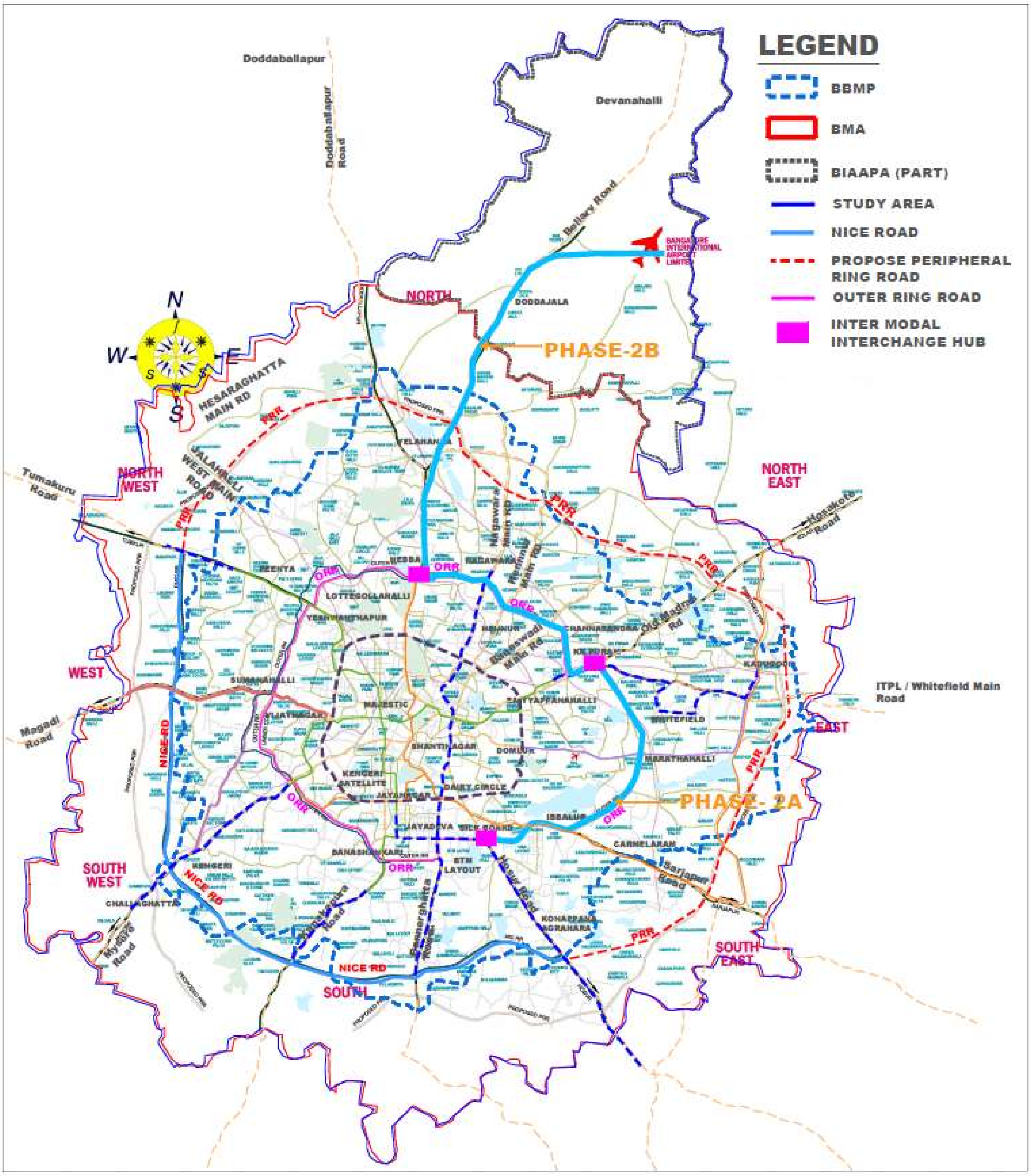
- Accessibility – pedestrian facilities should be accessible to all pedestrian, irrespective of their abilities.
- Connectivity – pedestrian facilities should be well networked for pedestrians to choose the most convenient path.
- Safety – pedestrian facilities should provide a sense of safety to the pedestrians and pedestrians should not be threatened or overwhelmed by vehicles.
- Comfort – pedestrian facilities should be comfortable to use for people of all ages and abilities.
- Ambience – Pedestrian facilities should have good ambience to make the facilities seem inviting for pedestrians to use.
- Place making – Pedestrian facilities should provide space for people to gather and socialize.

7.2 Study Area Description

This project deals with the Multi Modal integration between K R Puram and International Airport via Hebbal on the Outer Ring Road and NH-44. This Metro Corridor is 36.44 Kms long and is planned to have 17 Stations viz. Kasturi Nagar, Horamavu, HRBR Layout, Kalyan Nagar, HBR Layout, Nagawara, Veeranna Palya, Kempapura, Hebbal, Jakkur cross, Yelahanka, Bagalur Cross, Doddajala, Airport City and KIA Terminals.

Along this corridor Hebbal is identified for major hub of Multi modal integration as this is proposed to be the interchange stations of Metro lines. Apart from this bus bays are being proposed at all metro stations adjacent to service Road for BMTC buses and feeder services to ensure the multimodal integration. An additional area of 211 Sqm is being exclusively acquired for the same purpose. Since this Road is in addition to the existing service Road of ORR, this area will effectively function as Multimodal traffic integration point without causing to the usual traffic on the road.

Figure 7.3 Shows the stations identified for Multimodal Integration hub at K R Puram and Hebbal along Phase 2B line.



The study area is mainly surrounded by the important areas like HBR layout, Nagawara, Hebbal, Kodegehalli, Yelahanka and Bagalur Cross. It is located around commercial cum residential area, well planned townships, prominent Software Parks like Manyatha Tech Park etc., Esteem Mall, Columbia Asia

Hospital, GKVK Campus, Jakkur Aerodrome, Kendriya Vidyalaya and ITC factory etc.

As per data collected from DULT (DPR for Bangalore BRTS, 2014 July), usage of this stretch from K R Puram- Kempegowda International Airport is 70% by private vehicles, 11% by public transport, 12% by Auto/Taxi and 7% others. For efficient management of traffic in this stretch, it is essential to ensure undisrupted & free flow of traffic, which will effectively reduce the total traffic volume by 40-50%.

7.2.1 Integration with BMTC

The traffic from single occupancy private vehicles and Auto/Taxi can be significantly reduced if BMTC can provide dedicated services with increased frequency during peak hours starting and terminating at proposed metro stations as feeder services.

BMTC buses are flowing along ORR from Jyothipuram to Hebbal and further upto Yelahanka at a very high frequency. There after it is noticed that the trips of the BMTC buses are found as per demand along NH-44 from Yelahanka upto Trumpet. The trips of these BMTC buses can be rescheduled once the Airport link metro service starts and thus passengers can be ensured timely reach of destination as a last mile connectivity from each metro stations.

Along this corridor Hebbal is identified for major hub of Multi modal integration as this is proposed to be the interchange stations of Metro lines. Apart from this bus bays are being proposed at all metro stations adjacent to service Road for BMTC buses and feeder services to ensure the multimodal integration. An additional area of 211 Sqm is being exclusively acquired for the same purpose. Since this Road is in addition to the existing service Road of ORR, this area will effectively function as Multimodal traffic integration point without causing to the usual traffic on the road.

7.2.2 Integration with BBMP

Service roads exist all along this corridor in both directions in addition to the Main Road carriage way.

In order to achieve effective integration of metro with BMTC, a service road of 5.5 m width is planned around the entry structures on both the sides which will facilitate easy pick up and drop off of commuters without affecting the regular road traffic. This road is in addition to the existing service road and BMTC buses also will go through this road to serve the Metro commuters. At both ends of this service road, wider road width is planned to facilitate the buses to stop for commuters to board and alight.

7.2.3 Integration with Transport Department

There are two ways to restraint the growth of private vehicles on road either by pricing policy or by providing better level of service on public transport.

It should be possible to put constraints in some areas by restricting private vehicles entering into the congested roads particularly during peak hours.

Providing good public transport with feeder IPT modes like Mini buses for facilitating the commuters to reach their destinations from Metro stations would also induce many private vehicle users to shift to public transport.

In fact, with latest modernization/development in transport sector, we can substantially achieve the above objectives through following measures:

- Enough parking lots be provided outside the ORR and NH-44 easily accessible from the radials reaching the ORR and NH-44.
- Proper park & ride facilities for long term parking at the stations / termini of outside the ORR and NH-44 and providing comfortable, environmental friendly transport (Electrically operated /CNG mini buses) between these areas and the Metro stations.

7.2.4 Integration with Police Department

Scientific bus bays are the need for the city. Due to lack of bus bays, buses occupy service road. Also, road space is compromised for public parking. Bus priority lanes proposal are in the pipeline along with setting up of bus bays.

Presently, even though restricted, commonly two way movements are followed in Service roads of ORR and NH-44 on either side. Uni-directional movement may be re-implemented in Service roads, except where inevitable.

Parking of vehicles on Service road shall be strictly prohibited to ensure maximum utilization of Service Road and ensure smooth flow of traffic. Parking lots/lanes may be allocated on arterial roads where traffic is marginally less.

Removal of encroachments, illegal Taxi/CAB/OLA/UBER etc., parking on roads has to be strictly enforced. Preventing perpendicular entry to main carriage way by providing more number of Openings/Gates to company campuses, prevent concentrated traffic congestion etc., near ORR and NH-44are to be strictly followed.

To reduce traffic load on ORR, provision of entry/exit Gates on the other side of ORR has been proposed.

7.3 Physical Infrastructure Requirement for Integration with other Modes

7.3.1 Development of Arterial Roads Connecting ORR

a. BBMP has taken up improvements of following roads:

- White topping of outer ring road between Jyothipuram and Hebbal.
- Strengthening up of some of the alternate/arterial roads need to be taken up by BBMP and at locations where already work in progress, it needs to be expedited duly clearing the bottlenecks.
- Development of the above mentioned roads will help run feeder service to the Metro stations from the surrounding residential areas.

b. Sky Walks

To facilitate easy access for the pedestrians BBMP has planned Skywalks at many locations of Outer Ring Road. Also, skywalks are existing at Channasandra, HRBR Layout, Kalyan Nagar, Veeranapalya and Kodegehalli on outer ring road between KR Puram and Hebbal and at kodigehalli on NH-44. In addition to the above BMRCL is making a provision for skywalk integrated with individual station at all locations along Phase 2B corridor.

c. Junction Improvements

The improvements of the junction at Ramurthy Nagar, Kammanahalli, Nagavara, Dasarahalli, Kempapura road, Kodigehalli, Shakarnagar road, Jakkur cross (R K Hegde nagar main road), Yelahanka bypass junction, Kogillu cross, Bagulur cross, Sonappanahalli (Rajanukunte road), Sadarahalli road etc., will benefit all along ORR between K R Puram to Hebbal and along NH-44 between Hebbal and Airport.

7.3.2 Park-and-Ride Facility

To mitigate the traffic problem, it is necessary to reduce the single occupation vehicles of individuals which is currently contributing 70% of the total traffic volume, Taxi services like OLA, UBER etc. which is contributing 12% of the total traffic volume and provision of an efficient mass transport system like Metro rail to the convenience of the commuters will bring down the total traffic volume significantly. For this purpose, it is planned to provide ‘Park N Ride’ facility at vital junctions so that the commuters coming from their residences can park their personal vehicles at a nominated parking and catch a common transport, thus single occupation vehicles can be considerably reduced. Park and Ride facility at important metro stations such as Nagavara, Hebbal etc., are also considered to promote Metro rail travel as a preferred option to the commuters.

7.4 Non-Motorised Transport

7.4.1 Public Bicycle Sharing System

For the mass transit systems to be successful in influencing people to shift from private vehicles to mass transit for commuting, easy and safe access (last mile connectivity) to the Metro stations is very critical. Last mile connectivity could be achieved through multiple means such as pedestrian and cycling infrastructure, feeder buses and auto-rickshaws. In this direction, Government of Karnataka had announced in the Budget 2017-18 to take up bicycle rental/sharing scheme (PBS) in select clusters in Bengaluru. Accordingly, a detailed study for introducing PBS in Bengaluru was carried out and clusters where potential demand for PBS exists have been identified by, GoK through DULT. As per this, the Bruhat Bangalore Mahanagara Palike shall construct dedicated cycles tracks in the identified areas of the city for implementing PBS.

In order to provide First mile and Last mile connectivity to the Metro stations, space has been ear marked in the ground floor of the Metro stations for developing rent-a-bike facility. This will also help in promoting Non-Motorised Transport system in Bengaluru city and in reducing the Carbon emission.

7.4.2 Pedestrian paths.

7.4.3 BBMP is already implementing pedestrian and cyclist friendly roads under the Tender SURE model. The concept of the Tender SURE is to re-allocate road space equitably to all road users.

At Metro stations, adequate footpaths are being provided on both sides of the Service roads in both the directions, for ease of Pedestrian movement. In addition, Footpaths are also planned to be widened/ upgraded on important crossroads leading to the stations in order to promote walking to and from the metro stations for the residents and office goers in the vicinity of Metro stations.

7.4.4 Integration with Railways

Kasturi Nagar and Doddajala metro station are coming close to important Railway station i.e., Channasandra and Doddajala railway station, where many Express trains stop apart from passenger trains. This station is very popular because developments that came up in the vicinity. To integrate Metro and Indian railway station at Channasandra, a Foot Over Bridge is planned for direct connectivity between the two modes of mass transit.

7.5 Recommendations for Institutional Integration

The matter of Transport was split between different corporations handled by different departments, a multi-pronged approach was required to find solutions. While the bus services come under the Transport Department, the Metro being monitored by Urban Development Department and the traffic Police work as enforcing arm, lack of coordination between different departments being high, the government is in the process of setting up Bangalore Metropolitan Land Transport Authority to address the problem. For better traffic management, GoK has taken steps to set up Bangalore Metropolitan Land Transport Authority and Road Safety Authority. The UDD has already prepared a draft on this and shall be set up by the end of 2019.The State Budget has announced Integrated Transport Authority. Accordingly, the following management techniques for Operational Integration, Physical Integration, Fare Integration and Technology Integration are proposed.

7.5.1 Operational Integration

Phase-2B (Airport Line) will be extended upto Airport station and hence the headway in the year 2024 and 2031 between Silk Board to K R Puram of 2A corridor and KR Puram to Yelahanka of 2B corridor has been kept same so that passenger originating from Phase-2A corridor can travel upto Yelahanka without any interchange. Also, headway for 2A corridor is planned for the year 2024 and 2031 in such a way that every third train originating from Silk board will be extended to the Airport so that passenger can travel upto Airport without any interchange. But for the year 2041, there is high PHPDT between KR Puram to Kempapura cross and hence in this section, headway of 2.5 min is planned to meet the PHPDT requirement of 46245 passengers. Suitable turn back facilities at Kempapura cross and Kogilu cross are planned.

For passenger coming from Line-5 and travelling towards Phase-2A and 2B corridor, interchange facilities at Silk Board is planned. Similarly, interchange facilities at KR Puram is planned for passengers from East-West corridor travelling towards Phase-2A and 2B corridor.

7.5.2 Physical Integration

Integration of public transport modes with provision of jointly used facilities at intermediate points or at terminals with interchange facilities, the following Physical integration is planned for this corridor.

- Improvements of junctions at Hebbal.
- Uniform standard carriage way width from one junction to another.
- Clear road signs, markings, zebra crossings at junctions for pedestrian crossings.
- Properly designed footpaths providing ample space for pedestrians.
- Proper storm water drainage system on both sides of road to eliminate flooding.
- Dedicated utility ducts below footpaths for water, power, electricity, OFC etc.,

- Bus bays in all Metro Stations to accommodate easy egress and ingress of BMTC bus passengers.
- Bus station at Hebbal junction.
- Bicycle lines wherever feasible.
- Parking facilities for bicycles, IPT, rent a bike etc., at all Metro Stations
- Provision of Foot Over Bridge at Kasturi Nagar station connecting Channasandra Railway station.
- Provision for entry and exit for non-Metro commuters through unpaid area at all Metro Stations.
- Pick up and drop off facilities for different modes of transport at all Metro Stations.
- Multi-level mechanical parking near K R Puram Metro Station.

7.5.3 Fare Integration

The AFC system of Phase 2B shall be integrated with existing AFC systems of Phase I and Phase II of Bangalore Metro. The systems shall also have provision of integration with AFC system of other transport operators such as Suburban Rail /BMTC etc.

The AFC system shall support simultaneously ISO 14443 based type ‘A’ cards compatible with MiFare and EMV based open loop (National Common Mobility Cards, RuPay, Visa, Master etc.) cards. For the purpose, the system shall integrate with host systems/ CCHS of Acquirer/ issuer Bank. The system shall also be capable of processing and accepting NFC based fare media with the provision of mobile ticketing. The system shall have provision for QR code based mobile ticketing also.

7.5.4 Technology Integration

Technology for Rolling Stock, Power supply, Traction system, CBTC based signaling system, telecom and other system facilities of Phase-2A corridor and Phase-2B corridor are planned in such a way that the train can be extended from Phase-2A corridor to Phase-2B corridor without any operational constraints.

Chapter 8

Train Operations Plan

CHAPTER - 8

TRAIN OPERATIONS PLAN

8.1 SYSTEM OPERATION APPROACH

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

- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections.
- Economical & optimum train service frequency not only during peak period, but also during off-peak period.
- Multi-tasking of train operation and maintenance staff.

8.2 STATIONS

Table 8.1 List of Stations for 2B corridor: KR Puram to KIA Terminals Station

Sl. No	Name of Stations	Chainage (in m)	Inter Station Distance (in Kms)	Remarks
0.	K R Puram	17.133(Phase 2A)/ -1.294 (Phase 2B)	0.000	Elevated
1.	Kasturi Nagar	1,600.160	2.89	Elevated
2.	Horamavu	2,751.700	1.15	Elevated
3.	HRBR Layout	4,201.230	1.44	Elevated
4.	Kalyan Nagar	5,303.820	1.10	Elevated
5.	HBR Layout	6,560.920	1.25	Elevated
6.	Nagawara	7,508.790	0.94	Elevated
7.	Veeranna Palya	8,314.000	0.80	Elevated
8.	Kempapura	9,964.250	1.65	Elevated
9.	Hebbal	11,223.430	1.25	Elevated
10.	Kodigehalli	12,699.060	1.47	Elevated
11.	Jakkur Cross	14,120.040	1.42	Elevated
12.	Yelahanka	17,842.930	3.72	Elevated
13.	Bagalur Cross	20,022.280	2.17	Elevated
14.	Bettahalasuru	23,826.472	3.80	Elevated
15.	Doddajala	28,736.530	4.91	Elevated
16.	Airport City	33,705.170	4.96	At grade
17.	KIA Terminals	36,267.250	2.56	At grade

8.3 TRAIN OPERATION PLAN

8.3.1 Salient Features

- Running of services for 19 hours of the day (5 AM to Midnight) with a station dwell time of 30 seconds. No services are proposed between 00.00 hrs to 5.00 hrs, which are reserved for maintenance of infrastructure and Rolling Stock.
- Make up time of 5-10% with 8-10% coasting.
- Scheduled speed for 2B Corridor: KR Puram to Yelahanka has been taken 36Kmph and between Yelahanka to KIA Terminals station has been taken as 60 Kmph based on the detailed simulation carried out with the present inter station distance.

8.3.2 PHPDT: Airport Link Metro corridor (KR Puram to KIA Terminals station)

Peak hour peak direction traffic (PHPDT) demands for the 2B corridor for Airport Link Metro corridor (KR Puram to KIA Terminals station) for the Year 2024, Year 2031 & Year 2041, for the purpose of calculation of rake requirement are indicated in the tables below:

i. Year 2024: PHPDT Demand and Capacity Chart

Every second train from CSB Junction will be extended to KIA Terminals station matching the headway of 2B corridor with the headway of 2A corridor. Headway considered for the year 2024 is as under:

Table 8.2: Section and Headway

Sl. No.	Section	Head-way in minute
1	CSB Junction -K R Puram	5
2	K R Puram –Yelahanka	5
3	Yelahanka –KIA Terminals station	10

- Headway: 5 minutes from KR Puram to Yelahanka and 10 minutes from Yelahanka to KIA Terminals station.
- Available Peak Hour Peak Direction Capacity

Between KR Puram to Yelahanka	➢ 18,888 @6 persons per square meter of standee area (AW3 condition) ➢ 24,048 @8 persons per square metre of standee area (AW4 condition)
Between Yelahanka to KIA Terminals station	➢ 9,444 @6 persons per square meter of standee area (AW3 condition) ➢ 12,024 @8 persons per square metre of standee area (AW4 condition)

- Train composition - 6 car

- Capacity of train - 1574 in AW3 condition and 2004 in AW4 condition
- Schedule Speed - 36 kmph between KR Puram to Yelahanka and 60 Kmph between Yelahanka to KIA Terminals station.

Table 8.3 Year 2024: PHPDT Demand and Capacity Chart between KR Puram to Yelahanka

YEAR		2024			
No. cars per Train		6			
Passenger Capacity @6 Standee passengers/sqm		18,888			
Passenger Capacity @8 Standee passengers/sqm		24,048			
Headway (min)		5 min between KR Puram to Yelahanka			
Sl. No	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1.	K R Puram	Kasturi Nagar	12,310	18,888	24,048
2.	Kasturi Nagar	Horamavu	16,122	18,888	24,048
3.	Horamavu	HRBR Layout	20,472	18,888	24,048
4.	HRBR layout	Kalyan Nagar	20,751	18,888	24,048
5.	Kalyan Nagar	HBR Layout	**21,112**	18,888	24,048
6.	HBR Layout	Nagawara	15,792	18,888	24,048
7.	Nagawara	Veeranna Palya	16,094	18,888	24,048
8.	Veeranna Palya	Kempapura	16,195	18,888	24,048
9.	Kempapura	Hebbal	18,425	18,888	24,048
10.	Hebbal	Kodigehalli	15,166	18,888	24,048
11.	Kodigehalli	Jakkur Cross	10,427	18,888	24,048
12.	Jakkur Cross	Yelahanka	10,114	18,888	24,048

Maximum PHPDT is forecasted between Kalyan Nagar to HBR layout is to the extent of 21,112 in the year 2024.

Figure 8.1 PHPDT for Year 2024

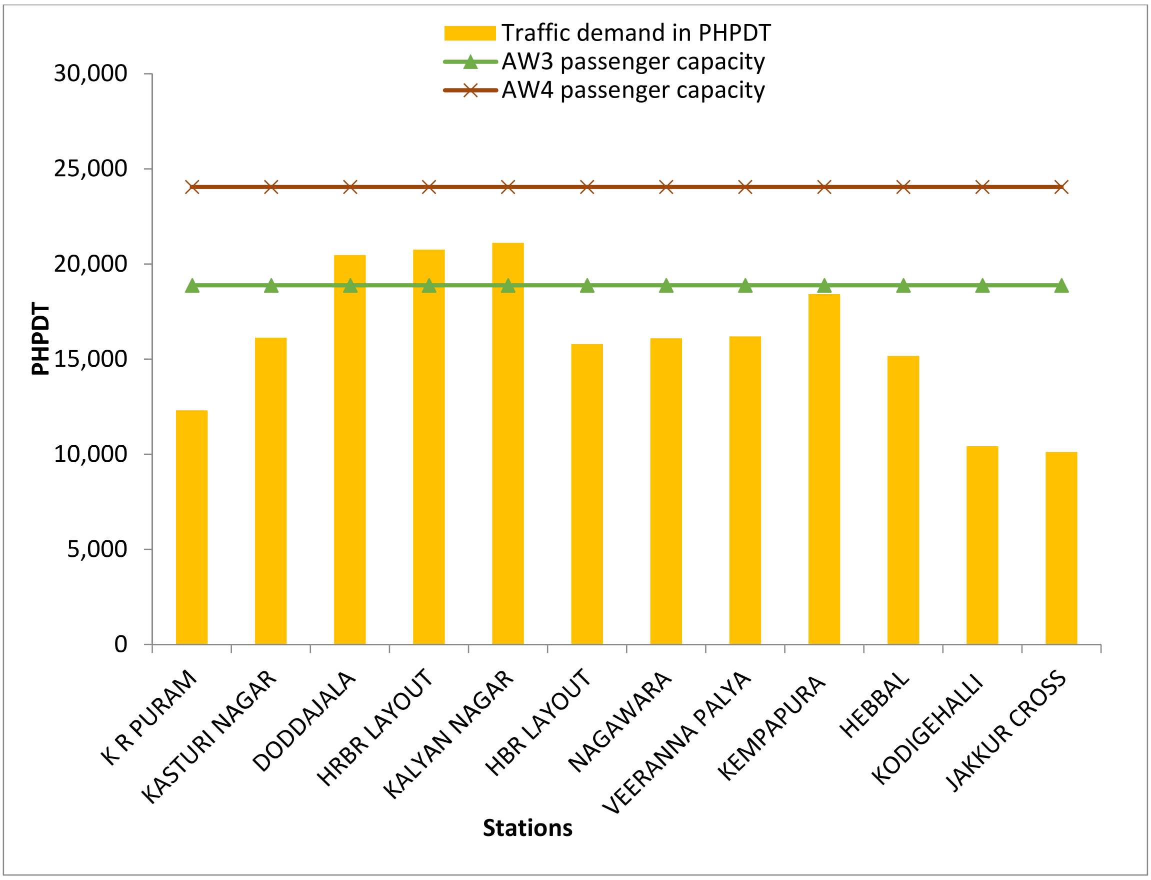


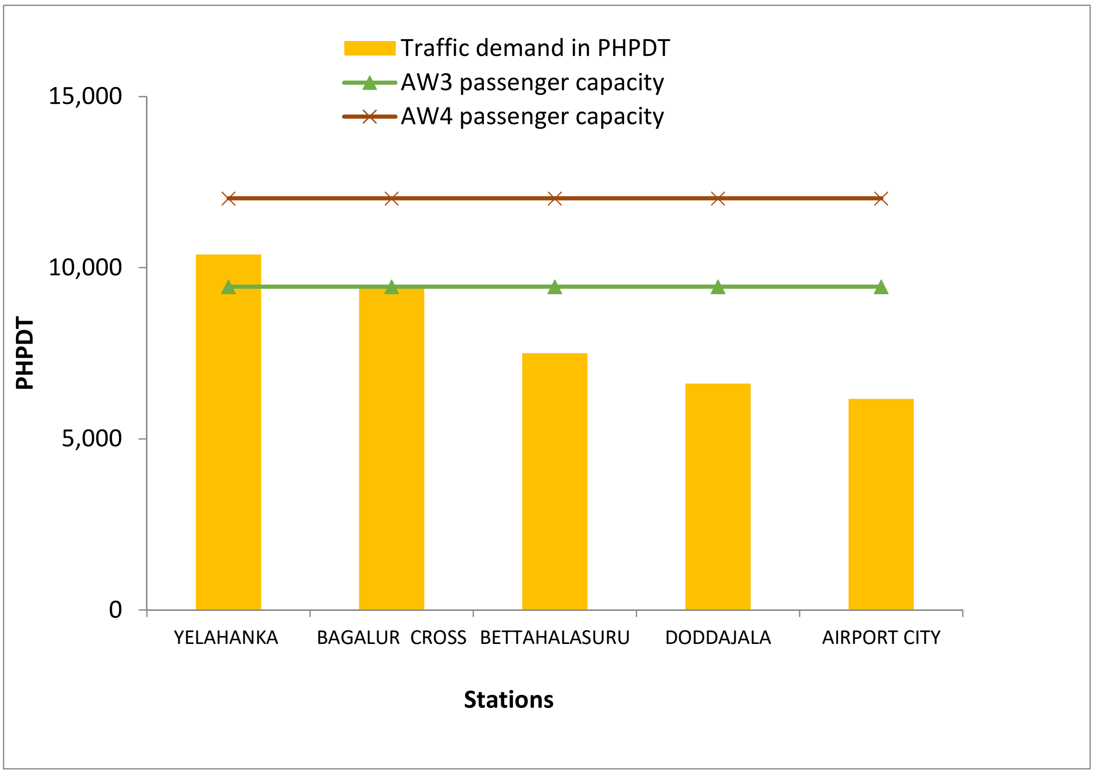
Table 8.4 Year 2024: PHPDT Demand and Capacity Chart between Yelahanka to KIA Terminals station

YEAR		2024			
No. cars per Train		6			
Passenger Capacity @6 Standee passengers/sqm		9,444			
Passenger Capacity @8 Standee passengers/sqm		12,024			
Headway (min)		10 minutes between Yelahanka to KIA Terminals station			
Sl. No	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1	Yelahanka	Bagalur Cross	**10,382**	9,444	12,024
2	Bagalur Cross	Bettahalasuru	9,460	9,444	12,024
3	Bettahalasuru	Doddajala	7,505	9,444	12,024

4	Doddajala	Airport City	6,613	9,444	12,024
5	Airport City	KIA Terminal	6,171	9,444	12,024

Maximum PHPDT is forecasted between Yelahanka to Bagalur Cross is to the extent of 10,382 in the year 2024.

Figure 8.2 PHPDT for Year 2024



ii. Year 2031: KR Puram to KIA Terminals station

Every second train from CSB Junction will be extended to KIA Terminals Station matching the headway of 2B corridor with the headway of 2A corridor. Headway considered for the year 2031 is as under:

Table 8.5: Section and Headway

Sl. No.	Section	Head-way in minute
1	Silk board -K R Puram	3
2	K R Puram -Yelahanka	3
3	Yelahanka – KIA Terminals station	6

- Headway: 3 minutes from KR Puram to Yelahanka and 6 minutes from Yelahanka to KIA Terminals station.
- Available Peak Hour Peak Direction Capacity

Between KR Puram to Yelahanka	➢ 31,480 @6 persons per square meter of standee area (AW3 condition) ➢ 40,080 @8 persons per square metre of standee area (AW4 condition)
Between Yelahanka to KIA Terminals station	➢ 15,740 @6 persons per square meter of standee area (AW3 condition) ➢ 20,040 @8 persons per square metre of standee area (AW4 condition)

- Train composition - 6 car
- Capacity of train - 1574 in AW3 condition and 2004 in AW4 condition
- Schedule Speed - 36 kmph between KR Puram to Yelahanka 60 Kmph between Yelahanka to KIA Terminals station.

Table 8.6 Year 2031: PHPDT Demand and Capacity Chart between KR Puram to Yelahanka

YEAR		2031			
No. cars per Train		6			
Passenger Capacity @6 Standee passengers/sqm		31,480			
Passenger Capacity @8 Standee passengers/sqm		40,080			
Headway (min)		3 min between KR Puram to Yelahanka			
Sl. No	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1.	K R Puram	Kasturi Nagar	20,456	31,480	40,080
2.	Kasturi Nagar	Horamavu	20,406	31,480	40,080
3.	Horamavu	HRBR layout	27,685	31,480	40,080
4.	HRBR layout	Kalyan Nagar	34,987	31,480	40,080
5.	Kalyan Nagar	HBR Layout	35,019	31,480	40,080
6.	HBR Layout	Nagawara	**35,705**	31,480	40,080
7.	Nagawara	Veeranna Palya	27,001	31,480	40,080
8.	Veeranna Palya	Kempapura	27,294	31,480	40,080
9.	Kempapura	Hebbal	27,592	31,480	40,080
10.	Hebbal	Kodigehalli	32,557	31,480	40,080
11.	Kodigehalli	Jakkur Cross	26,916	31,480	40,080
12.	Jakkur Cross	Yelahanka	20,228	31,480	40,080

Maximum PHPDT is forecasted between HBR layout to Nagawara is to the extent of 35,705 in the year 2031.

Figure 8.3 PHPDT for Year 2031

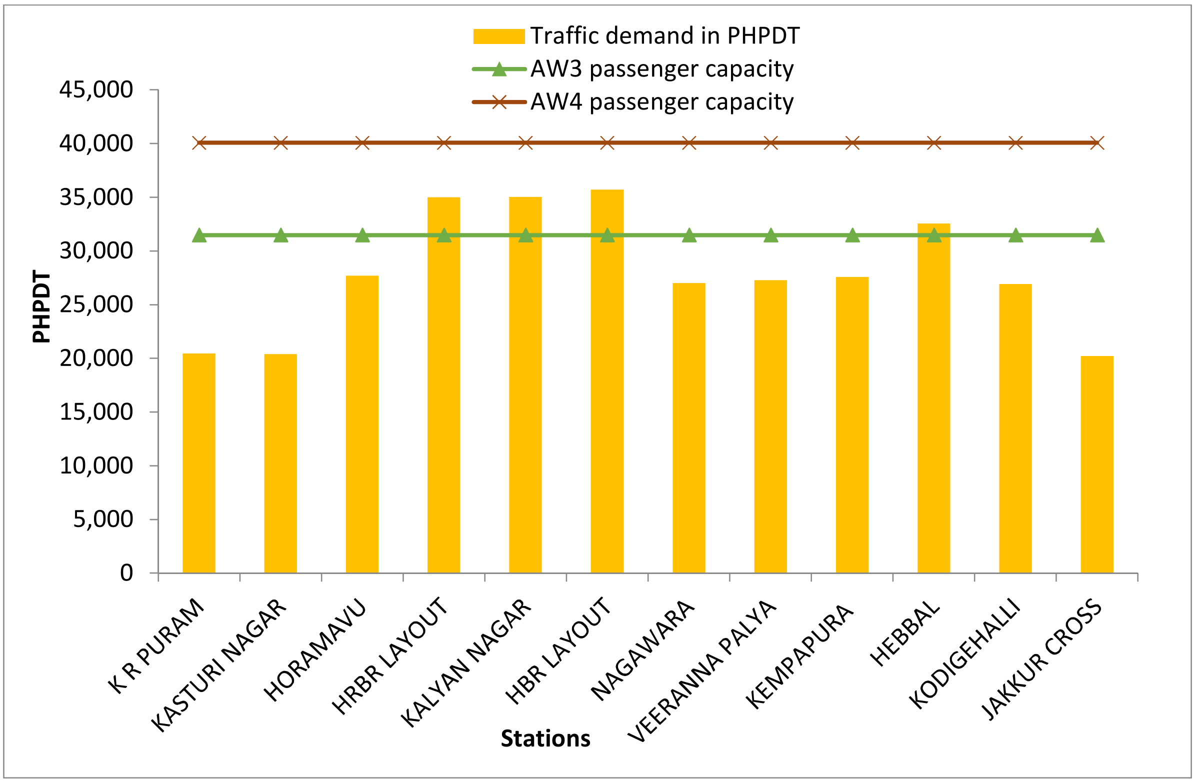
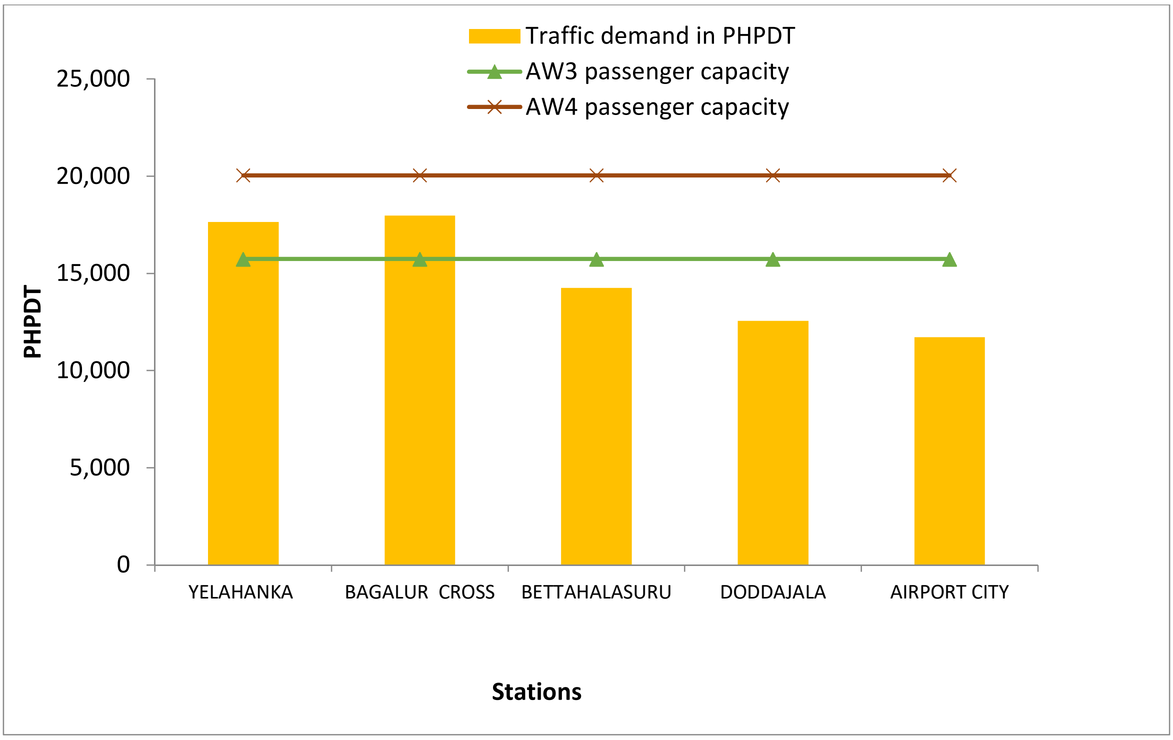


Table 8.7 Year 2031: PHPDT Demand and Capacity Chart between Yelahanka to KIA Terminals Station

YEAR		2031			
No. cars per Train		6			
Passenger Capacity @6 Standee passengers/sqm		15,740			
Passenger Capacity @8 Standee passengers/sqm		20,040			
Headway (min)		6 minutes between Yelahanka to KIA Terminals station			
Sl. No	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1.	Yelahanka	Bagalur Cross	17,650	15,740	20,040
2.	Bagalur Cross	Bettahalasuru	**17,975**	15,740	20,040
3.	Bettahalasuru	Doddajala	14,260	15,740	20,040
4.	Doddajala	Airport City	12,564	15,740	20,040
5.	Airport City	KIA Terminals	11,724	15,740	20,040

Maximum PHPDT is forecasted between Bagalur Cross to Bettahalasuru is to the extent of 17,975 in the year 2031.

Figure 8.4 PHPDT for Year 2031



iii. Year 2041: KR Puram to KIA Terminals station

Every second train from CSB Junction will be extended to KIA Terminals Station matching the headway of 2B corridor with the headway of 2A corridor. Headway considered for the year 2041 is as given in the **Table 8.8**:

Table 8.8: Section and Headway

Sl. No.	Section	Head-way in minute
1	CSB Junction -K R Puram	2.5
2	K R Puram –Yelahanka	2.5
3	Yelahanka–KIA Terminals station	5

- Headway: 2.5 minutes from KR Puram to Yelahanka and 5 minutes from Yelahanka to KIA Terminals station.

- Available Peak Hour Peak Direction Capacity

Between KR Puram to Yelahanka	➢ 37,776 @6 persons per square meter of standee area (AW3 condition) ➢ 48,096 @8 persons per square metre of standee area (AW4 condition)
Between Yelahanka to KIA Terminals station	➢ 18,888 @6 persons per square meter of standee area (AW3 condition) ➢ 24,048 @8 persons per square metre of standee area (AW4 condition)

- Train composition - 6 car
- Capacity of train - 1574 in AW3 condition and 2004 in AW4 condition
- Schedule Speed - 36 kmph between KR Puram to Yelahanka and 60 Kmph between Yelahanka to KIA Terminals station.

Table 8.9 Year 2041: PHPDT Demand and Capacity Chart between KR Puram to Yelahanka

YEAR		2041			
No. cars per Train		6			
Passenger Capacity @6 Standee passengers/sqm		37,776			
Passenger Capacity @8 Standee passengers/sqm		48,096			
Headway (min)		2.5 min between KR Puram to Yelahanka			
Sl. No	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1.	K R Puram	Kasturi Nagar	26,498	37,776	48,096
2.	Kasturi Nagar	Horamavu	26,434	37,776	48,096
3.	Horamavu	HRBR layout	35,863	37,776	48,096
4.	HRBR layout	Kalyan Nagar	45,322	37,776	48,096
5.	Kalyan Nagar	HBR Layout	45,363	37,776	48,096
6.	HBR Layout	Nagawara	**46,252**	37,776	48,096
7.	Nagawara	Veeranna Palya	34,977	37,776	48,096
8.	Veeranna Palya	Kempapura	35,356	37,776	48,096
9.	Kempapura	Hebbal	35,742	37,776	48,096
10.	Hebbal	Kodigehalli	42,174	37,776	48,096
11.	Kodigehalli	Jakkur Cross	34,867	37,776	48,096
12.	Jakkur Cross	Yelahanka	26,203	37,776	48,096

Maximum PHPDT is forecasted between HBR layout to Nagawara is to the extent of 46,252 in the year 2041.

Figure 8.5 PHPDT for Year 2041

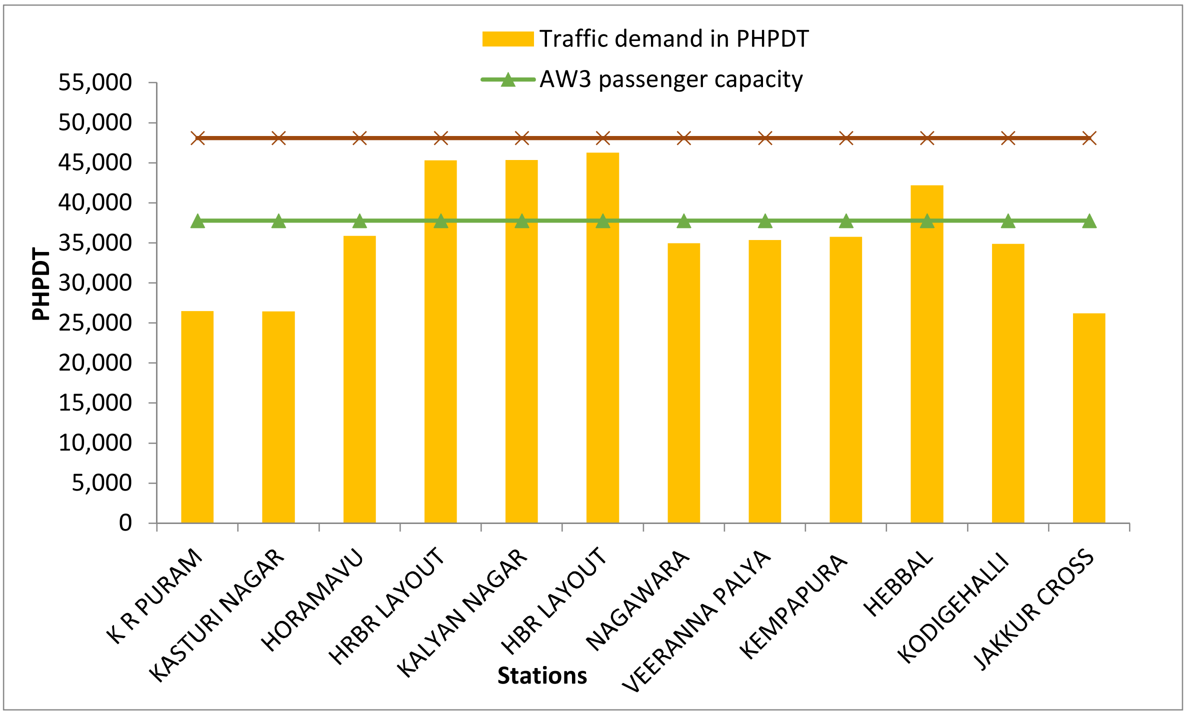


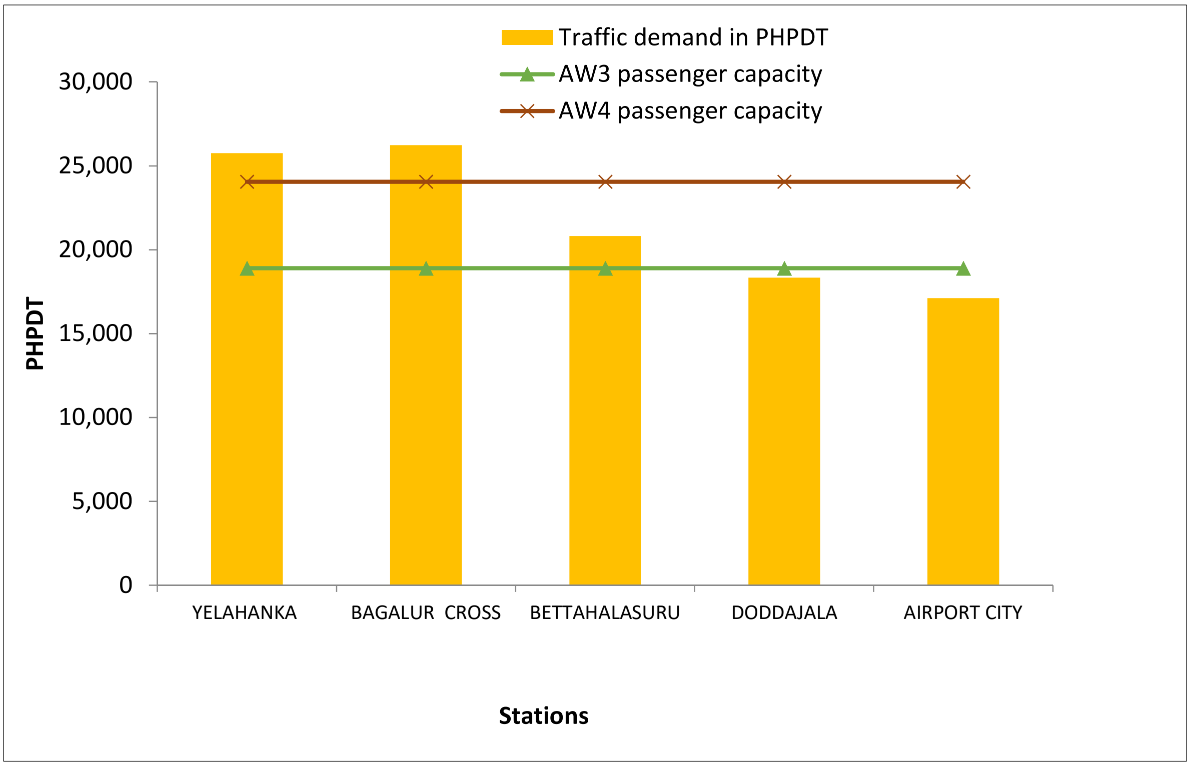
Table 8.10 Year 2041: PHPDT Demand and Capacity Chart between Yelahanka to KIA Terminals Station

YEAR	2041
No. cars per Train	6
Passenger Capacity @6 Standee passengers/sqm	18,888
Passenger Capacity @8 Standee passengers/sqm	24,048
Headway (min)	5 min between Yelahanka to KIA Terminals Station

Sl. No	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1.	Yelahanka	Bagalur Cross	25,751	18,888	24,048
2.	Bagalur Cross	Bettahalasuru	**26,226**	18,888	24,048
3.	Bettahalasuru	Doddajala	20,806	18,888	24,048
4.	Doddajala	Airport City	18,331	18,888	24,048
5.	Airport City	KIA Terminal	17,106	18,888	24,048

Maximum PHPDT is forecasted between Bagalur Cross to Bettahalasuru is to the extent of 26,226 in the year 2041.

Figure 8.6 PHPDT for Year 2041



8.3.3 Train Formation

To meet the above projected traffic demand, it has been planned for running trains with composition of 6 Car trains moderating the capacity with different headway and even may resort to short loop operation based on the traffic requirement.

Composition

6 Car Train Compositions	:	DMC - TC -MC - MC - TC – DMC
DMC	:	Driving Motor Car
MC	:	Motor Car
TC	:	Trailer Car

It is recommended to adopt AW3 Passenger loading for calculation of the passenger carrying capacity to meet the projected maximum PHPDT. Whereas, in emergency it shall be possible to carry the passenger under AW4 loading condition.

Different loading conditions:

Normal condition (AW2) : Seating + 4 passenger per Sq.m in standee area

Crush condition (AW3) : Seating + 6 passenger per Sq.m in standee area

Exceptional Dense crush condition (AW4): Seating + 8 passenger per Sq.m in standee area.

Table 8.11 Carrying Capacity with Crush@6 P/sqm of standee area

	Driving Motor car (DMC)		Trailer car (TC) / Motor car(MC)		6-Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	204	147	220	862	1288
Total	180	247	197	270	1148	1574

Table 8.12 Carrying Capacity with Exceptional Dense Crush@8 P/sqm of standee area

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Exception dense Crush	Normal	Exception dense Crush	Normal	Exception dense Crush
Seated	43	43	50	50	286	286
Standing	137	273	147	293	862	1718
Total	180	316	197	343	1148	2004

8.3.4 Train Operation Plan

Based on the projected PHPDT demand for the year 2024, train operation planned is with 15 numbers of 6-car trains between KR Puram to Yelahanka with headway of 5 minutes and 6 numbers of 6-car trainset between Yelahanka to KIA Terminals Station with headway of 10 minutes as detailed in **Table 8.13**:

Table 8.13 Train Operation Plan for the year 2024

Section	R Km	PHPDT as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
KR Puram to Yelahanka	19.13	21,112	24,048* (18,888)**	5 minute	15 Rakes (90 Cars)
Yelahanka to KIA Terminals Station	18.424	10,382	12,024* (9,444)**	10 minute	6 Rakes (36 Cars)
Total					21 Rakes (126 cars)

**AW4 condition.*

***AW3 Condition*

Based on the projected PHPDT demand for the year 2031, train operation planned is with 24 numbers of 6-car trains between KR Puram to Yelahanka with headway of 3 minutes and 10 numbers of 6-car trainset between Yelahanka to KIA Terminals Station with headway of 6 minutes as detailed in **Table 8.14**:

Table 8.14 Train Operation Plan for the year 2031

Section	R Km	PHPDT as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
KR Puram to Yelahanka	19.130	35,705	40,080* (31,480)**	3 minute	24 Rakes (144 Cars)
Yelahanka to KIA Terminals Station	18.424	17,975	20,040* (15,740)**	6 minute	10 Rakes (60 Cars)
Total					34 Rakes (204 Cars)

**AW4 condition.*

***AW3 Condition*

Based on the projected PHPDT demand for the year 2041, train operation planned is with 28 numbers of 6-car trains between KR Puram to Yelahanka with headway of 2.5 minutes and 12 numbers of 6-car train set between Yelahanka to KIA Terminals Station with headway of 5 minutes as detailed in **Table 8.15**:

Table 8.15 Train Operation Plan for the year 2041

Section	R Km	PHPDT as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
KR Puram to Yelahanka	19.130	46,252	48096* (37776)**	2.5 minute	28 Rakes (168 Cars)
Yelahanka to KIA Terminals Station	18.424	26,226#	24,048* (18,888)**	5 minute	12 Rakes (72 Cars)
Total					40 Rakes (240 cars)

**AW4 condition*

***AW3 condition*

 # Shortfall in PHPDT shall be met by introducing short loop operation between Yelahanka to KIA terminal station with the traffic spare train.

The above Train Operation Plan is based on calculations on the basis of available traffic data. Since, 2B corridor is extension of 2A corridor, trains originating from CSB Junction of 2A corridor is made through to the Airport. In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by adjusting the Headway.

8.4 Rolling Stock Requirement

Thus, Rake requirement based on the PHPDT demand for different years of operation (Year 2024, 2031 & 2041) is tabulated below:

Table 8.16: Rake requirement and capacity provided for the year 2024

Corridor	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
KR Puram to Yelahanka	5	15	**6-Car**	90 Cars	21,112	24048 (18,888)*
Yelahanka to KIA Terminals Station	10	6	**6-Car**	36 Cars	10,382	12,024 (9,444)*

**AW3 condition*

Table 8.17 Rake requirement and capacity provided for the year 2031

Corridor	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
KR Puram to Yelahanka	3	24	**6-Car**	144 Cars	35,705	40,080 (31480)*
Yelahanka to KIA Terminals Station	6	10	**6-Car**	60 Cars	17,975	20,040 (15740)*

**AW3 condition*

Table 8.18 Rake requirement and capacity provided for the year 2041

Corridor	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
KR Puram to Yelahanka	2.5	28	**6-Car**	168 Cars	46,252	48,096 (31480)*
Yelahanka to KIA Terminals Station	5	12	**6-Car**	72 Cars	26,226	24,048 (18,888)*

**AW3 condition*

8.4.1 System (Train) frequency

On this corridor (KR Puram to KIA Terminals station), proposed Train frequency (headway) envisaged based on PHPDT demand for different years of operation taking into consideration of capacity described in the previous paras is as under:

Table 8.19 Train Frequency year Wise

Corridor	2024		2031		2041	
	Peak Hour h/w	Lean Hour h/w	Peak Hour h/w	Lean Hour h/w	Peak Hour h/w	Lean Hour h/w
KR Puram to Yelahanka	5 min	10 min	3 min	6 min	2.5 min	5 min
Yelahanka to KIA Terminals station	10 min	15 min	6 min	12 min	5 min	10 min

Initially, the lean hour frequency will be as per the above table and the same will be modified based on the lean hour requirements.

8.4.2 Time Table: Hourly Train Operation plan

The hourly distribution of daily transport capacity is presented in Table below for 2B corridor (KR Puram to KIA Terminals station). Number of train trips per direction per day for above corridors are worked out as 150 between KR Puram to Yelahanka and 88 between Yelahanka to KIA Terminals station in the year 2024.

8.4.2.1 Hourly Train Operation plan for the year 2024

Table 8.20 Hourly Train Operation plan for the year 2024

Hourly Train Operation Plan for : KR Puram to Yelahanka			
YEAR	**: 2024**		
Configuration	**: 6 car**		
Headway	**: 5 Minutes**		
Time of Day in Hours	**Headway in Minutes**	**No. of Trains per Day**	
		Up	**Down**
05-06	10	6	6
06-07	10	6	6
07-08	10	6	6
08-09	5	12	12
09-10	5	12	12
10-11	5	12	12
11-12	10	6	6
12-13	10	6	6
13-14	10	6	6
14-15	10	6	6
15-16	10	6	6
16-17	10	6	6
17-18	5	12	12
18-19	5	12	12
19-20	5	12	12
20-21	10	6	6
21-22	10	6	6
22-23	10	6	6
23-24	10	6	6
Total No. of Trains Trips per Direction per Day		150	150

Table 8.21 Hourly Train Operation plan for the year 2024

Hourly Train Operation Plan for : Yelahanka to KIA Terminals Station			
YEAR	**: 2024**		
Configuration	**: 6 car**		
Headway	**: 10 Minutes**		
Time of Day in Hours	**Headway in Minutes**	**No. of Trains per Day**	
		Up	**Down**
05-06	15	4	4
06-07	15	4	4
07-08	15	4	4
08-09	10	6	6
09-10	10	6	6
10-11	10	6	6
11-12	15	4	4
12-13	15	4	4
13-14	15	4	4
14-15	15	4	4
15-16	15	4	4
16-17	15	4	4
17-18	10	6	6
18-19	10	6	6
19-20	10	6	6
20-21	15	4	4
21-22	15	4	4
22-23	15	4	4
23-24	15	4	4
Total No. of Trains Trips per Direction per Day		88	88

8.4.2.2 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for Airport Link Metro corridor is given in **Table 8.22**.

Table 8.22: Vehicle Kilometer

Year	**2024**	
Section	KR Puram to Yelahanka	Yelahanka to KIA Terminals Station
Section Length	19.13	18.424
No. of cars Per train	6	6
No. of working days in a year	340	340
Number of trains per day each way	150	88
Daily Train-KM	5730	3242.62
Annual Train-KM (10^5)	19.48	11.02
Annual Vehicle- KM (10^5)	116.89	66.14

8.4.2.3 Hourly Train Operation plan for the year 2031

Table 8.23 Hourly Train Operation plan for the year 2031

Hourly Train Operation Plan for : KR Puram to Yelahanka			
YEAR	: 2031		
Configuration	: 6 car		
Headway	:3 Minutes		
Time of Day in Hours	Headway in Minutes	No. of Trains per Day	
		Up	Down
05-06	6	10	10
06-07	6	10	10
07-08	6	10	10
08-09	3	20	20
09-10	3	20	20
10-11	3	20	20
11-12	6	10	10
12-13	6	10	10
13-14	6	10	10
14-15	6	10	10
15-16	6	10	10
16-17	6	10	10
17-18	3	20	20
18-19	3	20	20
19-20	3	20	20
20-21	6	10	10
21-22	6	10	10
22-23	6	10	10
23-24	6	10	10
Total No. of Trains Trips per Direction per Day		250	250

Table 8.24 Hourly Train Operation plan for the year 2031

Hourly Train Operation Plan for : Yelahanka to KIA Terminals Station			
YEAR	: 2031		
Configuration	: 6 car		
Headway	: 6 Minutes		
Time of Day in Hours	Headway in Minutes	No. of Trains per Day	
		Up	Down
05-06	12	5	5
06-07	12	5	5
07-08	12	5	5
08-09	6	10	10
09-10	6	10	10
10-11	6	10	10
11-12	12	5	5

12-13	12	5	5
13-14	12	5	5
14-15	12	5	5
15-16	12	5	5
16-17	12	5	5
17-18	6	10	10
18-19	6	10	10
19-20	6	10	10
20-21	12	5	5
21-22	12	5	5
22-23	12	5	5
23-24	12	5	5
Total No. of Trains Trips per Direction per Day		125	125

8.4.2.4 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for Airport Link Metro corridor is given in **Table 8.25.**

Table 8.25: Vehicle Kilometer

Year	**2031**	
Section	KR Puram to Yelahanka	Yelahanka to KIA Terminals Station
Section Length	19.130	18.424
No. of cars Per train	6	6
No. of working days in a year	340	340
Number of trains per day each way	250	125
Daily Train-KM	9565	4606
Annual Train-KM (10^5)	32.52	15.66
Annual Vehicle- KM (10^5)	195.12	93.96

8.4.2.5 Hourly Train Operation plan for the year 2041

Table 8.26: Hourly Train Operation plan for the year 2041

Hourly Train Operation Plan for : KR Puram to Yelahanka			
YEAR	**: 2041**		
Configuration	**: 6 car**		
Headway	**: 2.5 Minutes**		
Time of Day in Hours	**Headway in Minutes**	**No. of Trains per Day**	
		Up	**Down**
05-06	5	12	12
06-07	5	12	12
07-08	5	12	12
08-09	2.5	24	24

09-10	2.5	24	24
10-11	2.5	24	24
11-12	5	12	12
12-13	5	12	12
13-14	5	12	12
14-15	5	12	12
15-16	5	12	12
16-17	5	12	12
17-18	2.5	24	24
18-19	2.5	24	24
19-20	2.5	24	24
20-21	5	12	12
21-22	5	12	12
22-23	5	12	12
23-24	5	12	12
Total No. of Trains Trips per Direction per Day		300	300

Table 8.27: Hourly Train Operation plan for the year 2041

Hourly Train Operation Plan for : Yelahanka to KIA Terminals Station			
YEAR	**: 2041**		
Configuration	**: 6 car**		
Headway	**: 5 Minutes**		
Time of Day in Hours	**Headway in Minutes**	**No. of Trains per Day**	
		Up	**Down**
05-06	10	6	6
06-07	10	6	6
07-08	10	6	6
08-09	5	12	12
09-10	5	12	12
10-11	5	12	12
11-12	10	6	6
12-13	10	6	6
13-14	10	6	6
14-15	10	6	6
15-16	10	6	6
16-17	10	6	6
17-18	5	12	12
18-19	5	12	12
19-20	5	12	12
20-21	10	6	6
21-22	10	6	6
22-23	10	6	6
23-24	10	6	6

Total No. of Trains Trips per Direction per Day		150	150

8.4.2.6 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for Airport Link Metro corridor is given in **Table 8.28.**

Table 8.28: Vehicle Kilometer

Year	2041	
Section	KR Puram to Yelahanka	Yelahanka to KIA Terminals station
Section Length	19.13	18.424
No. of cars Per train	6	6
No. of working days in a year	340	340
Number of trains per day each way	300	150
Daily Train-KM	11478	5527.2
Annual Train-KM (10^5)	39.02	18.79
Annual Vehicle- KM (10^5)	234.15	112.75

8.5 Assumptions-

I. Train Composition planned as under
6 car Train Composition : DMC - TC - MC - MC – TC - DM
Train Carrying Capacity of 6 Car Train : 2004 passengers (AW4)
: 1574 passengers (AW3)

II. Coach requirement has been calculated based on headway during peak hours and scheduled commercial speed of 36 kmph between KR Puram to Yelahanka and 60 kmph between Yelahanka to KIA Terminals Station.

III. Traffic reserve train is taken as one train for KR Puram to Yelahanka for the year 2024 and one train from Yelahanka to KIA terminal station for the year 2031 and 2041 to cater to failure of train on line and to make up for operational time lost. Traffic reserve train for Yelahanka to KIA Terminals station shall be used for short loop operation during peak hours for the year 2041.

IV. Repair and maintenance reserve has been estimated as 8 % of total requirement (Bare +Traffic Reserve) as the time for maintenance may get reduced based on the Airport traffic demand.

V. The calculated number of rakes in fraction is rounded off to next higher number.

VI. Total Turn round time is optimized as 3 min at terminal stations considering the introduction of Automatic Turn Back (ATB).

8.6 Stabling details/yard planning

The details are provided in Chapter-13 (Train Maintenance Depot).

Chapter 9

Signalling / Train Control, Telecom System

CHAPTER– 9

SIGNALLING / TRAIN CONTROL, TELECOMMUNICATION SYSTEM

9.1 SIGNALLING / TRAIN CONTROL

9.1.1 INTRODUCTION

9.1.1.1 The Airport Metro line of Bengaluru is an extension of ORR Metro line between Central Silk Board & K R Puram and expected to carry a large number of passengers beyond K R Puram, requiring a very high level of safety enforcement and reliability as well as availability. At the same time, heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. The Signalling & Train Control system in Metro Railway plays a major role to provide frequent, fast and safe journeys in the urban areas including connection with International Airport. The telecommunication system acts as the communication backbone for Signalling system and provides telecommunication services to meet operational and administrative requirements of rail / metro network.

9.1.1.2 The Distance to Go (DTG) system provided on Purple and Green lines of BMRCL Phase-I is becoming obsolete and the latest Signalling / Train Control technology available is the Communication Based Train Control (CBTC) system.

9.1.1.3 The Phase-2B line from K R Puram to Airport line is the continuation of ORR line between Central Silk Board & K R Puram, which is proposed with CBTC system of signaling and in order to facilitate seamless connection with the International Airport line, similar system of CBTC with same Grade of Automation (GoA) is proposed to be adopted in the K R Puram –Airport line also.

9.1.2 CBTC based Signalling System:

9.1.2.1 Train control requirements of the metro are planned to be achieved by adopting Continuous Automatic Train Control (CATC) based on Communication Based Train Control (CBTC) System. The train location is determined by continuous communication with Central control. The Axle counters/track circuits are installed as a fall back option and to manage non-equipped vehicle movements. CBTC system includes Automatic Train Protection (ATP) and Automatic Train Operation (ATO) sub-systems using continuous bi-directional radio communication between track side and train along with Automatic Train Supervision (ATS) sub systems. CBTC system also provides Unattended Train Operation (UTO).

The CBTC system offers following advantages:

a) Provides higher traffic capacity.

b) High reliability, better availability and less prone to failures.
c) Reduction in cost.
d) Quicker recoveries in case of service delays.
e) Lesser maintenance due to Radio Communication
f) They are reported to be more energy efficient systems compared to DTG signalling.
g) Adaptable to any Grade of Automation and Scalable too.

This will:

i) Provide high level of safety ensuring continuous safe train separation and for bidirectional working.
ii) Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.
iii) Provides safety and enforces speed limit on section having permanent and temporary speed restrictions.
iv) Improves capacity with safer and smoother operations. Driver will have continuous display of Target Speed and other information in his cab enabling him to optimize the speed potential of the track section. It provides signal / speed status in the cab even in bad weather.
v) Improve maintenance of Signalling and telecommunication equipments by providing new ways of monitoring system status of track side and train borne equipments and undertaking preventive maintenance.

9.1.3 The Signalling and Train Control system shall be designed to meet the required headway on this line as well as on the contiguous section of ORR line. The signalling system shall also have secondary detection of trains through Axle counters/Track circuits. Radio for CBTC shall work in license free Industrial, Scientific & Medical (ISM) band.

9.1.4 The control of train operation will be done from a centralized Operation Control Center (OCC) and will be supervised by Traffic Controller. The OCC shall have required facilities for setting of the route and clearing of the signals and other supervisory and control facilities. The Backup Control Centre (BCC) shall also be provided at a suitable location geographically separated from the OCC.

The Signalling/Train Control System at OCC for this line shall be integrated with that of Phase-2A. To cater combined operation requirement for Central Silk Board to Airport Link Corridor, a new Operation Control Centre (OCC) is planned with equipment and display boards of CBTC system adjacent to Baiyappanahalli Depot with a suitable connectivity to the existing OCC as the present OCC is operationally saturated.

9.1.5 System Description and Specifications

The Signalling and Train Control system shall be as explained below:

a. Continuous Automatic Train Control:

Continuous Automatic Train Control based on CBTC will consist of – Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) sub-Systems. The train borne Automatic Train Control system will consist of Automatic Train Operation (ATO) & Automatic Train Protection (ATP). This will work on moving block principle. This will also cater for Unattended Train Operation (UTO).

(i) Automatic Train Protection (ATP)

Automatic Train Protection (ATP) is the primary function of the train control system. This sub-system will be inherently capable of achieving the following objectives in a fail safe manner.

- Cab Signalling
- Moving block
- **Generation of track related speed profile based on continuous data from track**side to train
- Continuous monitoring of braking curve
- Monitoring maximum permitted speed on the line and speed restrictions
- Detection of over speed and generation of audio visual warning and application of brake if necessary
- Maintaining safe distance between trains
- Monitoring of stopping points
- Monitoring of direction of travel and roll back
- Issuing command for correct side door opening in trains and PSG if provided
- Zero speed detection
- Train integrity
- Door control- Enable/disable
- Train location determination.

The train borne equipment will be of modular sub-assemblies for each function for easy maintenance and replacement.

(ii) Automatic Train Operation (ATO)

This system will operate the trains automatically from station to station within the safety envelope of ATP and open the train doors on the correct side. In conjunction with ATP/ATS, ATO can control the dwell time at stations and manage the train running in accordance with headway / time table.

(iii) Unattended Train Operation (UTO)

The proposed CBTC system shall also have the facility for Unattended Train Operation (UTO). In this system highest level of automation (GoA 4) is achieved and the train runs without a train operator on board. The entire train operation will be fully automated thereby reducing the requirement of man-power.

(iv) Automatic Train Supervision (ATS)

A train supervision system will be installed to facilitate the monitoring of the train operation and also remote control of the train operation. The train supervision will log each train movement and display it on work stations with traffic controller at OCC and in a work station for the station controller.

The centralized system will be installed in Operation Control Centre (OCC). The OCC will have a projection display panel showing the panoramic view indicating the dynamic position of train movement on a particular track / points. This will aggregate the train movements in various sections and display in a common video wall. ATS will provide the following main functionalities:

- Automatic Route Setting
- Automatic Train Regulation
- Continuous tracking of train position
- Display panel and work station
- Link to passenger information display system for online information
- Computation of train schedule and time table
- Issue special commands to train such as train hold, skip station etc.

b. Interlocking system

(i) Computer Based Interlocking (CBI)

The entire line including turn back, transfer track, pocket track and stabling depot will be equipped with CBI system for operation of points and crossings and setting of routes. The route setting and clearance of signals will be done from a workstation, which can be either locally (at station) operated or operated remotely from the OCC/BCC.

This system is used for controlling vehicle movements into or out of stations automatically from a workstation. All stations having points and crossings will be provided with workstations for local control. Track occupancy, point position, signal aspect etc will be clearly indicated on the workstation. It will be possible to operate the workstation locally if the central control hands over such control. The interlocking system design shall be of fail-safe design principle.

The signals operate for every train movement, points operate for every train turn back, short-loop and for induction/withdrawal and therefore the equipment will withstand tough environmental conditions encountered in a Metro system. Suitable IRS, IS standards or equivalent international standards will be followed in case of wiring, installation, earthing, cabling, power supply and for material used in axle counters/track circuits, relays, point machine etc.

(ii) Track vacancy detection

Primary mode for track vacancy detection system on main line may be through radio and for secondary detection it can be through track circuit/axle counters.

(iii) Signals on main line and Stabling depot

(a) Line side signals

Line side signals will be provided at diverging routes (i.e at point and crossing) as well as at other required locations, which shall serve as backup arrangements in case of failure of the ATP system. This consists of multi aspects colour Light Emitting Diode (LED) type signals installed on the main line and for depot entry/exit. All stations with points and crossing shall have the signalling arrangement to facilitate bi-directional train operation.

(b) Point machines

Non trailable electrical point machines capable of operating on 3 phase 380v AC will be used on main line, pocket track and stabling lines other than depot. The depot point machine will be trailable/non-trailable type electrical point machine capable of operating with either 3 phase 380v AC or 110v DC. The depot test track point machines and point machines on the route leading from main line to stabling lines shall be non-trailable type electrical point machine capable of operating with 3 phase 380v AC having availability performance.

(c) Fiber Optic Transmission System (FOTS) - Main CBTC Communication Bearer

The main bearer of the bulk of the CBTC Communication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a 48F (minimum) optical fiber cable is proposed to be laid in ring configuration with path diversity (both side of tracks on via duct).

A fully IP based, high capacity (Minimum 10 Gbps), highly reliable and fault tolerant Ethernet Network Metropolitan Area Network/ Local Area Network (MAN/ LAN) for backbone connectivity between stations and from stations to OCC/BCC shall be provided. Further small routers and switches shall be provided for LAN network at stations. Route diversity shall be provided for the backbone optic fibre through separate Optic Fiber Cable (OFC) cable on Up and down lines.

(d) On board surveillance system:

The Surveillance of Trains shall be possible at a central location/OCC through a Broad Band Radio System (BBRS) system, which may make use of the track side infrastructure like poles provided for the Signalling/Train control system. Start to end surveillance of passengers will be possible through the BBRS facility to monitor the on-Board images in OCC/BCC. Dedicated fibre shall be used for this purpose.

c. Network Monitoring and Management

For efficient and cost effective maintenance of the entire CBTC communication network, it is proposed to provide a Network Management System (NMS), which will help in diagnosing faults immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance. The proposed NMS system will be covering radio communication, Optical Fiber Transmission system, all sub systems of CBTC and Uninterrupted Power Supply (UPS) systems. The NMS will collect and monitor status from the individual NMS of the respective sub-systems and display on a common Work Station.

d. Platform Screen Gates (PSG)

It is proposed to provide Platform Screen Gates (PSG) at WEST KIA (Sky Garden) and KIA terminal stations at the airport, as required by KIA. The provision of PSG is necessary for achieving automatic turn back of trains and also ensuring passenger safety. These Platform Screen Gates shall be interlocked with signalling system such that their opening and closing is controlled automatically. Adequate provisions by way of providing Track Access Gates shall be made to meet the emergency requirements for passenger evacuation.

e. Train Depot cum workshop Signalling

Baiyappanahalli depot which will be serving the Outer Ring Road (ORR) line will also used partially for servicing the Phase-2B corridor. However, considering the combined route length of the silk board- Airport line of more than 57 kms, an additional depot facility is planned near the International Airport to meet the operational requirements. This depot shall also have Signalling and Train control facilities (CBTC System) which will facilitate the induction and withdrawal of train services to the main line. As the traction is 750v DC third rail system, manual operation of points is not feasible and therefore fully interlocked depot shall be provided. It is proposed to adopt appropriate Grade of Automation (GoA) and Train control arrangements on the depot lines considering the operational requirements.

In the depot control centre, work station shall be provided for electric operation of points, signals and routes of the depot lines. Audio frequency track circuits/axle counters shall be used in the depot as well. The signals in the depot will be of position light shunt signal or main line signals.

9.1.6 Preliminary Plan

Preliminary Plan for Airport Metro Corridor (conceptual plan) indicating the stations and chainages is enclosed.

9.1.7 Standards

Table 9.1 Standards that will be adopted with regard to the Signalling system.

Description	Standards
Interlocking	Computer Based Interlocking, adopted for station having switches and crossing. All related equipment as far as possible will be centralized in the equipment room at the station. All Depot lines shall be interlocked subject to track layout constraints. For sectioning purpose, even stations without points and crossings, can also be made as interlocking stations.
Block working	Moving block principle
Operation of Points	With 380 volts 3 phase, 50 Hz. AC point machines or Direct current 110V D.C. point machines.
Track Vacancy Detection systems	Primary mode for track vacancy detection system on main line, stabling lines and test track in depot may be through radio and for depot/secondary detection it can be through track circuit/axle counters.
Signals at Stations with points and crossings	Line Side signals to protect the points (switches). LED type signals for reduced maintenance.

UPS (uninterrupted power at stations as well as for OCC)	For Signalling, Telecommunications, AFC & Platform Screen Gate (PSG) and at stations to cover all S&T equipments in equipment Room and in station SCR/OCC.
Train protection systems	Train protection system shall be based on Communication Based Train Control (CBTC) system. The system architecture shall provide for redundancy. The system will conform to IEEE 1474 standards with latest amendments.
Train Describer System	Automatic train supervision system. Movement of all trains to be logged on to a central computer and displayed on video wall and workstations in the OCC/BCC and at the Station Control Room (SCR). Remote control of stations from the OCC/BCC. The system architecture shall provide for redundancy.
Cables	Outdoor Cables will be steel armoured, as far as possible.
Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for Signalling and Train Control system
Immunity to External Interface.	All data transmission on telecom cables/ OFC/Radio. All Signalling and telecom cables will be separated from power cables as per standards. CENELEC standards to be implemented for Electro Magnetic Compatibility (EMC).
Train Working Under Emergency	Running on site with line side signal with speed automatically restricted to 25kmph.
Environmental Conditions	All equipment rooms shall be Air conditioned
Maintenance Philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling equipments shall be followed. Card / module / sub-system level replacement shall be done in the field and repairs under taken in the central laboratory/ manufacturer's premises. Annual Maintenance contract for obsolescence and evolution management of relevant hardware and software with the vendor/Original Equipment Manufacturer (OEM).

9.1.8 Space requirement for signalling installations

Adequate space for proper installations of all signalling equipment at each of the stations has to be provided keeping in view the ease of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for signalling equipment shall be generally 50 sqm for UPS room (common for signalling, telecom, AFC and PSG) and for signalling equipment room 55 sqm at all the stations with points and crossing & 25 sqm at stations without points and crossings and 80 sqm for depot (depends on layout). The Station Control Room (SCR) including storage space shall be of 55 sqm and Maintainer Room shall be of 25 sqm located at stations with points and crossings.

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

9.1.9 Maintenance Philosophy for Signalling Systems

The philosophy of continuous monitoring of systems status and preventive & corrective maintenance of Signalling and Telecommunication equipments shall be followed. Card/module/sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Sub-system wise expert team shall be built-up for sustenance of the signalling system. Since the signalling system is mostly software based, the maintenance team shall have proficiency in IT/computer background. The maintenance team shall be equipped with transport vehicle for effectively carrying out the maintenance from station to station that is possible generally during short spells of traffic blocks.

The defective card/module/sub-system taken out from the section shall be sent for diagnostic and repair to a centralized S&T repair lab suitably located in the section/depot. Cards/modules/equipments requiring major repairs shall be sent to manufacturer's workshop.

Most of the computer systems undergo changes to their hardware and software on account of obsolescence, evolution and software patches within the specified life span. Annual Maintenance contract for such system with the vendor/OEM may be considered for sustainability and maintainability of the installed systems which are safety critical in nature.

9.2 Telecommunication System

9.2.1 Introduction

Telecommunication system shall cater to the needs of system traffic control, features to supplement Signalling system, operational/ maintenance and emergency communication, administrative communication, passenger information system, Closed Circuit Television (CCTV) surveillance etc., in Metro Network. It also provides communication backbone for other systems such as Signalling, Power Supervisory Controlled and Data Acquisition (SCADA), Building Management Systems, Automatic Fare Collection (AFC) systems and administrative Information Technology (IT) Local Area Network (LAN).

9.2.2 Major Telecom Sub-systems

Telecommunication system consists of following sub-systems.

i) Fiber Optic Transmission System (FOTS) - Main Telecommunication Bearer

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. The FOTS shall provide a common transmission backbone for the Telecommunication Sub-systems: Telephone System, Radio System, Public Address System (PAS), Closed Circuit Television (CCTV) System, Passenger Information Display System (PIDS), Centralized Clock System, Telecom-Supervisory Controlled and Data Acquisition (T-SCADA) and Network Management System(NMS) Considering the channel requirement and keeping in view the future expansion requirements, a 96F or 144F optical fiber cable is proposed to be laid in ring configuration with path diversity (both side of tracks on via duct).

A fully IP based, high capacity (Minimum 10 Gbps), highly reliable and fault tolerant Ethernet Network Metropolitan Area Network/Local Area Network (MAN/ LAN) for backbone connectivity between stations and from stations to OCC/BCC shall be provided. Further small routers and switches shall be provided for LAN network at stations.

ii) Telephone Exchange

The System shall be IP Based. The telephone extensions can be combination of IP, Digital and Analog. For an optimized cost effective solution small exchanges (Media Gateways with capability of standalone working) of minimum 40 port at each station and of minimum 120 Port Media Gateway at each Depot shall be provided. The station and depot exchanges will be connected to the IP call servers, installed at selected stations in redundant configuration. The redundant servers shall be installed at different station or OCC. The Exchanges will serve the subscribers at all the stations and Central Control. The exchanges will be interconnected at the channel level on optical backbone.

iii) Mobile Radio Communication

Mobile Radio communication system having 8 channels is proposed for on-line emergency communication between Train operator (Front end and Rear end) of moving train and the Central Control. The system shall be based on Digital Trunk Radio Technology to Terrestrial Trunk Radio (TETRA) International standard. All the stations, depots and the OCC will be provided with fixed radio sets. Mobile communication facility for maintenance parties and Security Personnel will be provided with handheld sets. These persons will be able to communicate with each other as well as with central control.

The frequency band for operation of the system will be that for TETRA in 400/800 MHz band, depending on frequency availability. The system shall provide Instant mobile radio communication between the Train Operator of the moving cars from any place and the Central Control. The Train Operator can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

To provide adequate coverage, based on the RF site survey to be carried out during Detailed Design stage, base stations for the system will be located at sites conveniently selected after detailed survey. Roof top antenna towers (about 40 mtrs height from ground) shall be provided at Base station locations. In addition, provision of In-building solution (IBS) for adequate coverage in station rooms shall also be made. The increased passenger footfalls at stations may call for improvement of signal strength of mobile telephone system. Enhancement of Mobile communication will be made available to the public by providing equipment on roof top of stations for which adequate Electrical power shall be made available.

iv) Centralized Clock System

This will ensure an accurate display of time through a synchronization system of slave clocks driven from a Master Clock at the operation control center. The Master Clock signal shall also be required for synchronization of FOTS, Telephone Exchanges, Radio, Signalling etc. The System will ensure identical display of time at all locations. Clocks are to be provided at platforms, concourse, Station Control Room, Ticket offices, Depots and other service establishments etc. The master clock synchronization may be derived from the Central clock provided for Phase-2 lines.

v) Passenger Announcement System

The system shall be capable of announcements from the local station as well as from OCC. Announcements from OCC will have over-riding priority in all announcements. The system shall be linked to Signalling System for automatic train actuated announcements.

vi) Passenger Information Display System

These shall be located at convenient locations at all stations to provide bilingual visual indication of the status of the running trains and will typically indicate information such as destination, arrival/departure time, and also special messages in emergencies. The Light Emitting Diode (LED) or Liquid Crystal Display(LCD)/Thin Film Transistor (TFT) based boards shall be provided at all platforms and LCD/TFT based monitor at concourses and entrances of all stations. The System shall be integrated with the Passenger Announcement system and available from same Man Machine Interface (MMI).

Provision to display the Flight arrival and departure may be extended to concourse in each station.

vii) Closed Circuit Television (CCTV) System

The CCTV system shall provide surveillance and recording function for the operations to monitor each station. All areas in stations where security, safety and crowd control purpose is necessary like Entry, Concourse, Entry to lift, escalators, Platforms, Passages to operation rooms, entry to PFs from emergency stair case, External station area for about 20 meters in front of entry gates shall be covered by CCTV coverage. CCTV shall consist of a mix of High definition Fixed camera and Pan-Tilt-Zoom (PTZ) cameras. The monitoring shall be possible both locally at each station and remotely from the OCC on the Video Wall. The system shall have video analytics features for enhanced monitoring and alerting capabilities.

viii)Broad Band Radio System (BBRS)

The Surveillance of Trains shall be possible at a central location/OCC through a Broad Band Radio System (BBRS) system, which may make use of the track side infrastructure like poles provided for the Signalling/Train control system. Start to end surveillance of passengers will be possible through the BBRS facility to monitor the on-Board images in OCC/BCC.

ix) Network Monitoring and Management(NMS)

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide a network management system (NMS), which will help in diagnosing faults immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance. The proposed NMS system will be covering radio communication, Optical Fiber Transmission system, Telephone Exchange and summary alarms of Passenger Announcement System/Passenger Information Display System (PAS/PIDS), CCTV and Clock and UPS systems. The NMS will collect and monitor status from the individual NMS of the respective sub-systems and display on a common Work Station.

9.2.3 Other sub-systems interface with Telecommunication Systems.

1. The other major sub-systems required or requiring to be interfaced to the telecommunications infrastructure are:
    1) Signalling ATP/ ATS and ATO;
    2) Rolling Stock onboard systems (with PIDS, PAS, BBRS, TETRA, CCTV);

3) Power Supply;
4) Automatic Fare Collection;
5) Building Management System;
6) Traction Power SCADA
7) Office LAN at stations.

2. Train arrival/departure related messages shall be actuated automatically by Signalling & Train Control system. The PIDS and PAS shall synchronise automatically to provide real time passenger audio broadcast and visual information on designated platform at each station and in concourse at each station. The PIDS and PAS shall respond to special train running interrupt messages from the Signalling and Train Control System. PIDS operator shall be able to display special or emergency messages for passengers and staff on individual or all display boards.
3. Train Radio system shall be installed in leading and trailing cabs operating in hot-standby mode to each other, but shall be fully independent of each other. The Train Radio along with Train Radio Control Panel (TRCP), Train Interface Radio Unit (TIRU), etc. shall have to be provided in Rolling Stock. Train Radio Interfacing Unit shall monitor the health of the radio transceivers and all other data interfaces to train borne signalling system and shall enable switching to the standby transceivers upon detection of communication failure.
4. The On Board Passenger announcement from OCC/BCC shall be integrated with Rolling stock. On board CCTV video monitoring at OCC surveillance room shall be possible through Broadband Radio system.
5. Automatic Fare Collection, Building Management System, Power supply and Traction Power SCADA shall connect to the stations' switches in separate Vide Local Area Network (VLAN) to connect their respective systems at OCC/BCC.
6. Dark fibers shall be allocated to Signalling system between stations and for Office LAN at stations to central office.

9.2.4 Space Requirement for Telecom Installations

Adequate space for proper installations of all Telecommunication equipment at each of the stations has to be provided keeping in view the ease of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for Telecom equipment shall be generally 40 sq.m each for Telecom Room and 50 sq.m. for UPS Room (common for signal, telecom, AFC and PSG). At the OCC and BCC, the areas required shall be as per the final configuration of the equipment and network configuration keeping space for further expansion. The Signalling system area requirement may be provided for in the Telecom room by increasing the area appropriately.

9.2.5 Maintenance Philosophy for Telecom Systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of telecommunication equipment shall be followed. Card / module / subsystem level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station.

The defective card/ module / sub-system taken out from the section shall be sent for diagnostic and repair to a centralized S&T repair lab suitably located on the section. This lab will be equipped with appropriate diagnostic and test equipment to rectify the faults and undertake minor repairs. Cards / modules / equipment requiring major repairs as specified in supplier's documents shall be sent to manufacturer's workshop.

Maintenance contract for hardware / software as necessary to manage the technology advancement/obsolescence will be undertaken. DLP warranty (Defect Liability Period) for entire Telecommunications System.

9.2.6 Back up Control Centre (BCC): A Back up control system (BCC) shall be provided for all critical Sub-systems at different location from OCC.

The sub-systems may work in active mode with OCC.

Figure 9.1: OCC

9.2.7 Environmental Conditions

All equipment rooms to be air-conditioned. Fire rated Door shall be provided. The Material of false floor and false ceiling shall be fire rated.

9.2.8 Estimate Cost (in crores)

Based on the benchmarking rates prescribed by MoHUA in Jan 2019, the summary of the Cost Estimates excluding Price Variation, Taxes & Contingency is given below for various system provided in the section.

Table 9.2 Cost Estimate:

Description	Unit	Qty	Rate (INR in Cr)	Amount (INR in Cr)
Signalling				
Main line including OCC/BCC	R Km	38.44	4.40	169.14
Depot including DCC	T Km	18.50	3.20	59.20
On board Equipment	Per Train	21.00	1.70	35.70
Sub Total Signalling				**264.04**
Telecommunication				
Station	Per Stn	17.00	4.50	76.50
Depot	Per Depot	2.00	3.50	7.00
Sub Total Telecom				**83.50**
Platform Screen Gates	Per Stn.	**2**	**3.00**	**6.00**
			Total (Rs Cr)	**353.54**

Chapter 10

Automatic Fare Collection System

CHAPTER - 10

AUTOMATIC FARE COLLECTION (AFC) SYSTEM

10.1 Ticketing and Access control

10.1.1 Ticketing

1) Metro Rail Systems handle large number of passengers. Ticket issue and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. In view of above, computer based automatic fare collection system is proposed.

2) AFC system proves to be cheaper than semi-automatic (manual system) in long run due to reduced manpower cost for ticketing staff, reduced maintenance in comparison to paper ticket machines, overall less cost of recyclable tickets (Smart Card/Token) in comparison to paper tickets and prevention of leakage of revenue.

3) The proposed ticketing system shall be similar to the system provided on the other lines of Phase-1 and Phase-2 i.e. of Contactless Smart Token/ Card type. The equipment for the same shall be provided at each station Counter/Booking office and at convenient locations and will be connected to a local area network with a computer in the Station Control room.

4) The AFC system shall support simultaneously ISO 14443 based type ‘A’ cards compatible with MiFare and EMV based open loop (National Common Mobility Cards, RuPay, Visa, Master etc.) cards. The system shall also be capable of processing and accepting NFC based fare media with the provision of mobile ticketing. The system shall have provision for QR code based mobile ticketing also.

10.1.2 Access control

1) Automatic Gates (AGs) are provided for controlling entry and exit from the paid and unpaid areas at stations. The AGs are operated automatically through use of tickets. Gates update data on cards and tokens as passengers pass through. The barrier shall operate in such a manner as to prevent passage of an unauthorized person. An alarm shall sound and notification shall be passed to the Station Computer System if unauthorized passage is attempted.

2) The AFC System shall, as a minimum, efficiently control the flow of passengers through the stations, prevent entry by unauthorized persons, minimize the use of ticketing staff, reduce fraud, provide revenue and traffic management information and provide input for future traffic planning. The

station equipments send the data to AFC Station computer (SC) through LAN for processing. SC further uploads this data to Central Computer for end-of-day processing and revenue and traffic reports.

3) All the fare collection equipment shall be connected in a local area network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control center through the optic fibre communication channels. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.

4) Type of access Gates

   i) Computer controlled retractable flap type Control Gates are installed in Phase-1 and similar type of gates are proposed in Phase-II, which offer high throughput, require less maintenance and are latest in modern metros internationally. The traffic on this line will reach peaks in one direction at certain time period and in the other direction during different time period. Therefore, a set of **Entry, Exit, Bi-directional and Wide Bi-directional (for disabled people and person carry luggage) gates** shall be provided for efficient management of the traffic.

   ii) Hinged Flap Barrier/ Gate in each barrier line with locking mechanism for authorized movement of station equipment / large groups of visitors etc.

10.2 Automatic Fare collection system options available, Ticketing and Pass system

10.2.1 Automatic fare collection systems have the following advantages:

- Less number of staff required.
- Less possibility of leakage of revenue due to 100% ticket check by control gates.
- Recycling of ticket fraudulently by staff avoided.
- Efficient and easy to operate, faster evacuation both in normal and emergency.
- System is amenable for quick fare changes.
- Management information reports generation easy.
- System has multi-operator capabilities. Same Smart Card can be used for other applications also.
- AFC systems are the worldwide accepted systems for Metro environment and being used in existing metro lines of BMRCL.

Computer controlled retractable flap type Control Gates are installed in Phase-1 and similar type of gates are proposed in Phase-II, which offer high throughput, require less maintenance and are latest in modern metros internationally. The traffic on this line will reach peaks in one direction at certain time period and in the other direction during different time period. Therefore, a set of **Entry, Exit, Bi-directional and Wide Bi-directional (for disabled people and person carry luggage) gates** shall be provided for efficient management of the traffic. The proposed ticketing system shall be same as that to be provided on the other lines of Phase-1 and Phase-2 i.e. of Contactless Smart Token/ Card type.

10.2.2 Ticketing and Pass system

10.2.2.1 Types of Fare Media - AFC system shall use following type of recyclable tickets.

a). Contactless Smart Token (CST) ISO 14443 (Type A)

b). Contactless Smart Card (CSC) (ISO 14443 Type A and Europay, Mastercard, Visa (EMV))

- i) MIFARE DES Fire or Equivalent Type A, ISO/IEC 14443 and ISO 18092 based card.
- ii) Contactless EMV based Stored Value Cards (National Common Mobility Card).

c). Near Field Communication (NFC)compliant mobile devices using Secure Element or Host Card Emulation

d). Mobile based Quick Response (QR) codes

10.2.2.2 Types of Fare Products

The system shall support and be capable of processing of multiple fare products such as single Journey/ multi journey tickets, trip tickets, stored value tickets, period tickets etc. with provision of issuing concession/ discount tickets, Peak/ Off-Peak fares etc.

10.3 Fare System integration with other Transport System

10.3.1 The AFC system shall be integrated with existing AFC systems of Phase I and Phase II. The systems shall also have provision of integration with AFC system of other transport operators such as suburban rail /Bus etc.

10.3.2 The system supports National Common Mobility Card (NCMC) based ticketing. For this purpose, the system shall integrate with host systems/ Central Clearing House System(CCHS) of Acquirer/ issuer Bank.

10.4 Ticket offices/ Customer care:

Ticket offices is direct human/operator interface with customer to issue the tickets, recharge the cards with cash or non-cash. Manned **Ticket office machine** shall be installed in the stations for selling cards/ tokens to the passengers. At stations, Ticket Offices of 3 m width to accommodate required ticket issue machines with future provision to add additional counters shall be constructed. The Customer care shall be constructed at suitable location at station concourse.

10.5 Add Value Machines:

These machines will be used to recharge the card using Credit/ Debit card and/or bank notes. These machines will also be used as add value device in case payment for card recharge is made through Internet based channels such as net banking.

10.6 NFC/QR based mobile ticketing

As NFC technology is advancing fast, mobile based ticketing is likely to be widely used in near future by Metro Rail operators. Hence a NFC based mobile ticketing solution is proposed to be included. The system shall also have provision for QR code based ticketing for single journey tickets.

10.7 Ticket Readers:

These machines will be used to analyze Card/ Token and display card/ Token balance, validity of card and last few transactions.

10.8 AFC equipment Requirement

Sample Calculations of AFC equipment requirement from K R Puram to Airport for the year 2024 are given as under- **Table 10.1**

Table 10.1 AFC equipment requirement from K R Puram to KIA Terminals

Sl. No	Station	Entry Gate	Exit Gate	Wide Gate	TOM	EFO	TR	AVM
1	K R Puram (Included in Ph- 2A)	9	10	2	9	2	2	2
2	Kasturi Nagar	4	4	2	4	2	2	2
3	Horamavu	4	4	2	4	2	2	2
4	HRBR Layout	4	4	2	4	2	2	2
5	Kalyan Nagar	4	4	2	4	2	2	2
6	HBR Layout	5	5	2	5	2	2	2
7	Nagawara	8	7	2	8	2	2	2
8	Veeranna Palya	4	4	2	4	2	2	2
9	Kempapura	4	4	2	4	2	2	2
10	Hebbal	9	9	2	9	2	2	2
11	Kodigehalli	4	4	2	4	2	2	2
12	Jakkur Cross	7	6	2	7	2	2	2
13	Yelahanka	6	5	2	6	2	2	2
14	Bagalur Cross	4	4	2	4	2	2	2
15	Bettahalasuru	4	4	2	4	2	2	2

Sl. No	Station	Entry Gate	Exit Gate	Wide Gate	TOM	EFO	TR	AVM
16	Doddajala	4	4	2	4	2	2	2
17	Airport City	4	4	2	4	2	2	2
18	KIA Terminals	4	4	2	4	2	2	2
Total		92	90	36	92	36	36	36

10.9 Design Parameters:

1. There will be two number of access from unpaid to paid area at concourse of each station.
2. Minimum AFC equipment at a station: 4 entry gates, 4 exit gates, 2 Excess Fare Offices (EFOs), 4 Ticket Office Machines (TOMs), 2 Ticket Readers (TRs) and 2 Add Value Machines (AVMs), equally distributed for each access (*In case of change in number of access to concourse, the equipment quantity may vary accordingly*).
3. Two bi-directional wide gates (for differently-abled persons) at each station (one for each access).
4. Throughput of gate 28 passengers per minute and for TOM 10 transactions per minute.
5. For Calculation purpose, It is assumed that 60 % passenger will use Smart Card.
6. In order to handle the variation in directional traffic load during peak hours bi-directional Gates may be planned (to the extent of about 30% of total gates)
7. The above calculations are made for the year 2024 based on projected ridership. The actual quantity may be recalculated according to projected traffic up to the year for which AFC system is designed to cater the traffic load.

10.10 Estimate Cost (in crores)

Rate of INR 3.5 Cr. Per station based on benchmarking rates prescribed by MoHUA in Jan 2019 has been considered for providing AFC System. The total estimated price of 17 stations works out to be INR 59.50 Crore, excluding price variation, taxes and contingencies.

Chapter 11

Rolling Stock

CHAPTER 11

ROLLING STOCK

11.1 Background

11.1.1 Introduction

K. R. Puram to KIA Terminals Station (2B Corridor) is to be operated with CBTC signaling system and with the existing Schedule of Dimension (SOD) so that with minimum changes, coaches can be interchanged in other reaches/sections with 750 V DC system as per the requirements.

However, the governing factor for deciding the requirements of coaches, forecasted Peak Hour Peak Direction Traffic (PHPDT) of this line was taken into consideration.

To facilitate the ease in operation, existing Depot at Baiyappanahalli shall be re-designated and remodeled suitably to meet operation and maintenance requirements of this line in addition to serving the requirement of Phase-2A. since, phase-2B line being longer in length (37.561 KM), it is necessary to provide depot towards Airport end to meet complete operational needs of Phase-2B Corridor.

11.1.2 Type of Rolling Stock and rational for deviation

Rolling Stock is planned as per MoHUA guidelines except with following deviations:

i) Min. Coach width is planned 2880 mm against MoHUA specification of 2900 mm with Axle load of 15 tonne against MoHUA specification of 16 tonne.

ii) In place of front evacuation, side evacuation has been planned.

This is being proposed for the following reasons:

i) BMRCL Rolling Stock in Phase-I and Phase-II has is with min. coach width of 2880 mm and axle load 15 tonne. Thus, any change in the coach width will lead to change of Schedule of Dimensions (SOD).

ii) 15 tonne train is more energy efficient in comparison to 16 tonne train.

iii) With the Phase-I experience, side evacuation is preferred option from the of view of ease of maintenance and operation.

iv) Baiyapanahalli depot at Phase-I has been constructed with Schedule of Dimensions of Phase-I and Phase-II. In future, this depot will be utilized for maintenance of trains of 2A and 2B corridors. Hence, the Schedule of Dimensions is retained.

11.2 Salient features of Coach dimensions & performance parameters have been described in the following para:

11.2.1 Size of Coach

Since the maintenance of the rake of Phase- 2B corridor will also be done at Baiyapanahalli depot, it is proposed to adopt the Schedule of Dimension of Phase-2B corridor as same as that of Phase-1.

Accordingly, optimum size of the coach adopted for Phase- 2B corridor has been chosen as mentioned in **Table 11.1**.

Table 11.1 - Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC)	21.05 m	2.88 m	3.8 m
Trailer car (TC)/Motor Car (MC)	20.8 m	2.88 m	3.8 m

* Over the body excluding coupler length.

11.2.2 Passenger Carrying Capacity

In order to maximize the passenger carrying capacity, longitudinal seating arrangement shall be adopted. The whole train shall be vestibuled to distribute the passenger evenly in all the coaches. Criteria for the calculation of standing passengers are 4 persons per square meter of standing floor area in normal state (AW2) and crush load 6 persons standee per sq meter (AW3) and exceptional dense crush load of 8 persons/sq meter (AW4).

Therefore, for the Rail Vehicles with 2.88 m maximum width and longitudinal seat arrangement, conceptually the exceptional dense crush capacity (AW4) of 43 seated, 273 standing thus a total of 316 passengers for a Driving Motor Car, and 50 seated, 293 standing thus a total of 343 for a trailer and motor car is envisaged.

Following train composition is recommended:

6-car Train: DMC–TC–MC-MC–TC–DMC

Thus for Phase-2B corridor, it is also recommended to adopt the above composition.

The seating and Standee capacity of DMC, MC and TC in the unit of “DMC–TC–MC-MC–TC–DMC” with external sliding door are given in **Table 11.2**.

Table 11.2: Carrying Capacity of Mass Rail Vehicles (Crush@6 P/sqm of standee area)

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	204	147	220	862	1288
Total	180	247	197	270	1148	1574

NORMAL (AW2) -4 P/sqm of standee area
CRUSH (AW3) -6 P/sqm of standee area

Table 11.3: Carrying Capacity of Mass Rail Vehicles (Exceptional dense Crush @8 P/sqm of standee area)

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	273	147	293	862	1718
Total	180	316	197	343	1148	2004

NORMAL (AW2) - 4 P/sqm of standee area
EXCEPTIONAL DENSE CRUSH (AW4) - 8 P/sqm of standee area

Based on the experience of Phase-I after commissioning of East-West Corridor, it is recommended to adopt AW3 Passenger loading (1574 passengers in 6 car) for calculation of the passenger carrying capacity to meet the projected PHPDT of busy section. Whereas, in emergency it shall be possible to carry the passenger under AW4 loading condition. However, maximum axle load to be calculated under AW4 loading condition.

11.2.3 Weight

The weights of driving motor car, motor car and trailer car have been estimated as in **Table 11.4**. The average passenger weight has been taken as 65 kg.

Table 11.4 Weight of Mass Rail Vehicles (TONNES)

	DMC	TC	MC	6 Car train
TARE (maximum)	38	36	37	222
Passenger				

	DMC	TC	MC	6 Car train
(Normal)	11.7	12.8	12.8	74.6
(Crush @6p/sqm)	16.05	17.55	17.55	102.3
(Exceptional Dense Crush @8p/sqm)	20.54	22.29	22.29	130.24
Gross				
(Normal)	49.7	48.8	49.8	296.6
(Crush @6p/sqm)	54.05	53.55	54.55	324.3
(Exceptional Dense Crush @8p/sqm)	58.54	58.29	59.29	352.24
Axle Load @6 p/sqm	13.51	13.39	13.64	
Axle Load @8 p/sqm	14.63	14.57	14.82	

The axle load @ 6p/sqm (AW3) of standing area works out in the range of 13.39 T to 13.64 T. Heavy rush of passenger, having 8 standees per sq. meter (AW4) can be experienced occasionally. It is advisable to design the coach with sufficient strength so that even with this overload, the design will not result in over stresses in the coach. Coach and bogie should, therefore, be designed for **15 T axle** load. Hence it is recommended to procure Rolling Stock for Phase-2B corridor with maximum axle load of 15 T.

11.2.4 Performance Parameters

11.2.4.1 The recommended performance parameters are:

(i) Maximum Design Speed : 90 Kmph
(ii) Maximum Operating Speed : 80 Kmph

11.2.4.2 Traction Performance

(i) Average acceleration rate from 0 to 30 Km/h : 1 m/s^2 ± 5%
(ii) Jerk : 0.7 m/s^3 ± 0.05

11.2.4.3 Brake Performances

(i) Average service deceleration from 80 to 0 Km/h : 0.95 m/s^2 ± 5%
(ii) Instantaneous full service deceleration : 1.1 m/s^2
(iii) Maximum jerk ($d\gamma/dt$) : 0.7 m/s^3 ± 0.05
(iv) Minimum average emergency deceleration : 1.3 m/s^2

11.2.4.4 Torque vs. Speed characteristics.

Constant torque zone in powering is recommended up to a speed of 30 Kmph. Constant torque zone in braking is recommended in the speed range of 60 Kmph to 5 Kmph to maximize the regenerated energy.

11.2.5 Coach design and basic parameters

The important criteria for selection of Rolling Stock are as under:

(i) Proven equipment with high reliability

(ii) Passenger safety feature

(iii) Energy efficiency

(iv) Light weight equipment and coach body

(v) Optimized scheduled speed

(vi) Aesthetically pleasing Interior and Exterior

(vii) Low Life cycle cost

(viii) Flexibility to meet increase in traffic demand

(ix) Anti-telescopic

The controlling criteria are reliability, low energy consumption, lightweight and high efficiency leading to lower annualized cost of service. The coach should have high rate of acceleration and deceleration.

11.2.6 Selection of Technology

Low life cycle cost

Low life cycle cost is achieved by the way of reduced scheduled and unscheduled maintenance and high reliability of the sub-systems. It is possible to achieve these objectives by adopting suitable proven technologies. Selection of following technologies has been recommended to ensure low life cycle cost.

11.2.7 Car body

It is now a standard practice to adopt stainless steel or aluminum for car body. However, the car bodies with aluminum require long and complex extruded sections which are still not manufactured in India. Therefore, aluminum car body has not been considered for use. With the improvement in Steel manufacturing technology, now it is possible to manufacture austenitic steel with carbon percentage of 0.03% and this increases the mechanical strength and hence it is possible to manufacture light weight stainless steel car body with higher mechanical strength and therefore, high tensile austenitic stainless steel with carbon content not more than 0.03% car bodies have been specified. No corrosion repair is necessary on stainless steel cars during their service life.

It also results in cost saving due to easy maintenance and reduction of repair cost from excellent anti corrosive properties as well as on improvement of riding comfort and safety in case of a crash or fire.

11.2.8 Bogies

Bolster less lightweight fabricated bogies with conical rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 520,000 km. Use of air spring at secondary stage is considered with a view to keep the floor levels of the cars constant irrespective of passenger loading unlike those with coil spring. Perturbation from the track is also dampened inside the car body on account of the secondary air spring along with suitable Vertical Hydraulic Damper. The primary suspension system improves the curve running performance by reducing lateral forces through application of conical rubber spring. A smooth curving performance with better ride index is being ensured by provision of above type of bogies.

11.2.9 Brake System

The brake system shall consist of: -

(i) Compressed air supply by an oil free piston type air compressor and air dryer unit.

(ii) An electro-pneumatic, microprocessor controlled direct service brake which performs the blending function depending on the brake demand signal and the dynamic brake performance.

(iii) A fail safe, pneumatic friction emergency brake.

(iv) A pneumatic indirect BP backup brake which is applied during rescue operation or in case of failure of direct service brake, which will be decided at detailed design stage.

(v) A spring applied air-release parking brake.

(vi) Air applied holding brake.

(vii) An electric regenerative service brake.

(viii) Provision of smooth and continuous blending of EP and regenerative braking

Direct service brake is blending of Electro-Pneumatic brake (EP) and Electro-Dynamic brake (ED). The electro-dynamic (ED) brake shall take priority over the electro-pneumatic friction brake (EP) and full use of its capability shall be made in attaining any rate of service braking. The objective is to use the regenerative brake to the maximum degree possible in order to reduce wear on the friction brakes.

The ED (regenerative braking) brake will be the main brake power of the train and will regenerate energy during braking and part of the regenerated energy is used by the auxiliary circuit of the train and the balanced is pumped back in to third rail system. The Electro-dynamic braking is possible because of the adoption of 3-Phase technology.

To maximize the regenerated energy, it is recommended to have constant torque zone in braking from 60 Kmph to 5 Kmph. Further it is recommended to improve the logic of ED brake so that in case of failure of any driving motor car/ motor car, ED brake by the other driving motor /motor car is increased automatically by the propulsion system.

During the stopping of the train when ED brake starts fading out, the propulsion system detects the fading out of ED brake and correspondingly holding brake (EP) is applied by the brake system to ensure safety of the train in case of ED becoming zero.

In addition, speed sensors mounted on each axle, control the braking force of the axles with anti skid valves, prompting re-adhesion in case of a skid. The brake actuator shall operate either a tread brake or a wheel mounted disc brake, and preferably a wheel mounted disc brake.

In Phase I Rolling Stock, oil free piston type compressor was used to avoid the frequent need to toping of oil in the compressor. These oil free compressors have been in service in Phase-1 for more than 4 years and so far no failure case was reported. As such it is recommended to use oil free piston type compressor only.

To improve the overall reliability of brake system, it is recommended to adopt brake system with Ethernet backbone where it shall be possible to feed MR pressure in the failed train from the healthy train and also braking can be controlled from the healthy train in the failed train. Also, it is planned to use a new generation of brake control system where in case of failure of brake of one bogie/one car, the same brake power of the isolated bogie/car will be compensated by the remaining 5 cars.

11.2.10 Propulsion System Technology

The brush less 3 phase induction motors which is lighter in weight and ideally suited for rail based Mass Rapid Transit applications is proposed to be used for this corridor. The motor tractive effort and speed is regulated by 'Variable Voltage and Variable frequency' control and can be programmed to suit the track profile and operating requirements. Another advantage of 3 phase a.c. drive and VVVF control is that regenerative braking can be introduced by lowering the frequency and the voltage to reverse the power flow and to allow braking to very low speed. Also, it is self-ventilated, highly reliable, robust construction and back up by slip/slide control, hence same have been recommended for adoption.

The DC voltage from the 3rd Rail is stepped up through a ‘STEP up Chopper’ to DC link voltage, which feeds Inverter operated with Pulse Width Modulation (PWM) control technology and using insulated Gate Bipolar Transistors (IGBT). Thus three-phase variable voltage variable frequency output drives the traction motors for propulsion.

Recently advanced IGBT has been developed for inverter units. The advanced IGBT incorporates its own over current protection, short circuit protection; over temperature protection and low power supply detection. The inverter unit uses optical fiber cable to connect the control unit to the gate interface. This optical fiber cable transmits the gate signals to drive the advanced IGBT via the gate interface. The optical fiber cable provides electrical isolation between the advanced IGBT and the control unit and is impervious to electrical interference. These are recommended for adoption in trains of this corridor.

11.2.11 Interior and Gangways

Passenger capacity of a car is maximized in a Metro System by providing longitudinal seats for seating and utilizing the remaining space for standing passenger. Therefore, all the equipments are mounted on the under frame for maximum space utilization. The gangways are designed to give a wider comfortable standing space during peak hours along with easy and faster passenger movement especially in case of emergency. However, detailed design to be finalized at Mock-up stage.

Figure 11.1 Interior View of Passenger Car

11.2.12 Luggage Rack

In most of the Airport Link Metro trains, luggage rack is proposed to be provided near the gangway area of every coach. However, the luggage rack will be suitably designed and accommodated within the depth of the seat (500mm) so that leg room area is utilized for standee passengers and thus the overall passenger capacity of the train is not compromised.

11.2.13 Passenger Doors

For swift evacuation of the passenger in short dwell period, four doors of minimum 1400mm width, on each side of the coach have been considered. These doors shall be of such dimensions and location that all the passenger inside the train is able to evacuate within least possible time without conflicting movement. As the alignment passes through elevated section above ground, automatic door closing mechanism is envisaged from consideration of passenger safety. Passenger doors are controlled electrically by a switch or Pushbutton in Driver cab. Electrically controlled door operating mechanism has been preferred over pneumatically operated door to avoid cases of air leakage and sluggish operation of doors.

The door shall be of Bi-parting Sliding Type as in the existing coaches of BMRCL.

In the present design of door leaf, top aluminium skin is bonded over aluminium honeycomb and bonding between these two materials is frequently failing and as such door swelling problems are being observed in several Rolling Stock Projects. Thus it is recommended to adopt a new door design with single material without any bonding.

Figure 11.2 Interior View of Passenger Car

11.2.14 Air–conditioning

With heavy passenger loading of 6 p/sqm for standee area and doors being closed from consideration of safety and with windows being sealed type to avoid transmission of noise, air conditioning of coaches has been considered essential. Each coach shall be provided with two air conditioning units capable of cooling, heating and dehumidifying and thus automatically controlling interior temperature throughout the passenger area at up to 25°C and relative humidity of 60%RH respectively all the times under varying ambient conditions up to full load. For emergency situations such as power failure or both AC failures etc, ventilation provision supplied from battery will be made. Provision shall be made to shut off the fresh air intake and re-circulate the internal air of the coach, during an emergency condition, such as fire outside the train causing excessive heat and smoke to be drawn in to the coach. Provision of vent mode shall be explored during detailed design stage to achieve energy saving.

11.2.15 Cab Layout and Emergency Detrainment Doors.

The modern stylish driver panel shall be FRP moulded which give maximum comfort and easy accessibility of different monitoring equipments to the driver along with clear visibility. The driver seat is recommended to be provided either in the middle or in the side of the cab.

Figure 11.3 View of Driving Cab

Emergency evacuation is recommended only through the side doors.

11.2.16 Communication

The driving cab of the cars are provided with continuous communication with base Operational Control Center and station control for easy monitoring of the individual train in all sections at all the time.

Public Address and Passenger Information Display System is provided in the car so that passengers are continuously advised of the next stoppage station, final destination station, interchange station, emergency situations if any, and other messages. Station announcement is recommended to be based on the bits provided by ATC. In case of failure of ATC announcement can be made manually. The Rolling Stock is recommended to be provided with Talk Back Units inside the cars, which permit conversation between passengers and the drivers in case of any emergency.

With the improvement in display technology, it is recommended to use Digital Display board on interior coving panel for advertisement as well as for station announcement.

11.2.17 Noise and Vibration

The trains will pass through heavily populated urban area. The noise and vibration for a metro railway becomes an important criterion from public acceptance view point. The source of noise are (i) rail-wheel interaction (ii) noise generated from equipment like Blower, Compressor, air conditioner, door, Inverter etc. (iii) traction motor in running train. For elimination and reduction of noise following feature are incorporated: -

- Provision of anti drumming floor and noise absorption material.
- Sound absorbent panels to under-frame.
- Insertion of sound absorbent infill in key-ways of load key place.
- Low speed compressor, blower and air conditioner.
- Mounting of under frame equipments on anti-vibration pad.
- Smooth and gradual control of door.
- Provision of GRP baffle on the via-duct for elimination of noise transmission.
- Provision of sound absorbing material in the supply duct and return grill of air conditioner.
- Sealing design to reduce the aspiration of noise through the gap in the sliding doors and piping holes.

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

11.2.18 Passenger Safety Features

(i) ATP/ATO/UTO

The Rolling Stock is provided with Continuous Automatic Train Protection to ensure absolute safety in the train operation. It is an accepted fact that 60-70% of the accidents take place on account of human error. Adoption of this system reduces the possibility of human error. The on-board computerized ATC system compares and verifies the continuous actual driving speed of the train with the target speed displayed on Driver Machine Interface (DMI) and in case speed of the train increases beyond the specified limit, Full Service Brake (FSB) and Emergency Brake (EB) are applied by the signaling system (ATC).

In ATO mode, the manual function of the driver with respect to driving such as powering, coasting and braking is made automatic through Automatic Train Control (ATC).

The Signaling system is recommended to be “Communication Based Train Control (CBTC)” system as the current “Distance To Go (DTG)” signaling system implemented in Phase I project has become obsolete.

As per the MoHUA guidelines, Rolling Stock will be UTO enabled and it will be suitable for GoA2/GoA4 Grade of operation.

(ii) Fire

The Rolling Stock is provided with flame-retarded materials having low fire load, low heat release rate, low smoke and toxicity inside the cars.

Flammability, Smoke Emission and Toxicity requirements of the material used in the car is recommended to be based on EN standard EN 45545, HL3, Flammable materials shall not be used or contained. Material emitting poisonous gas during combustion will not be used.

The insulation of all wires and cables including those used within equipment / subsystem is provided with halogen-free flame-retardant and formulated to minimise generation of smoke, noxious emissions and corrosive fumes.

(iii) Emergency doors

Each passenger saloon doors is provided with Emergency Egress device to ensure well directed evacuation of passengers in case of any emergency including fire in the train.

(iv) Crash worthiness features

The driving motor car and other cars of the train shall be designed to ensure safety of the train operator in case of collision as specified in EN 15227 under the collision scenario in clause-5 of EN15227 for Load Category C-II.

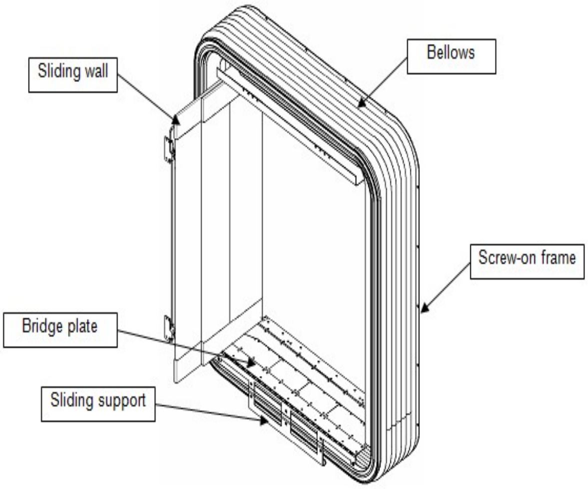
The Rolling Stock is provided with inter car couplers with energy absorption device in the front automatic/ semi-automatic coupler.

The car ends is designed to prevent over-riding and telescoping of the car in to any passenger area in the event of the collision. The anti-telescoping structure includes elements such as corner post, collision post and anti-climbers.

(v) Gangways

Broad gangways with interior paneling of minimum clear height of 1900mm are provided in between the cars to ensure free passenger movement between cars in case of any emergency.

Figure 11.4 View of Gangway



Gangway

The salient features of the proposed Rolling Stock are enclosed as Attachment-I.

Table 11.5 (Attachment I) Salient Features of Rolling Stock for Mass Rapid Transit System

Sl.No.	Parameter	Details
1	**Gauge** (Nominal)	1435mm
2	**Traction system**	
2.1	Voltage	750 V dc
2.2	Method of current collection	Third Rail Bottom Current Collection System
3	**Train composition**	
3.2	6 car train	*DMC-TC-MC+MC-TC-DMC*
4	**Coach Body**	Stainless Steel
5	**Coach Dimensions**	
5.1	Height	3.88 m
5.2	Width	2.88 m
5.3	Length over body (approx)	
	- Driving Motor Car (DMC)	21.05 m
	- Trailer Car (TC)	20.8 m
	- Motor Car (MC)	20.8 m
5.4	Floor height	1130mm (Maximum) for unloaded vehicle, 1100mm (Minimum) for loaded vehicle.
6	**Designed - Passenger Loading**	
6.1	Design of Propulsion equipment	8 Passenger/ m^2
6.2	Design of Mechanical	10 Passenger/ m^2

Sl.No.	Parameter	Details
	systems	
7	**Carrying capacity- @ 8 standees/sqm**	
7.1	Coach carrying capacity	
	DMC	316 (seating - 43 ; standing - 273)
	TC	343 (seating - 50 ; standing - 293)
	MC	343 (seating - 50 ; standing - 293)
7.2	Train Carrying capacity	
	6 car train	2004 (seating - 286 ; standing - 1718)
8	**Weight (Tonnes)**	
8.1	Tare weight (maximum)	
	DMC	38
	TC	36
	MC	37
8.2	Passenger Weight in tons(@ 8 person per sqm)	@ 0.065 T per passenger
	DMC	20.54
	TC	22.29
	MC	22.29
8.3	Gross weight in tons	
	DMC	58.54
	TC	59.29
	MC	59.29
9	**Axle load(T)(@ 8 persons per sqm of standee area)**	**Not more than 15T**
		System should be designed for 15T axleload
10	**Speed**	
10.1	Maximum Design Speed	90 Kmph
10.2	Maximum Operating Speed	80 Kmph
11	**Wheel Profile**	UIC 510-2, Appendix B
12	**Traction Motors Ventilation**	Self
13	Average acceleration rate from 0-30 Kmph	1.0 m/sec² ± 5%
14	**Average deceleration from 80 Kmph to 0 Kmph**	0.95 m/sec² ± 5%
15	**Instantaneous full service deceleration**	1.1 m/sec² (>1.3 m/sec² during emergency)
16	**Type of Bogie**	Fabricated
17	**Secondary Suspension springs**	Air

Sl.No.	Parameter	Details
18	**Brake system**	(i) Compressed air supply by an oil free piston type air compressor and air dryer unit. (ii) An electro-pneumatic, microprocessor controlled direct service brake which performs the blending function depending on the brake demand signal and the dynamic brake performance. (iii) A fail safe, pneumatic friction emergency brake. (iv) A pneumatic indirect BP backup brake which is applied during rescue operation or in case of failure of direct service brake. (v) A spring applied air-release parking brake. (vi) Air applied holding brake. (vii) An electric regenerative service brake. (viii)Provision of smooth and continuous blending of EP and regenerative braking
19	**Coupler**	
19.1	For 6 car Train between two MC car	Automatic coupler with mechanical, electrical & pneumatic coupling
19.2	Front cab end of DMC car	Automatic coupler with mechanical & pneumatic coupling but without electrical coupling head
19.3	Between cars of same Unit	Semi-permanent couplers
20	**Detrainment Door**	Side doors
21	**Type of Doors**	External sliding
22	**Passenger Seats**	Stainless Steel
23	**Cooling**	
23.1	VVVF & APS	Self/Forced
23.2	TM	Self ventilated
24	**Control System**	Train line control by 110V dc signals for vital safety equipments/items and Train Management System for other control equipment monitoring
25	**Traction Motors**	3 phase VVVF controlled
26	**Temperature Rise Limits**	
26.1	Traction Motor	The temperature rise limit for the stator winding shall be the maximum temperature index of the insulation minus 70°C.
26.2	VVVF & APS	The current rating of the semiconductor shall be such that the junction temperature has the minimum thermal margin of 10°C in the worst loading conditions taking into account the

Sl.No.	Parameter	Details
		extreme ambient conditions in Bengaluru and surrounding.
27	**HVAC**	- Cooling, Heating & Humidifier (As required) - Automatic controlling of interior temperature throughout the passenger area at 25°C with 60% RH all the times under varying ambient conditions up to full load. - Cab cooling for DMC car shall be provided by saloon HVAC only.
28	**PA/PIS (CCTV)**	ATC based station announcement.
29	**Passenger Surveillance CCTV system**	CCTV with automatic IP selection.
30	**Battery System**	Nickel Cadmium batteries with closed water loop system.
31	**Type of Headlight, Flasher & Taillight**	LED based
32	**Saloon Illumination**	Energy efficient, power LED based lights, in luminaries for saloon & gangway
33	**Cubical lighting**	LED based
34	**Coasting**	Minimum 8% coasting to achieve specified commercial speed.

11.3 Rolling Stock requirement of various horizon years

This has already been worked out and given in Chapter -8 (Train operations Plan).

11.4 Cost estimate

Based on the report on benchmarking for cost estimation of metro rail projects issued by MoHUA (Feb 2019), basic cost of INR 8.0 crores per car has been considered. The Price Variation has also been worked out as per para 6 of the benchmarking report which works out to be 16.64%. Output GST on complete train has been revised from 5% to 12% with effect from 01.10.2019. Total estimated price of 126 cars works out to be INR 1351.29 crores including price variation, taxes and contingencies.

Chapter 12

Power Supply & Traction

CHAPTER-12

POWER SUPPLY AND TRACTION

12.1 Choice of Electric Traction System

This line is an extension of ORR line from Silk Board to K R Puram which is extended further from K R Puram to Airport terminal. To achieve the seamless integration and operational flexibility, 750 V DC third rail bottom current collection system is proposed for this line. The traction system in the ORR line is also 750 V DC third rail bottom current collection system. Accordingly, power supply arrangement for traction and auxiliary is detailed in the following paragraphs.

12.2 Power Supply & Total Projected Power Demand

The electric power supply is required by Metro system for the following purposes:

- For running trains i.e traction power.
- For station services e.g. lighting, ventilation, lifts, escalators, signaling & telecom, fire-fighting and pumping etc.
- For workshops, depots and other maintenance infrastructure within premises of metro system.

In elevated section, traction requirement is the major component of power supply.

12.2.1 Power Demand Estimation

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

i. Specific energy consumption of rolling stock – 75 kwh/1000 GTKM
ii. Regeneration by rolling stock for 750 V DC traction – 20%
iii. Elevated station auxiliary loads - 350 kW (412 kVA)
iv. Depot auxiliary load – 1000 kW in the year 2024
1500 kW in the year 2031
1700 kW in the year 2041

Keeping in view of the Train Operation Plan and demand of auxiliary and traction power, power requirement for KR Puram to Airport has been worked out for the various years which is summarized in **Table 12.1**:

Table 12.1 Power Demand Estimation (MVA)

Corridor		Year		
		2024	2031	2041
K R Puram to KIA Terminals	Traction	13.68	22.06	26.25
	Auxiliary	9.57	10.19	10.44
	Total	23.25	32.25	36.69

The detailed calculations of Power Requirements are given at **Annexure 12.1**.

12.2.2 Need for High Reliability of Power Supply

For the proposed extension line from KR Puram (excl.) to Airport of Bengaluru Metro, traction system shall be designed to handle about 24048 passengers per direction (AW4) during peak hours between KR Puram to Yelahanka when trains are expected to run at about 5 minutes intervals and 12024 passengers per direction during peak hours between Yelahanka to Airport Terminal station when trains are expected to run at about 10 minutes intervals for the year 2024 and 48096 PHPDT between K R Puram to Yelahanka when trains are expected to run at about 2.5 minutes intervals & 24048 PHPDT between Yelahanka to Airport Terminal station when trains are expected to run at about 5 minutes intervals for the horizon year 2041. The tolerance level of any power interruption during this period is extremely low, as such incidences, apart from affecting train running, will cause congestion at stations.

Accordingly, Metro system requires a very high level of reliable and good quality of power supply. To ensure reliability of power supply, it is essential that both the sources of supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. Therefore, it is desirable to obtain power supply at high grid voltage of 220 kV or 66 kV from stable grid sub-stations and further transmission & distribution is done by the Metro Authority itself.

12.3 Source of power Supply

The high voltage power supply network along the corridor/alignment was studied in brief. In International Airport surroundings, 220/66 kV and 66 kV substations of KPTCL and KIAL respectively are existing to cater to the various types of demand. It is proposed to avail power supply for traction as well as auxiliary services at 66 kV voltage levels through double circuit cable feeder.

Electric power requirement for this line is likely to be 23.25 MVA approximately in year 2024, which may increase to 36.69 MVA by year 2041.

Under normal conditions, this power will be supplied by the three Receiving substations proposed to be at K R Puram (upcoming in ORR Line), Yelahanka (proposed) and International Airport. The capacity of transformers to be reviewed considering the load requirement/distribution of the corridor at the time of detailed design and for the purpose of ease of replicability and for reducing the requirement of spares, similar capacity of transformers (as being provided at other RSS) may be preferred. In case of failure of power supply from K R Puram RSS, entire power requirement of the stretch of KR Puram- Airport Line fed by KR Puram RSS will be catered from the Yelahanka RSS. In case of failure of power supply from Airport RSS, entire power requirement to be catered from the Yelahanka RSS or vice versa.

The transformers capacity of 25 MVA of RSS at Airport and Yelahanka will be reviewed further during detailed design stage considering the power requirement for future lines.

Since 66/33 kV RSS at K R Puram is part of Phase 2A, catering Silk Board – KR Puram Line which also planned to feed some stretch of KR Puram –Airport line. Hence, for the line from K R Puram –Airport two RSS at Yelahanka & KIAL Depot has been proposed which will suffice the power requirement. However, the actual locations of RSS may change as per the future development in KPTCL and based on the DDC's Traction Simulation Report.

Table 12.2: Sources of Power Supply

Corridor/Line	KPTCL Grid sub-station (GSS) (Input source)	Location of RSS of Metro Authority
K R Puram to Airport Terminal	ITI 220/66 kV Hoody 220/66 kV	K R Puram 66/33 kV
	Begur 220/66 kV Devanahalli Hardware Park 400/220 kV	International Airport 66/33 kV
	Puttenahalli DG plant 220/66 kV Hebbal 220/666 kV	Yelahanka 66/33 kV

Note: KR Puram RSS is under planning stage as part of Phase IIA. Input sources from KPTCL sources are provisional.

At the stage of detailed design and engineering, the 66 kV input sources from KPTCL GSS to be suitably chosen in consultation and agreement with KPTCL. RSS layout and power supply arrangement proposed shall be similar to Phase II RSSs.

The 66 kV power supply will be stepped down to 33 kV level at the above RSSs of metro authority. The 33 kV power supply drawn from the RSS will be distributed along the alignment through 33 kV ring main cable network for feeding to traction as well as auxiliary loads. These cables will be laid in dedicated ducts/hangers/brackets along the viaduct. However, in case of total grid failure, trains will come to stop but station lighting, firefighting & other essential services can be catered to by stand-by UPS/DG sets. Therefore, the proposed scheme is expected to ensure adequate reliability and cater to emergency situations as well.

Figure 12.1: Typical High Voltage Receiving Sub-Station

The 66 kV cables will be single core XLPE insulated with 630/1000 sq.mm copper conductor. The cables shall be laid through public pathways to RSSs of Metro Authority. RSS shall be provided with 2 nos. (1 as standby) 66/33 kV, 3 phase main receiving transformers for feeding to traction as well as auxiliary loads and also with a provision for future lines. In the normal condition both the RSS shall be sharing the loads i.e., feeding half of the section. In case of failure/interruption of power supply to any one of the RSS, the other RSS shall feed the entire line.

Conventional outdoor type 66 kV switchgear is proposed for RSS at Yelahanka and Airport to be located in approx. 40m x 80m (3200 sqm) land plots. However, requirement and feasibility of GIS can be assessed at detailed design and engineering stage and necessary action to be taken accordingly. The typical RSS layout as being used in Phase II may be followed.

12.4 Traction power supply and traction equipment

12.4.1 Design Criteria for Power Supply and Traction System:

Train Operation Plan envisages running of trains is 6 cars composition with 5 minutes headway between KR Puram to Yelahanka & 10 minutes headway between Yelahanka to Airport Terminal station for the year 2024 and the horizon year 2031 with 3 minutes headway between KR Puram to Yelahanka & 6 minutes headway between Yelahanka to Airport Terminal station and for year 2041 with 2.5 minutes headway between KR Puram to Yelahanka & 5 minutes headway between Yelahanka to Airport Terminal station.

With only 17 passenger stations in the line, the Traction system proposed and planned is to suit 2024 and 2031 scenario initially, which can be suitably augmented for 2041 scenario on need basis and as per the simulation. However, the space for TSS shall be kept at station/wayside to accommodate the 2041 Scenario. Presently, total 20 TSSs (18 mainline + 2 depot) are estimated for 2031 scenario. However, the precise requirement of TSSs shall be determined by simulations during detailed engineering stage. Accordingly, based on 2031 Scenario the cost provision is made in the estimate for Traction System.

12.4.2 Train Operation Plan

Table 12.3 Train Operation Plan

Year	Train configuration#	KR Puram to Yelahanka (19.13 kM)			Yelahanka to Airport (18.424 kM)		
		Peak Headway in mins	No. of trains in service during peak hours	No. of train trips per direction per day	Peak Headway in mins	No. of trains in service during peak hours	No. of train trips per direction per day
2024	6 car	5	12	150	10	6	88
2031	6 car	3	20	250	6	10	125
2041	6 car	2.5	24	300	5	12	150

DMC - TC - MC + MC – TC - DMC

12.4.3 Traction Sub-stations (33 kV/750 V DC)

Traction sub-stations (33 kV/750 V DC) are required to be set up for feeding 750 V DC power supply to the third rail. In order to cater to traction load as per design criteria, it is envisaged to provide wayside traction sub-stations (TSS) in additional to the TSS at stations which is to be determined by simulation studies during detailed design stage.

Wayside TSSs can be accommodated in the concourse to be specially constructed below the viaduct. Same can also be located on wayside based on the availability of the land. The requirement is estimated as 20 TSSs (18 Mainline + 2 Depot) for 2031 scenario for proposed line. The cost provision is made only for 2031 scenario in this DPR. The power supply schematic drawing showing 2031 scenario is attached as Annexure 12.3. During detailed design and engineering stage, feasibility of using 24 pulse rectifier and reversible TSS shall also be explored to optimize the number of TSS's.

The TSS along with Auxiliary Sub-Stations (ASS) will be located inside the room at station building/ specially built concourses at way side locations. Self-cooled, cast resin dry type rectifier-transformer is proposed, which is suitable for indoor application. From the traction sub-stations, 750 V DC cables will be laid up to third rail and return current cables will be connected to running rails.

12.4.4 Rating of Major Equipment

Based on demand expected at each RSS for the year 2041 as shown in Table 12.1, 2 nos. 66/33 kV main receiving substations at Yelahanka & Airport RSS is planned and both will be having transformers of 2 x 25 MVA capacity, one to be in service and second one to serve as standby. The RSS to be located at K R Puram will be provided with 2 x 25 MVA transformers which caters for K R Puram – Silk Board line with a provision for 10 MVA built-in for K R Puram –Airport line. The 66 kV UG cable for Airport RSS shall be 3-phase single core XLPE insulated with 630/1000 mm2 Copper conductor to meet the normal & emergency loading requirements and fault level of the 66 kV supply.

Traction transformer-rectifier set (33 kV/750 V DC) shall be of 2.8 MW rated continuous capacity with overload requirement of 150% for 2 hours and 300% for 1 minute. The traction transformer - rectifier set shall produce 750 V DC nominal output voltage with 12/24-pulse rectification so as to minimize the ripple content in the output DC voltage. All the connected equipment of traction i.e., 33 kV switchgear, rectifier transformer, bus duct, rectifier, HSCB, negative return panel, DC cables, third rail etc., shall comply with the overload duty cycle 100% continuous, 150% for 2 hours and 300% for 1 minute all in sequential.

The IEC 60850:2000-08 (Railway applications – Supply voltages of traction systems) envisages the maximum and minimum voltages for 750 V DC system with regenerative braking is as under:

Table 12.4 Maximum and Minimum Voltages for 750 V DC System with Regenerative Braking

Minimum voltage	Nominal voltage	Maximum voltage	Occasional maximum voltage during regenerative braking
U_{min1}	$\mathbf{U_n}$	U_{max1}	U_{max2}
V	**V**	V	V
500	**750**	900	1000

DC equipments shall be capable of giving desired performance in above mentioned voltage range. 33 kV cable network shall be adequately rated to transfer requisite power during normal as well as emergency situations and to meet the fault current requirement of the system. Accordingly, proposed 33kV cables sizes are as under:

- 3 x 1 core x 240 mm2 copper (parallel runs if required) from RSS to 33 kV cable network (nearest ASS/TSS)

- 3 x 1 core x 240 mm2 copper for 33 kV ring main cable network.

Entire 33 kV cables shall be 3 phase, single core, XLPE insulated with copper conductors. Cables shall be of FRLS (Fire Retardant Low Smoke)/ FRLSOH (Fire Retardant Low Smoke Zero Halogen) as section envisaged is elevated.

Adequate number of cables are required for transfer of power from TSS to third rail. Single phase XLPE insulated cables with 300 mm2 copper conductor are proposed for 750 V DC as well as return current circuit. Positive cables shall be of 3.3 kV insulation class and negative/return cables of minimum 1.1 kV insulation class. Based on current requirements, 8 x 1C x 300 mm2 cables are required for each of the four runs to feed power to third rail and accordingly 8 x 1C x 300 mm2 cables for each track for return circuit.

The above capacities of transformers, cables etc. to be worked out based on the conceptual design and therefore, these capacities may be required to be fine-tuned during design stage of project implementation.

12.4.5 Third Rail and Stinger System

Third rail with bottom collection system with shroud on top and sides is proposed considering the safety. 4500 A rating conductor rail is proposed and the manufacturing process can be co-extrusion, mechanically embossed, mechanically welded etc., which complies with the required contact resistance between aluminum & stainless steel and with proven record.

In order to avoid third rail in the maintenance areas from safety point of view, stinger is proposed in inspection bay lines similar to Bengaluru Metro Phase I.

Figure 12.2 Third Rail and Stringer System

12.4.6 Emergency Trip System (ETS)

Emergency Trip System (ETS) shall be provided at platform ends, station control room and TSS in accordance with the requirements of NFPA-130. ETS can be operated by passengers and metro staff in case of emergency situations to disconnect the power supply to the train(s). Operation of ETS push button will result in tripping of relevant section of third rail in order to stop the trains in that section. An interlock to be incorporated with the signaling system to block the train(s) entering the station/section of the ETS pressed. ETS cable shall be fire rated for one hour at 500 deg. C.

Figure 12.3 Emergency Trip System (ETS)

ETS cabinet housing shall be constructed of steel, painted with international orange, with the Blue light on the facial and red mushroom-shaped heavy duty push button capable of being padlocked in a locked position when pressed, can only be reset by a master key. The tripping logics are to be hardwired and locally functional i.e., not through SCADA.

12.4.7 STRAY CURRENT CORROSION PROTECTION MEASURES

12.4.7.1 Concept of DC Stray Current Corrosion

In DC traction systems, bulk of return current finds its path back to the traction sub-station via the return circuit i.e. running rails. The running rails are normally insulated to minimize leakage of currents to the track bed. However, due to leaky conditions, some current leakage takes place, which is known as ‘stray current’. The current follows the path of least resistance. Return current deviates from its intended path if the resistance of the unintended path is lower than that of intended path. The stray current may flow through the unintended path of metallic reinforcements, civil structures, public utilities etc., of the structure back to the substation.

It is also possible that part of the stray current may also flow into soil, where it may be picked up by metallic utilities and discharged back to soil and then to near the sub-station.

The DC stray currents cause metal detraction in watery (aqueous) electrolytes as per the following chemical reactions:

- Stray current enters in the metal

  $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (development of Hydrogen gas)

- Stray current exits from metal

  $Fe \rightarrow Fe^{2+} + 2e^-$ (Fe^{2+} ions migrate away from the metal)

That is how, DC stray currents cause corrosion of metallic structure where it leaves the metal. Pitting and general form of corrosion are most often encountered on DC electrified railways.

12.4.7.2 Effect of Corrosion

Detraction rate of metals can be calculated by Faraday's First Law:

m	=	c.i.t	(Where m = mass (kg))
c	=	Coefficient of detraction	(kg/Amp.year)
i	=	Current (Amp)	
t	=	time (year)	
c	=	2.90 for Aluminium	
	=	33.80 for Lead	
	=	9.13 for Iron	
	=	10.4 for Copper	

That means DC stray current of 1 Ampere flowing continuously can eat away approx. 9 kg of steel in a year. If 5000 amperes of current flows for one year to power the trains on a transit system, and that 2 percent of this current (100 amperes) leaks as stray current, the amount of steel metal loss is 0.9 ton per year. Therefore, the safety implications are considerable for structural reinforcements. In addition, corrosion may also affect neighboring infrastructure components such as buried pipelines and cables.

12.4.7.3 Measures for Protection against Stray Current Corrosion

Earthing & bonding and protection against stray current corrosion are interrelated and conflicting issues. Therefore, suitable measures are required to suppress the stray currents as well as the presence of high rail potentials. Safety of personnel is given preference even at a cost of slightly increased stray currents.

Following measures are required to restrict the stay current:

i. Decreasing the resistance of rail-return circuit – by usage of low resistance rails, long welded rails, suitably cross-bonding between rails and tracks, running insulated parallel conductors etc.,

ii. Increasing the resistance of rail to ground insulation – by providing suitable (preferably double insulation) fastening system for DC railway

Whenever buried pipes and cables are in the vicinity of DC railway, efforts shall be made to ensure that metal parts are kept away as far as practicable to restrict stray current by means of isolation and insulation.

Generally, 3 types of earthing arrangements (viz. Earthed System, Floating System & Hybrid Earthing System) are prevalent on metros World over for protection against stray current corrosion. Traditionally, Earthed system was used by old metros. Hybrid earthing system is being tried on experimental basis on few new metros. Floating system has been extensively used by recent metros. As per the trends World over, floating system (i.e. traction system with floating negative) is proposed which reduces the DC stray current to considerable level. The arrangement shall comply with following latest CENELEC standards:

- EN 50122-1: Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock
- EN 50122-2:- Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by DC traction systems

12.4.7.4 The conceptual scheme of proposed floating system is described below:

i. The running rails shall be adequately insulated as per EN50122-2. The insulation level between earth and rails shall be no less than 10 ohm/km of single track under normal operating conditions.

ii. Stray Current Collector Cables {commonly known as structural earth (SE) cable} of suitable size (calculated in accordance with EN 50122-2) shall be provided along the viaduct and all the metallic parts of equipment, cable sheath, viaduct reinforcement, signal post etc. shall be connected to SE cable.

iii. The longitudinal continuity of the reinforcement bars of the viaduct as well as track slabs has to be ensured along with a tapping point for connection with SE cable in order to drain back the stray current.

iv. A provision shall be made to earth the running rail (i.e. negative bus) in case of rail potential being higher than limits prescribed in relevant standard (EN 50122-1) in order to ensure safety of personnel. This will be achieved by providing track earthing panel (TEP)/over voltage protection device (OVPD) in all stations irrespective of ASS or ASS/TSS.

v. Provisions shall be made on the structures for measurement of average potential shift +200 mV for steel in concrete structures.

vi. In addition, stray current assessment by continuous monitoring rail insulation assessment using rail potential in accordance with EN 50122-2 to be installed in

OCC for monitoring of the rail potential supports the supervision of the continuity of the return circuit, detects connections between the return circuit and earth and degradation of insulation in rail fastenings.

vii. Measurements recommended in EN 50122-2 to be practiced to ensure the stray currents are not deteriorating the metro railway structures and public structures/utilities as well.

12.4.8 Special Arrangements in Depot

A separate traction sub-station (TSS) shall be provided for depot so as to facilitate isolation of depot traction supply from mainlines in order to prevent the leakage of return currents to depot area. Tracks of Depot area shall also be isolated from mainline through insulated rail joints (IRJ). Remote operated disconnection/sectionalizing switches shall be provided to feed power from depot to mainline and vice-versa in case of failure of depot TSS and nearest mainline TSS.

The prescribed limit of highest touch potential in depot shall be as per EN 50122-1 and therefore Track Earthing Panels (TEP)/Over Voltage Protection Device (OVPD) shall be provided at suitable locations to earth the rail in case the rail potential exceeds this limit.

12.4.9 Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC)

The rectifier-transformer used in DC traction system produces harmonic voltages, which may cause interference to telecommunications and train control/protection systems. The rectifier-transformer shall be designed with the recommended limits of harmonic voltages, particularly the third and fifth harmonics. The proposed 12-pulse rectifier-transformer reduces the harmonics level considerably. Detailed specification of equipment e.g. power cables, rectifiers, transformer, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signaling & telecomm, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMC plan will require to be developed during project implementation stage.

12.5 Auxiliary power supply network

Auxiliary sub-stations (ASS) are envisaged to be provided at each station. A separate ASS is required at International Airport depot. The ASS & TSS will be located at mezzanine/concourse level inside a room at station building. The auxiliary load requirements have been assessed to be about 350 kVA for elevated, accordingly two dry type cast resin transformers (33/0.415 kV) of 500 kVA for elevated stations (with one transformer as standby) are proposed to be installed. At Way side substations ASS of 2 x 200 kVA capacity is proposed to be installed.

The Depot ASSs will also be provided with 2 x 2000 kVA auxiliary transformers.

Figure 12.4 Typical Indoor Auxiliary Sub-station

12.5.1 Standby Diesel Generator (Dg) Sets

In the unlikely event of simultaneous tripping of two RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide stand-by DG set of 180 kVA capacity at Interlock and Interchange Elevated stations to cater the following essential services:

i. Signaling & telecommunications
ii. Elevators operation
iii. Essential lighting at Stations and on viaduct on account of emergency evacuation
iv. Ventilation requirements of stations
v. Firefighting system
vi. Signages
vii. Other emergency and essential services

Silent type of DG sets are proposed which have low noise levels.

12.5.2 Other Building Services (E&M works, Elevators and Escalators)

Station lighting is proposed with all LED lighting and Solar system is also proposed at the roof of the stations. Station emergency lighting shall have back-up from UPS and DG set as per existing norms. Each station shall have Elevators and Escalators to facilitate the movement of the passengers from ground to concourse and concourse to platform. Air conditioning for all the critical rooms like S & T, SCR and TO room is proposed. Ventilation system is proposed in ASS/TSS room.

To meet the emergencies on account of fire at station there is provision of fire detection and fire suppression system at stations as per NBC/NFPA. The main fire panel will be installed on SCR for early warning to the stall available there. The building management system will also be provided at station to monitor/control the various equipment like elevators, escalators, UPS, Air conditioning system, Pumps, Main DB, small lighting DB and lighting etc.

4 Elevators and 4 Escalators are estimated at each passenger station. Stations are also to be provided with latest fire detection, fire alarm and firefighting system.

12.5.3 Energy saving measures

Energy charges of any metro system constitute a substantial portion of operation & maintenance (O & M) costs. Therefore, it becomes imperative to incorporate energy saving measures in the system design itself. The proposed system of Bengaluru Metro includes the following energy saving features:

i. Modern rolling stock with 3-phase VVVF drive and light-weight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor. Therefore, suitable system for recuperation of braking energy to be considered during detailed design and engineering stage. Rolling stock has regeneration features and it is expected that 20% of total traction energy will be regenerated and fed back to 750 V DC third rail to be consumed by nearby trains.

ii. Use of energy efficient LED lights and fittings is proposed. The lighting system of the stations will be provided with different circuits and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc).

iii. Machine-room less type lifts with gearless drive have been proposed with 3-phase VVVF drive. These lifts are highly energy efficient and having regeneration facility also.

iv. The proposed heavy-duty public service escalators will be provided with 3-phase VVVF drive which gives energy efficiency & improved power factor and having regeneration facility also. Further, the escalators will be provided with infra-red sensors to automatically reduce the speed (to idling speed) when not being used by passengers.

v. The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc.) have been incorporated in the system design.

vi. Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.

vii. Solar panels to harvest the solar energy available on the station roofs, depot, parking and top of the buildings have been planned.

12.5.4 Electric power tariff

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of a metro system and it is expected to constitute about 20-30% of total annual operating cost. Therefore, it is the key element for the financial viability of the Project.

The annual energy consumption is assessed to be about 102.46 million units in the year (2024), which will reach 169.77 million units by horizon year 2041. The detailed calculations of annual energy consumption are given at Annexure 12.2.

In addition to keep the energy consumption to optimum, it is also necessary that the electric power tariff be kept at minimum in order to contain the O&M costs. Therefore, the power tariff for Bengaluru Metro should be at effective rate of purchase price (at 66 kV voltage level) plus nominal administrative charges i.e. no profit no loss basis.

It is proposed that Government of Karnataka take necessary steps to fix power tariff for Bengaluru Metro at “No Profit No Loss” basis.

12.6 Supervisory Control and Data Acquisition (SCADA) System

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fiber provided for telecommunications will be used as communication carrier for SCADA system.

Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 66/33 kV ac switchgear, transformers, 750 V DC switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system.

OCC for K R Puram –Airport line can be integrated with ORR Line, Gottigere – Nagavara Line or RV Road – Bommasandra Line based on the location decided during detailed engineering stage.

12.7 Cost Estimate: The summary of the Cost Estimates excluding Price Variation, Tax & Contingency is given below for various system provided in this section.

Sl. No.	System description	Estimated Cost in INR (Crores)
1	Traction & Power Supply including Third Rail, ASS, TSS, RSS & SCADA etc.,	613.18
2	E & M (including Elevators & Escalators)	158.00

ANNEXURE 12.1
POWER REQUIREMENTS

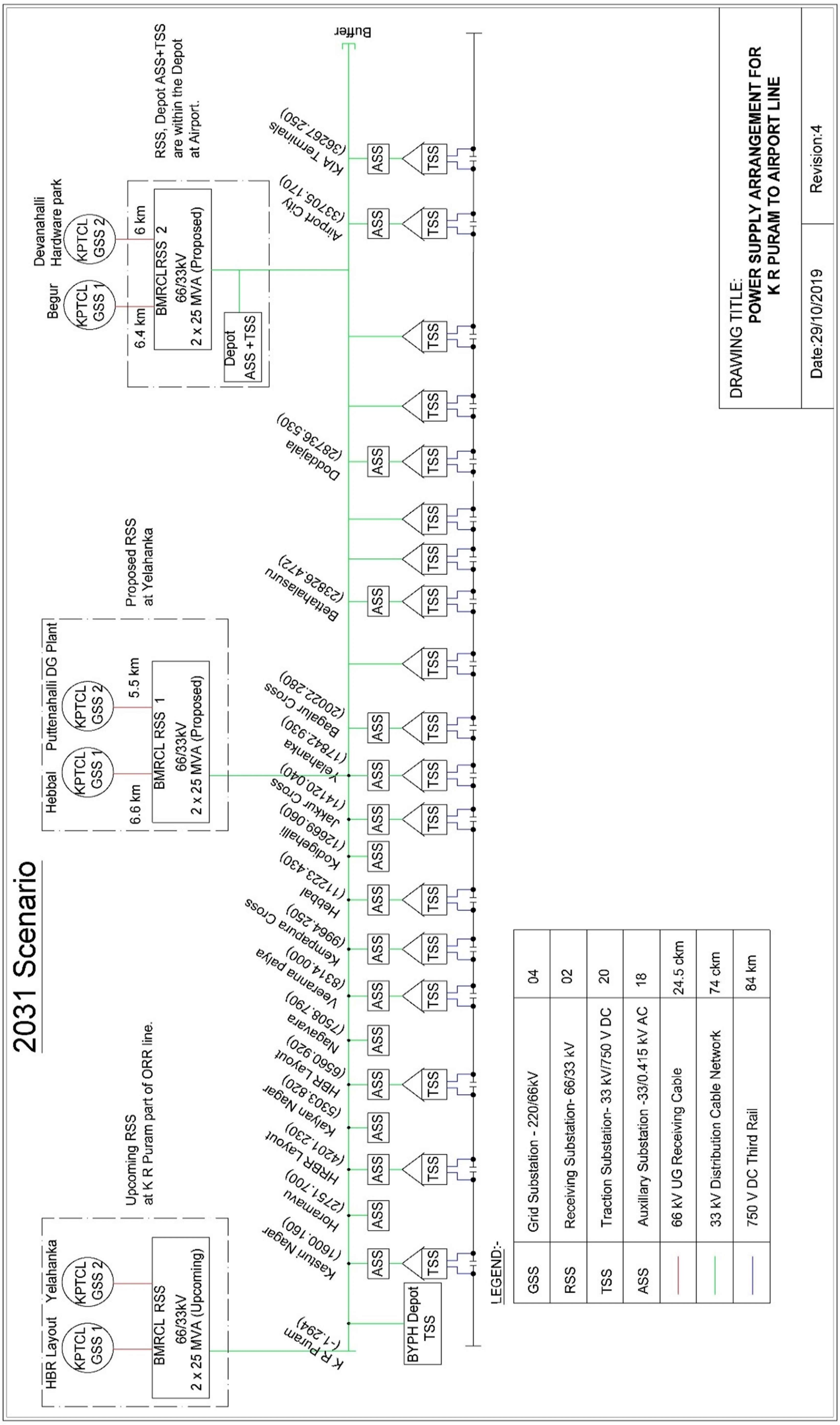
K R PURAM TO AIRPORT				
Description	**Values**			**Units**
Traction power requirements	**Year 2024**	**Year 2031**	**Year 2041**	
No of cars per rake	6	6	6	(2DMC+2TC+2MC)
Tare weight of train	222	222	222	T
Passenger weight	130	130	130	T
Total Train weight	352	352	352	T
Length (Route km)	39.487	39.49	39.49	km
Headway (during peak hours)	5 & 10	3 & 6	2.5 & 5	mts
Specific Energy Consumption (SEC)	75	75	75	KWhr/1000 GTkm
Power demand from one train set	0.79	0.79	0.79	MW
No. of train sets in operation during peak hour	18	30	36	Train sets
Total traction demand	14.22	23.70	28.44	MW
Less Regeneration @20%	2.84	4.74	5.69	MW
Depot traction power requirement	1.0	1.0	1.0	MW
Net traction power requirement	12.38	19.96	23.75	MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	**13.68**	**22.06**	**26.25**	**MVA**
Station auxiliary power requirement				
Elevated station load	0.25	0.25	0.25	MW
Property development load	0.10	0.10	0.10	MW
Total elevated station auxiliray load	0.35	0.35	0.35	MW
No. of elevated stations	17	17	17	
Way side traction station, auxillary load requirement	0.10	0.10	0.10	MW
No. of way side traction stations	8	8	8	
Total auxiliary power requirement	6.75	6.75	6.75	MW
Depot auxiliary power requirement	1.0	1.5	1.7	MW
Total auxiliary power requirement	7.75	8.25	8.45	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	**9.57**	**10.19**	**10.44**	**MVA**
Total traction & aux power requirement (MW)	20.13	28.21	32.20	MW
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	**23.25**	**32.25**	**36.69**	**MVA**

ANNEXURE 12.2
ENERGY CONSUMPTION

Energy Consumption							
Description	SECTION						
	K R PURAM TO YELAHANKA			YELAHANKA TO AIRPORT			
	Values			Values			Units
	Year 2024	Year 2031	Year 2041	Year 2024	Year 2031	Year 2041	
No of cars per rake	6	6	6	6	6	6	(2DMC+2TC+ 2MC)
Length (Route km)	19.13	19.13	19.13	18.424	18.424	18.424	KM
No. of trains per direction in a day*	150	250	300	88	125	150	
Weight of train and passenger	352	352	352	352	352	352	T
SEC (net) with 20% regen	60	60	60	60	60	60	KWH/1000 GTKM
Yearly traction energy consumption with 365 days working with 20% regen	**44.27**	**73.79**	**88.55**	**25.00**	**35.53**	**42.64**	**million units**
Station aux power requirement							
Elevated	0.35	0.35	0.35	0.35	0.35	0.35	MW
No. of elevated stations	**12**	**12**	**12**	**5**	**5**	**5**	
Way side traction station, auxillary load requirement	0.10	0.10	0.10	0.10	0.10	0.10	MW
No. of way side traction stations	8	8	8	8	8	8	
Depot auxiliary power requirement	1	1.5	1.7	1	1.5	1.7	MW
Total auxiliary power requirement	6	6.5	6.7	3.55	4.05	4.25	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	**7.41**	**8.03**	**8.28**	**4.39**	**5.00**	**5.25**	**MVA**
Diversity factor of auxiliary loads	0.5	0.5	0.5	0.5	0.5	0.5	
Yearly auxiliary energy consumption 20 hrs/day and 365 days working (million units)	**23.00**	**24.91**	**25.68**	**13.61**	**15.52**	**16.29**	**million units**
Net Annual Energy Consumption (Traction & Auxiliary)	**67.27**	**98.70**	**114.22**	**38.60**	**51.05**	**58.93**	**million units**

Section	Year	Net Annual Energy consumption in million units
K R Puram to Airport	2024	**105.87**
	2031	**149.75**
	2041	**173.15**

ANNEXURE 12.3



Chapter 13

Train Maintenance Depot

CHAPTER - 13

TRAIN MAINTENANCE DEPOT

13.1 INTRODUCTION

It is proposed to extend Phase-2A corridor (Central Silk Board Junction- K R Puram line) from KR Puram to Airport Terminal via Hebbal under Phase - 2B. Existing Depot at Baiyappanahalli is planned to be remodeled suitably to meet operation and maintenance requirements of this line in addition to serving the requirement of Phase-2A. Since, phase-2B line being longer in length (38.44 KM), it is necessary to provide depot facilities at either end of the Corridor to ensure smooth operation and maintenance. Therefore, a depot towards Airport end is planned in addition to the augmented depot facility at Baiyappanahalli to meet complete operational needs of Phase-2A & 2B Corridor.

Beside this, a provision of suitable entry/exit from Depot to main line of Phase-2B and exclusive feeder line (third line) at main line Station needs to be provided to ensure smooth operation in the Corridor.

Budgetary cost provision is made under Phase-2B for Depot at Airport end as well as for remodeling of Baiyappanahalli Depot. (refer Fig-13.1 remodeled Baiyappanahalli Depot and Fig-13.2 proposed Depot at Airport)

The chapter provides only conceptual design of the depot based on operational needs for the year 2041 and shall work as a guide for further detailed design.

13.1.1 Maintenance Philosophy

The outline of the maintenance philosophy followed is:

- Continuous monitoring of the performance of equipment by condition monitoring of key parameters using “Train Integrated Management System”, the concept is to evolve the need based maintenance regime, which can be suitably configured in the form of schedules like A& B checks “, “IOH” and “POH” (C overhaul) recommended by OEM of Rolling Stock.
- Unit replacement to minimize Rolling Stock detention in repair shop and to get essential repairs done through OEMs for ensuring reliability.
- More automation with state-of-the-art machinery to ensure quality and reliability.
- Minimize labor intensive procedures.
- Thrust on intensive and exclusive staff training periodically to ensure skill up gradation and assurance of quality and productivity through performance guarantee.
- Due thrust on energy conservation.

13.1.2 Operational Features.

For smooth induction, withdrawal from main line and depot movement, the following minimum features to be incorporated:

- The rake induction and withdrawal from depot to the main line shall be so designed to ensure proposed headway in the section is unaffected.
- The stabling area shall be interlocked with the main line to ensure safe and efficient induction and withdrawal of trains.
- Internal movements in the depot, viz from the stabling to the inspection shed or workshop and vice versa would be interlocked and suitable segregation will be made between UTO and Non UTO area.
- Exclusive line is provided for stabling of emergency rescue vehicle with direct access to main line in the event of emergency.
- Barring trains under scheduled maintenance, all trains would be in service as per peak hour demand. Whereas, during lean hours in daytime, approximately half of the trains will be withdrawn from the service to avoid idle run.
- To economize on the air conditioning energy, all the stabling lines would be under covered shed. There would be catwalk platforms between the alternate stabling lines to facilitate “Safe to Run” examination and safe movement of workers and trolleys for internal cleaning of trains.
- The scheduled inspections would be carried out during lean hours.
- The third rails would be laid on opposite side of walkway platforms.
- The track bed would be ballasted in the depot area to economize the cost.
- The stabling and yard layout would be at level for at least power requirements in shunting movements and to avoid accidental rolling of Rolling stock resulting into accidents and damages to the property

13.1.3 Rolling Stock Maintenance Schedule

The mandatory maintenance schedules as mentioned in Table 13.1 determined by the Rolling Stock Manufacturer have been envisaged for conceptual design of Depot assuming an average 503 km per train per day, and taking in to consideration of the six car passenger load with 2.5 min headway for Silk Board to KR Puram, 2.5 min headway from KR Puram to Yelahanka and with 5 min headway for Yelahanka to Airport Corridor requirement for the year 2041 and beyond.

Table 13.1 Mandatory Maintenance of Rolling Stock

Session	Interval	Downtime	Locations
Daily Night Check	Daily	1 hr	Stabling bays

Session	Interval	Downtime	Locations
Weekly Check	7 days	1hr	Inspection bays
A Service Check	6,000 km (15days)	1.5 hrs	Inspection bays
B1 Service Check	18,000 km (45days)	4 hrs	Inspection bays
B2 Service Check	36,000 km (90days)	6 hrs	Inspection bays
B4 Service Check	72,000 km (180days)	12 hrs	Inspection bays
B8 Service Check	150,000 km (360days)	20 hrs	Inspection bays
B16 Service Check	300,000 km (2years)	28 hrs	Inspection bays
C1 Overhaul	520,000 km (3.5years)	10 days	Workshop bays
C2 Overhaul	1,040,000 km (7years)	20 days	Workshop bays
C3 Overhaul	1,560,000 km (10.5years)	20 days	Workshop bays
C4 Overhaul	2,250,000 km (15years)	20 days	Workshop bays

13.1.4 Year-Wise Planning of Maintenance Facility at Airport Depot-Cum-Workshop:

The Central Silk Board - K. R. Puram line sanctioned under Phase-2 A is getting extended from K R Puram to Airport Terminal. Therefore, considering the limited facility provided at Baiyappanahalli Depot, the entire residual maintenance facility is required to be provided at Airport Depot.

A. Year wise rake requirement for K R Puram to Airport line as per operational plan.

Table 13.2 Year wise rake requirement for K R Puram to Airport line

Year	K R Puram to Airport line		
	Head way in minutes	No. of trains	No. of Coaches
2024	5 & 10	21 X 6-Cars	126
2031	3 & 6	34 X 6-Cars	204
2041	2.5 & 5	40 X 6-Cars	240

B. Year wise combined section rake requirement from Silk Board junction to Airport line.

Table 13.3 Year wise combined section rake requirement from Silk Board junction to Airport line

Year	Silk Board Junction to Airport line		
	Head way in minutes	No. of trains	No. of Coaches
2024	5 & 10	37 X 6-Cars	222
2031	3 & 6	58 X 6-Cars	348
2041	2.5 & 5	69 X 6-Cars	414

C. Requirement of stabling, inspection and workshop lines:

Based on the combined rake requirement for Central Silk Board –Airport line bare minimum requirement at proposed headway, considering maintenance facility being created at Baiyappanahalli Depot, residual facility proposed to be planned at Airport Depot detailed as in **Table 13.4**.

Table 13.4 Requirement of Stabling, Inspection and Workshop lines

Year	Central Silk Board to International Airport line					
	Baiyappanahalli Depot			Airport Depot (proposed)		
	SBLs	IBLs	RBLs	SBLs	IBLs	RBLs
2024	16 lines X 6-Car	3 lines X 6- Cars	4 lines X 6-Car	12 lines X 6-Car	4 lines X 6- Cars	2 lines X 6-Car
2031	42 lines X 6-Car	3 lines X 6- Cars	4 lines X 6-Car	12 lines X 6-Car	4 lines X 6- Cars	4 lines X 6-Car
2041	42 lines X 6-Car	5 lines X 6- Cars	4 lines X 6-Car	19 lines X 6-Car	4 lines X 6- Cars	4 lines X 6-Car

13.2 Depots

To meet the train operation & maintenance requirements of Phase 2B, provision of Airport depot facility is planned at Airport end and augmented depot facility at Baiyappanahalli Depot at KR Puram end.

13.2.1 Airport Depot

The construction of Airport Depot is planned to be taken up in two stages. In the first stage it is planned to construct 12 SBL and combined shed with 4 IBL and 2 RBL. In the second stage additional 7 SBLs and 2 RBLs will be constructed to meet train operation and maintenance requirement of Phase-2B.

Airport line may have higher traffic potential in future, hence PHPDT considered at this stage may increase substantially. To cater such eventualities, the space shall be made available for augmentation of stabling and associated facilities at Airport Depot.

13.2.2 Baiyappanahalli Depot (Augmentation and Re-modelling plan)

During remodeling of Baiyappanahalli Depot, following facilities are planned:

- The existing 16 SBL at grade to be converted into 2 transfer lines (common facility for 2A and 2B) and 14 SBL.
- Additional 12 SBL and 2 IBL to be provided at level (-1) along with associated E&M and M&P.
- Provision of entry-exit facility from K R Puram-Airport line to remodeled 26 SBL's.
- Pocket track provision at take-off station for operational flexibility.
- Modification of test track for testing of CBTC trains with suitable connectivity from IBL and RBL (common facility for 2A and 2B).
- Conversion of DTG to CBTC signaling system.
- Consequential upgradation of substations to meet Traction and E&M requirements.
- Provision of Train Wash Plant for ORR line.
- Augmentation train lifting facility from 3 cars to 6 cars.

Note: Remodeling work of Baiyappanahalli Depot related to 2B, shall be taken up only after construction of Airport depot facility

Figure 13.1 Conceptual Remodeled Depot layout for Baiyappanahalli depot

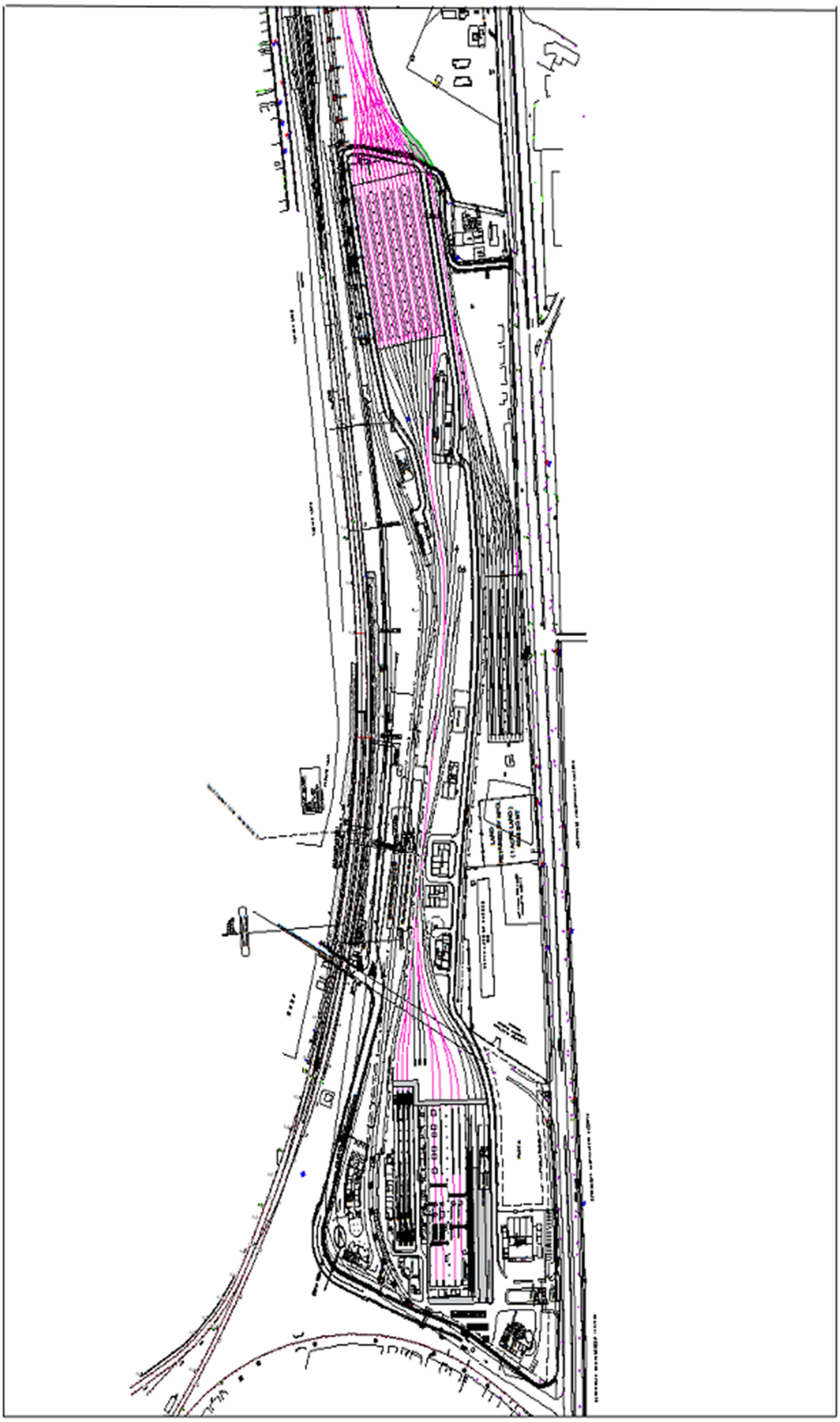
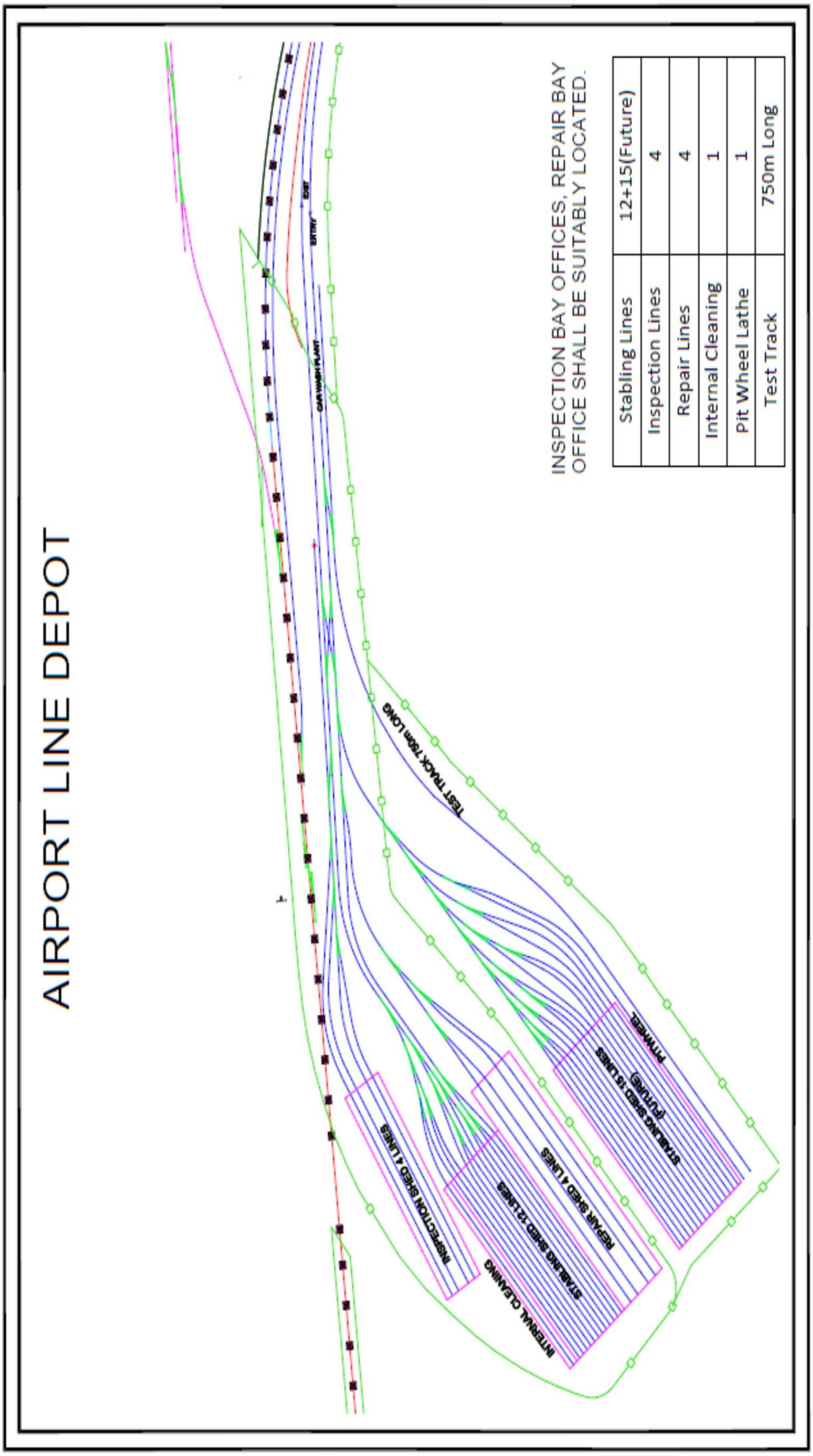


Figure 13.2 Conceptual Remodeled Depot layout for Airport depot



13.3 Depot Facilities

13.3.1 Depot Control Centre (DCC)

For Airport Depot, operation control, depot would be housed with Depot Control Centre (DCC) suitable for CBTC operation.

13.3.2 Operation Control Centre (OCC)

To cater combined operation requirement for Central Silk Board to Airport Link Corridor, a new Operation Control Centre (OCC) is planned with equipment and display boards of CBTC system adjacent to Baiyappanahalli Depot with a suitable connectivity to the existing OCC as the present OCC is operationally saturated.

13.3.3 Washing Needs of Rolling Stock

Washing provision shall be made for rolling stock exterior using a fully automated train washing system, one each at Baiyappanahalli and Airport Depots.

Figure 13.3: Washing Needs of Rolling Stock

13.3.4 Repair Facility

Presently, the total number of 16 stabling facility is created at Baiyappanahalli Depot, the residual maintenance facility proposed at Airport Depot to cater the requirements for year 2041 and beyond.

13.3.5 Test Track

A test track of 1000 m length with fence shall be provided with suitable alignment at Airport Depot. It shall be equipped with signaling equipment. It shall be used for the commissioning of the new trains, their trials and testing of the trains. Entry into the test track shall be planned for a 6 Car train directly from repair and inspection bay. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized tress passing across or along the track with red flashing lights all along the fencing line to indicate “live” on rail.

Figure 13.4: View of Test Track

13.3.6 Coach Unloading / Loading line

BMRCL has adopted standard gauge track and new coaches would be transported by road on trawlers. For unloading of coaches and forming the train, an unloading siding is provided with embedded rail and platform facility. Unloading platform shall be of 50 m x 20 m size with rails embedded.

13.3.7 Compressed Air Supply

An independent compressor unit shall be provided at designated/required locations for the supply of compressed air for workshop and Inspection bay preferably 400CFM each.

13.3.8 Water Supply, Sewerage and Drainage Works

In house facilities shall be developed for the water supply of the Depot. Tankage shall be designed to ensure adequate storage facility. Sewerage, storm water drainage shall be given due care while designing the Depots for efficient system functioning. Past records of Municipal Corporation shall be used to design the drainage system. Rainwater harvesting would be given due emphases to charge the underground reserves. ETP/STP shall be planned for adequate capacity.

13.3.9 Inspection Shed

The length of Inspection lines shall be approximately 160meter and shade of 160 X 32 Sqm. Activities such as inspection / Maintenance / minor repair shall be carried out in IBL. The A &B schedules shall be carried out at a frequency of 15 days and 45 days respectively keeping in view the average Km Earning /Train. Apart from this 72 hrs checks will also be carried out in IBL.

i. Stinger suitable for supply of 750 V DC with approximately 900 A shall be provided for all the lines and shore supply points of 3 Phase 415 V AC with 250 A shall be provided on either side of the inspection bay.

ii. Roof level platforms shall be provided with proper access.

iii. Lifeline shall be provided for all the inspection lines.

iv. Proper lighting shall be provided for inspection and repair of under frame equipment.

v. Material movement inside Inspection shed:

i. Ramps of 1:8 slopes with 3-meter width shall be provided with sunken floor for movement of material. Further 5 m wide pathways to be provided across the shed on either end for movement of material handling equipment such as fork lifter / Leister trucks / hand trolley.

13.3.10 Stabling Shed.

i. The length of stabling lines shall be 160 mtrs.

ii. The requirement of lines shall be in accordance with the table indicated above; the stabling siding in the Depot shall be covered with a roof in order to facilitate testing of trains and their pre-cooling under controlled temperature during day.

iii. Separate toilets adjacent to stabling lines shall be provided with small room for keeping cleaning aids and for utilization by the contractor's staff.

iv. **Figure 13.5:** View of Stabling Shed

13.3.11 Workshop Shed

i. All the Workshop lines shall be interconnected through turn–tables.

ii. Each bay of the workshop shall be provided with two 15T / 3T overhead Cranes.

iii. One embedded line shall be provided with Pit-jacks for lifting of 6-Car unit simultaneously.

iv. One independent line adjacent to wall shall be provided with roof platform for HVAC maintenance of 6-Car train.

v. Two lines shall be provided with Pits of suitable length to facilitate under-carriage inspection and disconnection of cables, pneumatic, communication lines etc. with mobile jack facility.

vi. Workshop will have an array of service rooms necessary for servicing & overhauling of Equipment.

vii. Assembling / disassembling overhauling testing facilities shall be facilitated and suitably placed, there shall be bogie assembly pits suitably located in repair area.

viii. There shall be washing & cleaning equipment available on shop floor. Air circulators, Power supply points and compressed air pipeline network shall be provided with tapping points on every column.

ix. Repair & stacking of heavy equipment such as HVAC, Convertors and Motors shall be so located that it does not affect movement inside the workshop.

x. Interconnectivity with mechanical repair section shall be so planned to ensure smooth work flow of Wheels / Bogies / brake equipment in the repair section without causing obstructions to any other activity.

xi. All the repair shop lines shall be extended upto half of the workshop bay length and 50% of the space shall be reserved overhauling, repairs, cleaning disassembling / assembling of Bogie and other major components.

xii. Proper lighting shall be provided for inspection and repair of under frame equipment.

xiii. Shore supply points of 3 Phase 415 V AC with 250 A shall be provided for one line.

Figure 13.6: View of Work Shop Shed

13.3.12 Train Operators Booking Office

Suitable office facility shall be provided adjacent to the stabling lines for train operators signing On/Off with lobby for waiting of crew. These offices shall have an attached a cycle/scooter/car stand facility for the convenience of the train operating staff.

13.3.13 Heavy Cleaning Shed

a. Monthly heavy cleaning of interior walls, floors, seats, windows glasses done manually in the heavy washing line. Thus this line shall be designed for cleaning of one six car train at a time. A line adjacent to inspection shed is preferred so as to ensure hassle free movement of trains from workshop or inspection lines & vice – versa.

b. Automatic Train Washing facility shall be suitably located on viaduct to facilitate exterior washing of trains during arrival in the Depot. Washing area shall be straight for 60m length to facilitate installation of washing gears on either side of the track. Equipment room of 20m x 10m shall be provided below the viaduct. The plant shall have capacity of washing at least six trains per hour.

13.3.14 RSS, TSS, ASS Building

Receiving substation (RSS) shall be planned to receive 66/33 kV power supply and distribution to Traction substation and Auxiliary substation for catering power supply requirement of the whole Depot. Details of connected load feeder shall be worked out during engineering stage. Taking diversity factor of 0.5 the maximum demands shall be computed. One Auxiliary substation is proposed, as the demand by machines in Repair-shop area would not be large. The standby power supply is proposed through DG set with AMF panel. The capacity of DG set shall be adequate to supply all essential loads without over loading.

In the proposed Depot to accommodate 66/33 kV, 2X25 MVA transformers with Depot TSS, ASS and DG set the RSS area shall require 3000 m^2.

13.3.15 Ancillary Workshop (ETU shed)

This Repair-shop will have a line at floor level with provision of pits. Arrangement for repairs of shunters, Rail Road Vehicles and other ancillary vehicles will be provided. These vehicles will also be housed here itself. Heavy lifting works can be carried out in main repair shop.

Ancillary workshop will be used for storing traction supply system equipment.

13.3.16 Watch Towers

There shall be provision of adequate number of watchtowers for the vigilance of Depot boundary.

13.3.17 Administrative Building

A Multistory administrative building close to the main entrance to be planned. It can be suitably sized and architecturally designed at the detailed design stage.

13.3.18 Time/Security office: -

A time and security office shall be provided close to main entrance. It shall be equipped with suitable Access control system for all the staff working in the complex.

13.3.19 Parking Facilities

a) Ample parking space shall be provided for the two wheelers and four wheelers at the following points.

- Close to the Depot entry.
- Close to the stabling lines.
- Close to repair bay.

b) Space for parking of road vehicles and re-railing equipment.

Since IOH/POH of equipment of Extension line has to be done at Baiyappanahalli and Airport Depot–cum-Workshop, a lot of road transport will have to be utilized. Both the Depots need to have enough space for parking of Road vehicles. Enough space will also have to be earmarked adjacent to workshop and repair bay.

Similarly, provision of space for parking of re-railing equipment shall have to be made close to the main exit gate of the Depots.

13.3.20 Shed and Buildings

The shed and buildings normally provided in the Depot with their sizes and brief functions are indicated in Annexure-13.1. Some of these buildings are not depicted on the layout drawing. At the detailed design stage depending upon the land availability, the decision to locate these buildings can be taken. These can then be architecturally and functionally grouped.

Moreover, the shed and buildings shall be suitable for installation of solar system in future. The requirement of Buildings and sheds is enlisted in Annexure- 13.1 (Table 13.7).

13.3.21 Under Floor Wheel Lathe Facility

A separate building is planned for housing Pit-Wheel lathe (PWL), approachable from repair-shop, inspection bay and stabling lines through rail and road for placement of cars for re-profiling of wheels within the Depot along with space for dumping of scrap. Pit Wheel Lathe (PWL) of 40m x 12 m shall be provided with a track length of 150m from Pit Wheel lathe center behind the shed.

13.3.22 Plants and Machinery

The requirement of major Plant and Machineries including material handling equipment, tools and measuring equipment is listed in Annexure- 13.2 (Table 13.8).

13.3.23 Safety Features and Other Facilities.

Following Safety features shall be incorporated in the design of all the Maintenance Depots.

a) Installation of red flashers lights along the inspection lines at conspicuous location to indicate the 3rd rail supply is ‘Live’.

b) In heavy repair bay inbuilt arrangement for multilevel wheel stacking and TM stacking.

c) Power sockets shall be provided on pillars in the inspection bay & workshop for charging and other utilities.

d) At cleaning area power supply and its isolation shall be interlinked for safety reasons.

e) The roof inspection platform shall have to facilitate staff to go up the roof for cleaning of roof.

f) Control Centre, PPIO & store Depot must be located close to Workshop.

g) The door width of repair section shall be 2 meters to enable free passage of equipment through them.

h) Provision of water hydrants shall be available in workshops and stabling yards.

i) Water supply shall be provided in all the buildings for cleaning.

j) Track isolation shall be provided for IBL.RBL, PWL and Heavy washing lines.

13.3.24 Provision of Other Infrastructure Facilities.

a) Rest house.

b) Staff/officer quarters.

c) Property development along the road side of Depot plot.

d) Basic training center.

(ANNEXURE –13.1)

Table 13.5 List of Buildings at upcoming Depot at Airport to be planned.

Sl.No.	Name of Building	Size	Brief Function
1.	Inspection Shed	160x32 m	Servicing of Cars for 15 days & 45 days inspection.
	Workshop	250X 63 m	Repair of overhauling of Rolling Stock
	Associated sections	160x8m	Rooms for carrying out the inspection & workshop activity.
	Pit Wheel lathe building	40x12 m	For installation of PWL
2.	Stores Depot & offices including goods platform with ramp	40x 40m	Stocking of spares for regular & emergency requirement including consumable items. This store caters for the requirement of Depot for rolling stock & other disciplines. To be provided with computerized inventory control. Loading/unloading of material received by road.
3.	Elect. Sub-station DG set room	25 x 22 m	To cater for normal and emergency power supply for Depot, workshop, service and all other ancillary buildings, essential power supply essential loads and security light.
4.	RSS,TSS,ASS and DG	500 x 60m	Stabling and routine maintenance of shunting engine etc. & traction maintenance Depot. For maintenance of lifts/escalators and other General service works.
5.	Cycle / Scooter / Car Parking	60 x 6 m 40 x 10 m	Close to the Depot entry. Close to the stabling lines. Close to the repair bay.
6.	(i) Auto coach washing plant	60 x 10m 20 x 10m	For automatic washing of coaches and its proper drainage.

	(ii) Space for AWP control room		
7.	Interior cleaning and washing shed.	130 x 6.5m	Heavy wet washing of rakes from inside, under frame, roof at 30 days interval.
8.	P. way office, store & Workshop including Welding plant	80 x 20m	For track maintenance of section and Depot. To weld rails for construction period only. To stable track Tamping machine.
9.	Security office &time office garages (4 Nos.)	15 x 8m	For security personnel. For time punching. For parking vehicle jeep, truck etc.
10.	Check post (2 Nos.)	5 x 3m	For security check of incoming/outgoing staff, material and coaches.
11.	Watch tower (3 Nos.)	3.5 x 2.5m	For security of the Depot especially during night time.
12.	Depot control center& Crew booking center	25x20m (double storey)	To control movement of trains in and out of the Depot & out of the Depot & for crew booking.
13.	Water service facility-O.H raw water Tank	1,00,000 ltrs Capacity	Storage of water, capacity 1, 00,000 Ltrs each.
14.	Pump house Bore well	7.3 x 5.4 200 mm	Submersible type pump planned with 200 mm diameter bore well.
15.	Waste Water Treatment Plant	12 x 6m	For treating the discharge waters from Depot and remove the oil, acids etc. before discharging into the river, with U/G tank.
16.	Canteen	400 Sqm.	Canteen to cater staff of Depot and workshop staff shall be in a separate building with modern kitchen ware and facilities. Obligatory as per statuary requirements

(ANNEXURE –13.2)

Table 13.6 List of Machinery and Plant

SL. No	Description of Equipment	Quantity
1	Pit wheel lathe & shunter with Chip crusher and conveyor.	1 set
2	Pit lifting jacks (6-car unit)	1 set
3	Mobile lifting jacks (6 cars unit)	2 sets
4	Automatic train wash plant with side, roof and end washing facility.	1 set
5	Bogie turn tables	5 sets
6	Electric bogie tractor	2 Nos
7	Bogie test stand	1 unit
8	Wheel mounting and demounting press	1 unit
9	Battery powered electric loco with third rail	1 unit
10	CNC vertical turret lathe (wheel boring)	1 No
11	CNC axle journal turning and burnishing lathe	1 unit
12	Road cum rail vehicle with set of re railing equipment	1 unit
13	Travelling overhead (EOT) cranes for inspection bay (1.5 ton)	One at each bay.
14	Travelling overhead (EOT) cranes of 15/3 and 5 ton at each bay of repair bay.	4 nos
15	Travelling overhead (EOT) crane of 5 Ton for pit wheel lathe building	1 set
16	Pillar hoist of 3 ton capacity for ETU building	1 set
17	Jib cranes 2 ton capacity	2 set
18	Fork lift truck 5 ton (diesel)	1 Nos

SL. No	Description of Equipment	Quantity
19	Fork lift truck 3 ton (electrical)	3 Nos
20	Storage system including tubular steel pallets	Lump sum
21	Vertical carousel storage system	Lump sum
22	Vehicle mounted aerial work lift platform 15 meters	2 set
23	Mobile lifting table 3 ton	2 Nos
24	Other lifting devices	Lump sum
25	Car body stands	Lump sum
26	Accommodation bogie	Lump sum
27	Bogie wash plant	1 unit
28	Under frame bowing plant	1 unit
29	Cleaning booth for Traction Motor	1 unit
30	Ultrasonic cleaning tank	1 unit
31	Ultrasonic machine for cleaning electronic equipment	1 unit
32	Self-driven floor cleaning machine	2 units
33	High pressure washing pump 200 PSI	2 unit
34	Hand pallet truck	10 Nos
35	Automatic filter cleaning machine	1 unit
36	Compressor for workshop and inspection bay 400 CFM	2 unit
37	Mobile Compressors	3 units
38	Automatic welding plant	2 unit
39	Electric Stacker	2 unit
40	Minor equipment and collective tools	Lump sum
41	EMU battery charger	1 unit

SL. No	Description of Equipment	Quantity
42	Set of machine tools one radial drilling machine, one universal cleaning machine, one slide lathe, one panel sawing machine, one grinding machine.	Lump sum
43	Mechanical and electrical measuring and testing equipment	Lump sum
44	Mechanical, pneumatic and electrical tools	Lump sum
45	Oven for traction motor drying	1 unit
46	mobile safety steps	4 unit
47	Maintenance management system	Lump sum
48	Induction heater	1 nos
49	Special jigs, fixtures	Lump sum
50	Test benches for Rolling stock	Lump sum
51	Work tables and trolleys	Lump sum
52	Industrial furniture	Lump sum
53	Miscellaneous	Lump sum

Chapter 14

Environment & Social Impact Assessment

CHAPTER 14

ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

14.1 Existing scenario

a. The proposed International Airport Metro line starting from K R Puram will mean advancing the construction of Metro line on the ORR stretch between K R Puram to Hebbal from Phase-3 to Phase-2. Stretch between K R Puram and Hebbal is having large number of employment opportunities. It will also help in mitigating heavy traffic congestion on the ORR. Further, establishment of Inter Modal Transit Hub at Hebbal in coordination with BMTC will help Airport travelers as well as the people working in the IT companies on ORR, Whitefield area and in Electronic City who are residing in western and northern parts of the city. The proposal will also help in better integration with operations of BMTC and for facilitating non-motorized transport.

b. Metro system on Phase 2B corridor not only facilitate easy and quick movement of people but also have a positive impact on the economic growth and quality of life. This results in increased income and various benefits like reduced external cost due to reduction in traffic congestion, road and parking cost, transport cost and per-capita vehicle ownership and usage and encourage more compact and walkable development pattern which provide developmental benefits. Reduction in cost and time of travel lowers the cost of production of goods and services which significantly improves city's competitiveness by substantial reduction in per-capita pollution emission bringing down various chronic diseases, thus, resulting in huge public health benefits.

c. Environmental Pollution refers to the contamination of the natural environment which has adverse direct effects on the physical environment like air, water, soil and also has negative impacts on health, socio-economic conditions of humans. Most of our air, water and soil resources are gradually becoming polluted due to the addition of foreign materials from the surroundings. These include organic matter of plant and animal origin, land surface washing, industrial and sewage effluents and vehicular emissions. Rapid urbanization and industrialization with improper environmental planning often has lead pollution and depletion of the environment. This section discusses on air, noise, water, and soil pollution in the context of BMA. For all forms of pollution, the sources can be classified into two types:
    1. Point Source: Contamination is introduced into the environment from a single area.
    2. Non-point Source: Contamination is introduced into the environment from multiple/ large area.

14.1.1 Air Pollution

Air pollution is a major hazard that has been growing steadily in Bengaluru. The increased number of vehicles on road, industrial activity, construction activity, poor quality of roads and dust on road add to the suspended particulate matter in air. Old vehicles with worn out engines, adulterated fuels, and slow moving traffic lead to increased emissions. The increasing vehicles as can be seen have a direct correlation to increasing levels of air and noise pollution. Reducing the number of private vehicle trips, and increasing public transport share is expected have a positive impact in reducing the emissions due to vehicular traffic. The vulnerabilities of air pollution include people living along the major roads, travelers, pedestrians and especially children and the elderly. Mining and quarrying activities within BMA are also adding to air pollution.

14.1.2 Noise Pollution

Another important source of pollution in Bangalore is of excessive noise. The sources of Noise pollution can be attributed to Vehicular traffic, flying aircraft near airports (four air funnels are operational in city at present – highest in any Indian city), Drilling of bore wells, Industries, Construction activities, DG sets, Public address systems playing loud music during festivals, etc.

14.1.3 Water Pollution

Pollution of surface and groundwater is prevalent in Bengaluru. The rivulets Arkavathy, Vrishbhavathy, along with the lakes and the natural streams are highly polluted due to inflow of sewage, industrial effluents and municipal waste. The Dissolved oxygen (DO) level in lake waters is decreasing indicating organic pollution load leading to a phenomenon called eutrophication. Untreated Sewage flowing into lakes cause the lake to decay, and loss of aquatic life. The people living around the polluted lakes are very vulnerable as the area in the vicinity of the lake is covered in foul smell emanating from the lake. The froth and smell affects the commuters and the water pollution has led to ground water getting polluted in the area. Ground water in BMA is polluted due to sewage pollution and industrial pollution, over exploitation of ground water resources and high Nitrate concentration in ground water.

14.2 Environmental Norms and Regulations

14.2.1 The objective of the study is to assess the condition of existing environment such as air, noise, water, soil, traffic, biological and socio economic conditions to identify negative and positive impacts due to the proposed project. Further, the Environment Management Plan (EMP) and monitoring programme will be suggested to control any adverse environmental impacts arising from the proposed project.

14.2.2 Ministry of Environment and Forests (MoEF), Government of India, has issued various notifications on Environmental Impact Assessment since 1994 and the latest being in 2009. According to the notification, 32 types of projects under Schedule-I require environmental clearance from MoEF while Rail projects are exempted from this schedule. This clearly indicates that the proposed project does not require Environmental Clearance and don't create any major environmental problems under the Notification of 14th September 2006, MOEF, Government of India.

14.2.3 Environmental impact assessment has not been done for this project. However, this chapter tries to identify environmental and social impacts and their mitigation measures.

14.2.4 Policies, Legal and Institutional Framework:

The need for a well-developed legal mechanism to conserve resources came into existence during a conference on Human Environment which was held at Stockholm in 1972. Abiding to the discussions which were held in the conference Government of India has framed several policies and formulated number of Acts, Rules and Notifications aimed at Management and Protection of Environment.

As stated in Constitution of India, the responsibility of state with regard to environmental protection has been laid down under Article 48-A. As per this article "The State shall endeavor to protect and improve the environment and safeguard the forests and wildlife of the country".

It is the right of every citizen to treat their surrounding as their home, Article 51-A(g) states that "The fundamental duties of every citizen is to protect and improve the natural environment including forests, lakes, rivers, wildlife and to have compassion for living creatures"

Many laws and regulations were laid down by Government of India and State Government. These laws and regulations should be followed prior to implementation of any project. The project area lies in heart of Bangalore city with heavy population, structures and green cover. Hence, the project has to be scrutinized with various laws and regulations summarized below.

14.2.4.1 Legal Framework

a. Water (Prevention and Control of Pollution) Act, 1972

   This Act was enforced to prevent and control water pollution and maintain or restore wholesomeness of water.

b. Water Cess Act, 1974

   The Act provides for levy and collection of Cess on water consumed by the local authorities and by persons carrying on certain industrial activities with a view to generate resources for prevention and control of water pollution. Water prevention and control of pollution provides prevention and control of water pollution and maintaining or restoring of wholesomeness of water.

c. Karnataka Municipal Corporations Act, 1976

This Act was enforced to protect the public places and people from developing projects. Section 288 discusses regarding power to allow certain projections and erections. Prior permission should be obtained from commissioner.

There is prohibition of structures or fixtures which cause obstruction in public streets, no person shall except with the written permission of the commissioner under section 288 erect or set up any wall, fence, rail, booth or other structures or fixtures in or upon any public street or upon or over any open channel, well or tank in any street so as to form an obstruction to or an encroachment upon or a projection over or to occupy any portion of such street, channel, drain, well or tank.

According to section 288A, there is prohibition of structures or fixtures which cause obstruction in public streets, therefore the project proponent should get a written permission of commissioner under section 288

d. Karnataka Preservation of Trees Act, 1976

This Act was enforced to provide preservation of trees in the state by regulating the felling of trees and for the planting of adequate number of trees to restore ecological balance. A census of existing trees should be carried out and reported to Tree Officer (Dy. Conservator of Forest).

In case of widening of existing roads, if tree felling is inevitable then, planting and transplanting of trees is mandatory. New Plantation should be carried out according to the prescribed standards on roads. According to law, nearly 10 trees should be planted for single tree felling.

When the tree felling is granted for the proposed project, the project proponent should plant another 10 trees of the same or any other suitable species on the same site or other suitable place within thirty days from the date the tree is felled or within such extended time. However, nothing in this section shall apply to felling of Casuarina, Coconut, Erythrina, Eucalyptus, Glyrecidia, Hopea, Wightina, Prosopis, Rubber, Sesbania, Silver Oak and Subabul trees.

e. Forest Conservation Act, 1980

This Act provides for the conservation of forests and regulating diversion of forestlands for non-forestry purposes. If the project falls within the Forest land or the land belonging to Forest Department, prior clearances are required from Forest department under the Forest Conservation Act.

The route alignment should be undertaken in close consultation with representatives from State Forest departments and the Department of Revenue to avoid environmentally sensitive areas and settlements.

If tree felling is inevitable for the proposed alignment, natural regeneration should be practiced and tree plantation is undertaken whenever and wherever it requires. A Compensatory Afforestation should be carried-out to compensate loss of vegetation in twice the area of affected land.

f. Air (Prevention and Control of Pollution) Act, 1981
The Air (Prevention and Control of Pollution) Act, 1981 was enacted to prevent, control and reduce air and noise pollution. The Act lays down national ambient air quality standards for common pollutants like SPM, Sulphur-di-oxide, Oxides of Nitrogen, Carbon Monoxide and Lead etc., with intent of managing air quality for different category of areas (residential, industrial and sensitive). Ambient Air Quality Standards have been notified by the Central Pollution Control Board (CPCB) vide Gazette Notification dated 11th April 1994. Recently, NABET accreditation was introduced for all environmental consultants and also introduced few additional parameters under air monitoring.

g. Karnataka Parks, Play-fields and Open Spaces (Preservation and Regulation) Act, 1985.
This Act was enforced to provide preservation and regulation of parks, play-fields and open spaces. The Act has prohibited construction of buildings under Section 8. According to Subsection (1) no person is allowed to construct any building that is likely to affect the utility of park, play-field or open space or make any enforcement in or over any park, play-filed or open space specified under Section 4 (Approval of list by Government) or Section 5.
According to subsection (2) No land or building within a park, play-field or open space specified in the list published under section 4 or section 5 shall be alienated by way of sale, lease, gift, exchange, mortgage or otherwise and no license for the use of any such land or buildings for any other purposes shall be granted and any alienation made or license granted in contravention of this section shall be null and void.
Section 9 describes about obligation of owner of parks and play-fields. In case of any projection, encroachment or obstruction in park or play field the project proponent should maintain such park or play-field in a clean and proper condition or remove or alter the projection, encroachment or obstruction or execute such repairs under supervision of executive authority.

h. Environment Protection Act, 1986
This Act was introduced as an umbrella legislation to provide a framework for the protection and improvement of environment. Under this Act, the Central Government is empowered to take measures necessary to protect and improve the quality of the environment by setting standards for emissions and discharges; regulating the location of industries;

management of hazardous wastes and protection of public health and welfare.

From time to time, the Central Government issues notifications under the Environmental Protection Act (EPA) for the protection of ecologically sensitive areas or issues guidelines as and when required.

i. Hazardous Waste (Management and Handling) Rules, 1989

In order to manage hazardous waste (HW) that consists of solids, semi-solids and other industrial wastes which are not covered by the Water & Air Acts, and to enable the authorities to control handling, treatment, transport and disposal of waste given in this Act.

j. Land Acquisition - KIAD Act 1966

The Act states that the basic compensation for the Project Affected Persons (PAPs)should be provided according to the market value of the land as at the date of its acquisition. It also entitles PAPs to a hearing before acquisition

k. Noise Pollution (Regulation and Control) Rules, 2000

The rule was enforced to regulate the increasing ambience of noise level in public places from various sources such as industrial activity, construction activity, generator sets, loud speakers, public address systems, music systems, vehicular horns and other mechanical devices that have deleterious effects on health and the psychological wellbeing of the people. The noise quality standard in respect to different category of areas is based on weighted equivalent noise level (Leq)

l. Municipal Solid Waste (MSW) Rules, 2000

According to this rule, every municipal authority within the territorial area of the municipality will be responsible for implementation of the provision of these Rules and for any infrastructure development for collection, storage segregation, transportation, processing and disposal of municipal solid wastes.

14.2.4.2 Policies Framework

Several environment policy statements have been formulated during the last few decades as a part of the Government's approach to integrate environmental and developmental aspects of planning. These policies are intended to mainstream environmental concerns in all development activities in the country. Some of the policies essential for the present study are described below.

a. National Forest Policy, 1988

This policy applicable, whether is any diversion of forest lands for the project purpose to non-forest use. As per the National Forest Policy, the projects which interfere with forests should be severely restricted and no activity is allowed to be carried out until the Government approves the management plan. The projects which involve such diversion should at least provide in their investment budget, funds for regeneration/compensatory afforestation.

b. Policy Statement on Abatement of Pollution, 1992

The commitment of Government on abatement of pollution for preventing deterioration of the environment is stated here. The policy elements seek to shift emphasis from defining objectives for each problem area towards actual implementation, but the focus is on the long term, because pollution particularly affects the poor.

The complexities are considerable given the number of industries, organizations and government bodies involved. To achieve the objectives maximum use will be made of a mix of instruments in the form of legislation and regulation, fiscal incentives, voluntary agreements, educational programmes and information campaigns. The emphasis will be on increased use of regulations and an increase in the development and application of financial incentives.

c. National Environmental Policy, 2007

The dominant theme of this policy is that while conservation of environmental resources it is necessary to secure livelihoods and well-being of all, the most secure basis for conservation is to ensure that people dependent on particular resources to obtain better livelihoods from the fact of conservation than from degradation of the resource.

The policy also seeks to stimulate partnerships of different stakeholders, i.e. public agencies, local communities, academic and scientific institutions, the investment community and international development partners, in harnessing their respective resources and strength for environmental management.

d. National Policy on Resettlement and Rehabilitation (R &R), 2007

The new policy states that wherever possible, projects should limit displacing people. The project proponent should come up with alternative sites when making requests for acquisition. Only the minimum area of land commensurate with the purpose of the project may be acquired.

Also, as far as possible project may be set up on waste, degraded or un-irrigated land. The government as well as project proponent should consider options that would minimize displacement of people. This policy states that Social Impact Assessment (SIA) will be necessary for projects resulting in "involuntary displacement" - meaning displacement of people unwilling to move - of at least 400 families in plains. The policy laydown that the community to be displaced will have be to kept informed at every stage through public hearings and newspaper advertisements.

This policy also states that while undertaking a SIA, the appropriate government shall consider the impact that the project will have on public and community properties, assets and infrastructure; particularly, roads, public transport, drainage, sanitation, sources of safe drinking water, sources for drinking water for cattle, community ponds, grazing lands, plantations; public utilities, such as post offices, fair price shops, electricity supply, health care facilities, schools and educational/training facilities, places of worship, land for traditional tribal institutions, burial and cremation grounds etc. The new policy prohibits transferring land acquired for public purpose for any activity that is not for public benefit. However, this can be done only with the government's approval. If the acquired land transferred to a private company remains unutilized for five years or more, it will revert to the state. Also, if the land is sold or transferred, 80 per cent of any net unearned income shall be shared with the persons from whom the land was acquired.

14.2.4.3 Administrative Framework

There are two administrative responsibilities are responsible to formulate acts and policies at Ministry of Environment & Forest and Central Pollution Control Board. The following section describes the objective of each administration.

a. Ministry of Environment and Forest (MoEF)

In view of the growing importance of environmental affairs, the Government of India set up a Department in November1980 under the portfolio of the Prime Minister. The Department, later renamed as the Ministry of Environment and Forests (MoEF) plays a vital role in environmental management for sustained development and for all environmental matters in the country.

The major responsibilities of MoEF includes - Environmental resource conservation and protection, Environmental Impact Assessment of developmental projects, Co• ordination with the other ministries and agencies, voluntary organizations and professional bodies on environmental action plans, Policy-planning, Promotion of research and development, manpower planning and training and creation of environmental awareness; Liaison and coordination with international agencies involved in environmental matters.

Developmental project proponents are also required to submit Environmental Impact Statements/Assessments to establish that preventive measures are planned by installing adequate pollution control and monitoring equipment, and that effluent discharged into the environment will not exceed permissible levels. The MoEF appraises these statements/ assessments and approves the project from the environmental angle. The respective State Pollution Control Board is to give a No Objection Certificate (NOC) before the EIA exercise is undertaken.

b. Central Pollution Control Board (CPCB)

The Central Pollution Control Board (CPCB) indirectly responsible for pollution control throughout the country. The two main objective of CPCB is to promote cleanliness of streams and wells through prevention, control, and abatement of water pollution and to improve the quality of air and to prevent, control or abate air pollution. In addition to the control of air, noise and water pollution it is also responsible to ensure effective control on disposal of hazardous wastes and storage and handling of hazardous chemicals and substances.

Additionally, with the enactment of air and water pollution laws, states have set-up their own Pollution Control Boards (SPCBs) to monitor industrial emissions and effluents and to approve the operation of new industries after careful scrutiny. The functions of the SPCBs includes,

i. The planning of comprehensive state programs for the prevention and control of air and water pollution and to ensure the implementation thereof.
ii. Inspection of control equipment, industrial plants, etc.
iii. Establishing norms in consultation with the Central Board and having regard to national air quality standards, gaseous emission standards from industrial plants, automobiles, etc.

Different emission standards may be laid down for different industrial plants, regard to the quantity and composition of emissions into the atmosphere from such plants and the general pollution levels in the area; advising the State Government on setting of new polluting industry.

c. Karnataka State Pollution Control Board (KSPCB)

The KSPCB was constituted in the year 1974 under the provision of Water (Prevention and Control of Pollution) Act, 1974. Subsequently the Water (Prevention and Control of Pollution) Cess Act, 1977, Air (Prevention and Control of Pollution) Act, 1981 and Environmental Protection Act, 1986 in addition to Rules framed under these Acts were also entrusted to the State Board. The prime objective of all these Acts is maintaining, restoring and preserving the wholesomeness of quality of environment and prevention of hazards to human beings and terrestrial flora and fauna.

The Board has its Central Office at Bangalore. The enforcement of the above stated Acts and Rules are being implemented through thirty-three

Regional Offices. The Central Office of the Board is responsible for making general policies relating to enforcement of the above said Acts and Rules and it also carries out general administration and co-ordination with other agencies. The Central Laboratory of the Board is well - equipped and can take up analysis of water, waste water, stack emission samples, ambient air samples, bio-assay tests, bacteriological analysis, etc.

14.3 Environmental Baseline Studies

14.3.1 General

The baseline environmental status of the project area is essential to assess the impacts on the neighboring environment. The study consists of field studies to ascertain the present baseline environmental conditions such as air, noise, traffic, water, soil, socioeconomic, flora and fauna. It also includes literature review in the disciplines of physiography, geology, minerals, soils, seismicity, rainfall, temperature, humidity and land use of the project area. The secondary data on physiography, geology, minerals, soils, seismicity, rainfall, temperature, humidity and land use of the project area was collected from various sources and presented below.

14.3.2 Physiography

The project area comprises of urban and semi-urban areas of Bangalore city. The average elevation of Bangalore is 920 m above MSL covering an area of about 751sq km. The city lies between 12.97°N and 77.56°E. The city is bounded by Kolar District in the northeast direction, Chikballapur District in the north, Tumkuru District in the Northwest, Mandya District in the Southwest, Ramanagaram District in the South and the neighboring State of Tamilnadu in the South-East. The city is generally flat, but it has a prominent ridge in North East and South West. Northern part of the project area is relatively more level plateau. Southern part represents uneven landscape with rocky features raising from 30-70 meters above ground level. Eastern part of the project area is almost plain with minor undulations. The highest point measured is Doddabettahalli, which is 962 m and lies above this ridge. There is no river flowing in the city, only few freshwater lakes and water tanks existing within the city serve as source of groundwater recharge. Some of the important lakes are Madivala Tank, Hebbal Lake, Ulsoor Lake, Sankey Tank etc.

14.3.3 Geology and Minerals

The geology of the city is unique having various types of rock such as granites, gneisses and migmatites found in the area. The area has mature topography with scattered isolated hillocks around, where rocks are exposed. The rock type exposed in the district belongs to Saugar Group, Charnockite Group, Peninsular Gneissic Complex (PGC), Closepet granite and basic younger intrusive. Saugargroup comprises ultra-morphic rocks, amphibolites, Quartzite banded magnetites, quartzite occurring as small bands and lenses within the migmatites and gneisses. PGC is the dominant unit and covers about two-thirds of the area, which includes granites, gneisses and migmatites. The bed rocks essentially consist of granites and gneisses intruded by number of basic dykes.

14.3.4 Soils

The project area has Red Loamy and Laterite soils. Red loamy soils are mainly seen in the eastern and southern parts of Bangalore north and south taluks. It generally occurs on hilly to undulating landscape on granite and gneissic terrain. Laterite soils are mainly covered in Anekal taluk and western parts of Bangalore North and South taluks. Laterite soils occur on undulating terrain forming plain to gently sloping topography of peninsular gneissic region.

14.3.5 Seismicity

The study area has no major threat of an earthquake because it is located in seismically stable zone (Zone II). The city has generally remained untouched by major seismic activity but only mild tremors have been recorded occasionally to till date as per records of Directorate of Mines and Geology, Government of Karnataka and Bhabha Atomic Research Centre.

14.3.6 Land Use and Land Cover

Urban land activities/ uses are numerous like residential, mixed residential, commercial, mixed commercial industrial, mixed industrial or recreational and with various combinations. Activities with similar nature have been clubbed together and Land Use classification prescribed under KTCP Act and Rule 30 of the Karnataka Planning Authority Rules have been followed for land use codification, for capturing the data on ground and preparation of Existing Land Use Map 2015. The ELU maps are based on field surveys that have been carried upto Dec 2015. To collect information and map the existing land use of the BMA a comprehensive approach and methodology was taken, wherein satellite imagery interpretation and an extensive existing land use field survey across BMA formed the basis for mapping and ELU map preparation. Since the city is a dynamically growing entity it is difficult to capture the exact land use in detail. The existing land use survey exercise is primarily aimed at capturing the overall land use pattern, general growth trends and other ground conditions. This is to assists in the preparation of the overall master plan. The ELU maps were finalized after due scrutiny. After completing the existing land use mapping exercise, the overall land use pattern has been studied. The ELU maps have been printed out at 1: 5000 in a standardized format and have been utilized for preparing the proposals. Overall composite ELU Map is presented in **Figure1.9**, whereas the ELU Area Statement for LPA of BDA is given in **Table 1.8** of Chapter 1.

14.3.7 Meteorological Data

Meteorological data has been collected from Indian Meteorological Data Centre (IMD), Bangalore. The data recorded reveals that, the total annual rainfall in year 2008 is about 1286.6 mm. The annual maximum temperature ranges from 27.3°C to 34.1°C and minimum temperature ranges from 16.1°C to 21.6°C. The highest humidity of 89% was recorded during the month of August, while the lowest of about 69% was recorded during the month of March.

The wind rose diagrams available for the period 1976 – 1994 shows that easterly winds dominated over the months of December, January and February while, the westerly winds dominated over the months of May to July. The wind rose diagrams are given for day and night observations in **Figure 14.1, Figure 14.2** and **Figure 14.3**. During the year, the month of March appears to have maximum number of calm periods (30% frequency) while, the months of June, July and December recorded the least calm periods (3% each). The dominate wind speed during the morning observation period is in the range of 6 – 11 km/hr, predominantly of an east-west direction. In the evening observation period, slightly increased wind speeds, ranging from 7 – 13 km/hr.

Figure 14.1 Wind rose diagram for Bangalore city (morning observations)

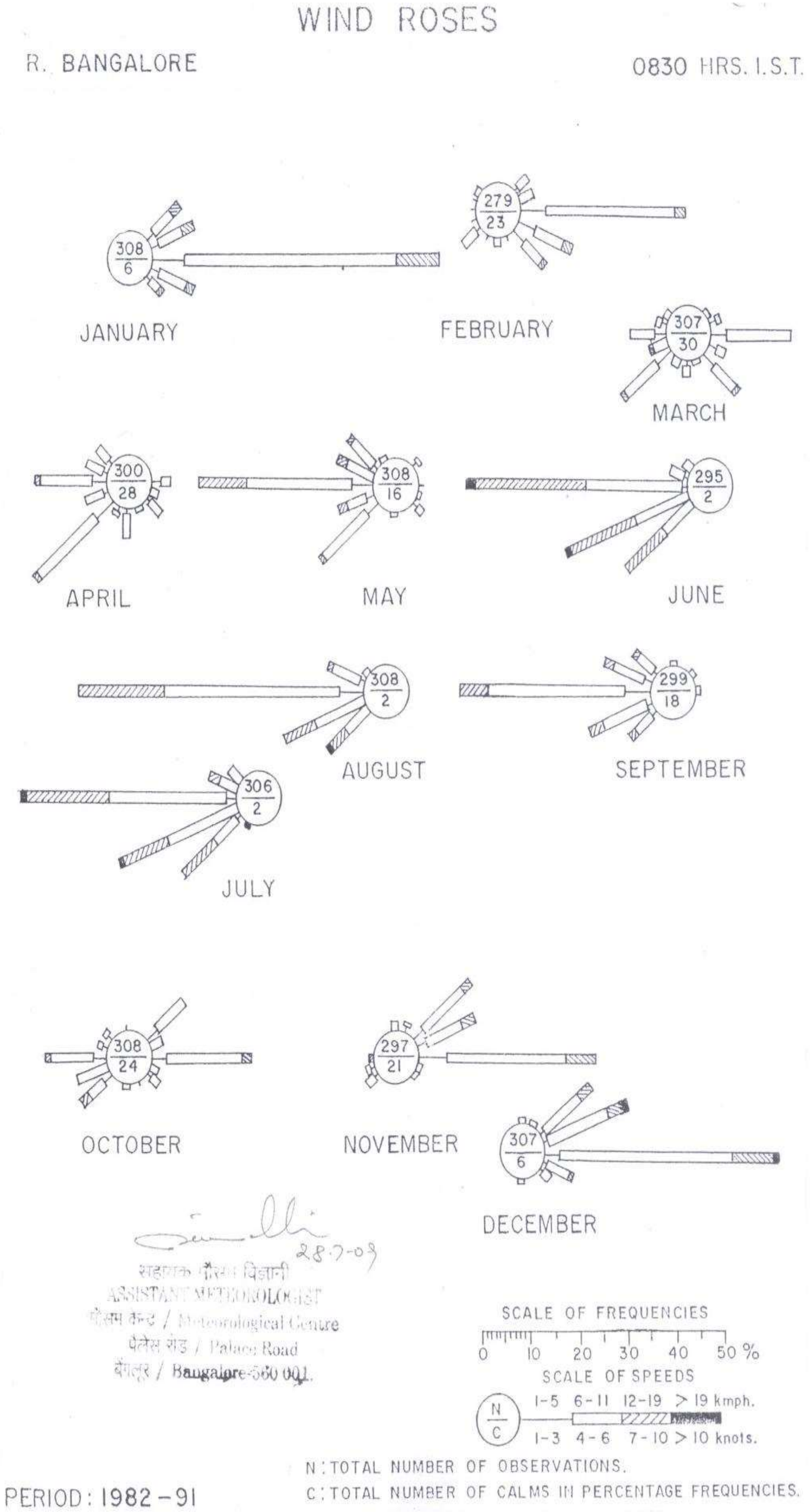
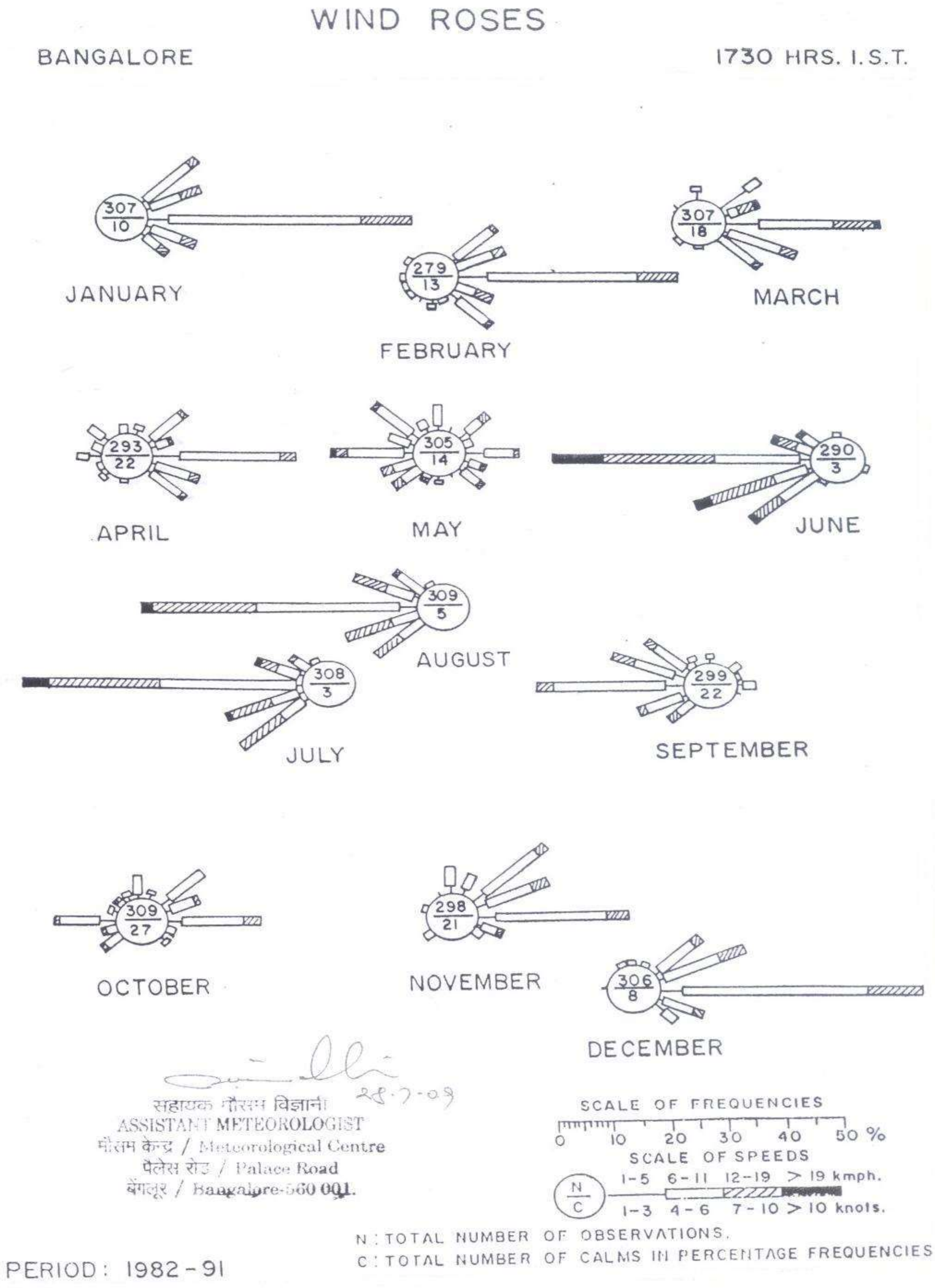


Figure 14.2 Wind rose diagram for Bangalore city (morning observations)



Wind rose of Bangalore-Airport

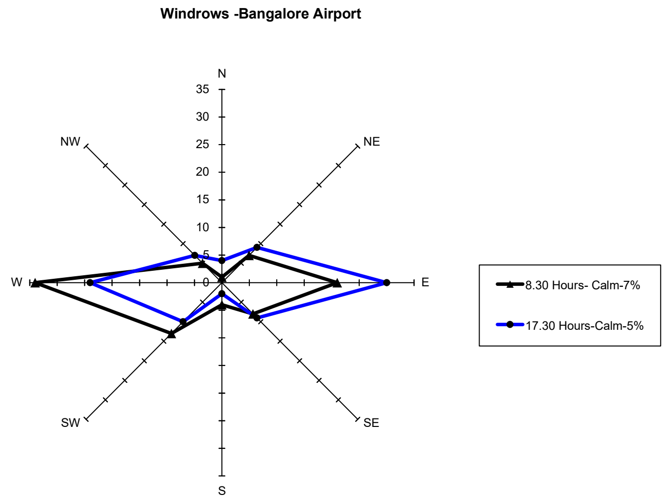


Figure14.3: Wind rose Bangalore Airport Meteorological Station

Bangalore-AP-Station		
Direction	%	%
N	1	4
NE	7	9
E	21	30
SE	8	9
S	4	2
SW	13	10
W	34	24
NW	5	7
Calm	7	5
Mean Wind Speed 12.30 KMPH		
Source: Indian Meteorological Department		

Table 14.1 Details of Major Environmental Components Along the Alignment of Phase-2B Airport Line Metro Project

SL NO	PARTICULARS	SIDE		CHAINAGE		Location	From C/l Alignment (m)	IMPACT
		LHS	RHS	FROM	TO			
1	BENNIGANAHALLI LAKE		√	0	700	KASTURINAGAR	35.00	Likely
2	RMZ INFINITY		√	0	50	LINK LINE	40.00	Unlikely
3	COCO COLA FACTORY	ALIGNMENT		450	500	LINK LINE	0.00	Likely
4	BDA PARK	√		500	650	KASTURINAGAR	20.00	Likely
5	BBMP GARDEN	√		1100	1200	KASTURINAGAR	70.00	Unlikely
6	STEEL FACTORY		√	1260	1840	CHANNASANDRA	130.00	No Impact
7	BHUVANAGIRI PARK	√		2140	2200	CHANNASANDRA	25.00	Unlikely
8	BIGBAZAAR	√		2900	2950	HORMAVU	35.00	Unlikely
9	BWSSB WATER TANK WITH PUMP	√		3900	3950	HRBR LAYOUT	50.00	Likely
10	NALA	ALIGNMENT		4450	4480	HRBR LAYOUT	0.00	Likely
11	CHELKERE AND BBMP PARK		√	4500	4565	HRBR LAYOUT	150.00	Unlikely
12	ROYAL CONCORDE SCHOOL		√	4750	4850	HRBR LAYOUT	70.00	Unlikely
13	PARK	√		4850	4950	HRBR LAYOUT	150.00	Unlikely
14	BMTC BUS DEPOT		√	5150	5350	KALYAN NAGAR	35.00	Unlikely
15	MANTRA ACADEMY		√	5450	5480	KALYAN NAGAR	60.00	Unlikely
16	INDO ASIAN ACADEMY		√	5500	5600	KALYAN NAGAR	45.00	Likely
17	BWSSB WATER TANK WITH PUMP	√		5600	5700	KALYAN NAGAR	45.00	Likely
18	MARY'S MALANKARA CHURCH	√		5700	5750	KALYAN NAGAR	48.00	Unlikely
19	CHRIS HOSPITAL		√	5800	5900	KALYAN NAGAR	90.00	Unlikely
20	FLORENCE & FLORIDA INSTITUTE	√		5850	5900	KALYAN NAGAR	60.00	Unlikely
21	SREE SAI EYE HOSPITAL		√	5900	5930	KALYAN NAGAR	120.00	Likely
22	MASJID E-YOUSUF	√		6000	6050	KALYAN NAGAR	30.00	Likely
23	PARK	√		6150	6200	KALYAN NAGAR	35.00	Likely
24	BDA PARK	√		6490	6660	HBR LAYOUT	35.00	Likely
25	NATIONAL FOREST	√		6800	7200	HBR LAYOUT	35.00	Likely
26	NALA	ALIGNMENT		7200	7250	NAGAWARA	0.00	Likely
27	GOVERNMENT SCHOOL	√		7300	7400	NAGAWARA	25.00	Likely
28	OPEN LAND		√	7300	7400	NAGAWARA	25.00	Likely
29	MASJID E-NOOR E FATHIMA		√	7500	7580	NAGAWARA	120.00	Unlikely

SL NO	PARTICULARS	SIDE		CHAINAGE		Location	From C/l Alignment (m)	IMPACT
		LHS	RHS	FROM	TO			
30	JMJJ HOSPITAL	√		7650	7690	NAGAWARA	100.00	Unlikely
31	MANYATHA TECH PARK		√	8000	8200	VEERANAPALYA	25.00	Likely
32	BEL LIMITED	√		8400	8500	VEERANAPALYA	25.00	Likely
33	LUMBINI GARDEN & NAGAWARA LAKE		√	8830	10120	KEMPAPURA	25.00	Likely
34	STP PLANT	√		9800	10220	KEMPAPURA	25.00	Likely
35	BETHEL AG CHURCH		√	10850	10950	HEBBAL	25.00	Likely
36	BMTC BUS DEPOT		√	11100	11270	HEBBAL	25.00	Likely
37	BDA PARK	√		11050	11450	HEBBAL	25.00	Likely
38	LAKE	√		11400	11720	HEBBAL	30.00	Likely
39	NALA	ALIGNMENT		11680	11700	HEBBAL	0.00	Likely
40	DHOBI GHAT		√	11700	11850	HEBBAL	25.00	Likely
41	ESTEEM MALL		√	11860	11890	HEBBAL	25.00	Likely
42	DEFENCE LAND	√		11720	12360	KODIGEHALLI	25.00	Likely
43	COLUMBIA ASIA HOSPITAL		√	12030	12100	KODIGEHALLI	25.00	Likely
44	CAUVERY MEDICAL CENTER	√		12360	12490	KODIGEHALLI	25.00	Likely
45	MORE MEGASTORE	√		12780	12850	KODIGEHALLI	25.00	Unlikely
46	PROLIFE HOSPITAL		√	13600	13660	KODIGEHALLI	25.00	Likely
47	L & T CONSTRUCTION & EQUIPMENTS	√		14120	14400	JAKKUR	25.00	Unlikely
48	GKVK CAMPUS	√		14400	14840	JAKKUR	25.00	Likely
49	JAKKUR AERODROME		√	14550	15600	JAKKUR	25.00	Likely
50	VIDHYA SHILPA SCHOOL		√	16120	16400	JAKKUR	25.00	Likely
51	RAITHARA SANTHE		√	17340	17390	KOGILU CROSS	25.00	Likely
52	ASHWINI HOSPITAL	√		17450	17480	KOGILU CROSS	25.00	Likely
53	NDR MULTI SPECIALITY HOSPITAL		√	18200	18240	KOGILU CROSS	25.00	Likely
54	HOLY ROSARY CHURCH		√	18740	18800	KOGILU CROSS	25.00	Unlikely
55	JEEVAN HOSPITAL	√		18920	18930	PRR	25.00	Likely
56	CYTECARE HOSPITAL	√		19880	19920	PRR	25.00	Likely
57	BSF	√		20500	21320	PRR	25.00	Likely
58	AIR FORCE	ALIGNMENT		21320	22240	PRR	25.00	Likely
59	KENDRIYA VIDHYALAYA		√	21200	21650	PRR	25.00	Likely
60	HUNSMARANAHALLI LAKE	√		22300	22620	PRR	25.00	Likely

SL NO	PARTICULARS	SIDE		CHAINAGE		Location	From C/l Alignment (m)	IMPACT
		LHS	RHS	FROM	TO			
61	SJP PU COLLEGE	√		22860	22980	PRR	25.00	Likely
62	GOVERNMENT SCHOOL	√		23090	23150	PRR	25.00	Likely
63	NRV HOSPITAL		√	25450	25490	PRR	75.00	Unlikely
64	DECATHLON		√	26100	26200	PRR	40.00	Unlikely
65	CHICKJALA FORT		√	26780	26900	TRUMPET	30.00	Likely
66	ITC FACTORY	√		27900	28720	TRUMPET	45.00	Likely
67	PLANTATION		√	30300	31700	TRUMPET	25.00	Likely
68	NALA	ALIGNMENT		31870	31900	TRUMPET	0.00	Likely
69	MEDIAN PLANTATION (ENTIRE STRETCH)	√	√			ALL ALONG THE ALIGNMENT		Likely
70	AVENUE TREES	√	√			ALL ALONG THE ALIGNMENT		Unlikely
71	NATIONAL PARK BANNERGATTA (PERIPHERY 36KM)NO WILDLIFE AND HUMAN CONFLICT						36 (km)	No impact

14.3.8 Ambient Air Quality

Karnataka State Pollution Control Board is monitoring Ambient Air Quality at 15 locations. The monitoring of these stations are carried out by Bengaluru Regional Office, Karnataka SPCB, the monitoring of pollutants is carried out for 24 hours (4- hourly sampling for gaseous pollutants and 8 hourly sampling for particulate matter) with a frequency of twice in a week. The parameters monitored are Sulphur dioxide (SO2), Nitrogen dioxide (NO2), Particulate Matter (PM10, PM 2.5), Ammonia (NH3), Lead (Pb) and Carbon Monoxide (CO). The annual average values of air pollutants of Bangalore city b/w 2015-17 are given in the table 14.2 below from which it is observed that the Ambient Air Quality in the city at present ranges from moderate to good as per the classification given in **Figure 14.4**. The levels of PM10/PM 2.5 are attributed to the vehicular emissions/movement, re- suspension of road dust and construction activities.

Table 14.2 Annual average values of Air Pollutants at Bangalore City during the years 2015-16,2016-17 and 2017-18

Sl. No	Name of the Station	SO_2 µg/m3			NO_2 µg/m3			PM 10 µg/m3			PM 2.5 µg/m3			NH_3 µg/m3			Lead µg/m3			CO µg/m3			AQI				
		15-16	16-17	17-18	15-16	16-17	17-18	15-16	16-17	17-18	15-16	16-17	17-18	15-16	16-17	17-18	15-16	16-17	17-18	15-16	16-17	17-18	15-16	16-17		17-18	
1	CAAQMS at S.G.Halli	3.7	3.7	2.2	25.7	30.3	24	*	45.9	50.4	*	0	*	*	0	*	*	0	*	*	0.5	0.5	*	54	Satisfactory	50	Good
2	Urban Ecopark Peenya	*	2	2	*	37	31.9	*	109	95.2	*	51.7	44.2	*	36.6	31	*	0.1	0.15	*	*	*	*	107	Moderate	95	Satisfactory
3	Swan Silk Pvt. Ltd ,Peenya	3.9	2.3	2	20.2	37.9	32	*	98.9	96.6	*	50.2	44.8	*	35	32.1	*	0.1	0.133	*	*	*	*	102	Moderate	97	Satisfactory
4	Yeshwanthpura Police Station	3.6	2	2	22.6	39.6	33	*	93.3	95	*	45.9	44.5	*	36	32.7	*	0.1	0.101	*	*	*	*	93	Satisfactory	95	Satisfactory
5	AMCO Batteries, Mysore Road	4	2	2	20.2	38	32.7	*	107	86.1	*	51	39.9	*	36.1	33.6	*	0.2	0.202	*	*	*	*	103	Moderate	86	Satisfactory
6	Banaswadi police station	*	*	2	*	26.8	24.3	*	80.3	68.7	*	41.2	32	*	22	20.7	*	0.3	0.145	*	*	*	*	89	Satisfactory	69	Satisfactory
7	Madavachari house, Kajisonnenahalli	3.6	2	2	12.6	24.3	30.6	*	83.2	69	*	40.3	*	*	22	29.8	*	0.1	0.196	*	*	*	*	79	Moderate	69	Satisfactory
8	UVCE, K.R Circle		2	2		26.3	23.8	*	86.2	70.9	*	38.2	34.5	*	22.9	21.8	*	0.2	0.132	*	*	*	*	87	Satisfactory	71	Satisfactory
9	Victoria Hospital, Bangalore	4	2	2	23	36.3	31.7	*	77.9	65.3	*	39.7	40	*	32.4	32.1	*	0.1	0.083	*	*	*	*	79	Satisfactory	67	Satisfactory
10	Indira Gandhi Child Health Care Centre	3.8	2	2	17.5	31	31.9	*	77.6	65.6	*	35.9	30.4	*	28	32	*	0.1	0.085	*	*	*	*	75	Satisfactory	66	Satisfactory
11	Export promotional Park , ITPL Whitefield Industrial Area	3.8	2	2	21.1	33.1	31.7	*	131	103.9	*	54.8	50.8	*	29.3	30.9	*	0.1	0.148	*	*	*	*	127	Moderate	103	Moderate
12	Rail Wheel Factory, Yelahanka		2	2	*	28.5	29.7	*	111	101.9	*	53.8	65.8	*	25.4	30.3	*	0.1	0.118	*	*	*	*	106	Moderate	119	Moderate
13	Central Silk Board, Hosur Road	3.9	2.3	2	21.1	39.4	32	*	132	118.8	*	58	*	*	37.8	33.5	*	0.1	0.104	*	*	*	*	124	Moderate	113	Moderate
14	CAAQM City Railway Stn.	9	6.5	7.5	45.6	45.8	52	*	102	100.9	*	0	*	*	0	*	*	0	*	*	0.9	1.3	*	97	Satisfactory	101	Moderate
15	TERI Office, Domlur	*	2	2	*	32	32.4	*	120	118.4	*	55.4	52.1	*	39.3	30.8	*	0.2	0.182	*	*	*	*	122	Moderate	112	Moderate
	Standards, µg/m3	**50**			**40**			**60**			**40**			**100**			**0.5**			**2**							
Note : * Monitoring not carried out																											

Source: KSPCB

Figure 14.4 Classification of Impact of Air Pollution on People

Good (0–50)	Minimal Impact	**Poor (201–300)**	Breathing discomfort to people on prolonged exposure
Satisfactory (51–100)	Minor breathing discomfort to sensitive people	**VeryPoor (301–400)**	Respiratory illness to the people on prolonged
Moderate (101–200)	Breathing discomfort to the people with lung, heart disease, children and older adults	**Severe (>401)**	Respiratory effects even on healthy people

Source: KSPCB

14.3.9 Noise Quality

The ambient noise levels are recorded at appropriate locations with a time interval of about 30 minutes using Sound Level Meter as per IS:4954 and procedures of CPCB. Noise source often fluctuates widely during a given period of time. Hence, Equivalent Noise Levels (Leq) is essential to assess the impact. Equivalent noise levels are computed with the help of Lday and Lnight of the study area. Lday is defined noise level measured over a period of 16 hours during day (6 am to 10 pm). Lnight is defined as noise level measured over a period of 8 hours during night (10 pm to 6 am).

Table 14.3 Noise levels measured at Ten Continuous Noise Monitoring Stations in Bengaluru city for the months of April 2017 - January-2018

Noise levels measured at Ten Continuous Noise Monitoring Stations in Bangalore city for the months of April 2017 - January-2018.

Date	Limits in dB(A) Leq*	Day Time			% Increase	Limits in dB(A) Leq*	Night Time			% Increase	No. Of Days
		Leq	Lmin	Lmax			Leq	Lmin	Lmax		
1. Indira Gandhi Institute of Child Health (NIMHANS), Sensitive Area											
April-17	50	59.4	52.8	104.3	18.8 %	40	56.1	43.1	71.4	40.3 %	30 Days
May-17	50	59.9	52.2	79.1	19.8 %	40	55.1	41.9	77.9	37.3 %	31 Days
June-17	50	60.5	52.7	89.7	21.0 %	40	58.2	44.4	70.2	45.5 %	30 days
July-17	50	62.8	38.6	111.1	25.6 %	40	61.9	46.7	110.9	54.7 %	31 Days
Aug-17	50	63.7	38.6	111.4	27.4 %	40	64.3	47.5	110.6	60.8 %	31 Days
Sep-17	50	56.8	43.6	102.7	13.6 %	40	55.4	42.1	84.8	38.5 %	30 Days
Oct-17	50	50.4	43.6	92.1	0.8 %	40	53.3	16.7	70.5	33.2 %	31 Days
Nov-17	50	55.2	43.6	87.9	10.4 %	40	54.8	23.3	69.6	37.0 %	30 Days
Dec-17	50	57.8	43.6	91.8	15.6 %	40	55.9	35.7	88.2	39.8 %	31 Days
Jan-18	50	54.7	43.6	85.1	9.4 %	40	52.1	21.0	78.7	30.3 %	31 Days
2. RVCE Mysore Road, Sensitive Area .											
April-17	50	44.07	47.6	110.9	Within limit	40	44.6	46.9	110.5	11.5 %	30 Days
May-17	50	49.4	48.7	109.2	Within limit	40	49.7	47.2	109.5	24.3 %	31 Days
June-17	50	59.3	52.0	73.7	18.6 %	40	54.0	45.7	74.9	35.0 %	30 Days
July-17	50	59.7	38.6	74.9	19.4 %	40	53.9	47.2	67.5	34.7 %	31 Days
Aug-17	50	58.7	38.6	74.9	17.4 %	40	53.5	46.5	65.4	33.8 %	31 Days
Sep-17	50	56.4	48.6	102.2	12.8 %	40	57.8	47.9	74.4	44.5 %	30 Days
1Oct-17	50	58.4	43.6	86.9	16.8 %	40	54.4	47.8	68.1	36.0 %	31 Days
Nov-17	50	57.2	43.6	73.9	14.4 %	40	55.1	47.2	69.2	37.8 %	30 Days
Dec-17	50	57.7	43.6	76.1	15.4 %	40	52.7	46.6	74.7	31.8 %	31 Days
Jan-18	50	57.8	43.6	79.3	15.6 %	40	53.2	43.3	80.2	33.0 %	31 Days
3. TERI Office, Domlur, Residential Area											
April-17	55	61.0	51.1	104.6	10.9 %	45	54.2	40.8	76.5	20.4 %	30 Days
May-17	55	61.4	52.5	86.4	11.6 %	45	56.1	40.8	86.9	24.7 %	31 Days
June-17	55	65.1	52.7	80.5	18.4 %	45	60.7	41.2	74.7	34.8 %	30 Days
July-17	55	65.5	38.6	81.6	19.1 %	45	60.2	43.1	74.2	33.7 %	31 Days
Aug-17	55	62.4	38.6	82.4	13.5 %	45	56.7	39.7	79.2	26.0 %	31 Days
Sep-17	55	62.1	48.6	104.5	12.9 %	45	55.2	40.7	76.8	22.6 %	30 Days
Oct-17	55	61.2	43.6	108.1	11.3%	45	51.4	38.0	109.3	14.2%	31 Days
Nov-17	55	54.4	43.6	109.6	Within limit	45	54.0	41.8	109.2	20.0 %	30 Days
Dec-17	55	60.9	43.6	109.6	11.8 %	45	61.2	41.8	109.0	36.0 %	31 Days
Jan-18	55	61.6	43.6	72.4	12.0 %	45	55.2	40.1	69.3	22.7 %	31 Days
4. BTM Layout, Residential Area											
April-17	55	64.9	60.9	71.1	18.0 %	45	64.3	61.4	72.4	42.8%	30 Days
May-17	55	65.6	57.7	80.9	19.3 %	45	65.8	52.9	91.3	46.2%	31 Days

June-17	55	67.0	62.0	85.0	21.8 %	45	66.5	60.1	80.0	47.8%	30 Days
July-17	55	68.1	38.6	95.4	23.8 %	45	68.2	63.2	87.9	51.5%	31 Days
Aug-17	55	65.6	38.6	87.6	19.2 %	45	65.6	61.7	83.3	45.8 %	31 Days
Sep-17	55	69.1	38.6	104.7	25.6 %	45	69.4	63.1	89.2	54.2 %	30 Days
Oct-17	55	64.2	43.6	75.4	16.7%	45	64.7	50.4	82.6	43.8%	31 Days
Nov-17	55	63.4	43.6	76.1	15.3 %	45	63.4	50.4	71.2	40.9 %	30 Days
Dec-17	55	63.1	48.6	70.8	14.7 %	45	64.8	50.4	78.4	44.0 %	31 Days
Jan-18	55	30.25	43.6	64.2	Within limit	45	50.4	43.9	82.4	12.0 %	31 Days
5. Regional Office Complex, KSPCB, Nisarga Bhavan, S.G.Halli, Residential Area											
April-17	55	54.3	42.2	80.5	Within limit	45	50.8	41.3	95.6	12.0 %	30 Days
May-17	55	44.3	41.4	85.2	Within limit	45	43.9	41.1	84.2	Within limit	31 Days
June-17	55	50.4	38.6	85.2	Within limit	45	53.2	41.6	77.3	18.2 %	30 Days
July-17	55	56.1	38.6	84.6	2.0 %	45	48.2	41.7	75.4	7.1 %	31 Days
Aug-17	55	56.3	38.6	81.3	2.4 %	45	47.9	41.1	71.2	6.4 %	31 Days
Sep-17	55	53.9	38.6	104.3	Within limit	45	49.2	41.6	71.9	9.3 %	30 Days
Oct-17	55	55.2	43.6	85.7	0.4 %	45	48.6	37.7	75.5	8.0 %	31 Days
Nov-17	55	54.7	43.6	80.7	Within limit	45	47.8	40.6	73.7	6.2 %	30 Days
Dec-17	55	54.2	43.6	82.5	Within limit	45	49.1	44.0	63.9	9.1 %	31 Days
Jan-18	55	21.4	43.6	69.2	Within limit	45	23.8	43.0	69.1	Within limit	31 Days
6. Parisara Bhavan, Church Street, KSPCB, Commercial Area											
April-17	65	66.1	55.7	75.4	1.6 %	55	59.6	49.1	73.2	8.3 %	30 Days
May-17	65	66.3	55.2	80.9	2.0 %	55	59.7	49.5	76.3	8.5 %	31 Days
June-17	65	66.3	38.6	79.1	2.0 %	55	59.2	49.0	76.0	7.6 %	30 Days
July-17	65	65.7	38.6	86.6	1.1 %	55	57.7	47.5	81.1	4.9 %	31 Days
Aug-17	65	65.6	38.6	80.1	0.9 %	55	57.6	48.6	78.3	4.7 %	31 Days
Sep-17	65	64.7	38.6	104.1	Within limit	55	58.2	48.6	77.3	5.8 %	30 Days
Oct-17	65	64.6	43.6	95.6	Within limit	55	59.1	47.9	75.9	7.4%	31 Days
Nov-17	65	65.5	43.6	80.3	0.8 %	55	58.4	48.3	79.6	6.2 %	30 Days
Dec-17	65	65.3	53.8	95.8	0.5 %	55	59.4	47.6	93.4	8.0 %	31 Days
Jan-18	65	64.1	43.6	84.5	Within limit	55	57.0	47.1	76.9	3.7 %	31 Days
7.CAAQMS of CPCB at BWSSB site, Kadubisanahalli Marathahalli, Commercial Area											
April-17	65	46.9	38.1	83.2	Within limit	55	44.6	28.7	74.1	Within limit	30 Days
May-17	65	43.1	21.3	90.1	Within limit	55	43.9	21.4	83.4	Within limit	31 Days
June-17	65	40.5	37.3	80.9	Within limit	55	41.6	41.9	70.2	Within limit	30 Days
July-17	65	39.6	33.8	98.4	Within limit	55	41.1	34.6	75.9	Within limit	31 Days
Aug-17	65	33.8	34.5	95.2	Within limit	55	30.1	37.8	89.7	Within limit	31 Days
Sep-17	65	48.4	34.8	84.5	Within limit	55	42.4	36.4	82.3	Within limit	30 Days
Oct-17	65	63.2	43.6	92.5	Within limit	55	63.2	23.2	93.5	14.9 %	31 Days
Nov-17	65	65.6	43.6	95.2	0.9 %	55	63.9	42.8	63.9	16.2 %	30 Days
Dec-17	65	64.5	41.6	106.4	Within limit	55	58.4	45.3	100.5	6.2 %	31 Days
Jan-18	65	53.9	43.6	83.4	Within limit	55	54.4	31.6	78.9	Within limit	31 Days
8.Yeshwanthpur, Police Station, Commercial Area											
April-17	65	71.7	66.9	103.2	10.3 %	55	62.8	54.2	81.7	14.2 %	30 Days
May-17	65	71.7	66.9	82.7	10.3 %	55	63.3	54.9	80.4	15.0 %	31 Days

June-17	65	72.0	67.2	79.3	10.7 %	55	64.1	55.7	74.3	16.5 %	30 Days
July-17	65	72.3	38.6	83.1	11.2 %	55	63.9	55.2	84.3	16.2 %	31 Days
Aug-17	65	72.0	38.6	82.9	10.8 %	55	64.5	54.7	111.4	17.3 %	31 Days
Sep-17	65	71.9	38.6	104.3	10.6 %	55	62.9	53.9	78.4	14.4 %	30 Days
Oct-17	65	71.6	43.6	80.1	10.1%	55	62.3	50.4	75.3	13.3%	31 Days
Nov-17	65	71.3	43.6	77.1	9.7 %	55	62.3	50.4	74.3	13.3 %	30 Days
Dec-17	65	71.1	48.6	85.3	9.4 %	55	61.7	50.4	71.3	12.2 %	31 Days
Jan-18	65	70.8	43.6	76.8	8.9 %	55	61.8	50.4	74.2	12.4 %	31 Days
9.Near ITPL, White field Industrial Area (Graphite India) Industrial Area											
April-17	75	65.3	60.0	104.0	Within limit	70	59.9	50.9	68.9	Within limit	30 Days
May-17	75	66.1	59.3	77.1	Within limit	70	60.9	50.5	73.1	Within limit	31 Days
June-17	75	67.5	60.6	78.5	Within limit	70	63.0	53.3	73.2	Within limit	30 Days
July-17	75	67.7	38.6	77.5	Within limit	70	62.9	54.0	74.8	Within limit	31 Days
Aug-17	75	67.7	38.6	78.5	Within limit	70	63.7	51.0	78.1	Within limit	31 Days
Sep-17	75	64.9	48.6	110.4	Within limit	70	61.8	50.2	109.3	Within limit	30 Days
Oct-17	75	60.7	43.6	111.8	Within limit	70	67.1	50.4	110.9	Within limit	31 Days
Nov-17	75	65.5	43.6	111.8	Within limit	70	66.7	42.6	111.9	Within limit	30 Days
Dec-17	75	65.6	43.6	110.8	Within limit	70	64.0	50.4	110.6	Within limit	31 Days
Jan-18	75	65.5	43.6	79.1	Within limit	70	60.9	50.4	70.4	Within limit	31 Days
10.CAAQMS of CPCB at ACE Manufacturing System, Peenya Industrial Area											
April-17	75	46.37	51.9	90.89	Within limit	70	47.4	51.1	95.2	Within limit	30 Days
May-17	75	27.8	47.7	104.2	Within limit	70	28.8	40.6	94.9	Within limit	31 Days
June-17	75	65.1	38.6	82.0	Within limit	70	56.0	49.5	75.9	Within limit	30 Days
July-17	75	64.2	38.6	94.2	Within limit	70	61.1	52.4	94.8	Within limit	31 Days
Aug-17	75	62.7	38.6	91.0	Within limit	70	61.5	51.1	89.9	Within limit	31 Days
Sep-17	75	63.9	43.6	88.0	Within limit	70	62.6	51.0	104.9	Within limit	30 Days
Oct-17	75	64.2	43.6	88.1	Within limit	70	62.8	50.4	104.9	Within limit	31 Days
Nov-17	75	67.4	43.6	89.7	Within limit	70	64.9	50.4	82.0	Within limit	30 Days
Dec-17	75	67.3	48.6	87.9	Within limit	70	62.8	50.4	83.7	Within limit	31 Days
Jan-18	75	63.1	43.6	89.8	Within limit	70	54.9	50.4	65.4	Within limit	31 Days

Note:

1. Day time shall mean from 6.00 AM to 10.00 PM
2. Night time shall mean from 10.00PM to 6.00 AM
3. Silence zone is an area comprising not less than 100 meters around Hospitals, Educational Institutions, Courts, Religious places or any other which is declared as such by the competent authority.
4. dB(A) Leq denotes the time weighted average of the level of sound decibels on scale "A" which is relatable to human hearing.
5. "A" decibel is a unit in which noise is measured.
6. "A" in dB(A) Leq, denotes the frequency weighting in the measurements of noise and corresponds to frequency response characteristics of the human ear.
7. "Leq" it is energy mean of the noise level over a specific period.

Source: KSPCB

14.3.10 Traffic Survey

14.3.10.1 Transport Characteristics

About 37% of the daily trips are Non-Motorized Transport (NMT) (1% by Bicycle + 36% by walk) trips. 51% of the trips are carried by Public transport, 46% of the trips by private vehicles and 3% of the daily trips by Intermediate Public Transport (IPT).

14.3.10.2 Vehicle Statistics

The number of registered vehicles in Bangalore has increased rapidly from 36.66lakhs (2011) to 71.08lakhs (2018). Two wheelers contribute about 72.22% of total vehicle population and Cars contributes about 20.15% of total vehicle population.

Table 14.4 Registered Vehicles for the year 2017-18 in Bangalore

Category of Vehicles Registered in Lakhs	2017-2018
Two Wheelers	51.34
Cars	14.32
Autos	1.85
Buses	0.96
Trucks	1.13
Maxi Cab	0.38
Tractors/Trailers	0.27
Others	0.83
Total	**71.08**

Source: Transport Department Annual Report 2017-18 (Table 35)

With increasing road traffic growth, Bangalore city faces raised level of injuries and fatalities. Level of fatality is an indication of road safety which should be monitored.

Table 14.5 Road Accidents in Bangalore City

YEAR	Fatal	Killed	Non-Fatal	Injured	Total
2006	880	915	6681	6048	7561
2007	957	981	7469	6591	8426
2008	864	892	6908	6150	7772
2009	737	761	6138	5668	6875
2010	816	858	5667	5343	6483
2011	727	757	5297	4976	6024
2012	740	760	4767	4471	5502
2013	737	771	4493	4289	5230
2014	711	737	4293	4096	5004
2015	714	740	4114	4047	4828
2016	754	793	6752	4193	7506
2017	609	642	4455	4256	5064
2018 (Nov)	594	611	3578	3752	4172

Source: www.bangaloretrafficpolice.gov.in

14.3.10.3Traffic Study along the Proposed Alignment (Extracted from Chapter3)

14.3.10.3.1 TRAFFIC AND TRANSPORTATION STUDIES

Traffic and Transportation Study analyzes the traffic volume and assesses the variation of traffic level, composition, growth rate and forecasts the future traffic for a particular location or area.

14.3.10.3.2 Study Area

The study area includes the Bengaluru Metropolitan Area (BMA area) i.e. 1307 Sq.km. (including part BMICAPA area – 65.31 Sqkm.) and adjoining areas around International Airport Area Planning Authority (BIAAPA). Adjoining BIAAPA area has been including in the study area as public transport corridors are connecting International Airport and some of the localities where proposed development has been listed out in BIAAPA Master Plan.

14.3.10.3.3Modeling Approach

An urban transport model to replicate the Bengaluru Metropolitan Area transportation system (roads, congestion delays, transit system, etc.) has been developed with a state-of-the-art software and modeling technology. This model would be used for forecasting, using altered model inputs to reflect future year scenario. By simulating roadway conditions and travel demand on those roadways, deficiencies in the system would be assessed. Potential major future network enhancements such as introduction of an MRTS or land use modifications would be analyzed using this tool. The model is planned is at an aggregated level and its efficacy can be established at a planning level.

There are several software programs that are available for developing travel demand models, however, the Consultant have used CUBE (a state-of-the-art Travel Demand Modeling software developed by CITILABS- USA) for developing the Transport Demand Model. It is important to note here that the transport model has been prepared for Bengaluru Metropolitan Region (8005 Sqkm) – a much larger canvas, than Bengaluru Metropolitan Area (1307 Sqkm) – the study area, considering the metropolitan character of the city and future growth in BMR.

The model is based on a conventional 4-stage transport model approach, which includes:

- **Trip Generation** - calculating the number of origins and destinations for each zone.
- **Trip Distribution** - attaching the origins and destinations for complete trips
- **Mode Choice** - determining the mode for each trip, car, Intermediate Public Transport (IPS, Public transport).

- Assignment - assigning passengers to their respective highway and transit networks.
- The details of the study are available in Chapter 3 of this Report

14.3.11 Water and Soil Quality

a. Water Quality

The extraction of data of ground water samples collected from bore wells at different locations for Phase 2A of Metro for analysis of Physico-chemical characteristics and the same has been used for Phase 2B Corridor. The collected samples were analyzed as per CPCB drinking water standards. The results of the samples are summarized below.

Table 14.6 Physico-Chemical Characteristics of ground water

Parameter	Observed range	CPCB Limits (Drinking water)
pH	6.95-7.51	6.5-8.5
Total Chlorides (mg/l)	112.14-265	250
Total Hardness (mg/l)	105.6-221	300
Calcium as Ca (mg/l)	35.27-60.74	75
Magnesium as Mg (mg/l)	13.15-32.14	30
Sulphate as So_3 (mg/l)	8.75-28.65	200
Nitrate as NO_3 (mg/l)	11.25-20.33	45
Total Dissolved Solids (mg/l)	415-518	500

Source: Phase 2A

The ground water samples collected shows that, most of the parameters analyzed were below the CPCB standards. However, the total Chlorides, Magnesium and Total Dissolved Solids are slightly higher as compared to CPCB standards. This may be due to industrial and high domestic discharge which leads to ground water contamination in city area.

b. Soil Quality

The extraction of data of the surface soil samples from a depth of 0 - 20 cm were collected for Phase 2A of Metro and collected samples were analyzed for soil Physico-Chemical properties. The results of the same have been used for Phase 2B Corridor. Bulk Density of soil ranges from 1.25-1.63 g/cm3. Thus, the porosity and water holding capacity also varies to a large extent and found to being the range of 38.1 - 51.7 % and 40.5 - 50.3 % respectively. The soil pH is ranging from 6.21 - 7.89 while Electrical Conductivity (EC) is ranging from 0.321- 0.885 dS/m. The soil organic matter measured in terms of Soil Organic Carbon (SOC) is very important from the point of soil health as it regulates soil physical, chemical and biological properties. The soil organic carbon was found to be in the range of 0.23 - 0.46 per cent. Slightly lesser range of organic carbon may be due to degradation of land from urban infrastructure activities which varies to a great extent depending on the land use. Similarly, the available N, P202 and K20 are also in lesser range compared to productive soils.

Table 14.7 Physico-Chemical Characteristics of Soil

Sl No	Parameters	Measured Range
1.	pH	6.21-7.89
2.	EC (dS/m)	0.321-0.885
3.	Bulk density (g/cm^3)	1.25-1.63
4.	Porosity (%)	38.1-51.7
5.	Water Holding Capacity (%)	40.5-50.3
6.	Organic Carbon (%)	0.23-0.46
7.	Available Nitrogen (Kg/ha)	223-378
8.	Available P_2O_3 (Kg/ha)	15.6-31.5
9.	Available K_2O (Kg/ha	156-321

Source: Phase 2A

14.3.12 Green Cover Assessment

a. Bangalore city has the dubious distinction of being one of the fastest growing metropolitan city in Asia. Despite this fast growth, Bangalore is still known as the 'Garden City of India' with well-planned parks and huge green spaces dot the city landscape, which is scattered over the city vast spread out areas. The city is continuously growing further with the surrounding villages and towns being absorbed into the city limits following the creation of Greater Bangalore. This has led to large scale conversion of agricultural lands, lakes and tanks to urban areas rapidly thus adversely affecting the environment and ecosystem of the city and the immediate fringe areas.

b. Green cover assessment study has been carried out to record the plant species existing all along the proposed Metro rail alignment. The trees from the central line of the alignment at distance of 0-5 m and in the area proposed to be acquired for elevated stations as per alignment drawing on google map were recorded. The trees likely to be cut or trimmed due to Metro rail alignment were identified. The girth of the tree was measured at a height of 1.0 m above ground and the height of the tree was measured through visual observation. Canopy cover was calculated by measuring the length of the longest branch in all the four directions (CEE, 1994). The tree biomass was estimated using Regression Equations available for each species.

c. Baseline Tree Resources: There is no forest area existing along the proposed alignment. The green cover on either side of the alignment and median of the road has been assessed and trees to be affected are identified and recorded.

14.4 Positive and negative Environmental Impacts

15.4.1 Employment Opportunities

The proposed Metro construction work is expected to commence from April 2020 and is expected to be operated completely by March 2024. There will be provision for employment during construction and operational phases of the project. During peak hour of the construction phase, manpower requirement will be more. Further, there will be several ancillary activities which give rise additional employment. It is estimated that, about 6600 people per day are expected to be deployed during the peak period of construction activity for the project. On an average **7.5** lakhs man-days are required annually. During operational phase, there will be employment generation for about 750 people for operation and maintenance of the proposed Metro rail network. In addition, more people would be indirectly employed for allied activities. Therefore, the proposed project is expected to create substantial direct and indirect employment opportunities during construction and operational phases.

15.4.2 Benefits of Economy

The proposed alignment will facilitate the commuters to use public transportation, this adds in to the state's economy. The Metro rail will greatly reduce the travelling time of the commuters and hence it will influence people to travel and invest in surrounding companies or industries. On the contrary socio-economic conditions of people along the corridor will also be benefited. The reduction in bus quantity and private vehicles directly reduces fuel consumption and pollutants. The proposed alignment will facilitate people to move quickly towards other parts of city, henceforth it is likely that people will be involved in trade and commerce and other services easily. Reduction in number of vehicles will also reduce the vehicle operating cost, fuel consumption, pollution load, accidents etc.

The number of vehicles plying on road will determine the periodicity of road maintenance. The proposed project will reduce the number of vehicles. The vehicle's wear & tear on the road surface will be reduced. Therefore, instead of regular maintenance of road, periodic maintenance can be carried out and it will reduce the city road maintenance cost significantly.

14.4.3 Reduction in Number of Vehicles on Road

The existing road network is used by pedestrians, cyclists, motorists, buses and trucks etc, this has caused traffic congestion. The factors responsible for the rise in vehicles are due to increase in income levels, preference of people of 20-35year age group to use personalized vehicles, and the absence of an adequate public transport system. Since the proposed alignment carries around 2004 passengers per trip, people will be encouraged to use public transportation to a larger extent because of its various benefits such as reduction in traveling time, safe/comfort journey and the cost will be reasonable. These factors will attribute in a substantial reduction of vehicles on the road.

14.4.4 Less Fuel Consumption

The main fuels used in vehicles are petrol, diesel and CNG. About three and half million vehicles are registered in Bangalore ply on its roads. Annual consumption of diesel and petrol is in the range of 4,50,000 and 2,50,000 T respectively which costs about 3000 crores to the State economy. Over the past 5 years, the consumption of petrol, LPG and diesel has been growing due to increase in human and vehicular population. The fuel consumption of vehicles plying on road parallel to the proposed alignment is calculated as per the alignment distance.

The projected vehicles in the proposed alignment from K R Puram to Airport will save 18000 liters / day of petrol and 9000 liters/ day of diesel after initiation of Metro rail.

14.4.5 Reduction in Air Pollution

The urban air pollution generally means unacceptable levels of pollutants emitted from vehicles such as Carbon Monoxide (CO), Hydro Carbons (HC), Nitrogen oxides (NOx), Sulphur Dioxide (SO_2) and particulates in the atmosphere. The environmental study conducted by CPCB/KSPCB indicates that the high level of air pollution in the Bangalore City is mainly due to urban transportation. The baseline environmental study carried out in the present study supports this statement. The survey conducted clearly indicates that two and three wheelers are seen predominantly on the proposed alignment. With the operation of both Phase-I and Phase-II corridors of Metro, many commuters are expected to shift from the private/public transportation to Metro rail. This shift will considerably reduce the usage of personalized vehicles, which is eventually reduced the air and noise pollution at source itself. Currently, the emission of CO, NOx and HC of vehicles plying on road is within the CPCB standard while particulate matter found to be exceeded the permissible limit. An attempt has been made to estimate the pollution load by colligating exhaust emission factor and the petrol consumption

14.4.6 Reduction in Passenger Time

The train is designed to travel around 90 kmph with an average speed of 36kmph from KR Puram to Yelahanka and 60 kmph from Yelahanka to Kempegowda International Airport. The carrying capacity of 6 coach train would carry 2004 passengers with longitudinal seating arrangement. The expected frequency of the train in the year 2024 is 5 minutes during peak hour from KR Puram to Yelahanka and 15 minutes between Yelahanka to Kempegowda International Airport accounting for 226 trips. Since the Metro is in urban area passengers will be more during day while hardly few passengers can be expected to travel at night. Considering the average train movement, around 18.11 lakhs passenger/day is expected.

The existing transportation system on the city roads takes 2.0 to 2.5 hours to reach Kempegowda International Air Port from KR Puram, while the estimated travel time using Metro rail takes <1 hour (with an average speed of 36kmphfrom KR Puram to Yelahanka and 60 kmph from Yelahanka to Kempegowda International Airport) to cover the same distance. Thus, the Metro rail used can thus cut down travel time by more than half which works out to a substantial saving on productive man hours and improve working efficiency. Considering an average 30 minutes' time savings / passenger / trip, per day (as per Economic Analysis) can save approximately 9.1 lakhs man hours.

14.4.7 Reduction in Accidents

As per the Bangalore traffic data, nearly 5802 deaths and 56251 accidents were reported in Bangalore during 2001-2007. According to the statistics obtained, the accidents in 2007 was in peak. But in the last three years, between 2008 and 2010, accidents have come down. During 2008, fatal ones decreased to 864 from 957 in 2007. Subsequently, number of persons killed decreased to 892 as against 981 in 2007. However, the traffic offenders have shot up from Rs 14 crore in 2003 to Rs 38 crore in 2009.Total fatal and non-fatal cases reported in the year 2017 are 5064 as compared to 7506 in the year 2016.

With the introduction of Metro, two, three and four wheeler vehicle category will be reduced significantly. As their population reduces there will be some marginal reduction in public bus usage hence this will also reduce the Congestion Index of the road. Induction of Metro rail will significantly reduce road related accidents and increase in speed with a greater public safety.

14.4.8 Improve City Aesthetic Value

Metro rail project will increase the city aesthetic value and will attract the investors from other parts of the city. Similarly, the construction of Metro rail will encourage the economic opportunities of the people residing along alignment by promoting both business establishments and tourism. The architecturally designed elevated corridor above the median of the road could be aesthetically pleasing to the people.

14.4.9 Impacts due to Project Construction

a. Air Pollution

The major source of air pollution during the construction is dust emission. This is due to the movement of vehicles carrying construction materials and workers moving in and around the project site. The emission from these vehicles depends on the type and capacity of the vehicles. It is anticipated that on a rough estimate, there would be average movement of 80 vehicles per day in a single alignment. As the vehicle movement is of temporary nature and restricted only to the construction period, these impacts relatively would be insignificant. However, efforts should be still made to minimize the dust pollution arising from these activities. Since there is no much demolition of structures along the proposed alignment, dust is not much envisaged.

b. Noise Pollution

Noise levels during construction will be from crushing plants, asphalt-mixing plants, movement of heavy vehicles, loading, transportation and unloading of construction materials etc. In addition to the noise mentioned above, there will also be background noise of the usual traffic resulting due to traffic congestion and confusion arising due to traffic diversion measures. Efforts should be made to keep the noise levels under control by appropriate noise attenuation and adopting employee safety measures. Temporary route direction markings will be placed in appropriate locations to avoid any confusion in the traffic rules and diversions.

c. Soil Erosion and Health Risk at Construction Site

The Phase 2B alignment from KR Puram to Kempegowda International Airport is entirely elevated section; hence excavation is minimal limiting only at the pillars. From the estimations made on the basis of preliminary drawings, it is estimated that the total quantum of excavated soil will be approximately of about 16.36 lakhs cubic meters and a portion of this can be used for backfilling. Dumping of construction spoils like concrete, bricks, waste material from camps etc. cause surface and ground water pollution. Movement of vehicles carrying construction materials/spoils will also cause dust to accumulate in air causing air pollution.

Health is usually affected due to lack of sanitation facilities (water supply and human waste disposal) and insect vector disease hazards of local workers. Problems could arise due to difference in cultural habits of imported workers and local residents.

d. Traffic Diversion

Temporary traffic diversion is essential for smooth flow during construction hence this will cause temporary impact on commuters using the existing roads. The signboards, flags and barricades will pose traffic congestion along the diversion. The temporary route selected will be in residential colonies hence this will cause traffic congestion in residential colonies and thus cause air and noise pollution. This impact is however only temporary in nature, as the diversion will last only till the construction phase is completed.

e. Impact on Water Quality

Due to increased sediment load near the construction site there will be degradation of nearby water sources. The movement of the soil sediment through runoff from the construction site will result in silt deposition in the low laying water bodies. Uncontrolled runoff would also carry soil nutrients to the water bodies and may induce eutrophication. This type of pollution is purely temporary and restricted only during the project construction period.

The length of this corridor is 36.678 km covering 17 stations. Hence the construction activity requires enormous amount of water. Some of the construction activities are concrete mixing, curing, washing, dust suppression etc. The water demand estimated for the proposed project is ≈ 1232 m^3/day. This requirement is met by the BWSSB recycled water and the additional water would be from private water supplier chain. Workers water demand will be fulfilled through ground water source.

f. Natural Disaster

The Bangalore city is not prone to floods. The city is located in seismically stable zone (Zone II) hence there is no major threat of earthquake. Hence any disaster activity from these natural causes can be expected to be minimal. The structure should follow specific design criteria for these seismic zones.

g. Loss of Historical and Cultural Monuments

The proposed alignment does not involve any loss of historical/cultural monuments and alignments are not coming under any sensitive areas.

h. Utility/Drainage Problems

The proposed alignment from KR Puram to Kempegowda International Airport is traversing along the Outer Ring Road. Number of sub-surface, surface and overhead utility services viz. sewers, water supply lines, storm water drains, telephone cables, overhead electrical transmission lines, GAIL Lines, electric poles, traffic signals etc. are existing along the proposed alignment. These utility services are essential and have to be maintained in working order during different stages of construction by temporary / permanent diversions or by supporting in position. The affected portion of the services with reference to the proposed alignment have been identified and details of existing utility services along the proposed alignment have been collected from the concerned authorities i.e. BWSSB, BSNL, BESCOM, GAIL, KPTCL.

Underground sewer/sanitary lines and water lines are infringing with the alignment. The diameter of sewer lines which are infringing are 300mm, 450mm, 600mm, 900mm, 1000mm, 1800mm. The diameter of water lines which are infringing are 150mm, 200mm, 250mm, 300mm,400mm, 450mm, 600mm, 800mm, 1300mm. However, the alignment/ spans shall be rearranged in order to avoid shifting of higher diameter utilities. In exceptional cases, where shifting of utilities is unavoidable, the diameter of affected utility shall be restricted to the minimum.

220/33kV and 220/66 kV OH electrical lines are crossing the alignment and hence need to be shifted. These utilities shall either be taken underground or their height shall be increased so as to provide the required clearance to the elevated Metro system.

i. Loss of Trees or Forest

The details of affected tree population are given in **Table 14.8**

Table 14.8 List of affected trees in Phase 2B KR Puram to Air Port line

Sl.No.	Locations	No. of trees to be
1	Stations	637
2	Road median (length of a tree: 8-10 feet)	963
	Total	**1,600**

Note: The trees along the median are small trees 8-10 feet height and with small girth. Only trees required for constructing pier will be cut and remaining will be allowed to grow underneath the viaduct.

14.4.10 Impacts due to Project Operation

a. Oil Pollution

Oil pollution is found during maintenance of rolling stock, change of lubricants, cleaning and repair processes. The spilled oil should be trapped in oil and grease traps. The collected oil should either be auctioned or incinerated, so as to avoid any underground/ surface water contamination.

b. Noise Pollution

The main source of noise during operation is from traction motors, cooling fans, wheel-rail interaction, electric generator and miscellaneous noise from rolling stock. The maximum speed of the Metro rail is about 90 km per hour and the average speed is about36kmph from K R Puram to Yelahanka per hour and 60 kmph from Yelahanka to Kempegowda International Airport. The noise produced by movement of train is mainly due to rolling stock and traction motor. The vibration of concrete structures also radiates noise and this has lower frequencies than rail wheel noise. The improved technologies in recent days will minimize noise sources.

c. Water Supply and Sanitation at Stations

Water is essential component in operation phase, the public health facilities such as water supply, sanitation and toilets are necessary at stations. As per the review, around 45 liters'/ day water is required for one person working at stations. The railway staff at each station is expected to be around 50 nos, therefore around 2,250 liters/day of water will be required for railway staff. The water requirement for the proposed alignment having 17 stations is 38250 liters/day. In addition, water demand at stations for cleaning, sanitation, firefighting and washing purpose will be about 425 m3/day. Municipal water or ground water supply will be tapped for drinking purposes. The sewage treated water from the nearest water treatment plant has been proposed for toilets cleaning, washing etc. As per the waste water discharge, about 0.425 MLD sewage treatment plant has been proposed

Water pollution may be due to spilling of oil, grease, fuel and paint in the equipment yards. However, since the Metro rail runs through electricity the quantities of such spills are very negligible.

d. Solid Waste Generation

The solid waste generated from stations and rail includes garbage, rubbish from wrappers, discarded boxes, rags etc. Based on the data generated, it is estimated that about 6 gm of refuse will be generated per person per day at Indian Railway Stations. There is no shop or cafes at these stations hence there is no much generation of garbage. Due to unavailability of solid waste data, it is assumed about 3g/person/day of refuse generation at the proposed Metro stations. Thus, it is estimated that about 5.06tonnes of solid waste is likely to be generated from the proposed Metro alignments. There has to be storage containers of 50 litres capacity for temporarily storing refuse and it should be equipped with side handles to facilitate handling. Generated solid waste will be disposed through approved solid waste recycling agencies.

14.4.11 Environment Impact Evaluation

The impact evaluation for Phase 2B from KR Puram to Kempegowda International Airport is obtained by considering physical, biological and socioeconomic parameters and public perception. Impact evaluation has been accomplished as per Batelle Environmental Evaluation System (BEES), USA. Parameter Importance Units (PIU) or Weighting Techniques is ranked for each environmental parameter. Based on the baseline and the predicted data an index is calculated in terms of Environmental Impact Unit (EIU) for each parameter and for different environment conditions.

$$EIU = \sum_{i=1}^{n} EQij.PIUi$$

EIU=Environmental Impact Unit

EQij=Environmental Quality Relative Scale value for i^{th} factor of j^{th} alternative

PIUi=Parameter Importance Unit for i^{th} factor

Environmental parameters have been identified under three categories viz Physical
Environment, Biological Environment and Socio-Economic Environment.

14.4.12 Checklist for impact identification

Assessment of the environmental impacts is conducted using Checklist. The checklist portrays environmental parameters or impact indicators and helps in identifying the potential impacts of the project. A typical checklist identifying the anticipated environmental impacts is shown in **Table 14.9**.

Table 14.9 Checklist for impact identification

Sl No	Parameters	No Impact	Negative Impact	Positive Impact	Remarks
1.0	**Impacts Due to Project Location**				
1.1	Projected Affected People		*		R&R will be according to NRRP 2003
1.2	Land Acquisition		*		Land requirement planned based on availability of open land
1.3	Loss of Trees/Forests		*		Afforestation @ 10 trees per tree cut. Green belt will be developed
1.4	Utility/Drainage Problems		*		Utility diversion will be taken care without any adverse effect
1.5	Aesthetics	*			
1.6	Natural Disasters	**			
2.0	**Impacts due to Project Construction**				
2.1	Air Pollution		*		The emission of vehicles will be monitored regularly
2.2	Noise Pollution		*		Noise reduction levels will be taken care
2.3	Soil Erosion and Health Risk at Construction Site		*		Reuse methods will be adapted
2.4	Traffic Diversion		*		Traffic management will be taken care
2.5	Impact on Water Quality		*		Water management practices
2.6	Construction Spoils		*		Disposed as per approved agencies
2.7	Loss of Historical and Cultural Monuments	**			
2.8	National Park/ZOO/Any other similar	**			
2.9	Water Requirements		*		Recycled water will be used for construction
3.0	**Impacts due to Project Operation**				
3.1	Oil Pollution		*		Waste management plan will be adapted

Sl No	Parameters	No Impact	Negative Impact	Positive Impact	Remarks
3.2	Noise Pollution		*		Not much envisaged
3.3	Water Supply and Sanitation at Stations		*		Water and waste management plan will be adapted
3.4	Employment Opportunities			**	
3.5	Benefits of Economy			**	
3.5.1	Reduction in number of vehicles on the road			**	
3.5.2	Less Fuel Consumption			**	
3.5.3	Reduction Air Pollution			**	
3.5.4	Carbon-di-Oxide Reduction			**	
3.5.5	Reduction in Passenger Time			**	
3.5.6	Reduction in Accidents			**	
3.5.7	Reduction in road maintenance cost			**	
3.5.8	Improve city aesthetic value			*	

14.5 Environmental Management Plan

The proposed alignment has more positive and less negative impacts on environment. The project provides quick and safe transportation, increase employment opportunity, reduce traffic congestion and increase economy. On the contrary some of the adverse effects have also been identified viz air/noise pollution, water pollution, soil pollution, land acquisition, rehabilitation, resettlement of people, traffic diversion, utility dislocation etc. These adverse impacts can be minimized by making necessary provision in design phase by implementing Environment Management Plans (EMP) and the management plan should be integrated in all phases of the project. An adequate amount of fund is essential to implement management plan. Environment Management Cell should be setup to provide training for employees to carryout out post monitoring actives. Environmental Management Plan discussed in the following section is to mitigate the adverse impacts caused by implementation of the proposed project and to maintain the quality of safe environment. It covers all aspects of planning, construction and operation of the project.

14.6 Environmental Monitoring

a. The Environmental Team shall carry out the monitoring of environmental impacts during construction. Representative sensitive receivers in the vicinity of the works shall be monitored for noise and air quality impacts.

b. For carrying out impact monitoring for noise and air, equipment shall be provided, operated and maintained by the Contractor. The equipment shall be kept in a good state of repair in accordance with the manufacturer's recommendations and maintained in proper working order with sufficient spare equipment available in the event of breakdown to maintain the planned monitoring program.
c. Suspended Particulate Matter (SPM) levels shall be measured by following the standard high volume sampling method as set out in High Volume Method for Suspended Particulate, BIS: 5182-1981
d. Engineer will undertake baseline monitoring to establish background levels. Action Level of the Contractor shall be based on the results of baseline monitoring program, which will be made available to him prior to start of construction.

14.7 Event Contingency Plan

The Engineers shall prepare an Event Contingency Plan under his Site Environmental Plan. The purpose is to provide, in addition to monitoring activities, procedures for ensuring that if any environmental exceedance of limiting values (either accidental or through inadequate implementation of mitigation measures on part of the Contractor) does occur, the cause is quickly identified and remedied, and that the risk of a similar event recurring is reduced.

14.8 Air Quality

a. The engineers shall take all necessary precautions to minimise fugitive dust emissions from operations involving excavation, grading, and clearing of land and disposal of waste. He shall not allow emissions of fugitive dust from any transport, handling, construction or storage activity to remain visible in atmosphere beyond the property line of emission source for any prolonged period of time without notification to the Employer.
b. The engineers shall use construction equipment designed and equipped to minimise or control air pollution. He shall maintain evidence of such design and equipment and make these available for inspection by Employer.

14.9 Water Quality

a. The engineers shall comply with the Indian Government legislation and other State regulations relate to water pollution control and monitoring. A drainage system should be constructed at the commencement of the Works, to drain off all surface water from the work site into suitable drain outlet.
b. The engineers shall provide adequate precautions to ensure that no spoil or debris of any kind is pushed, washed, falls or deposited on land

adjacent to the site perimeter including public roads or existing stream courses and drains.

c. The bentonite mixing, treatment and handling system shall be established by the contractor giving due regard to its environmental impacts. The disposal of redundant bentonite shall be carefully considered whether in bulk or liquid form.
d. The engineers shall take measures to prevent discharge of oil and grease during spillage from reaching drainage system or any water body. Oil removal / interceptors shall be provided to treat oil waste from workshop areas etc.

14.10 Landscape and Greenery

As far as is reasonably practicable, the engineers shall maintain ecological balance by preventing deforestation and defacing of natural landscape

14.11 Felling of Trees

Special care shall be exercised where trees or shrubs are exposed to injuries by construction equipment, blasting, excavating, dumping, chemical damage or other operation and the engineer team shall adequately protect such trees by use of protective barriers or other methods approved by the Employer. Trees shall not be used for anchorage.

14.12 Waste

The Environmental engineer is required to develop, institute and maintain a Waste Management Programme (WMP) during the construction of the project for his works, which may include: -

i) Identification of disposal sites.
ii) Identification of quantities to be excavated and dispose off.
iii) Identification of split between waste and inert material
iv) Identification of amounts intended to be stored temporarily on site location of such storage.
v) Identification of intended transport means and route.
vi) Obtaining permission, where required, for disposal.

The agency shall remove waste in a timely manner and dispose off at landfill sites after obtaining approval of the competent authorities namely BBMP, BDA, BMRDA, BWSSB.

14.13 Hazardous Waste Management

a. If encountered or generated as a result of project activity, then waste classified as hazardous under the “Hazardous Wastes (Management & Handling) Rules, 1989, amendments 2000, 2003” shall be disposed off in a manner in compliance with the procedure given in the rules under the aforesaid act.

b. Chemicals classified as hazardous chemicals under "Manufacture, Storage and Import of Hazardous Chemical Rules, 1989 of Environment (Protection) Act, 1986 shall be disposed off in a manner in compliance with the procedure given in the rules under the aforesaid act.

c. The engineer shall approach only Authorised Recyclers of Hazardous Waste for disposal of Hazardous Waste, under intimation to the Employer.

14.14 Energy Management

Measures to conserve energy include but not limited to the following:

i) Use of energy efficient motors and pumps
ii) Use of energy efficient lighting, which uses energy efficient luminaries
iii) Adequate and uniform illumination level at construction sites suitable for the task
iv) Proper size and length of cables and wires to match the rating of equipment
v) Use of energy efficient air conditioners

14.15 Occupational Health and Welfare

Physical fitness of workmen

a. The executive agency shall ensure that his employees/workmen subject themselves to such medical examination as required under the law or under the contract provision and keep a record of the same.

b. The contractor shall not permit any employee/workmen to enter the work area under the influence of alcohol or any drugs.

14.16 Medical Facilities-Medical Examination

The executive agency shall arrange a medical examination of all his employees including his sub-contractor employees employed as drivers, operators of lifting appliances and transport equipment before employing, after illness or injury, if it appears that the illness or injury might have affected his fitness and, thereafter, once in every two years up to the age of 40 and once in a year.

14.17 Occupational Health Centre

The executive agency shall ensure at a construction site an occupational health center, mobile or static is provided and maintained in good order. Services and facilities as per the scale lay down in Schedule X of BOCWR. A construction medical officer appointed in an occupational health center, possess the qualification as laid down in Schedule XI of BOCWR.

The following facilities shall be extended.

i. **Ambulance van and room**
ii. **First-aid boxes**
iii. **HIV/ AIDS prevention and control**

a. The contractor shall adopt the Employer's Policy on "HIV / AIDS Prevention and Control for Workmen Engaged by Contractors".
b. The contractor shall also extend necessary organizational support to the appointed agency for the effective implementation of the Employers' workplace policy on HIV/AIDS for workmen of the Contractors.
c. As laid down in the policy the contractor shall identify peer educators (1 for every 100 workers) and refer them for professional training to the Employers' appointed agency for the purpose.

iv. Prevention of mosquito breeding

Measures shall be taken to prevent mosquito breeding at site. The measures to be taken shall include:

a. Empty cans, oil drums, packing and other receptacles, which may retain water shall be deposited at a central collection point and shall be removed from the site regularly.
b. Still waters shall be treated at least once every week with oil in order to prevent mosquito breeding.
c. Contractor's equipment and other items on the site, which may retain water, shall be stored, covered or treated in such a manner that water could not be retained.
d. Water storage tanks shall be provided.
e. Posters in Kannada, Hindi and English, which draw attention to the dangers of permitting mosquito breeding, shall be displayed prominently on the site.
f. The contractor at periodic interval shall arrange to prevent mosquito breeding by fumigation / spraying of insecticides. Most effective insecticides shall include SOLFAC WP 10 or Baytex, The Ideal Larvicide etc.

v. Alcohol and drugs

a. The contractor shall ensure at all times that no employee is working under the influence of alcohol / drugs which are punishable under Govt. regulations.

Smoking at public worksites by any employee is also prohibited as per Govt. regulations.

14.18 Noise

a. Without prejudice to the generality of the foregoing, noise level reduction measures shall include the following:

i. The executive agency shall ensure that all powered mechanical equipment used in the Works shall be effectively sound reduced using the most modern techniques available including but not limited to silencers and mufflers.

ii. The Contractor shall construct acoustic screens or enclosures around any parts of the Works from which excessive noise may be generated.

b. In no case shall the Contractor expose the public to construction noise levels exceeding 90dBA (slow) or to impulsive noise levels with a peak sound pressure level exceeding 140dB as measured on an impulse sound level meter.

c. Where there are no ambient noise measurements, the construction activities shall be limited to levels measured at a distance of 200 feet from the construction limits or at the nearest affected building, whichever is closer, as given in **Table 14.10**.

Table-14.10 Allowable Construction Noise

LAND USE	**MAXIMUM NOISE LEVELS- L_{max} dB (A)**	
	Day Time	Night Time
Residential	75	65
At all Times		
Commercial	85	
Industrial		90

Table- 14.11 Construction Vibration Limits Vibration Type and Permissible

AGGREGATE DURATION	**LIMIT**
Sustained (1 hr/day)	0.01 in/sec (80 VdB re 10^{-6} in/sec)
Transient (<1 hr/day)	0.03 in/sec (90 VdB re 10^{-6} in/sec)
Transient (<10 min/day)	0.10 in/sec (100 VdB re 10^{-6} in/sec)

14.19 Control Requirements

Construction material should be operated and transported in such a manner as not to create unnecessary noise as outlined below:

i) Perform Work within the procedures outlined herein and comply with applicable codes, regulations, and standards established by the Central and State Government and their agencies.

a. Keep noise to the lowest reasonably practicable level. Appropriate measures will be taken to ensure that construction works will not cause any unnecessary or excessive noise, which may disturb the occupants of any nearby dwellings, schools, hospitals, or premises with similar sensitivity to noise. Use equipment with effective noise-suppression devices and employ other noise control measures as to protect the public.

14.20 Occupational Noise

i) Protection against the effects of occupational noise exposure should be provided when the sound level exceeds the threshold values as provided in Project SHE Manual.

ii) When employees are subjected to sound levels exceeding those listed in the Table, feasible administrative or engineering controls should be utilized as given in this document and BMRC's Project SHE Manual.

14.21 Vibration Level

In locations where the alignment is close to historical / heritage structures, the contractor shall prepare a monitoring scheme prior to construction at such locations. This scheme for monitoring vibration level at such historical / heritage sites shall be submitted to Employer for his approval.

14.22 Ventilation and illumination

i. Ventilation

The contractor shall ensure at a construction site of a building or other construction work that all working areas in a free tunnel are provided with ventilation system as approved by the DG and the fresh air supply in such tunnel is not less than $6m^3$/min for each building worker employed underground in such tunnel and the free air flow movement inside such tunnel is not less than 9m/min.

The oxygen level shall not be less than 19.5% in the working environment.

ii. Illumination

The contractor shall take every effort to illuminate the work site as per the Employer's requirement illustrated in general instruction ***BMRC/SHE manual***.

14.23 Radiation

The use of radioactive substances and radiating apparatus shall comply with the Govt. regulatory requirements and all subsidiary legislation

14.24 Welfare measures for workers

a. Latrine and Urinal Accommodation

The contractor shall provide one latrine seat for every 20 workers up to 100 workers and thereafter one for every additional 50 workers. In addition, one urinal accommodation shall be provided for every 100 workers.

When women are employed, separate latrine and urinals accommodation shall be provided on the same scale as mentioned above.

Latrine and urinals shall be provided as per Section 33 of BOCWA and maintained as per Rule 243 of BOCWR and shall also comply with the requirements of public health authorities.

b. Canteen

In every workplace wherein not less than 250 workers are ordinarily employed the contractor shall provide an adequate canteen conforming to Section 37 of BOCWA, Rule 244 of BOCWR and as stipulated in Rule 247 of BOCWR the changes for food stuff shall be based on 'no profit no loss' basis. The price list of all items shall be conspicuously displayed in such canteen.

c. Drinking water
As per Section 32 of BOCWA the contractor shall make in every worksite, effective arrangements to provide sufficient supply of wholesome drinking water with minimum quantity of 5 liters per workman per day. Quality of the drinking water shall conform to the requirements of national standards on Public health.

d. Labour Accommodation
The contractor shall provide free of charges as near as possible, temporary living accommodation to all workers conforming to provisions of Section 34 of BOCWA. These accommodations shall have cooking place, bathing, washing and lavatory facilities.

e. Creches
In every workplace where in more than 50 female workers are ordinarily employed, there shall be provided and maintained a suitable room for use of children under age of 6 yrs, conforming to the provisions of Section 35 of BOCWA.

14.25 Mitigation Measures

a. Compensation for Loss of Trees

The Tree authority is responsible for conservation and management of urban trees in the city. According to the Karnataka Preservation of Trees Act, 1976, the felling of trees should be regulated by planting adequate number of trees to restore ecological balance of the area. However, there is no restriction in felling of Casuarina, Coconut, Erythrina, Eucalyptus, Glyrecidia, Hopea, Wightina, Prosipis Rubber, Sesbania, Silver Oak and Subabul trees according to Karnataka Preservation of Trees Act, 1976.

Pending finalization of alignment and identification of species by tree officers the tree survey has been done by our own team based on alignment drawing on Google Map and following number of trees have been identified to be infringing the metro corridor. It is estimated that220 trees are likely to be lost due to the proposed corridor and the total value of these trees lost is Rs. 4.20lakhs. According to the MoEF guidelines for compensatory afforestation, entrees have to be planted for each tree cut. Hence, out of 1600trees, 1380 trees will be transplanted in the area identified by BBMP. Balance 220 being felled, amount for compensatory plantation of 2200 trees will be deposited to BBMP @ Rs.1911 /tree

(These trees would have occupied about 0.22 ha area). The cost includes saplings, tree guard, watering, control of pest and weed, trimming and maintenance for 5 years excluding the land cost. Thus, the compensatory reforestation cost for the proposed alignment will be 42.04 lakhs.

The alignment is predominantly above the road median or road center line. The alignment and stations is sited preferably where the loss of trees is negligible by trials of alternatives. It is emphasized to reduce the tree removal and where it is inevitable replacement of tree will be practiced strictly. According to the MoEF guidelines for compensatory afforestation, entrees have to be planted for each tree cut.

Environmentally beneficial tree species such as Micheliachampaca, Bauhinia variegata, Plumeria alba, Muntingiacalabura, Ficusreligiosa, Dendrocalamusstrictus,Caryotaurens,Azadirachtaindica, Pongamiapinnata has been proposed all along the station borders under compensatory afforestation. Apart from the above trees species few climbers and flower baring plants such as Jasmin, Thunbergia, Orchids, Thevetia, Cassia, Adhatoda, Euphorbia, etc., will also be integrated within the stations. These species not only give aesthetic look to the stations but also provide habitat for butterflies and birds.

As per the carbon sequestration estimate, one acre of 50-year-old forest can sink 1000 metric-tonnes carbon. Therefore, it is estimated that planting 2200 trees in 0.22 hectares of land under compensatory afforestation can sequester 543.4 metric tonnes of carbon in 50years, thus the proposed project can sequesteran average10.868Metric Tonnes of carbon in a year.

b. Green Belt Development

In addition to the compensatory plantation, green belt area can be developed for the total 36.678 Km under the elevated corridor using native shrubs, herbs and grasses. The design of the project shows that in the elevated section of the track, the lower edge of the track will be at 5.5 m height from the ground level with pillars at every 25 m interval, each pillar having 1.5 m diameter. A central ribbon area will be planted with small tree species which grows up to height of 4-5 m. The peripheral ribbons will be planted with grasses and perennial herbs interspersed with medicinal plants like Tulasi, Vinca, Evolvulus, Hemidiscus etc. Appropriate shade loving and light loving trees could be preferred depending on the location. Thus the green belt will provide aesthetic view of elevated track and also helps to serve as dust and noise absorbent barrier.

i. Cost estimates for 1 km Green belt development under the elevated track (width of ribbon = 1.5m) is calculated and presented in **Table 14.12**

ii. One row of small trees at three meter intervals in the central ribbon @ Rs. 125/sapling for 333 saplings (for 1 km elevated length) =Rs. 41600.00

iii. Small shrubs on both sides of central ribbon to cover 0.75 m width @ Rs. 50/sapling or 1333 saplings for two sides = 2666 seedlings
= Rs. 50 x 2666= Rs. 133300.00

iv. Grasses and perennial herbs on both the sides of 1000 m @ Rs. 50/m2 to cover balance 0.75 m width
= Rs. 50 x 0.75 m2 x 2000 m = Rs. 75000.00.

Table 14.12 Cost Estimate for Green Belt Development along the proposed alignment

Green Belt Type	Establishment cost for 1Km Rs	K R Puram to Airport(KIA) (36.678 Km) Rs
Small trees	41,600	15,25,805
Shrubs	1,33,300	48,89,177
Grass/herbs	75,000	27,50,850
Total	**2,49,900**	**91,65,832**

c. Translocation of trees

Among the 1600trees to be cut, about 1380 trees can be translocated to nearby park, which are having shallow root systems. This requires Rs. 10,750/tree towards translocation expense resulting in total Rs. 148.35 Lakhs is required to translocation of
1380 trees without any damage.

d. Water Supply and Sanitation

The water demand for the proposed project is expected to be around 1232 m^3/day and 986 m^3/day during construction and operation phases respectively. Much of the water required for construction would be met by treated water from nearest BWSSB and the additional water would be procured from private water supplier chain. Runoff from the construction site can be a source of water pollution. Cement based products/ dust carried by the runoff from the land surface can pollute surface water bodies. Surface covers are proposed to be spread on the land to prevent dust settlement on the land surface. Proper sanitary facility will be made available for the construction workers. The construction workers drinking water demand will be fulfilled only through ground water. Efforts shall be made to reduce the wastage of water during construction by encouraging water recycling techniques. During the operation phase, adequate water supply and sanitation facilities would be made available at all the stations.

e. Oil Pollution Control

There should be provision for the collection of oil and grease generated from construction equipment and sent for their treatments. Precautionary measures have been suggested to prevent these wastes moving in to ground or surface water bodies, as they are important sources of water for domestic use. Oil traps in the heavy machinery area are suggested to collect oil based materials. Similarly, sedimentation basins would be erected prior to the water discharge point to reduce the sedimentation load in the storm water. Since Metro rail is operated through electricity, there will be less chance of oil pollution.

f. Noise Pollution Control

For elevated corridors, ballast less track structure is supported on two layers of rubber pads to reduce noise and vibrations. In addition, baffle wall as parapets will be constructed upto the rail level so as reduce sound levels. Noise at source will be controlled or reduced by incorporating suitable feature in the design of structures and layout of machines and by use of resilient mounting and dampers etc.

To reduce the harmful effects, personnel working at high noise levels would be provided with noise protective gears such as ear mufflers, sound barriers etc. Vehicles used for transportation of construction materials would be equipped with proper silencers. Careful planning has been made to operate the construction equipment to have minimal disturbances. The construction equipment would be run only during the daytime and their noise would be monitored as per CPCB standards. Establishment of tree cover all along the corridor will further reduce the noise levels during operation phase. In addition, an appropriate chronological land use planning would be made available to prevent and minimize noise and vibration impacts.

g. Vibration Control

The vibration is generally caused from rail-wheel interaction. This can be reduced by minimizing any surface irregularities on the wheel and rail. To minimize the vibration shock absorbing pad has to be provided and there has to be a distance between rail seat assembly and concrete plinth.

h. Soil Disposal

The construction activities will generate approximately 9.4 lakhs cubic meter of soil/debris causing soil erosion during excavation. This can be mitigated by utilizing around 35 % of excavated soil for land filling purposes. The excavated top fertile soil is suggested to be preserved and used later for gardening and lawn establishment. Soil erosion by runoff will be controlled by installing proper drainage systems using contour information. Proper land use plan has been suggested with technical evaluation. It is suggested to avoid bringing soil from outside the project boundary and to use the excavated mounds for filling low laying area where it is necessary. Thus, both cost and time saving suggestions have been made in land leveling and soil transportation.

i. Rain Water Harvesting

Roof top rain water harvesting can be carried out at all stations. The rooftop of the stations will become catchment area for rain. Rain water will be collected and stored in a tank or diverted into artificial recharge tanks. This method is less expensive and very effective to augment the ground water level of the area. Rain Water Harvesting potential for 1000 sqm roof area will be 7, 68,000 liters annually based on the rainfall characteristics. Therefore, around 69907sqm of the station area can harvest approximately 53.69 million liters of rainwater annually in the proposed alignment from KR Puram to Kempegowda International Airport.

Table 14.13 Rain Water Harvesting potential along the proposed alignment

Items	**K R Puram to KIAL**
Station roof area	69907 (calculated)
Total rainfall available for harvest (Million liters)	53.69

j. Air Pollution Control

The main source of air pollution in the proposed project occurs only during construction. Transportation of construction materials, excavation and filling of land are the major sources of dust. This can be reduced to a greater extent by optimized use of soil material within the vicinity. Water should be sprayed at the construction site / vehicle movement areas regularly to reduce dust emissions. Adequate dust suppression measures particularly near habitation, such as water sprinkling, covering / area concealing etc should be practiced to control fugitive dust during construction. All vehicles, equipment and machinery used for construction shall be regularly maintained to ensure that the pollution emission levels to meet the prescribed norms of CPCB.

Vehicles carrying earth, cement and other construction material shall be suitably covered during transportation in order to reduce spreading of material all along the road. There will not be any built up pollutants in the long run. Operational phase will not have any impact and management plan may not be required as the Metro rail does not pollute environment.

During power failures, DG sets may be commissioned at stations. To monitor environmental quality, these DG sets will be monitored as per CPCB guidelines.

Some of the effective species which absorb air pollutants are Azadirachtaindica, Terminalia chebula and Dalbergiasissoo, Albiziaamara and Mangifera-indica are proposed along the road sides.

Table 14.14 - Pollution load details and monetary values

Type of vehicles	Total No. of vehicles	CO emission load (ton/km)	HC emission load (ton/km)	NOx emission load (ton/km)	TSP emission load (ton/km)
2-Wheeler	49531	0.4111073	0.25558	0.004953	0.004953
3- wheeler	24765.5	0.3033774	0.192428	0.002477	0.002477
Cars	116397.9	2.7970403	0.41554	0.182745	0.01164
Buses & HTV	81726.15	0.3580423	0.108451	0.676774	0.022475
Total pollution load		3.8695673	0.971999	0.866949	0.041544
cost saving 1,00,000Rs. / ton		386956.73	97199.88	86694.85	4154.413
Total cost of treatment for per day per km		575005.8743			
Total cost of treatment for per year per km		**20,98,77,144.00 Rs.**			

k. Utility Restoration

There are many utilities such as water supply and sewer pipe lines, storm water drains, telephone cables, overhead transmission lines, electric poles, sub ways, traffic signals etc. are essential and have to be maintained in working conditions during different stage of construction. These assets will be maintained without affecting any damages by shifting temporary/ permanently where it is necessary.

l. Disaster Management

Any unexpected event occurring due to sudden failure of the system like leakage of gas, external threats, internal disturbances, earthquakes, fire and accidents is termed as disaster. A Management Cell is proposed to act at a quick response in any emergency encountered.

For the proposed Metro project all relevant safety codes, acts and regulations such as Electricity Act, Explosive Act, Public Liability Insurance Act, Safety Codes, Policies and Guidelines laid down by Ministry of Railways should be observed during various stages of the project to minimize risk and disaster. Through good design, operation and maintenance and regular inspection any unexpected risks and disaster can be minimized. Hazard has to be controlled by minimizing and mitigating the risk and disaster.

To prevent any unexpected accidents, overall ramp safety management system approach is required that involves Risk Analysis and Risk Management. Risk Analysis involves establishing the organization's risk profile and risk management encompasses the various measures that can be implemented to minimize accidents, control loss and transfer risk by insurance on the basis of the identified risk profile of an organization. New safety assessment methods are needed to assess the safety of new concepts.

Workers need to be trained to mitigate the risk. In addition, workers should fallow the safety rules. Emergency medical aid has to be adopted in the event of accidents involving the hazardous substance. Good sanitation practices should be followed such as proper water supply, sanitation, drainage, health care and human waste disposal facilities etc. In addition, efforts shall be made to avoid water spills, adopt disease control measures and employment of local labour.

14.26 Summary of Costs

All costs involved in Environmental Management and monitoring has been taken into account in cost chapter. Overall cost for implementing environmental management plans is depicted in **Table14.15**

Table 14.15 Overall cost for implementing environmental management plans

Sl. No.	Item	Cost in Lakhs (INR)
1.	Compensatory Afforestation	42.04
2.	Green Belt Development beneath the elevated track	91.66
3.	Translocation of Trees	148.35
4.	Disposal of excavated soil	377.15
5.	Shifting of utilities/ drainage	19913
6.	Rain Water Harvesting	49.93
7.	Water Quality Epidemiological	75.43
8.	Air & Noise Monitoring	66.00
9.	Establishment of Environmental Management Cell	94.28
	Total	**20857.84**

14.27 Social Impact Assessment (SIA)

1. There would be less land acquisition involved for the construction of viaduct from KR Puram to Kempegowda international Airport. For station construction and entry structures, land acquisition is involved. In addition, the land acquisition would also be required for running the viaduct link line as single

lane towards Baiyappanahalli depot and Parking Area Near Hebbal elevated station.

2. The depot for this line is proposed to be located on the International Airport road on the left hand side, where 40 acres of land is available. Out of this 30 acres is Govt. land and 10 acres is Pvt. Land.

3. Social impact assessment and rehabilitation plan is required when the project results in either physical or economic displacement of the people. The proposed alignment will be on the median of the road from K R Puram to Hebbal and in the 5.0m dedicated strip of HSRL land between Hebbal to Trumpet, there will be no relocation of any residential buildings along the alignment. So, resettlement issue doesn't arise in this project.
    a. However, few shops and establishments need to be relocated along the proposed corridor. Compensation for relocation of these affected structures shall be paid. BMRCL has its own rehabilitation policy which was adopted for Phase-I of the Metro project. It is comprehensive and covers most of the aspects of National Rehabilitation and Resettlement Policy.
    b. A linking line starts from the existing ramp of phase-2 Reach-1 extension at Baiyappanahalli as Y junction crossing railway line and connects the proposed International Airport line at outer ring road after the flyover. Necessary land proposed for acquisition along this stretch is highlighted in Detailed Project Cost Estimate.

14.28 Conclusion

Above observations clearly shows that, the proposed Metro project provides various positive environmental impacts and comfortable journey to commuters. Some of the benefits are listed below,

a. Reduction in air pollution level is the single most important indication due to Metro Rail alignment and economic benefit due to reduction in Air Pollution is Rs 12 Cr for the Year 2024.
b. Metro Rail would effectively bring down the traffic congestion problems on city's roads and economic benefit due to savings in vehicle operating cost(VOC) both on account of Modal shift due to passengers opting for Metro and for non-Metro Users due to reduced congestion amounts to Rs 503 Cr for the Year 2024.
c. By using Metro, it will cut down travel time by more than half which works out to a substantial saving on productive man hours and improve working efficiency. Economic benefit on account of time saving due to reduction in travel time owing to Metro amount to Rs. 749.71Cr for the Year 2024.
d. Economic benefit due to reduction in Number of Accidents is Rs 2.17 Cr for the Year 2024.

e. Introduction of Metro Rail provides good infrastructure and improve city aesthetic and economic growth by attracting global investors. There will be less strain on the roads and consequently provides longer durability to the existing roads. Economic benefit due to Road Infrastructure Maintenance cost is Rs. 2.14 Cr for the Year 2024.
f. The proposed Metro will improve Socio-Economic benefits of the common Public through Employment, Trade and Tourism.

Chapter 15

Disaster Management & Security Measures

CHAPTER–15

DISASTER MANAGEMENT & SECURITY MEASURES.

15.1 Disaster Management, Disaster Management imperatives.

15.1.1 A disaster is a tragic event which arises out of events such as, Accidents, Fires, Floods, Earthquakes, Explosions etc. It is a situation when an organisation becomes immediately incapable to handle it.

15.1.2 A Disaster is a sudden or great calamity leading to deep distress affecting men and machinery. Many of the accidents/incidents lead to distress but only incidents where the extent of distress affecting passengers is acute shall come under the purview of disaster. All disasters are not accidents, neither are all accidents are disasters. Accidents are occurrences where safety has been affected, disasters are those situations which cause acute distress to passengers.

15.2 Need for Disaster Management

15.2.1 All transport systems are vulnerable to Disasters. The International Airport line is more vulnerable in view of connectivity to the International Airport and the international traffic.

15.2.2 Disasters can occur all of a sudden anytime and anywhere without any pre warning. But the impacts and after effects do not disappear as quickly as they appear.

15.2.3 The proposed K R Puram-International Airport line will mostly cater to the International Airport bound national and international travellers. In view of the security threats from anti-social elements from foreign lands a robust disaster management plan is to be in place.

15.2.4 Therefore, a proper disaster management plan is required to manage such disasters and to optimize the efficiency of planning and response is required. In order to meet the challenge, the organisation shall organise all the resources at its disposal, seek assistance of civil, government and other agencies, if required.

15.2.5 It is necessary that for disasters the action to be taken shall be so codified that the management of the disaster is initiated without any delay and the situation is tackled in the most appropriate and efficient manner so that distress is relieved expeditiously. BMRCL has a comprehensive disaster management manual where the actions are codified in detail.

15.2.6 The Metro Railway's Disaster Management Manual specifies the broad details of the action to be taken by various officials as soon as a disaster takes place in Metro Railway premises.

15.2.7 Depending on the magnitude of disaster the management is to be done with collaborative efforts of the organisation and civil/govt agencies. The objective of collaboration is to prepare for, respond to, and recover from emergencies and their effects in the shortest possible time.

15.3 Types of Disasters in MRTS

15.3.1 In any Mass Rapid Transit System disasters can be either due to Natural calamities or due to human or equipment failures.

15.3.2 Bengaluru city does not have a history of cyclones, typhoons of high velocity storms to affect the Metro Operations. The elevated corridor of Bengaluru Metro is not likely to be affected by floods and the underground section has adequate provision for drainage and pumping. The proposed K R Puram-International Airport line is not likely to be affected by floods.

15.3.3 With regard to earthquakes, Bengaluru city is located in the seismic zone (2) and the entire infrastructure of Bengaluru Metro is designed to withstand earthquakes of the intensity of 4 on Richter scale. Therefore, the proposed International Airport line is not likely to be affected.

15.3.4 However, in the event of any earthquake in Bengaluru city, detailed guidelines have been laid for the staff in Hand book for dealing disasters.

15.3.5 The following disasters due to equipment or human failure are likely to occur causing serious repercussions to the passengers and system assets.

i. Fire, smoke emission, Explosion in Metro premises including metro trains.
ii. Derailment of a passenger carrying train
iii. Collision of train/trains.
iv. Security threats/Terrorist attacks, widespread violence, bomb explosion and other insurgent activities.
v. Release of Chemical or biological gas in trains, stations or tunnels

15.4 Objectives of Disaster Management Plan, Systems to cater for disasters

15.4.1 Disaster management plan for BMRCL provides protection to travelling public, staff and other displaced persons. The following are the objectives of Disaster Management plan in the order of priority

i. To save lives and alleviate personal sufferings such as injuries and emotional stress following a hazard
ii. To attend to the injured rendering first aid and to move the seriously injured to the nearby hospitals.
iii. To provide help to the stranded passengers, by providing food, water, shelter etc and arrange their prompt evacuation
iv. To instil a sense of security amongst all concerned by providing accurate information
v. To protect Metro Rail property from damages

vi. To protect vital information and records, and ascertain the cause of the disasters.
vii. To expedite restoration of train operations

15.4.2 The following systems/facilities are available with Bengaluru Metro Railway to cater for disasters.

15.4.2.1 Medical Facilities:

i. For minor injuries and ailments, first aid boxes are provided in all trains and at all the metro stations.
ii. In case of any critical injuries/illness, private and state government hospitals are tied up with the metro organisation. Patients shall be referred to nearest hospital
iii. The hospital network in Bengaluru is widespread and is not more than one kilometre from any of the metro station.
iv. The proposed International Airport line has got multiple super speciality private hospitals along with the corridor.

15.4.2.2 Ambulance Service:

i. Plenty of private Ambulance services are available in Bengaluru City along with the ambulances attached to the private and government hospitals.
ii. Services of any of the ambulance can be obtained at short notice.

15.4.2.3 Fire Fighting Facilities:

i. Firefighting equipments available at all stations.
ii. Water Tanks for supplying water to fire hydrants
iii. Fire extinguishers, Fire Alarms and AFX machines (Automatic Fire Extinguishers)
iv. Hose pipes and Breathing Apparatus units at stations.
v. Fire buckets.
vi. Fire resisting clothing.

15.4.2.4 Telecommunication Facilities

i. Digital Telephone Communication
ii. Direct Line Telephone Communication
iii. Intercom Communication
iv. Digital Radio Communication (Tetra Radio Communication)
v. PIDS/PAS Control Terminals
vi. CCTV Monitors & Control
vii. Train Operators of trains may communicate with each other through Tetra communication telephone.
viii. Tetra communication telephones are provided with Traffic Controller, TPC and RS controller for intercommunication

among themselves as also with any subscriber provided with Tetra telephone unit.

15.4.2.5 AFC Control Equipment:

i. A computerized control has been provided with the Station Controller to enable him, among other functions, to control the operation of the AFC gates. Through this control, he may make gates inoperative or in case of emergency he may make all the gates free to enable faster movements of passengers through them. In case of emergency, needing quick evacuation of passengers from the station, he should set all the AFC gates free and the swing gates, which are kept normally locked, should also be opened for easy passage.

15.4.2.6 Power Change-over Switch:

i. In case of power supply failure in Station Controller service area the SC may operate this switch (which is a two position switch) through the use of which he may restore the power supply to all the equipments under his control by changing over to the alternate supply source.

15.4.2.7 Battery Operated Locos:

i. Two battery operated locos are available for dealing with disasters; one at Baiyappanahalli Depot and one is Peenya Depot. These locos can take relief trains to disaster sites inside tunnel and can be used for pulling out coaches of disabled train from inside the Metro System when 3rd rail power is not available. These locos shall be made available to other depots catering for the proposed line.

15.4.2.8 Road cum Rail (RRV) with Re-railing Equipment:

i. Accident relief train is available at two places, viz. at BYPT and PYND Car Sheds. Re-railing equipments are also available at these two places. These equipments can be taken by RRV to the site of disaster, either by road or by rail as required.

15.4.2.9 Pumps for de-watering tunnel accumulations: -

i. Pumps are provided at station sumps and these pumps are provided with "Liquid Level Controller" for operation. One/two or all the three pumps operate through liquid level controller for pumping out water from the tunnel depending upon the situation i.e. ingress and accumulation of water. These pumping installations are provided with duplicate power supply to ensure reliability.

ii. Spare high capacity pumps are available with Metro Railway as standby; to be installed and used as and when required.

15.4.2.10 Dispersal Facilities:

i. In cases of disasters, the main object is to disperse the affected persons, as early as possible, from the affected site of occurrence.

ii. This calls for proper dispersal facilities at stations so that a person can reach the surface with the least possible loss of time.

iii. Under the circumstances, the endeavour of the guiding Railway staff should always be to disperse the disaster affected persons through the nearest station.

iv. The dispersal arrangements as available at present, at platform levels and mezzanine levels, and on to the public roads on the surface are indicated in the plans formulated by Bengaluru Metro

15.4.2.11 Facilities available in trains:

i. For assistance to running staff and helping passengers, the following facilities are provided in trains with Train Operators.

1. First Aid Box
2. Fire extinguishers
3. Emergency door key (for detrainment of passengers through front door)
4. Door key (for locking of defective door)
5. Torch light (with dry cells)
6. Door operating facility from either end
7. Short Circuiting Device for earthing of Third Rail
8. Train Radio communication
9. Train PA system
10. Equipment for recorded announcement

15.5 Preparedness of staff for Disasters, Preparedness for Disaster Management, Authorities to be coordinated with in case of disaster, command & control of the National, state and District level.

15.5.1 Bengaluru Metro system is worked by a set of fresh staff with a learning curve to improve and stabilize with time.

15.5.2 Intensive mock drills for the staff are being carried out at regular intervals to train them to become fully conversant with the action required to be taken while handling emergencies.

15.5.3 The mock drills are carried out in the following fields:

i. Fire drills
ii. Rescue of disabled train
iii. Detrainment of passengers between stations
iv. Passenger evacuation from stations
v. Use of rescue and relief train.

15.5.4 The drills shall be held on the mainline only after revenue hours or in the depot in a manner which does not affect depot working adversely. The aim is to make the staff fully conversant with all the equipments and emergency procedure. Members of Disaster Management team will attend the mock drills.

15.5.5 The organization in Bengaluru Metro Railway for Management of Disasters has a standing Disaster Management Team having the following officers:

1.	Chairman & Coordinator	ED(O&M)	Incident commander
2.	Member	GM (RS)	Planning Officer
3.	Member	GM (S&T)	Planning Officer
4.	Member	DGM (O)	Chief of Operations
5.	Member	DGM (Sig)	Safety Officer
6.	Member	DGM (Tel)	Admin Officer
7.	Member	DGM (RS)	Logistic Officer
8.	Member	DGM (Traction)	Electrical Officer
9.	Member	DGM (P.Way)	Infrastructure Officer
10.	Member	CSO	Liaison Officer
11.	Member	CPRO	Information Officer

15.5.6 As soon as a disaster takes place the Chairman and the Members shall be informed regarding the situation so that the Team can start functioning in the management of the crisis.

15.5.7 Depending on the type and magnitude of disaster, it may become necessary to contact organizations other than Metro Railway and seek their assistance for management of disasters. Disaster Management committees function at every level viz. District level, station level and national level.

15.5.8 At the district level the Disaster Management committees function under the District Collectors with members from various departments including health and Police.

15.5.9 At the state level State Disaster Management Force (SDRF) headed by the Chief Secretary with Members from different departments and Scientific organizations

15.5.10 At the national level a specialised force NDRF comprising 12 battalions of 13000 Para military forces is under the control of NDMA to manage the disasters. National Disaster Management Authority (NDMA) is a nine member board headed by the Prime Minister of India with Members nominated based on their expertise in areas such as, planning, infrastructure management, communications, meteorology and natural sciences

15.5.11 The services made available by the authorities shall be entirely under the exclusive control and command of Incident Commander of Disaster Management Committee.

15.5.12 The contact nos. of such organizations should be available with all station controllers and the Traffic Control and Traction Power Control and with all the members of the Disaster Management Team.

15.6 Security measures, essentials of security management. Security system design parameters, door frame metal detectors, X-ray scanning etc.

15.6.1 Every transport system poses risks and threats from anti-social elements, criminals and terrorists to its system and its network. In order to prevent such risks, the transport system needs to have a security plan.

15.6.2 The proposed K R Puram-International Airport line poses greater risks and threats in view of the connectivity to the International Airport.

15.6.3 A security plan is a set of rules that apply to all activities that belong to an organization. These rules cover areas such as physical security, personnel security, administrative security, and network security.

15.6.4 The security policy defines what is required to be protected and what is expected of the system users. It provides a basis for security planning for the existing system and design new applications or expand the network.

15.6.5 It describes responsibilities of both system provider and users of the system. The security policy also describes how the provider will monitor the effectiveness of security measures. Such monitoring helps to determine whether someone may be attempting to circumvent the safeguards.

15.6.6 The following security measures are provided by Bengaluru Metro to prevent untoward incidents, crimes, terror threats etc:

15.6.7 Security at Entrances:

15.6.7.1 The commuters shall be subjected to security checks at the entry gate/before entering the paid area. All the security equipments like Door Frame Metal Detector (DFMD), Hand Held Metal Detector (HHMD), X-Ray Baggage Inspection system (BIS), are installed at the 1st entry point in metro stations.

15.6.7.2 Frisking booth is provided at each entry points. Separate Ladies' Frisking Booth (covered space) is also provided at each entry points.

15.6.7.3 At a few places, DFMDs are kept at the 1st entrance and other equipments installed inside at convenient locations before AFC due to space constraint.

15.6.8 Biometric Access

15.6.8.1 Vital non-public areas in stations consisting of Station Controller's room, signalling and telecom maintenance and equipment rooms, Electric Substation etc. shall be provided with strong doors which are normally closed and opened using biometric access control system.

15.6.8.2 Biometric Access control system based on finger prints for employees and outsourced staff shall be provided to enter Depot and other vital installations. Contractor labors will be allowed entry with written permission from authorized BMRC official supported with ID card issued by the contractor.

15.6.9 CCTV surveillance

15.6.9.1 All stations, Depots, Operations Control Centre (OCC), trains and all vital installations and machinery, shall be elaborately covered with CCTV surveillance. At stations, CCTV Cameras of Fixed/PTZ types are provided for cover operational area of Platforms and public area of concourse.

15.6.9.2 All the CCTV cameras over the entire network can be monitored from the security surveillance room at the OCC.

15.6.9.3 CCTV fixed cameras are also installed at important passenger areas like, outside Ticket Office Machines (TOMs,) AFC Gates, Lifts/Escalators, station entry gates, emergency exit and platforms. CCTV MMI — CCTV monitor MMI with key board with soft and hard control(joystick) facility is provided in SCR with the help of which Station Controller can select any camera within station premises and zoom PTZ for specific area for the purpose of monitoring.

15.6.9.4 Every coach is provided with four CCTV Cameras and the Train Operator is provided with video monitor and Radio contact with OCC. The analysis shall help real time monitoring inside coaches by the Train Operator and also from the OCC.

15.6.9.5 CCTV Recording — for recording of images from cameras at stations and the adjoining station facilities are provided in Telecom Equipment Room (TER). The images can remain stored for a minimum period of 7 days. Required footage can be permanently saved for further reference/investigations.

15.6.10 Video analytics

15.6.10.1 Video analytics software to detect unusual behavior/movement, Line control, overcrowding, camera tampering, unattended baggage etc. shall be provided. The analysis shall provide information and data for incidents like crossing the tracks, placing an object on the tracks. This helps in providing Preliminary alert and incident prevention, alerting to illegal access to restricted area and reducing the risk of electrocution.

15.6.10.2 The analysis shall detect intrusion to tracks like failing, jumping, crossing on tracks, placing an object on the tracks intentionally or accidentally. This shall help preliminary alert and incident prevention, reduction in system down time and preliminary alert reducing physical damage to the train and passengers

15.6.10.3 The analysis shall help overcrowding detection on escalators and stairs, at concourse area and on platforms, this shall help reducing the risk of people falling onto the tracks, reducing the risk of injuries, reducing the risk of criminal activities like Pick pocketing, sexual harassment, violence between passengers risk of verbal and physical confrontation between passengers and staff. This shall also help in improving the service provided to users.

15.6.10.4 The analysis shall help in quick detection of any Improvised Explosive Devices. This shall help in preventing any explosion and causing injuries and causalities.

15.6.10.5 The analysis shall help detecting unauthorised entry to non-public areas like station control rooms, electrical sub stations during closing hours and preventing theft, vandalism and sabotage of equipment. This shall help prevention of unauthorised entry and monitoring the closing and opening time of station

15.6.10.6 The analysis shall help Reduce the risk of vehicle Borne Improvised Explosive Devices. This shall help Detect unauthorized/illegal parking for safety purposes.

15.6.10.7 At parking areas contractor who are operating the Parking Space shall be responsible for security of this area.

15.6.11 Emergency Fire Exits fitted with intrusion detection system shall be provided with alarm panels at SC rooms, OCC and Central security control room which shall be integrated with CCTV surveillance system. Adequate arrangements for firefighting in metro trains, stations and Depot shall be made.

15.6.12 Separate room shall be allotted in metro stations/depot for Quick Reaction Team (QRT), Bomb Detection and Disposal Squad (BDDS) and Dog Squad are with the state police and their services will be called as and when required.

15.6.13 Retail commercial areas shall be located only in unpaid areas. Personnel and merchandise will be subject to security check at the 1st entry point itself. In case of Malls/multiplexes, X-Ray BIS shall be used at the metro entry point for scanning of incoming materials.

15.6.14 Contingency plans shall be prepared for various disasters like terrorist attack, bomb threat, Fire, Train accident, Chemical, Biological, Radiological, Nuclear (CBRN) attack etc. and periodic mock drills shall be conducted to manage mass causality situations.

15.6.15 As modern explosives contain chemical, radiological, biological agents, X-Ray baggage inspection system cannot detect these agents. Metro network shall have sensors at stations to detect these kinds of explosives.

15.6.16 Security/Metro staff shall be trained on CBRN mitigation aspects with the help of State Disaster Management Agency (SDMA), National Disaster Management Agency (NDMA) and National Disaster Response Force (NDRF). Provision for incident command post, digital maps, walk through models of stations etc shall be made.

15.6.17 Quick Reaction Teams consisting of armed personnel shall move about around the system during operation hours.

15.6.18 Security of entire metro network is the responsibility of the BMRCL Security Organisation which is headed by the Chief Security Officer (CSO) and assisted by Fire Officers and the personnel of KSISF.

15.6.19 The CSO will take all steps as are considered necessary with respect to the security and protection of metro property, staff and passengers. Adequate protection shall be made available at all times, to maintain essential metro services and ensure safety of, Depots and all Installations like RSS, TSS, DG Room etc, Stations, Viaduct, Tunnels and Track, Critical Locations, Metro Property, Passengers & Passenger area

15.6.20 The underground stations shall have adequate and proper security management and planning system due to multiple entry-exit points as threat sensitivity is the highest in the Metro's underground sections.

15.6.21 If it is necessary to obtain Police or military aid, it will be the responsibility of the CSO to liaison with the concerned authorities and arrange for it.

15.6.22 The CSO will employ specially selected officers to obtain secret/confidential information on all matters relating to security and Liaisoning with management and civil police.

15.6.23 The architectural design of Bengaluru Metro stations, viaduct and other installations are well designed to employ the crime prevention principles. Metro Rail depots, OCC and other important installations are well protected through perimeter walls, watch towers, special access gates, surveillance, day and night patrolling, etc.

15.6.24 Trains are subject to thorough anti-sabotage checking in the depots and stabling yards before the start of daily operations. Security rooms at each station and special facilities for centralized monitoring at the central security control room are provided.

15.6.25 Security for the project works in BMRCL is provided as part of the General Security provided to the city of Bengaluru by the Bengaluru City Police.

15.6.26 Government of Karnataka (GOK) is proposing to establish Karnataka Industrial Security Force (KISF) on the lines of CISF. Once KISF comes into being, the security will be provided by KISF. The command structure/supervision level of KISF will be decided by DGP/Karnataka.

15.6.27 Till such time the KISF is operational, Bengaluru Metro is provided with a three-tier security to achieve the security objectives.

15.6.27.1 Lower level Tier-1 security shall be done by a private agency, which would be doing the routine security duties, including physical security, access control/detection, screening of baggage, frisking and guarding of vital installations and general security duties in the train, station and depot. The agency also provides the services of X-Ray BIS, HHMDs, DFMDs and Ladies' Frisking Booth. At each station entry constables with a lady constable shall be operating in shifts with at least one armed guard for each entry.

15.6.27.2 The Tier-2-Middle Level Security is provided by BMRCL. This includes electronic surveillance system with blanket cover of the station areas and vital installations inside and at the gate of Depot by CCTV with video analytics, biometric access control system based on fingerprint, Turnstile gate and electronic barrier at Depot gate etc.

15.6.27.3 The High Level Tier-3 Security shall be provided by the Bengaluru City Police. The responsibility of the Bengaluru City Police includes supervision of security guards provided by the Private Agency, provision of the gadgets and equipments required for security like Dog Squad, Bomb Detection and Disposal Squad etc. The State Police is also coming up with a separate Metro Police Station at Baiyappanahalli.

15.7 Security systems recommended for MRTS.

15.7.1 Every transport system poses risks and threats from anti-social elements, criminals and terrorists to its system and its network. In order to prevent such risks, the transport system needs to have a security plan.

15.7.2 A security plan is a set of rules that apply to all activities that belong to an organization. These rules cover areas such as physical security, personnel security, administrative security, and network security.

15.7.3 The security policy defines what is required to be protected and what is expected of the system users. It provides a basis for security planning for the existing system and design new applications or expand the network.

15.7.4 It describes responsibilities of both system provider and users of the system. The security policy also describes how the provider will monitor the effectiveness of security measures. Such monitoring helps to determine whether someone may be attempting to circumvent the safeguards.

15.7.5 The success of any security system on any metro depends on factors like:

i. Architectural design, which employs crime prevention principles;
ii. Vigilant maintenance policies; and
iii. Stringent enforcement of rules and laws.

15.7.6 Every Mass Rapid Transit System should have a multiple layer advanced security system, along with the latest equipments, gadgets to protect the commuters and the assets of the MRTS.

15.7.7 Bengaluru Metro began operations in October 2010. Since then it has been one of the safest, relatively "crime-free" metro systems. No major security incidents have occurred since the commencement of operations.

15.7.8 BMRCL is provided with most advanced security system which is proposed to be extended to the new line, can also be recommended for all other MRTS.

Chapter 16

Project Cost Estimates

CHAPTER 16

DETAILED COST ESTIMATES

16.1 Capital cost of the project

a. The revised detailed cost estimates for Bengaluru Metro Phase-2B from K R Puram to Kempegowda International Airport have been prepared covering Civil, Electrical, Signaling and Telecommunication Works, Rolling Stock etc., considering 750V DC 3rd Rail Traction at February 2019 Price level of MoHUA.

b. While preparing the cost estimates, of various components, have generally been grouped under three major heads on the basis of (i) Total length of alignment, (ii) Number of units of that items and (iii) Items being an independent entity. All items related with Elevated alignment, stations, Permanent way, Traction, Signaling & Telecommunications, whether on mail line or in maintenance depot, have been estimate at the rate per km basis as per MoHUA guidelines. Present cost of each civil component of BMRCL is compared with LARs (Last Accepted Rates) of BMRCL and also with the rate analysed based on KPWD schedule of rates. It was found that the bench marking cost for different components are lower than BMRCL cost. Therefore, only the bench marking cost as given in MoHUA report of Feb 2019 have been adopted in the revised DPR.

c. Further the entire stretch of metro alignment for Phase-2B was originally planned as elevated section from KR Puram to KIAL terminal. In order to bring down the project cost, the metro alignment is now planned at grade as much as possible near IAF Yelahanka and within Airport boundary for about 3.6 km with on IAF and BIAL consent. The cost of the alignment at these locations is considered as Rs. 24.78 cr/km as against MoHUA bench marking cost of Rs. 37 cr/km in the DPR which results in saving of about Rs. 12.22 cr/km in-turn leading to overall savings of Rs. 44 cr.

d. Cost thus arrived based on MoHUA guidelines is detailed as below-
   1. Alignment elevated/at-grade : MoHUA February 2019 rate + taxes 12% +PV as per MoHUA guidelines.
   2. Station buildings (Civil & E&M)
      a. Civil: MoHUA Feb 2019 rate + taxes 12% +PV as per MoHUA guidelines.
      b. E&M: MoHUA Feb 2019 rate + taxes 18% +PV as per MoHUA guidelines.
   3. Permanent Way: MoHUA February 2019 rate + taxes 12% +PV as per MoHUA guidelines.
   4. Traction & Power Supply & E&M Station Works: MoHUA February 2019 rate + taxes 18% +PV as per MoHUA guidelines.
   5. Signalling & Telecom: MoHUA February 2019 rate + taxes 18% +PV as per MoHUA guidelines.
   6. AFC: MoHUA February 2019 rate + taxes 18% +PV as per MoHUA guidelines.
   7. PSD: MoHUA February 2019 rate + taxes 18% +PV as per MoHUA guidelines.
   8. Utilities, cable trough and Signages:
      a. Utilites:MoHUA Feb 2019 rate + taxes 12% +PV as per MoHUA guidelines.

b. Cable trough:September 2018 price + taxes 12% + PV as per MoHUA guidelines.

c. Signages:September 2018 price + taxes 18% + PV as per MoHUA guidelines.

9. Multimodal Integration Works: MoHUA February 2019 rate + taxes 12% +PV as per MoHUA guidelines.
10. Depot E&M Works:
    a) Civil: MoHUA Feb 2019 rate + taxes 12% +PV as per MoHUA guidelines.
    b) E&M & M&P: MoHUA Feb 2019 rate + taxes 18% +PV as per MoHUA guidelines.
11. Rolling Stock: MoHUA February 2019 rate + taxes 12% +PV as per MoHUA guidelines
12. Security: MoHUA February 2019 rate + taxes 12% +PV as per MoHUA guidelines.
13. Road Restoration: September 2018 prices + taxes 12% +PV as per MoHUA guidelines.
14. Land: Prevailing area wise rates and guidance value of September 2018.

e. Contingencies at 3% of the cost have been considered for all items except Land cost including taxes to account for Consultancies and Variations during construction and implementation of the project.

f. Similarly, 5% of the project cost excluding Land cost and including contingencies towards Departmental and General charges as necessary for implementation of the project.

g. Interest during construction is considered for Rs. 536.76 Cr as necessary for implementation of the project.

h. The overall revised capital cost of Bangalore Metro Phase-2B in line with MoHUA February 2019 rates Rs. 9934.58 Crores for the Airport line from KR Puram to Kempegowda International Airport. The cost details including Taxes and Duties and excluding contingencies are given separately. The capital cost estimate is shown in the **Table16.3.**

16.2 Civil Engineering Works

16.2.1 Alignment/Viaduct

The cost of the Viaduct from KR Puram to Kempegowda International Airport (Phase 2B) for 34.84 km is Rs.1289.08 Cr (Excluding taxes) as per MoHUA February 2019.

In the proposed corridor, 1.0 km length of Ramp is expected for which the cost considered is Rs.22.36 Cr. Further for length of Alignment at grade of 2.00 Km and Alignment with covered shell of 0.6 Km the cost considered is Rs.44.72 Cr & Rs.22.12 Cr respectively (the rates are based on September 2018 prices).

Additional cost towards portal piers and special spans for railway crossings is considered for Rs. 2.11 Cr. & Rs. 46.28 Cr. (the rates are based on September 2018 prices).

Thus the total cost of viaduct portion is worked out to Rs. 1426.67 Cr (Excluding taxes).

16.2.2 Station Buildings:

I. Civil works:

a. The cost of 16 elevated stations including civil finishes as per MoHUA February 2019 rate (Rs. 26.00 Cr per station) is Rs. 416.00 Cr (Excluding taxes).

b. Cost of one partialy underground station at Airport terminal at the rate of 50% of MoHUA February 2019 rate (Rs. 125.00 Cr per station) is Rs. 62.50 Cr (Excluding taxes).

c. Additional cost towards area of property development is lumpsum of (Rs. 1.08 Cr per station) Rs. 17.28 Cr (Excluding taxes).

d. Additional cost towards pedestrian walk way from Horamavu metro station to Underpass junction is lumpsum of Rs. 2.24 Cr (Excluding taxes).

e. Additional cost for FOB/Subway 70 mtr length for 6 stations across National Highway is lumpsum of Rs. 1.88 Cr (Excluding taxes).

f. Additional cost towards 10% increase in area in Kempapura station and KIA Terminals station due to increase in platform width is lumpsum of Rs. 3.50 Cr (Excluding taxes).

II. E&M works:

a) The cost of 16 elevated stations as per MoHUA February 2019 rate (Rs. 8.00 Cr per station) is Rs. 128.00 Cr (Excluding taxes).

b) Cost of one partialy underground station at Airport terminal at the rate of 60% of MoHUA February 2019 rate (Rs. 50.00 Cr per station) is Rs. 30.00 Cr (Excluding taxes).

Thus the total cost of 17 elevated stations for Civil & E&M works is worked out Rs. 661.40 Cr (Excluding taxes).

16.2.3 Permanent Way

a) The cost of ballastless track for 38.44 Kms based on MoHUA February 2019 rate (Rs. 6.60 Cr per Km) is Rs. 253.70 Cr (Excluding taxes).

b) The cost of ballasted track for 18.50 TKM based on MoHUA February 2019 rate (Rs. 3.90 Cr per Km) is Rs. 72.15 Cr (Excluding taxes).

Thus the total cost of Permanent way is worked out to Rs. 325.85 Cr (Excluding taxes).

16.2.4 Traction & power Supply :

a) The cost of Traction & power supply for elevated section for 38.44 Kms based on MoHUA February 2019 rate (Rs. 11.00 Cr per Km) is Rs. 422.84 Cr (Excluding taxes).

b) The cost of Traction & Power supply for depot for 18.5 TKM based on MoHUA February 2019 rate (Rs. 3.00 Cr per TKM) is Rs. 55.50 Cr (Excluding taxes).

c) The cost of 2 RSS as per MoHUA February 2019 rate (Rs. 25.00 Cr per RSS) is Rs. 50.00 Cr (Excluding taxes).

d) Additional cost towards RSS incoming cables of 23.8 Circuit Kms length (above 0.5 Kms) is lumpsum of Rs. 84.84 Cr (Excluding taxes).

Thus the total cost of Traction & Power Supply work is worked out to Rs. 613.18 Cr (Excluding taxes).

16.2.5 Signaling & Telecomunnication:

I. Signaling

a) The cost of Signalling for main line including OCC/BCC for 38.44 Kms based on MoHUA February 2019 rate (Rs. 4.40 Cr per Km) is Rs. 169.14 Cr (Excluding taxes).

b) The cost of Signalling in Depot including DCC for 18.50 TKM based on MoHUA February 2019 rate (Rs. 3.20 Cr per TKM) is Rs. 59.20 Cr (Excluding taxes).

c) The cost of onboard equipment based on MoHUA February 2019 rate (Rs. 1.70 Cr per train) is Rs. 35.70 Cr (Excluding taxes).

Thus the total cost of Signalling is worked out to Rs. 264.04 Cr (Excluding taxes).

II. Telecomunnication:

a) The cost of Telecommunication works for 17 elevated stations as per MoHUA February 2019 rate (Rs. 4.50 Cr per station) is Rs. 76.50 Cr (Excluding taxes).

b) The cost of Telecommunication works for 2 depots works as per MoHUA February 2019 rate (Rs. 3.50 Cr per depot) is Rs. 7.00 Cr (Excluding taxes).

Thus the total cost of Telecommunication is worked out to Rs. 83.50 Cr (Excluding taxes).

16.2.6 Automatic Fare Collection System

a) The cost of AFC works for 17 elevated stations as per MoHUA February 2019 rate (Rs. 3.50 Cr per station) is Rs. 59.50 Cr (Excluding taxes).

16.2.7 Platfrom Screen Doors:

a) The cost of PSD works for 2 stations within Airport boundary as per MoHUA February 2019 rate (Rs. 3.00 Cr per station) is Rs. 6.00 Cr (Excluding taxes).

16.2.8 Shifting of miscellaneous Utilities:

a) The cost of utilites (Civil & E&M) for 38.44 Kms based on MoHUA February 2019 rate (Rs. 6.00 Cr per Km) is Rs. 230.64 Cr (Excluding taxes).

b) The cost towards cable torugh on 38.44 Kms viaduct is lumpsum of Rs. 38.44 Cr (Excluding taxes).

c) The cost of Signage for 17 stations is lumpsum of Rs. 12.75 Cr (Excluding taxes).

Thus the total cost of Shifting of miscellaneous Utilities is worked out to Rs. 281.83 Cr (Excluding taxes).

16.2.9 Multi Modal Integration:

a) The cost of MMI for 17 stations as per MoHUA February 2019 rate (Rs. 3.00 Cr per station) is Rs. 51.00 Cr (Excluding taxes).

16.2.10 Depot, Admin building & Operation & control Sysytem:

a) The cost of Civil works for two depots as per MoHUA February 2019 rate (Rs. 105.00 Cr per depot) is Rs. 210.00 Cr (Excluding taxes).
b) The cost of E&M and M&P works for two depots as per MoHUA February 2019 rate (Rs. 65.00 Cr per depot) is Rs. 130.00 Cr (Excluding taxes).

Thus the total cost of Depot, Admin building & Operation & control System is worked out to Rs. 340.00 Cr (Excluding taxes).

16.2.11 Rolling Stock:

a) The cost of Rolling stock for 126 coaches based on MoHUA February 2019 rate (Rs. 8.00 Cr per coach) is Rs. 1008.00 Cr (Excluding taxes).

16.2.12 Security Capital cost:

a) The Security Capital cost for 17 stations as per MoHUA February 2019 rate (Rs. 0.37 Cr per station) is Rs. 6.29 Cr (Excluding taxes).

16.2.13 Road Restoration:

a) The cost of Road Restoration for 11 RKM based on MoHUA February 2019 rate (Rs. 2.00 Cr per RKM) is Rs. 22.00 Cr (Excluding taxes).

16.2.14 Land Acquisition

a) As the Metro alignment has to be planned on set standards and parameters, apart from alignment, various structures like stations, parking facilities, Traction sub stations, Communication towers, etc. require large plots of land. The land being scarce, costly and acquisition being complex process in the Metropolitan City, the alignment is so planned that barest minimum land acquisition is involved. Land is mainly required for;
   - Viaduct including Pocket Track.
   - Metro Station Structures, Entry/Exit Structures, Traffic Integration Facilities etc.
   - Receiving/Traction Sub-stations.
   - Baiyappanahalli link line
   - Depot near Airport

   i. The K R Puram-International Airport Terminal line of Phase 2B starts beyond Jyothipuram station of Phase 2A and will generally follow median of the Outer Ring Road upto Hebbal and further continues till Trumpet on the 5 Mtr. stretch of land reserved for metro rail project between main road and service road on NH-44, alignment deviates towards right before trumpet toll plaza and enters open private land before it reaches Airport road median and it continues along median of airport road till KIAI boundary. 17 Stations are planned on KR Puram-International Airport as detailed in Table 6.1. The total land required for the viaduct & Station including Depot and Baiyappanahalli link line is 2,07,871 sqm excluding 1,05,500 sqm NHAI land.

ii. The stations are located above the main carriage way on ORR except Veeranna palya Station Which is located on Service road. Hebbal Station is located in private land and Kodigehalli, Jakkur Cross, Yelahanka, Bagalur Cross and Doddajala Stations are located mainly on service road along NH-44. Only the Entry / Exit structures and bus bays are planned on either side of the road and the land required for these structures is proposed to be acquired. Airport City and KIA Terminals Station are located inside KIAL boundary. The land for viaduct & station has to be notified for acquisition by BMRCL.The land of 5.0 mtr strip width for viaduct along NH-44 is already in possession of BMRCL for a length of 17.84 Kms.Thus the total land cost is 2171.39 Cr (Refer Table 16.2).

iii. Land is readily available at Baiyappanahalli for construction of depot and 91532 Sqm of land to be acquired for depot near Airport.

iv. The total land requirement for Viaduct, Stations, Link line to Baiyappanahalli and Parking facilities on this line is 1,16,339 Sqm, excluding NHAI land of 1,05,500 Sqm. The detail of land proposed for acquisition including breakup of land for viaduct, stations, Baiyappanahalli link line and Depot near Airport are Shown at **Table 16.1**.The cost for land acquisition including rates there on is shown at **Table 16.2**.The Airport Metro alignment is proposed to have Kempapura, Yelahanka, Doddajala as interchange station in future as they are part of other extentions planned in phase 3. Also, Nagawara station on Airport alignment is integrated with the proposed station of R6 (UG) alignment, thus forming the station as interchange station which is proposed as inter change station for future line to Aero Space park.

Table 16.1: Land area KR Puram to KAIL Boundary

Sl No	Viaduct (Elevated)		Station	Unit	Private Land area	Remarks
	From	To				
1	Jyothipuram to Kasturi Nagar including Link line to Baiyappanahalli			Sqm	8,577	Viaduct
2	Road widening for viaduct before Kasturi Nagar Station by the side of Benniganahalli flyover			Sqm	4,308	Road widening
3			Kasturi Nagar	Sqm	1,973	Station
4			Horamavu	Sqm	2,223	Station
5			HRBR Layout	Sqm	2,223	Station
6			Kalyan Nagar	Sqm	2,223	Station

Sl No	Viaduct (Elevated)		Station	Unit	Private Land area	Remarks
	From	To				
7			HBR Layout	Sqm	1,614	Station
8			Nagawara	Sqm	79	Station
9			Veeranna Palya	Sqm	2,469	Station & Viaduct
10	Veeranna Palya	Kempapura		Sqm	163	Viaduct
11			Kempapura	Sqm	1,935	Station
12			Hebbal	Sqm	18,724	Station, Viaduct & Parking
13			Kodigehalli	Sqm	3,342	Station & Viaduct
14			Jakkur Cross	Sqm	3,368	Station & Viaduct
15			Yelahanka	Sqm	8,020	Station, Viaduct & RSS
16			Bagalur Cross	Sqm	7,216	Station & Viaduct
17			Bettahalasuru	Sqm	2,663	Station & Viaduct
18			Doddajala	Sqm	4,943	Station & Viaduct
19	Doddajala	BIAL Boundary	Part-A	Sqm	7,347	Viaduct
			Part-B	Sqm	33,079	Viaduct & Depot entry
20	**Sub Total**				**1,16,486**	
21	Depot near Airport (Private land-22.62 Acres)			Sqm	91,532	Depot
22	**Sub Total**				**2,08,019**	
23	5 m wide strip along NH 44 from Hebbal to Doddajala			Sqm	1,05,500	
24	**Total Land**				**3,13,519**	

Note:

1) Land within KIAL boundary is not considered as same is to be provided by BIAL.
2) The land will be acquired as per provisions of the Karnataka Industrial Area Development Act 1966.

Table 16.2 Detail of cost towards Land Acquistion

Sl No	Viaduct (Elevated)		Station	Unit	Private Land area in sq.mts.			Remarks
	From	To			Area	Rate INR,in Crores	Amount INR,in Crores	
1	Jyothipuram to Kasthuri Nagar including Link line to Baiyappanahalli			Sqm	8,577	0.02282	195.73	Viaduct
2	Road widening for viaduct before Kasturi Nagar Station by the side of Benniganahalli flyover			Sqm	4,308	0.02282	98.32	Road widening
3			Kasturi Nagar	Sqm	1,973	0.02282	45.02	Station
4			Horamavu	Sqm	2,223	0.01680	37.34	Station
5			HRBR Layout	Sqm	2,223	0.01680	37.34	Station
6			Kalyan Nagar	Sqm	2,223	0.02734	60.76	Station
7			HBR Layout	Sqm	1,614	0.02734	44.11	Station

Sl No	Viaduct (Elevated) From	To	Station	Unit	Private Land area in sq.mts. Area	Rate INR,in Crores	Amount INR,in Crores	Remarks
8			Nagawara	Sqm	79	0.01594	1.25	Station
9			Veeranna Palya	Sqm	2,469	0.02408	59.46	Station & Viaduct
10	Veeranna Palya	Kempapura		Sqm	163	0.02408	3.92	Viaduct
11			Kempapura	Sqm	1,935	0.02100	40.63	Station
12			Hebbal	Sqm	18,724	0.02632	492.81	Station, Viaduct & Parking
13			Kodigehalli	Sqm	3,342	0.03640	121.63	Station & Viaduct
14			Jakkur	Sqm	3,368	0.02156	72.60	Station & Viaduct
15			Yelahanka	Sqm	8,020	0.02156	172.92	Station, Viaduct & RSS
16			Bagalur Cross	Sqm	7,216	0.02156	155.58	Station & Viaduct
17			Bettahalasuru	Sqm	2,663	0.02156	57.42	Station & Viaduct
18			Doddajala	Sqm	4,943	0.00076	3.76	Station & Viaduct
19	Doddajala	BIAL Boundary	Part-A	Sqm	7,347	0.00076	5.59	Viaduct
			Part-B	Sqm	33,079	0.00054	17.98	Viaduct & Depot entry
20			**Sub Total**		**1,16,486**		**1,724.17**	
21	Depot near Airport (Private land-22.61 Acres)			Sqm	91,532	0.00215	197.22	Depot
22					**2,08,019**		**1,921.39**	
23	5 m wide strip along NH 44 from Hebbal to Doddajala			Sqm	1,05,500		200.00	
26			**Total Land**		**3,13,519**		**2,121.39**	
27	Building & Structure Cost			LS			**50.00**	
28	**Total Amount in Crores**						**2,171.39**	

i. Land is readily available at Baiyappanahalli for construction of depot and 91,532 Sqm of land to be acquired for depot near Airport. The depot for this airport line is proposed to be located near Airport beside Trumpet toll plaza on right side of NH-44, where 22.62 acres of private land is available which is proposed to be acquired.

ii. Rehabilitation / Resettlement: There will be no relocation of any residential buildings along the alignment. However, few shops and establishments need to be relocated. Compensation for relocation of these affected structures shall be paid and it has been considered in the project cost estimate. The alignment and the location of the stations have been so chosen that it remains mostly within the Government land, vacant lands and the road median. A lumpsum provision of Rs. 50 Cr has been made towards Building & Structure cost.

16.2.15 Taxes

The Taxes on the Capital cost of Rs.7320.65 Crs which works out to **Rs.697.53 Crs.** Detailed in **Table 16.4.**

16.2.16 Contingencies

The Contingency charges (excluding land and including tax) is 3% of Capital cost of Rs.5846.79 Crs which works out to **Rs 175.40 Cr.**

16.2.17 Departmental and General Charges

The Departmental and General Charges (excluding land) is 5% of Capital cost of Rs. 5324.66 which works out to **Rs 266.23 Cr.**

16.2.18 Interest during Construction:

The Charges towards Interest during Construction works out to **Rs 536.76 Cr.**

16.3 Innovations

Few innovations are included in this Report to reduce the cost of Civil works

a. The Station layout is prepared in such a way that the concourse floor is eliminated at Stations. The unpaid area, Ticketing and AFC gates are provided in the entry structures on either side of the Road for ease of commuters reaching the station from both sides. A foot bridge is provided below the platforms to facilitate the commuters to reach any of the Two Platform from both the sides.

b. Removal of concourse reduces the height of station and making the structure lighter and reduction in cost. This arrangement also reduces the height of Viaduct on either end of the stations resulting in cost saving.

c. The Viaduct will pass through the stations also with the same structural arrangement as in the mid-section which will facilitate early completion of the Viaduct. Other System Contractors such as Track, Traction, Signalling & Telecom can start their works early to facilitate early completion of the project.

d. The Piers of the Viaduct are planned in Circular shape reducing the size of the Pier and making them aesthetically pleasing and resulting in reduction in cost.

16.4 Capital Cost Estimate

The revised capital cost of the construction of the project with breakup of taxes is given in Table below. The Estimated cost may however vary along with FIRR and EIRR estimates at appraisal stage of the DPR.

Table 16.3 Capital Cost Estimate at Febrauray 2019 MoHUA prices for Phase-2B.

SI No	Item	Unit	Qty	Unit Cost (INR in Cr)	Amount (INR in Cr)
1	2	3	4	5	6
1	**Alignment and Formation**				
1.1	Elevated section (Viaduct) including in Station portion and elevated Ramp	R Km	34.84	37.00	1289.08
1.2	Additional cost towards Portal piers for alignment along 3 split flyovers, part of single flyover & Subway along outer ring road				2.11
1.3	Additional cost towards 12 Special spans with composite girders for Railway span.				46.28
1.4	Length of Ramp to Reach at Grade	R Km	1.00	22.36	22.36
1.5	Alignment at Grade	R Km	2.00	22.36	44.72
1.6	Alignment with Covered Shell	R Km	0.60	36.87	22.12
	Sub Total (1)				**1426.67**
2	**Station Buildings**				
2.1	Elevated Station (Including civil finishes) excluding Viaduct in Stn portion	Per Stn	16	26.00	416.00
2.1.1	Additonal area for Property Development	Per Stn	16	1.08	17.28
2.1.2	Additional cost towards providing pedestrain walkway from Horamavu metro stn. to underpass jn.				2.24
2.1.3	Additional cost for FOB / Sub-Way (70 mtr length) for 6 stn. across National Highway				1.88
2.1.4	Additional cost towards 10% increase in area of Kempapura interchange Station & Airport Terminal stn (5mtr wide platform)				3.50
2.3	Partially Underground Station at Airport Terminal (Including civil finishes)	Per Stn	1	62.50	62.50
2.2	Elevated Station (E & M including Lifts & Escalators)	Per Stn	16	8.00	128.00
2.4	Underground Station at Airport Terminal (E & M including ECS, TVS, Lifts & Escalators)	Per Stn	1	30.00	30.00
	Sub Total (2)				**661.40**
3	**Permanent Way**				
3.1	Ballastless Track	R Km	38.44	6.60	253.70
3.2	Ballasted Track for Depot, At grade section	T Km	18.50	3.90	72.15
	Sub Total (3)				**325.85**
4	**Traction & Power Supply**				
4.2	**750V DC Third Rail**				
4.21	Elevated section	R Km	38.44	11.00	422.84
4.23	Depot	T Km	18.50	3.00	55.50
4.24	RSS	Each	2.00	25.00	50.00
4.25	Addition of Cost towards RSS incoming cables length above 0.5 km				84.84

Sl No	Item	Unit	Qty	Unit Cost (INR in Cr)	Amount (INR in Cr)
1	2	3	4	5	6
	Sub Total (4)				**613.18**
5	**Signalling and Telecom**				
5.1	**Signalling**				
5.11	Main line including OCC/BCC	R Km	38.44	4.40	169.14
5.12	Depot including DCC	T Km	18.50	3.20	59.20
5.13	On board Equipment	Per Train	21.00	1.70	35.70
	Sub Total (5.1)				**264.04**
5.2	**Telecommunication**				
5.21	Station	Per Stn	17.00	4.50	76.50
5.22	Depot	Per Depot	2.00	3.50	7.00
	Sub Total (5.2)				**83.50**
6	**Automatic Fare Collection (AFC) system**	Per Stn	17.00	3.50	59.50
	Sub Total (6)				**59.50**
7	**Platform Screen Doors (PSD)**	Per Stn	2	3.00	6.00
	Sub Total (7)				**6.00**
8	**Shifting of Miscellaneous Utilities**				
8.1	Civil	R Km	38.44	6.00	230.64
8.2	E & M	R Km	38.44		
8.3	Cable trough	R Km	38.44	1.00	38.44
8.4	Signage	Per Stn.	17.00	0.75	12.75
	Sub Total (8)				**281.83**
9	**Multimodal integration and last mile connectivity**	Per Stn	17.00	3.00	51.00
	Sub Total (9)				**51.00**
10	**Depot, Admin Building and Operation & Control center**				
10.1	Civil	Per Depot	2.00	105.00	210.00
10.2	E & M and M & P	Per Depot	2.00	65.00	130.00
	Sub Total (10)				**340.00**
11	**Rolling Stock**	Per coach	126.00	8.00	1008.00
	Sub Total (11)				**1008.00**
12	**Security-Captical Cost**	Per Stn	17.00	0.37	6.29
	Sub Total (12)				**6.29**
13	**Road Restoration**	R Km	11.00	2.00	22.00
	Sub Total (13)				**22.00**
	Total (1 to 13)				**5149.26**
14	**Land**				

Sl No	Item	Unit	Qty	Unit Cost (INR in Cr)	Amount (INR in Cr)
1	2	3	4	5	6
14.1	Jyothipuram to KIAL Boundary (Station, Viaduct, RSS, Link line, Pocket Track, etc.,) Refere Sl No.1 to 18 of Annexure.	Sqm	115996.04	-	1724.17
14.2	Depot near Airport, Refer Sl No.20 of Annexure-L1	Sqm	91532.09	-	197.22
14.3	NHAI Land	LS	105500.00	-	200.00
14.4	Building /Structure cost	LS		50.00	50.00
	Sub Total (14)				**2171.39**
15	**Total including land**				**7320.65**
16	**Taxes (excluding Land)**				**697.53**
17	**Contingencies @ 3% (excluding land & including tax)**				**175.40**
	Total (1 to 13+16+17)				**6022.19**
18	**D&G charges @ 5% (excluding land)**				**266.23**
19	**Price variation during construction (except Land)**				**978.61**
20	**Interest During Construction (IDC)**				**496.16**
21	**Grand Total including Land**				**9934.58**

Table 16.4 Details of Taxes for Phase-2B.

Sl No	Description	Amount (INR in Cr)	Tax Amount (INR in Cr)
1	Alignment and Formation	1426.67	171.20
2	Station Buildings	661.40	88.85
3	Permanent Way	325.85	39.10
4	Traction & Power Supply	613.18	110.37
5	Signalling and Telecom	347.54	62.56
6	Automatic Fare Collection(AFC) system	59.50	10.71
8	Shifting of Miscellaneous Utilities	281.83	34.58
9	Multimodal integration and last mile connectivity	51.00	6.12
10	Depot, Admin Building and Operation & Control center	340.00	48.60
12	Rolling Stock	1008.00	120.96
13	Security-Capital Cost	6.29	0.75
14	Road Restoration	22.00	2.64
15	Land	2171.39	0.00
	Total	**7320.65**	**697.53**

16.4.1 The Financing plan for the Airport line envisages contribution from Bangalore International Airport Ltd. (BIAL) by leavying user development fee on air travelers.

Table 16.5: Cost from Trumpet Metro Depot to Airport Terminals (Phase-2) Ch:31600 to 36545.43 (as per Revised DPR)for 4.95 Km Depot (Excluding) to Airport Terminals.

Sl. No	Item	Unit	Qty.	Unit cost (INR Cr.)	Amount (INR Cr.)
1	2	3	4	5	6
1	**Alignment and Formation**				
	a. Including Viaduct length in station	R.Km	2.45	37.00	90.47
	b.Alignment at Grade	R.Km	2.00	22.36	44.72
	c.Length of Ramp to Reach at grade	R.Km	0.50	22.36	11.18
2	**a. Station Building**				
	a. Regular station	Per Stn	1.00	26.00	26.00
	b. Partly underground station	Per Stn	1.00	62.50	62.50
	b. E&M works				
	a. Regular station	Per Stn	1.00	8.00	8.00
	b. Partly underground station	Per Stn	1.00	30.00	30.00
3	**Permanent Way**				
	a. Ballastless track	R.Km	4.95	6.60	32.64
4	**Traction & Powersupply**				
	a.Elevated section	R.Km	4.95	11.00	54.45
5	**Signalling & Telecom**				
	a. Signalling	R.Km	4.95	4.40	21.78
	b. Telecom	Per Stn	2.00	4.50	9.00
6	**AFC**	Per Stn	2.00	3.50	7.00
7	**PSD**	Per Stn	2.00	3.00	6.00
8	**Shifting of Utilities**				
	a. Civil utilities	R.Km	4.95	6.00	29.70
	b. Electrical Utilities	R.Km	4.95		
	c. Cable trough	R.Km	4.95	1.00	4.95
	d. Signages	Per Stn	2.00	0.75	1.50
9	**MMI**	Per Stn	2.00	3.00	6.00
12	**Rolling Stock**	Each	11.00	8.00	88.00
13	**Security Capital cost**	Per Stn	2.00	0.37	0.74
16	**Total**				**534.62**
17	**Taxes**				**72.42**
18	**Add Contingencies @ 3%(Basic + Tax)**				**18.21**
	Total (1 to 13+17+18)				**625.25**
19	**Add D&G @ 5%(Basic + Cont.)**				**27.64**
20	**PV**				**101.60**
21	**IDC**				**45.51**
22	**Total**				**800.00**

16.5 Operational and Maintenance Cost

16.5.1 Introduction:

The cost of operations includes the cost of running as well as maintaining the metro trains. These costs can be classified into fixed and variable costs.

Fixed cost:

These costs are those which do not increase with the increase in volume of operations or in other words with the increase in train Kilometers.

Variable cost:

These are costs, which vary according to the quantum of operations or in other words according to the number of Train Kms / stations.

For the purpose of the present analysis, the operation & maintenance costs are classified as:

i. Human Resource Cost
ii. Maintenance Cost
iii. Energy Cost

16.5.2 Cost of Human Resource:

These are basically the cost of human resources, which are engaged to run the trains as well as to provide the different services for running the trains. This cost is a fixed cost and it will not vary with the quantum of operations. This includes, basically, the salary paid to the operations as well as maintenance staff of BMRCL employees and cost of outsourced employees. It may be noted that this cost is a fixed cost and therefore it is included as a part of Human Resource Cost.

This Human Resource Cost has the following components:

i. Cost of BMRCL Permanent Employees.
ii. Cost of Outsourced Employees

16.5.3 Cost of BMRCL Employees

The staff costs for this line has been derived by working out the number of staff who would be engaged for operation & maintenance of train services.The staff cost has been estimated from the year 2023-24 as it is presumed that the line will be operational during that year.

Estimated requirement of staff and cost there of is detailed in **Table 16.6.**

Table 16.6 Estimation of Employees Cost (on Cost to Company basis) for 2018-19 For O&M Staff for Phase – 2B (36.44 km)

Designation	Staff	Basic	IDA DA 135.6%	HRA @ 30%	Allowances @15%	S A @ 12%, Gratuity& Others	Total Per Month (In Rs)	Total Per Annum (In Rs)
Director	0.25	75000	101700	22500	11250	21204	231654	694962
Executive Director (O&M)	0.25	62000	84072	18600	9300	17529	191501	574503
GM	4	51300	69563	15390	7695	14504	158452	7605696
Dy.GM	18	29100	39460	8730	4365	8227	89882	19414512
Manager	24	24900	33764	7470	3735	7040	76909	22149792
AM	60	20600	27934	6180	3090	5824	63628	45812160
Total-A	**102**	**74600**	**101158**	**22380**	**11190**	**21091**	**230419**	**95677122**
Section Eng	127	16000	21696	4800	2400	4524	49420	75316080
Jr.Eng	310	14000	18984	4200	2100	3958	43242	160860240
Maintainer	787	10170	13791	3051	1526	2875	31413	296664372
Station Suprntt.	60	16000	21696	4800	2400	4524	49420	35582400
SC/TO	230	14000	18984	4200	2100	3958	43242	119347920
Asst Fire Officer	4	16000	21696	4800	2400	4524	49420	2372160
Superintendent	10	10170	13791	3051	1526	2875	31413	3769560
Senior Asstt.	14	14000	18984	4200	2100	3958	43242	7264656
Assistants	20	10170	13791	3051	1526	2875	31413	7539120
EL , Conveyance/TA/DA for the FY-2018-19								8556057
Total-B	**1562**	**120510**	**163413**	**36153**	**18078**	**34071**	**372225**	**717847068**
Grand Total (A+B)	**1664**	**195110**	**264571**	**58533**	**29268**	**55162**	**602644**	**813524190**

Thus the staff cost for the required number of personnel as indicated in **Table 16.6** for the year 2018-19 is estimated at Rs. 81.35 Crores. Taking into consideration annualized increment @ 3% in basic and the increase in the DA component for the whole year at 12%, the gross increase year on year comes to about 7%. Thus for the year 2023-24, the staff cost is estimated at Rs114.10 crores per annum.

16.5.4 Cost of Outsourced personnel

The cost of outsourced personnel includes cost of Housekeeping, Ticket Operating Machine personnel and the security personnel costs. These staff would be engaged through a private outsourcing agency.

16.5.5 Cost of Outsourced Security Personnel:

The average monthly cost of outsourced Security personnel for September 2018 is Rs1.19 crores for 13 stations and 1 depot of R3, 3A and 3B section and is estimated at Rs1.53 crores, For 17stations and 1 depot on the proposed line. For the year 2018-19, it is estimated as Rs. 18.36 Crores and the same is likely to be Rs 25.75 crores for the year 2023-24 at an increase at 7% p.a (annualized).

16.5.6 Cost of outsourced Housekeeping personnel:

The average monthly cost of Housekeeping for September 2018 is Rs 0.61 crores for 13 stations and 1 depot of R3, 3A and 3B section and is estimated at Rs 0.78 crores for 17 stations and 1 depot on the proposed line. For the year 2018-19, it is estimated as Rs. 9.36 Crores and the same is likely to be Rs13.12 crores for the year 2023-24 at an increase at 7% p.a (annualized).

16.5.7 Cost of outsourced TOM Operators:

The average monthly cost of TOM Operators for September 2018 is Rs 0.25 crores for 13 stations of R3, 3A and 3B section and is estimated at Rs 0.33 crores for 17 stations on the proposed line. For the year 2018-19, it is estimated as Rs. 3.96 Crores and the same is likely to be Rs5.55 crores for the year 2023-24 as an increase at 7% p.a (annualized).

Thus the total staff cost for this line for the year 2023-24 is Rs. 114.10+ 25.75+ 13.12+ 5.55= **158.52 crore**. For the period of next 30 years, the staff cost & outsourced manpower cost has been escalated at the rate of 7% per annum year on year on year basis.

16.6 Maintenance Cost:

The maintenance cost basically includes the cost of spares, cost of repairs and consumables, cost of Insurance, civil and structural works, licensing fees for wireless etc. and administrative & contingency expenses (overheads). The maintenance cost has components of both fixed cost as well as variable cost. However, for the purpose of financial analysis, the maintenance cost has been worked out based on the actual expenditure of maintenance for entire 42 Kms of Phase-1, the maintenance cost for the year 2018-19 (to end of Sep’18) has been taken at Rs. 34.28 Crores per annum. For arriving at the maintenance cost for the year 2023-24, the same has been escalated by an annualized increase at 10% year on year in the proposed new line thereby the estimated maintenance cost for 2023-24 is **Rs.55.21 Crores.**

16.7 Energy Cost:

The system consumes energy for the movement of trains as well as for auxiliary services at stations. While the energy cost for the trains is a variable factor, the energy cost of auxiliary power stations is generally fixed. The energy cost for the new line is based on the actual energy consumption for Phase-1. For Phase-1, which is, having 120 round trips on a daily basis, but with a train, which has only 3 cars, the energy consumption per train Km for movement of train, is 8.17 Kwhr.

For the new line, though the Rolling Stock proposed is with the improved regeneration but due to increase in the average commercial speed in the section between KR Puram to Yelahanka (19.13 km) with a frequency of 5 minutes during peak hours and a frequency of 10 minutes during non-peak hours, the energy consumption per train Km (6-car train set) would be 16.34 kwhr. Total number of train trips per direction per day will be 150. Similarly in the section between Yelahanka to KIA Terminal station (18.424 km) with a frequency of 10 minutes during peak hours and 15 minutes during non-peak hours, total number of train trips per direction per day will be 88.

Accordingly, the total train kms for KR Puram to Yelahanka (19.13 km) section would be 5739 kms per day and for Yelahanka to KIA Terminal station (18.424 km) section would be 3242.624 kms per day. Thus, the total train kms would be 8981.624 kms per day for the full line length. The Energy consumed by trains is 1,46,759.736 kwh per day. The monthly consumption is 44, 02, 792 .084 kwh. For the next 30 years, the escalation of energy cost is taken at 5% per annum YoY basis.

For consumption of power at the stations, it is estimated that each station on an average would consume 1000 kwh per day. Thus, the total energy for 17 stations per month would be 5,10,000 kwh. In addition, the power consumption in the Depot ASS + TSS and losses have been estimated at 2,50,000 units per month.

Thus, the total energy cost per month for the new line would be Rs 2.95 Crs in the base year of 2018-19.

Table 16.7 Energy cost calculations

Energy usage	No of Trips/ Day in section 1/2	Total Train Kms / Month	KWHr /TKM	Kwhr / month	Cost per Kwhr In Rs	Cost per Month In INR Crores	Cost per annum In INR Crores
Train Energy Consumption	150/88	2,69,448.72	16.34	44,02,792.08	5.72	2.518	30.22
Axillary Energy for 17 stations- (1000 units / day/ station)				5,10,000	5.72	0.2917	3.50
Depot, OCC & Electrical loss				2,50,000	5.72	0.143	1.71
Total				**51,62,792.08**	**5.72**	**2.95**	**35.43**

The energy cost increase as notified by the Government on a year on year basis and the increase has been in the range of 4.34%, 8.33% and 2.88% over the period 2011-12 to 2017-18. Thus, the average year on year increase in the energy cost is around 5%. Therefore, the energy cost for the year 2023-24 for the new line would be **Rs 45.22 Crores**.

Further while computing energy cost the No of trips /day for this line is estimated and considered is as in **Table 16.8**:

Table 16.8: Nuber of Trips/day:

Year	Number of Trips/Day	
	KR Puram to Yelahanka (19.13 km)	Yelahanka to KIA Terminal station (18.424 km)
2024-2030 :	300 (5 minutes)	176 (10 minutes)
2031-2040 :	500 (3 minutes)	250 (06 minutes)
2041-2050 :	600 (2.5 minutes)	300 (5 minutes)

16.8 Conclusion:

The total Operations and Maintenance cost for the year 2023-24 is **Rs.258.95** Crore for the new line of 38 Kms with 17 stations, for running 6 coach train sets.

Based on the actual cost for 17 stations of Ph-2B of the project, the proportionate cost for the year 2023-24 has been worked out and projected cost for the next 30 years with annualized increase as stated above is summarized in **Table 16.9.**

Table 16.9 Operation & Maintenance cost (INR IN CRORE)

Year	Staff including outsourced manpower (annualized increase @ 7%)	Maintenance Cost (10%)	Energy Cost (annualized increase @ 5%)
2023	158.52	55.21	**45.22**
2024	169.62	60.73	47.48
2025	181.49	66.80	49.85
2026	194.19	73.48	52.35
2027	207.79	80.83	54.96
2028	222.33	88.92	57.71
2029	237.90	97.81	60.60
2030	254.55	107.59	63.63
2031	272.37	118.35	**99.78**
2032	291.43	130.18	104.77
2033	311.83	143.20	110.01
2034	333.66	157.52	115.51
2035	357.02	173.27	121.28
2036	382.01	190.60	127.35
2037	408.75	209.66	133.71
2038	437.36	230.63	140.40
2039	467.98	253.69	147.42
2040	500.74	279.06	154.79
2041	535.79	306.96	**191.77**
2042	573.29	337.66	201.36
2043	613.42	371.43	211.43

Year	Staff including outsourced manpower (annualized increase @ 7%)	Maintenance Cost (10%)	Energy Cost (annualized increase @ 5%)
2044	656.36	408.57	222.00
2045	702.31	449.42	233.10
2046	751.47	494.37	244.75
2047	804.07	543.80	256.99
2048	860.36	598.18	269.84
2049	920.58	658.00	283.33
2050	985.02	723.80	297.50
2051	1053.97	796.18	312.37
2052	1127.75	875.80	327.99
Total	**14,973.92**	**9,081.71**	**4,739.25**

Chapter 17

Transit Oriented Development Plan

CHAPTER – 17

TRANSIT ORIENTED DEVELOPMENT (TOD) PLAN

17.0 Back Ground

Transit Oriented Development (TOD) is defined as the development of concentrated nodes of moderate-to-high density mixed land use within 5 to 10 minutes of walking distance from mass transit stations. The nodes are planned and integrated around the transit stations as its core. In TOD approach, housing, employment, shopping and recreation are concentrated along a network of walkable and bikeable streets within 400 to 1000 m of the transit. TOD requires the development of mixed neighbourhoods which are well integrated with pedestrian, bicycle, feeder and transit networks.

The draft TOD policy for Bengaluru has broadly classified the transit ststion influence area into three zones :

(i) Intense TOD Zone : 500 either side.
(ii) Standard TOD Zone : 500-1000m either side.
(iii) Transition TOD Zone : 1000-2000m either side.

The Intense and Standard Zones will be planned for higher densities and improved accessibility whereas the Transition Zone will be planned for only improved accessibility and feeder services.

17.1 Components of TOD

TOD framework can be broadly explained through six components (known as 6Ds) which are important in achieving the TOD.

17.1.1 Density

TOD zones need to be designed to support high density development. Density is defined as concentration of population/employment per hectare or sq.km. Higher population/employment density near transit stations will heighten convenience; reduce trip lengths and private vehicle use and results in higher patronage of sustainable modes i.e. walking, cycling and public transport. Various studies have shown that 10% increase in population and employment density results in 5% to 8% increase in transit ridership.

17.1.2 Diversity

Diversity is achieved by placing the mixed land use, housing for diverse income groups and wide range of amenities within TOD zones. Diversity helps in achieving reasonable population to job ratio, availability of basic amenities within walking distance and reduces the trip lengths. Diversity reduces peak crowding on transit and enables spread of the travel demand on both directions and throughout the day and thus helps in optimal utilization of transit capacity.

17.1.3 Design

Good design creates lively environment that encourages walking and cycling and promotes the use of public transit for all age groups. Complete street design with continuous pedestrian/biking environment and safe and smooth access to transit stations is a major component of design. Further, active frontages, weather protection, multi-modal integration facilities, public art, landscaping, parks, benches, avenue trees, public meeting places and kiosks are some of the other components of Design.

17.1.4 Destination Accessibility

Transit stations and surrounding network need to be planned so as to facilitate access to wide variety of destinations such as homes, schools, work places, shops, service centres and recreational facilities. However, lack of accessibility to the transit system often discourages people from using the transit.

Destination accessibility can be achieved through (a) Inter-connected fine-grained street network (b) Multi-modal integration (c) First & Last mile connectivity (d) feeder services

17.1.5 Distance to Transit

Distance to transit has substantial impact on viability and effectiveness of transit system. This component measures the proximity of the transit station from residential, work and shopping places. Therefore, direct routes which are shortest shall be developed.

17.1.6 Demand Management

Demand management reduces private vehicle trips and promotes sustainable modes such as walking, cycling and public transit. These measures can be site specific within TOD zone or city-wide. The examples for demand management are parking management, congestion pricing in core areas, pedestrianisation and hawker management.

17.2 Value Capture Financing (VCF) for TOD

The New Metro rail policy requires that the additional benefits earned by private land and Buildings from actions other than the land owner's direct investment, i.e., from public investment in infrastructure and policy decisions of the Government, should be captured to fund projects. Land Value Capture can be used as a mechanism to finance the required up-gradation of infrastructure and amenities within the influence zone and expansion of the public transport system.

The NMP suggests that land value capture can be done through enhanced or additional land value taxor one-time betterment levy, development charges or impact fee, transfer of development rights (TDRs), or other such mechanisms in the TOD influence zones.

Further, the resources generated should be credited into a TOD fund created for funding the infrastructure upgradation/ maintenance, enhancement of viability of transit systems, development and maintenance of transit corridor and public transport etc. within and beyond the influence zone.

17.3 Public Private Partnership (PPP)

17.3.1 Innovative Financing

Notwithstanding the suitability of the sovereign loans from MDBs and BDBs, in order for the pace of expansion of the Metro network to match with the pace at which the demand of Metro network is growing, there is need to constantly explore other avenues for mobilization of funds for Metro systems. BMRCL has approached Corporates along the proposed corridor by offering a bundle of rights such as Naming Rights, advertising space, commercial space for a period of 30 years and provision of direct access to their facilities through a dedicated walkway below the Metro viaduct for a period of 99 years.

Appreciating the advantages that an efficient Public Transport facility will provide, namely not only augmenting productivity by decreasing travel time and reduced pollution and related health care costs, but also improving the quality of life of employees, several companies on this corridor are coming forward expressing their willingness to participate in this innovative model.

It is expected to raise approximately an amount of Rs 350 crore through these arrangements and this amount would be available for project financing.

17.3.2 Back-ended PPP with BIAL

The AERA's regulation for private airports do not allow for levy of Advance User Development Fee (ADF), i.e., a fee which can be levied even before commissioning of the project and can be used for financing capital expenditure. In view of the guidance received from AERA, the upfront contribution from BIAL is not possible and therefore the funding plan needs to be modified.

Back-ended PPP with BIAL during the operational phase is envisaged by transferring assets in the Airport area upon commissioning to BIAL and leasing them back to facilitate levy of user development fee on air travelers by BIAL as AERA guidelines. The revenue streams generated through transfer of this amount would aid in debt servicing, thus mitigating the need for shadow cash support from GOK.

Considering the above aspects, it is proposed to factor-in the funding from BIAL on post-commissioning basis. Hence an amount of Rs 800 crore is projected as cash inflow to service the debt in operational phase in the form of back-ended PPP.

17.4 Corridor Details

The Bengaluru Metro Phase 2B project corridor covering a total service route length of 38 Kms (36.44 Kms from Jyothipuram to International Airport Terminal) with 17 stations was proposed to be taken up for construction from December-2018 based on the DPR prepared in September-2017. Sanction of Government of India for the project is awaited. In order to get the Project approved on priority, the DPR has been revised as per the requirement in Metro Policy-2017 including this Chapter on TOD.

17.4.1 Financing Pattern

The Phase-1 of Bangalore Metro costing Rs 13,845 Crores as well as the Phase-2 of Bangalore Metro costing Rs. 26,405 Crores have been funded jointly by the State Government and the Government of India. For this project of Phase-2B of BMRCL also, it is proposed to approach the Government of India for 50% Equity participation to be matched by the Government of Karnataka under the New Metro Rail Policy 2017. Accordingly, the equity shares of GoI and GoK have been worked out at 11.47% each and in addition to sharing the Tax burden equally as subordinate debt along with GoI, the GOK will also bear the cost of Land Acquisition and R&R. Senior Debt of Rs 4,287.12 Crores (43.15%) of the project cost is planned to be raised through Sovereign loans / Non Sovereign loans .

Bangalore Metro has been funded primarily by the contributions from the State Government and the Central Government apart from borrowings from various domestic and foreign financial institutions. Funding of such large infrastructure projects exerts a heavy pressure on the budgetary resources of the State Government as well as the Government of India. As a result, the pace at which the Metro network should expand, does not match the pace at which the travel demand for Metro network is growing and therefore, the need to explore other avenues for mobilization of the funds for Metro systems is felt. In response to this need to raise Funds, BMRCL has approached Corporates along the proposed corridor by offering a bundle of rights such as Naming Rights, advertising space, commercial space and direct access to their facilities through a dedicated walkway below the Metro viaduct.

17.4.2 TOD and Airport line

The proposed Metro Corridor connects IT Industries of Whitefield and Electronic city with International Airport. Along with these Industries, a number of major Residential colonies have come up on either side of this Road. The Metro Stations are planned in such a way that they are located close to the Industrial establishments and to the Residential conglomerations. This was done with the aim to keep the distance from Metro Stations to the points of work short and primarily to promote walking to and from the Metro Stations. It is also planned to have bicycle docking facility and bicycle hiring facility at Metro Stations to promote NMT from and to the Metro Stations. Concourse level cross overs as well as elevated walkways have been planned below the Metro viaduct to enable comfortable and safe passage for commuters which will obviate the need to cross roads amid heavy traffic and pollution and make the Metro a preferred transport option.

In order to integrate the Commercial and Office spaces with the Metro Stations and to encourage Public Transport as a preferred mode of Transit, a provision has been made to construct elevated walkways below the viaduct between the Stations which can be extended to give direct access to the major Industries directly. This facility will improve Last Mile Connectivity thereby making it more convenient to the Employees of the Companies to reach the Metro Stations without going through the busy Roads and this will greatly increase the attractiveness of Public Transport and wean away commuters from use of Private vehicles.

In order to promote and facilitate last mile connectivity by operating feeder services by BMTC, pick up and drop facilities have been provided in the Service Roads at the Metro Stations, apart from provision of parking at ground level as well as integrating the BMTC bus stops wherever possible, with the Metro stations. These service roads are planned around the Entry/Exit structures of Metro Stations and are in addition to the existing service roads on ORR and NH-44. In addition, the stations are planned in such a way that they are closer to important cross roads, so that people from beyond the Metro influence zone will also be able to utilize the Metro Rail services by travelling by feeder services and BMTC buses.

Back-ended PPP with BIAL during the operational phase is envisaged by transferring assets in the Airport area upon commissioning to BIAL and leasing them back to facilitate levy of user development fee on air travelers by BIAL as AERA guidelines. The revenue streams generated through transfer of this amount would aid in debt servicing, thus mitigating the need for shadow cash support from GOK.

17.4.3 Value Capture Financing (VCF) Plan

By implementing TOD policy and thereby realizing revenues from VCF, the GOK would be able to fund the Metro and other infrastructure projects in Karnataka. The following instruments have been identified vide GO Number - UDD 364 MNJ 2016, Bengaluru, dated 03.09.2016, the revenue from which can be pooled in a common infrastructure Fund and allocated by the GOK for various Infrastructure projects, including the Metro

i. Premium FSI / FAR (Floor Space index / Floor Area Ratio)
ii. Cess on approval of new layouts
iii. Construction and exploitation of commercial spaces near important infrastructure projects
iv. Generation of revenue through other sources like premium for roads developments etc.
v. Betterment Tax

The proceeds would go to a Transport Development Fund or the Urban Infrastructure Fund from which the construction of mass transit system could be funded. BDA or other Development Authorities will make suitable amendment to their Zoning Regulations to direct a part these funds to BMRCL.

GOK through amendment of Karnataka Town and Country planning act has taken progressive steps for innovative financing of metro rail through cess /TDR while sanctioning the Phase-II of Metro and allocating the portion of revenue thus generated to BMRCL.

i. Levy of Cess and Surcharge under Section 18A of the Karnataka Town and Country Planning Act at 5% of the market value of land or land building in future Developments, to be credited to Metro Infrastructure Fund and to be shared by BMRCL, BWSSB and BDA at 65%, 20% and 15% respectively.
ii. To extend the benefit of 4 FSI for all properties lying within a distance of 150 m from the Metro alignment. To levy a cess of 10% in respect of residential buildings and 20% in respect of commercial buildings on the additional FAR granted in respect of Phase-I and Phase-II of the Metro Rail Project and the share among BMRCL, BBMP, BWSSB and BDA in the ratio of 60%, 20%, 10% and 10% respectively.
iii. To allow BMRCL to issue TDRs in lieu of compensation for acquisition on of land for Metro Rail Project.

Recently Government of Karnataka issued new GO for TOD with following features, which is expected ease of land acquisition without monetary compensation. This is expected to support the TOD related project

i. TDR shall be applicable as per provisions Section 14-B of KTCP Act and the Rules notified by the Government vide notification number UDD 283 BEMRUPRA 2015 dated 04 March 2017
ii. New regulations have removed zoning classification and linked to market value
iii. TDR shall not be applicable for plots with adjacent road less than 9 m
iv. Additional floor area based on the notional land may be utilized in the remaining portion of the original plot with the condition that the

maximum additional FAR shall not exceed 0.6 times the ordinary permissible FAR. Notional land is defined as twice the area of land surrendered.

v. Relaxation in setbacks and coverage may be permitted to the extent of 25% of the prescribed setback.

vi. Cost of the buildings demolished will be compensated.

It is expected that an amount of Rs 150 crores will be raised through means of Value Capture Finance.

17.4.4 Construction and Exploitation of Commercial Spaces Near Important Infrastructure Projects

The appreciation in land value immediately next to the transport infrastructure project is substantially high. Therefore, it would make economic sense to acquire lands and then later on these could be exploited for generation of commercial revenue either by leasing of lands or through Public Private Partnerships. Some of the infrastructure projects also lend themselves for exploitation of air space above the infrastructure projects. For example, the air space over the Metro Station or above the major depots can be commercially exploited for mobilization of resources. It is planned to develop a few parcels of land for getting Non-Fare Box Revenue.

As discussed earlier, Government of Karnataka through amendment in Karnataka Town and Country planning Act has ensured tapping revenue for funding the Metro through value capture methods.

BMRCL is exploring the possibility of commercial development of air space above metro stations and depots as additional sources of Non-fare box revenue. And in future, the GOK could consider tapping some of the following avenues to raise further revenue for funding infrastructure projects including the Metro:

i. Vacant land tax
ii. Enhanced property tax along the TOD Zone
iii. Cess on registration of new vehicles
iv. Green tax on old vehicles etc.

A separate chapter shall be incorporated on TOD in Master Plan describing the overall objective, demarcation of TOD zones, Land-Use and Transport strategy, provisions and incentives for redevelopment and promotion of TOD.

Chapter 18

Financial Analysis & Non-Fare Box Revenue Assessment

CHAPTER – 18

FINANCIAL ANALYSIS AND NON-FARE BOX REVENUE ASSESSMENT

18.1 Financial Analysis:

Financial analysis for the Airport Metro line from KR Puram to Airport is done based on estimated net cash flows on account of Capital investment and expenditure and Revenue earnings and expenditure including finance costs.

18.2 Estimations and Inputs for The Corridor, Phasing of Construction

18.2.1 Analysis Period and Sequence

Construction period for the period for the proposed project is envisaged as nearly 45 months and it is expected to be commissioned in December 2023.

18.2.2 Project Cost

The Project cost estimated to be Rs 9,934.58 crores. The details may be seen at chapter 16. This is the updated cost as per price level of year 2018 and as per MoHUA benchmarking report of February 2019 and includes enhanced requirement of land to facilities inter- modal transit.

The financing plan is based on "Equal Equity sharing" model envisaged in the Metro Rail Policy 2017.

18.3 Operation And Maintenance Cost

Please refer to chapter 16 (para 16.5) for estimations of Operation & Maintenance cost.

18.3.1 Benchmarking and Innovations to ensure profitability at O&M level

The BMRCL Phase-1 Operation and Maintenance (O&M) costs have been taken as benchmarks for projection of O&M costs for Phase-2B.

Some of the innovations proposed to enhance the profitability at O&M level are :

(i) Creation of Inter-modal transit hubs for operational and economic integration with other modes.
(ii) Extensive use of non-motorized transport for last mile connectivity.
(iii) Economic integration of fare by common fare card for metro and public bus system.
(iv) Augmenting road infrastructure by building metro-cum-road flyover.
(v) Support development of aerospace industrial cluster near the airport by providing connectivity to city centre.
(vi) Back-ended PPP with Bangalore international Airport Limited (BIAL) to mobilize about cash support USD 150 million (Present value) during operational phase.
(vii) Promote planned urbanization through transit-oriented development (TOD) along metro corridors, land value capture and partnerships with private sector for setting up economic clusters, industrial and logistic parks and future debt servicing.

(viii) Procurement of system maintenance services for rolling stock, signaling and telecom, traction, housekeeping and security to be outsourced during operational phase.

18.4 Means of Finance

18.4.1. Revenue from Different Sources:

The revenue earnings of BMRCL can be classified as Fare Box Revenue (FBR) and Non Fare Box Revenue (NFBR).

18.4.1.1 Fare Box Revenue

The main source of revenue for this line would be the fare box revenue. The fare box revenue is a function of the ridership (ridership is the number of passenger trips) and operational revenue per km. The traffic ridership figures for this line have been estimated in Chapter 3 and the total ridership station wise ridership is tabulated **Table 18.1**.

Table: 18.1 Daily Ridership – Station wise – Phase-2B

Stations	2024	2031	2041
KR Puram	51,983	89,845	1,16,398
Kasturi Nagar	13,794	22,924	29,695
Horamavu	12,790	25,507	33,041
HRBR Layout	14,488	28,893	37,427
Kalyan Nagar	19,777	32,582	42,206
HBR Layout	17,811	40,271	52,166
Nagawara	50,470	77,165	99,959
Veeranna Palya	19,535	32,923	42,648
Kempapura	24,013	35,960	46,583
Hebbal	60,987	1,05,406	1,36,542
Kodigehalli	20,228	51,137	66,243
Jakkur Cross	16,699	40,345	52,263
Yelahanka	30,647	58,526	75,813
Bagalur Cross	8,382	25,145	36,688
Bettahalasuru	8,048	24,145	35,228
Doddajala	5,365	16,096	23,485
Airport City	10,842	32,527	47,458
KIA Terminals	48,113	96,225	1,40,396
Total	**4,33,972**	**8,35,622**	**11,14,239**

Note: It has been observed that there is a slight reduction of passenger traffic on weekends, hence for the purpose of Financial Analysis module (FIRR) and Economic Analysis module (EIRR) the passenger traffic for Saturday has been considered at 75% of weekday traffic and for Sunday, it has been considered at 60% of the same. Hence, cumulatively there will be reduction of 9% in passenger traffic.

Revenue assumptions in detail:

i. **Passenger growth rate:** Please refer to **Chapter 3.** The passenger growth has been arrived at based on the population growth rate as per Draft Comprehensive Mobility Plan for Bengaluru and the per capita trip rate of 1.1 and tabulated below in Table 18.2 :

Table: 18.2 Passenger Growth rate for Phase 2B	
Year on Year (Growth)	% Increase
Year 2024 to Year 2030	4.18
Year 2031 to Year 2040	2.64
Year 2041 onwards	2.31

ii. **Operational Revenue**: Operational revenue per km has been worked out to Rs 3.30 and detailed in Table 18.3:

Table : 18.3 Operational Revenue per Km				
Particulars		Mar'19	Year 2019	Year 2024
A. Fare Box Revenue (In lakhs)		2,996.40	-	-
B. Ridership numbers (In lakhs)		113.35	-	-
C. Revenue per km (Phase-1)	A/B	26.44	-	-
D. ATL (Km)		10	-	-
E. Operational Revenue per km	C/D	2.64	2.75	-
Operational revenue per km for year 2024			-	3.30

Further, for Airport line passengers, ATL has been assumed at 30 km and operational revenue per km has also been considered at Rs 3.30 per km.

Operational revenue per km from year 2024 has been increased at **4%** year on year for next 30 years for computing FIRR.

iii. **Projected Ridership and Average Trip Length:** The Airport line is connected to Reach-6 of Phase-II Gottigere to Nagawara and extension of East – West line at K R Puram Junction, joining the Airport line making a continuous 55 km stretch. It has been assumed that people using this Airport line would travel on other lines and then reach the Airport line. However, Average Trip Length is divided in 3 groups along with passengers and year of travel in which such passengers are considered for a total length of 38 route kms as detailed in **Table 18.4**

Table 18.4. Projected Ridership and Average Trip Length

Sl No	Passengers	Ridership per day	ATL	Operational Revenue per Km	Year considered
1	**K R Puram station to Yelahanka station (**Including Bettahalasuru Station)	3,61,270	10	3.30	2024
2	**Bagalur Cross Trumpet and KIA West** [Since in these stations ridership is expected to pick up significantly only after the construction of the Peripheral ring road and Aero-city, ridership has been considered after 10 years of operation i.e., year 2034 onwards]	73,768	20	4.88	2034
3	**Airport station** [Passengers commuting exclusively to Airport station]	48,113	30	3.30	2024

18.4.1.2 Non – Fare Box Revenue

The Non-fare box revenue during the operational phase includes rentals from spaces at Metro stations, advertising income, income from property development, income from parking charges, and other sources like leasing of spare capacity of optical fibre, conducting training, leasing of rail grinding machine etc. The non-fare box revenue for the year 2024 has been estimated at Rs 20 crore for the first year of Operation of the line. Non-fare box revenue is expected to increase at a rate of 6% year on year.

Non Fare Box Revenue for the purpose of sensitivity analysis is tabulated in **Table 18.5**:

Table 18.5 : Non- Fare Box revenue under sensitivity analysis

Scenarios	Amount (INR crore)
Most Likely scenario	20
Optimistic scenario (110% of Most Likely scenario)	22
Pessimistic scenario (90% of Most Likely scenario and one year time overrun and increase in capex by 10 %)	19

Thus the total revenue (cash inflow) projected to be earned from fare box and non-fare box revenue is shown in **Table 18.6.**

Table 18.6: Details of Revenue (Fare Box and Non Fare Box Revenue) (Rs. In Cr.)

Year	Most Likely Scenario			Optimistic Scenario			Pessimistic Scenario		
	Fare Box Revenue	Non Fare Box Revenue	Total	Fare Box Revenue	Non Fare Box Revenue	Total	Fare Box Revenue	Non Fare Box Revenue	Total
2024	547	20	567	601	22	623	-	-	-
2025	592	21	613	651	23	675	533	19	552
2026	642	22	664	706	25	731	577	20	598
2027	695	24	719	765	26	791	626	21	647
2028	753	25	779	829	28	856	678	23	701
2029	816	27	843	898	29	927	735	24	759
2030	884	28	913	973	31	1,004	796	26	821
2031	944	30	974	1,038	33	1,071	850	27	877
2032	1,008	32	1,039	1,108	35	1,143	907	29	936
2033	1,076	34	1,109	1,183	37	1,220	968	30	998
2034	1,384	36	1,420	1,523	39	1,562	1,246	32	1,278
2035	1,478	38	1,516	1,625	42	1,667	1,330	34	1,364
2036	1,577	40	1,617	1,735	44	1,779	1,420	36	1,456
2037	1,684	43	1,726	1,852	47	1,899	1,515	38	1,554
2038	1,797	45	1,842	1,977	50	2,027	1,617	41	1,658
2039	1,918	48	1,966	2,110	53	2,163	1,727	43	1,770
2040	2,048	51	2,099	2,253	56	2,309	1,843	46	1,889
2041	2,179	54	2,233	2,397	59	2,456	1,961	48	2,010
2042	2,318	57	2,376	2,550	63	2,613	2,087	51	2,138
2043	2,467	61	2,527	2,714	67	2,780	2,220	54	2,275
2044	2,625	64	2,689	2,887	71	2,958	2,362	58	2,420
2045	2,793	68	2,861	3,072	75	3,147	2,514	61	2,575
2046	2,972	72	3,044	3,269	79	3,348	2,675	65	2,739
2047	3,162	76	3,238	3,478	84	3,562	2,846	69	2,915
2048	3,364	81	3,445	3,701	89	3,790	3,028	73	3,101
2049	3,580	86	3,666	3,938	94	4,032	3,222	77	3,299
2050	3,809	91	3,900	4,190	100	4,290	3,428	82	3,510
2051	4,053	96	4,149	4,458	106	4,564	3,648	87	3,734
2052	4,312	102	4,415	4,744	112	4,856	3,881	92	3,973
2053	4,588	108	4,697	5,047	119	5,166	4,130	98	4,227
2054	-	-	-	-	-	-	4,394	103	4,497
Total	**62,065**	**1,581**	**63,646**	**68,272**	**1,739**	**70,011**	**59,761**	**1,508**	**61,269**

18.5 Financing Options:

18.5.1 Owner's contribution in terms of Equity and Sub ordinate debt

Metro projects are highly Capital-intensive projects. Phase 1, Phase-2 and Phase 2A of the Bangalore Metro Rail project have been financed by contributions from Govt. of Karnataka as well as Govt. of India. In addition, borrowings to the extent of 45% (Appx) of the project cost were mobilised primarily from multilateral and bilateral development agencies and domestic financial Institutions. The same pattern of funding is proposed to be followed for Phase-2B.

18.5.2 Senior Debt such as borrowings from MDBs

The highly capital intensive Metro projects are a public utility with huge positive economic externalities but typically very low financial returns. Domestic commercial borrowings are not a viable option for financing as not only the cost of funds is on the higher side, but the tenures are also not long enough to match the long pay back periods which characterise a long gestation infrastructure project. Therefore, there is the need to explore avenues of financing with moderate rates, long tenures and a long enough initial moratorium. This requirement is fulfilled by the sovereign loans extended by Multilateral and bilateral development agencies such as ADB, EIB, JICA, AFD, etc. The Loan tenures range from 20 to 40 years, with moratorium of 4 to 12 years, and the interest rate ranges between 0.20%(fixed) to 0.9% plus LIBOR (floating).

Finance Cost

Though, efforts will be made to borrow the funds on a long term basis, say, 20 years or more primarily from multilateral and bilateral development agencies, for the purpose of computation of IRR, it is presumed that the borrowings would be made with a repayment period of 15 years (including moratorium for principal repayment during project execution period of 3 years) and the rate of interest would be @ 8% per annum.

The principal amount would be repaid over a period of fifteen years i.e. the repayment would start from the year 2024. The interest during construction has been assumed to be at Rs. 496 crore and it is expected that the interest earned on the various cash inflows may offset the interest during construction, partially.

Based on these presumptions, the cash inflow and outflow on account of loans, repayment of loans and interest cost for the borrowings of Rs 4,287 Crore as per Equity model of New Metro Policy 2017 is tabulated in Table **18.7**.

Table 18.7 Principal Drawal, Principal and Interest Repayment (Rs in Cr)

Year	Principal Drawal	Principal Repayment	Interest Repayment
2021	1,286.14	-	(42.34)
2022	1,714.85	-	(169.34)
2023	1,286.14	-	(287.88)
2024	-	(285.81)	(338.68)
2025	-	(285.81)	(316.10)
2026	-	(285.81)	(293.52)
2027	-	(285.81)	(270.95)
2028	-	(285.81)	(248.37)
2029	-	(285.81)	(225.79)
2030	-	(285.81)	(203.21)
2031	-	(285.81)	(180.63)
2032	-	(285.81)	(158.05)
2033		(285.81)	(135.47)
2034		(285.81)	(112.89)
2035		(285.81)	(90.32)
2036		(285.81)	(67.74)
2037		(285.81)	(45.16)
2038		(285.81)	(22.58)
Total	**4,287.12**	**(4,287.12)**	**(3,209.02)**

18.5.3 Value Capture Financing:

By implementing TOD policy and thereby realizing revenues from VCF, the GOK would be able to fund the Metro and other infrastructure projects in Karnataka. The following instruments have been identified, the revenue from which can be pooled in a common infrastructure Fund and allocated by the GOK for funding various Infrastructure projects, including the Metro.

- **(i)** Premium FSI / FAR (Floor Space index / Floor Area Ratio)
- **(ii)** Cess on approval of new layouts.
- **(iii)** Construction and exploitation of commercial spaces near important infrastructure projects
- **(iv)** Generation of revenue through other sources like premium for roads developments etc.
- **(v)** Betterment Tax

It is expected that an amount of Rs 150 crores will be raised through means of Value Capture Financing.

18.5.4 Public Private Partnership (PPP):

The New Metro rail Policy,2017 envisages private participation as an essential requirement for either the complete provisioning of metro rail or for some unbundled components for all metro rail project proposals seeking central financial assistance. However, a private player would want to price the risk associated with the uncertain revenue streams owing to uncertainties in both projected ridership and fare materialising and this will invariably raise the cost of private investment in an already highly capital intensive project with public good characteristics leading to very unattractive returns on investment. Thus, finding private partners for construction of new Metro Rail systems through DBFOTs (Design-Build-Finance-Operate- Transfer) is rather more difficult. Therefore, BMRCL has focused on leveraging on the private resources, expertise and entrepreneurship for funding the project by way of unbundling the various activities and components.

To this end, BMRCL is actively exploring possibilities of PPP in Operation & Maintenance in the existing as well as the upcoming lines and getting private partners to help maximising the real estate potential of the stations by constructing multi storied towers on station land to create commercial, office, recreational and residential spaces. One of the forms of PPP for unbundled components that has been successfully tapped to generate sizeable amounts to fund project cost is detailed below:

18.5.4.1 Innovative Financing

Notwithstanding the suitability of the sovereign loans from MDBs and BDBs, in order for the pace of expansion of the Metro network to match with the pace at which the demand of Metro network is growing, there is need to constantly explore other avenues for mobilization of funds for Metro systems.BMRCL has approached Corporates along the proposed corridor by offering a bundle of rights such as Naming Rights, advertising space, commercial space for a period of 30 years and provision of direct access to their facilities through a dedicated walkway below the Metro viaduct for a period of 99 years.

Appreciating the advantages that an efficient Public Transport facility will provide, namely not only augmenting productivity by decreasing travel time and reduced pollution and related health care costs, but also improving the quality of life of employees, several companies on this corridor are coming forward expressing their willingness to participate in this innovative model.

It is expected to raise approximately an amount of Rs 350 crore through these arrangements and this amount would be available for project financing.

18.5.4.2 Back ended PPP with BIAL for Debt servicing:

The financing plan for the Airport line envisages contribution from Bangalore International Airport Ltd (BIAL) by levying user development fee on air travellers.

As per the discussions held by the State Government and BIAL with Airport Economic Regulatory Authority (AERA), the User Development Fee (UDF) can be levied only under following circumstances:

i) The capital assets are owned by the Airport Company, i.e., BIAL.

ii) The project gets commissioned.

The AERA's regulation for private airports do not allow for levy of Advance User Development Fee (ADF), i.e., a fee which can be levied even before commissioning of the project and can be used for financing capital expenditure. In view of the guidance received from AERA, the upfront contribution from BIAL is not possible and therefore the funding plan needs to be modified.

For facilitating contribution by BIAL during the operational phase of the Airport line, it is proposed to transfer the asset from Trumpet Junction to the Airport to BIAL at cost and then lease back those assets at mutually agreed terms. Such Public Private Partnership will enable BIAL and BMRCL with support from the State Government to approach AERA for permitting user development fee on the air travellers. Those revenues can be used by BIAL to pay for the cost of assets to be transferred to the company. Those revenues will help BMRCL to service the debt in operational phase and thereby reducing the burden on the State Government for supporting BMRCL for the shortfall in the company's revenues for servicing the debt. State Government has accorded an in-principle approval for such Public Private Partnership (PPP).

Therefore, the arrangement with BIAL during the operational phase by transferring assets in the Airport area upon commissioning to BIAL and leasing them back to facilitate levy of user development fee on air travelers by BIAL as per AERA guidelines will work as Back-ended PPP. The revenue streams generated through transfer of this amount would aid in debt servicing, thus mitigating the need for shadow cash support from GOK.

Considering the above aspects, it is proposed to factor-in the funding from BIAL on post-commissioning basis. Hence, future value of Rs 800 crore projected as cash inflow spread over for a period of 30 years.

(Equated annual instalment of Rs 58 crore every year as a cash inflow, Equated @ 6% annual interest rate year on year).

18.5.5 Funding Pattern:

After evaluating various parameters, the BMRCL has decided to opt for the Equity form of model as per New Metro Policy 2017 [Para E page 10] to obtain financial support from Government of India in form of Equity and Subordinate debt, subject to an overall celling of 20% of cost of project excluding private investment, cost of land, rehabilitation and resettlement, IDC and State share of taxes, the revised funding pattern under equity model for Phase-2B is tabulated in **Table 18.8**.

Table 18.8 Revised Funding pattern (Equity sharing model) - Phase-2B

Sources		Amount (Rs in crore)	(% of Share)
GoI - Equity		1,139.27	11.47%
GoI - Sub-debt		174.38	1.76%
GOI Share sub total	**(1)**	**1,313.65**	**13.22%**
GoK - Equity		1,139.27	11.47%
GoK - Sub-debt		174.38	1.76%
GoK - Sub-debt (Land Cost)		2,171.39	21.86%
Subordinate-debt (State Taxes)		348.76	3.51%
GoK Share sub total	**(2)**	**3,833.81**	**38.59%**
Value Capture Financing	**(3)**	**150.00**	**1.51%**
Innovative Financing	**(4)**	**350.00**	**3.52%**
Senior Debt (Sovereign/Non Sovereign Loans)	**(5)**	**4,287.12**	**43.15%**
Total Sources	**(1) to (5)**	**9,934.58**	**100.00%**

18.6 Financial Returns (FIRR):

Financial analysis is done based on estimated Capital inflows on account of equity, subordinate debt and borrowings as well contribution from innovative financing and Capital outflows are comprised of expenditure during construction and IDC. The inflows from Fare and Non fare Box revenue comprise the Revenue inflow and the revenue expenditure on operations and Operational, staff and energy cost as well as finance cost constitute the Revenue outflow.

18.6.1 Estimated Capital Cost:

Please refer chapter 16 on Detailed Project Cost Estimates for estimated capital cost, Capital Expenditure (with taxes, escalation, IDC) is tabulated in **Table 18.9**

Table 18.9 Construction phasing and Projected Project expenditure (INR in Crores)

Details	2020-21	2021-22	2022-23	2023-24	Total
Construction Phasing	13%	25%	34%	28%	**100%**
Projected Project expenditure	1,297	2,386	3,448	2,803	9,935

18.6.2 Revenue Projections:

Please refer 18.4.1 of this chapter “Revenue from Different Sources” and assumptions therein.

18.6.3 Operation and Maintenance Expenditure:

Please refer chapter 16 (para 16.5): Detailed Project Cost Estimates for Estimations of Operations and Maintenance cost.

18.6.4 Finance Cost:

Please refer 18.5.2 of this chapter "Finance cost" and assumptions therein.

18.6.5 Sensitivity Analysis:

FIRR has also been made with 30 years' time horizon for scenario building with variation in Ridership estimates scenarios, costs estimate and Time overrun as per appraisal guidelines of New Metro Policy 2017.

18.6.6 Ridership Estimates Scenarios:

FIRR is calculated for the three scenarios on ridership based on following 3 scenarios,

(i) **Most likely scenario** is worked out based on Transport Demand Assessment as detailed in chapter 3 "Travel Characteristics and Demand Estimates".

(ii) **Optimistic scenario** has been worked out at 110% of Passengers of the Most likely scenario.

(iii) **Pessimistic scenario** has been worked out at 90% of Passengers of the Most Likely scenario estimated with one-year time overrun and increase in capital cost by 10%.

18.6.7 Conclusion:

As seen from the above, the project is financially viable as FIRR is positive as detailed below in **Table 18.10.**

Table: 18.10: Summary of Sensitivity Analysis and FIRR results

SL No	Ridership Scenarios	Pax per day	Capital Outflow including IDC (Rs in crores)	Net cash inflow (after redemption of borrowings) (Rs in crores)	FIRR	Reference
1	**Most Likely scenario**					
	Year 2024 onwards	4,09,383	(9,935)	21,695	6.83%	Annexure-18.1
	Year 2034 onwards	73,768				
2	**Optimistic scenario** (Pax 110% of Most likely scenario)					
	Year 2024 onwards	4,50,321	(9,935)	30,720	8.60%	Annexure-18.2
	Year 2034 onwards	81,145				
3	**Pessimistic Scenario** (Pax 90% of Most likely scenario with one year time overrun + CAPEX increase by 10%)					
	Year 2025 onwards	3,68,445	(10,933)	18,530	5.55%	Annexure-18.3
	Year 2035 onwards	66,391				

Note: It has been observed that there is a slight reduction of passenger traffic on weekends, hence for the purpose of Financial Analysis module (FIRR) and Economic Analysis module (EIRR) the passenger traffic for Saturday has been considered at 75% of weekday traffic and for Sunday, it has been considered at 60% of the same. Hence, cumulatively there will be reduction of 9% in passenger traffic.

Further, the following benefits outweigh financial considerations:

1. Cost of construction on this line will be less as compared to other corridors because there is no tunnel and even the height of the viaduct is being optimized
2. Large number of the passengers are expected to travel by Metro Rail due to various benefits, like savings in time and cost, safety, reliability, comfort travel and above all, to avoid traffic congestion during peak hours.
3. larger economic and social benefits to the society in terms of substantial reduction in per capita pollution emissions resulting in reduction in chronic diseases, reduction in road accidents, bringing down noise pollution etc.,

Thus, there is enough justification to take up this project.

ANNEXURE : 18.1 PHASE-2B - FIRR MOST LIKELY SCENARIO AMOUNT IN CRORES

SNAP SHOT - INFLOW	INR	SNAP SHOT - OUTFLOW	INR
OWNERS FUNDS	5,147	OUTFLOW CAPEX	9,438
BORROWINGS	4,287	IDC	496
INNOVATIVE FINANCING	350		
VALUE CAPTURE FINANCING	150		
TOTAL INFLOW	9,935	Total	9,935

CASH FLOW PROJECTIONS FROM OPERATIONS

Year	CAPITAL								REVENUE							FIRR
	INFLOW					OUTFLOW			INFLOW			OUTFLOW				6.83%
	GOI CONTRIBUTION	GOK CONTRIBUTION	INNOVATIVE FINANCING	VALUE CAPTURE FINANCING	BORROWING	CAPEX	Interest during Construction	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	BIAL - UDF	Staff Cost	Energy Cost	Maintenance Cost	Interest cost	Net cash flow
2021	1,314	958	88	38	1,286	(3,641)	(42)									(2,397)
2022		1,534	140	60	1,715	(3,279)	(169)									(1,734)
2023		1,342	123	53	1,286	(2,518)	(284)									(1,517)
2024								(286)	547	20	58	(170)	(47)	(61)	(339)	(278)
2025								(286)	592	21	58	(181)	(50)	(67)	(316)	(229)
2026								(286)	642	22	58	(194)	(52)	(73)	(294)	(177)
2027								(286)	695	24	58	(208)	(55)	(81)	(271)	(123)
2028								(286)	753	25	58	(222)	(58)	(89)	(248)	(67)
2029								(286)	816	27	58	(238)	(61)	(98)	(226)	(7)
2030								(286)	884	28	58	(255)	(64)	(108)	(203)	56
2031								(286)	944	30	58	(272)	(100)	(118)	(181)	75
2032								(286)	1,008	32	58	(291)	(105)	(130)	(158)	127
2033								(286)	1,076	34	58	(312)	(110)	(143)	(135)	181
2034								(286)	1,384	36	58	(334)	(116)	(158)	(113)	473
2035								(286)	1,478	38	58	(357)	(121)	(173)	(90)	546
2036								(286)	1,577	40	58	(382)	(127)	(191)	(68)	622
2037								(286)	1,684	43	58	(409)	(134)	(210)	(45)	701
2038								(286)	**1,797**	45	58	(437)	(140)	(231)	(23)	**784**
2039									1,918	48	58	(468)	(147)	(254)		1,155
2040									2,048	51	58	(501)	(155)	(279)		1,222
2041									2,179	54	58	(536)	(192)	(307)		1,256
2042									2,318	57	58	(573)	(201)	(338)		1,321
2043									2,467	61	58	(613)	(211)	(371)		1,389
2044									2,625	64	58	(656)	(222)	(409)		1,460
2045									2,793	68	58	(702)	(233)	(449)		1,534
2046									2,972	72	58	(751)	(245)	(494)		1,611
2047									3,162	76	58	(804)	(257)	(544)		1,692
2048									3,364	81	58	(860)	(270)	(598)		1,775
2049									3,580	86	58	(921)	(283)	(658)		1,862
2050									3,809	91	58	(985)	(297)	(724)		1,952
2051									4,053	96	58	(1,054)	(312)	(796)		2,045
2052									4,312	102	58	(1,128)	(328)	(876)		2,141
2053									4,588	108	58	(1,207)	(344)	(963)		2,240
Total	**1,314**	**3,834**	**350**	**150**	**4,287**	**(9,438)**	**(496)**	**(4,287)**	**62,065**	**1,581**	**1,744**	**(16,022)**	**(5,038)**	**(9,990)**	**(2,709)**	**21,695**

Note : Income tax is considered as zero for all these years due to depreciatio and carry forward lossess of BMRCL as a whole.

ANNEXURE : 18.2 PHASE-2B - FIRR OPTIMISTIC SCENARIO AMOUNT IN CRORES

SNAP SHOT - INFLOW	INR	SNAP SHOT - OUTFLC	INR
OWNERS FUNDS	5,147	OUTFLOW CAPEX	9,438
BORROWINGS	4,287	IDC	496
INNOVATIVE FINANCING	350		
VALUE CAPTURE FINANCING	150		
TOTAL INFLOW	9,935	Total	9,935

CASH FLOW PROJECTIONS FROM OPERATIONS

Year	CAPITAL								REVENUE							FIRR
	INFLOW					OUTFLOW			INFLOW			OUTFLOW				8.60%
	GOI CONTRIBUTION	GOK CONTRIBUTION	INNOVATIVE FINANCING	VALUE CAPTURE FINANCING	BORROWING	CAPEX	Interest during Construction	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	BIAL - UDF	Staff Cost	Energy Cost	Maintenance Cost	Interest cost	Net cash flow
2021	1,314	958	88	38	1,286	(3,641)	(42)									(2,397)
2022		1,534	140	60	1,715	(3,279)	(169)									(1,734)
2023		1,342	123	53	1,286	(2,518)	(284)									(1,517)
2024								(286)	601	22	58	(159)	(52)	(55)	(339)	(209)
2025								(286)	651	23	58	(170)	(55)	(61)	(316)	(154)
2026								(286)	706	25	58	(181)	(58)	(67)	(294)	(97)
2027								(286)	765	26	58	(194)	(61)	(73)	(271)	(36)
2028								(286)	829	28	58	(208)	(64)	(81)	(248)	28
2029								(286)	898	29	58	(222)	(67)	(89)	(226)	96
2030								(286)	973	31	58	(238)	(70)	(98)	(203)	167
2031								(286)	1,038	33	58	(255)	(74)	(108)	(181)	227
2032								(286)	1,108	35	58	(272)	(90)	(118)	(158)	277
2033								(286)	1,183	37	58	(291)	(94)	(130)	(135)	341
2034								(286)	1,523	39	58	(312)	(99)	(143)	(113)	668
2035								(286)	1,625	42	58	(334)	(104)	(158)	(90)	754
2036								(286)	1,735	44	58	(357)	(109)	(173)	(68)	845
2037								(286)	1,852	47	58	(382)	(114)	(191)	(45)	939
2038								(286)	**1,977**	50	58	(409)	(120)	(210)	(23)	**1,038**
2039									2,110	53	58	(437)	(126)	(231)		1,427
2040									2,253	56	58	(468)	(132)	(254)		1,513
2041									2,397	59	58	(501)	(139)	(279)		1,595
2042									2,550	63	58	(536)	(170)	(307)		1,658
2043									2,714	67	58	(573)	(179)	(338)		1,749
2044									2,887	71	58	(613)	(188)	(371)		1,844
2045									3,072	75	58	(656)	(197)	(409)		1,943
2046									3,269	79	58	(702)	(207)	(449)		2,048
2047									3,478	84	58	(751)	(217)	(494)		2,157
2048									3,701	89	58	(804)	(228)	(544)		2,272
2049									3,938	94	58	(860)	(239)	(598)		2,392
2050									4,190	100	58	(921)	(251)	(658)		2,518
2051									4,458	106	58	(985)	(264)	(724)		2,650
2052									4,744	112	58	(1,054)	(277)	(796)		2,787
2053									5,047	119	58	(1,128)	(291)	(876)		2,930
Total	**1,314**	**3,834**	**350**	**150**	**4,287**	**(9,438)**	**(496)**	**(4,287)**	**68,272**	**1,739**	**1,744**	**(14,974)**	**(4,335)**	**(9,082)**	**(2,709)**	**30,720**

Note : Income tax is considered as zero for all these years due to depreciation and carry forward losses of BMRCL as a whole.

Annexure : 18.3 PHASE-2B - FIRR - SENSTIVITY- PESSIMISTIC SCENARIO (TIME HORIZION + CAPEX) AMOUNT IN CRORES

SNAP SHOT - INFLOW	INR	SNAP SHOT - OUTFLOW	INR	CASH FLOW PROJECTIONS FROM OPERATIONS
OWNERS FUNDS	5,766	OUTFLOW CAPEX	10,202	
BORROWINGS	4,667	IDC	731	
INNOVATIVE FINANCING	350			
VALUE CAPTURE FINANCING	150			
TOTAL INFLOW	10,933	TOTAL OUTFLOW	10,933	

Year	CAPITAL								REVENUE							FIRR
	INFLOW					OUTFLOW			INFLOW			OUTFLOW				5.55%
	GOI CONTRIBUTION	GOK CONTRIBUTION	INNOVATIVE FINANCING	VALUE CAPTURE FINANCING	BORROWING	CAPEX	Interest during Construction	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	BIAL - UDF	Staff Cost	Energy Cost	Maintenance Cost	Interest cost	Net cash flow
2021	803	832	70	30	933	(2,637)	(31)									(1,735)
2022	803	1,248	105	45	1,400	(3,472)	(129)									(2,201)
2023		1,248	105	45	1,400	(2,559)	(240)									(1,398)
2024		832	70	30	933	(1,534)	(332)									(932)
2025								(311)	533	19	58	(170)	(55)	(61)	(369)	(355)
2026								(311)	577	20	58	(181)	(58)	(67)	(344)	(305)
2027								(311)	626	21	58	(194)	(61)	(73)	(320)	(254)
2028								(311)	678	23	58	(208)	(64)	(81)	(295)	(200)
2029								(311)	735	24	58	(222)	(67)	(89)	(270)	(143)
2030								(311)	796	26	58	(238)	(70)	(98)	(246)	(83)
2031								(311)	850	27	58	(255)	(74)	(108)	(221)	(33)
2032								(311)	907	29	58	(272)	(90)	(118)	(197)	6
2033								(311)	968	30	58	(291)	(94)	(130)	(172)	58
2034								(311)	**1,246**	32	58	(312)	(99)	(143)	(147)	324
2035								(311)	1,330	34	58	(334)	(104)	(158)	(123)	393
2036								(311)	1,420	36	58	(357)	(109)	(173)	(98)	465
2037								(311)	1,515	38	58	(382)	(114)	(191)	(74)	540
2038								(311)	1,617	41	58	(409)	(120)	(210)	(49)	**617**
2039								(311)	1,727	43	58	(437)	(126)	(231)	(25)	698
2040									1,843	46	58	(468)	(132)	(254)		1,093
2041									1,961	48	58	(501)	(139)	(279)		1,149
2042									2,087	51	58	(536)	(170)	(307)		1,183
2043									2,220	54	58	(573)	(179)	(338)		1,243
2044									2,362	58	58	(613)	(188)	(371)		1,306
2045									2,514	61	58	(656)	(197)	(409)		1,371
2046									2,675	65	58	(702)	(207)	(449)		1,439
2047									2,846	69	58	(751)	(217)	(494)		1,510
2048									3,028	73	58	(804)	(228)	(544)		1,583
2049									3,222	77	58	(860)	(239)	(598)		1,659
2050									3,428	82	58	(921)	(251)	(658)		1,738
2051									3,648	87	58	(985)	(264)	(724)		1,820
2052									3,881	92	58	(1,054)	(277)	(796)		1,904
2053									4,130	98	58	(1,128)	(291)	(876)		1,991
2054									4,394	103	58	(1,207)	(305)	(963)		2,080
Total	**1,606**	**4,161**	**350**	**150**	**4,667**	**(10,202)**	**(731)**	**(4,667)**	**59,761**	**1,508**	**1,744**	**(16,023)**	**(4,588)**	**(9,990)**	**(2,949)**	**18,530**

Note : Income tax is considered as zero for all these years due to depreciation and carry forward lossess of BMRCL as a whole.

Chapter 19

Economic Analysis

CHAPTER – 19

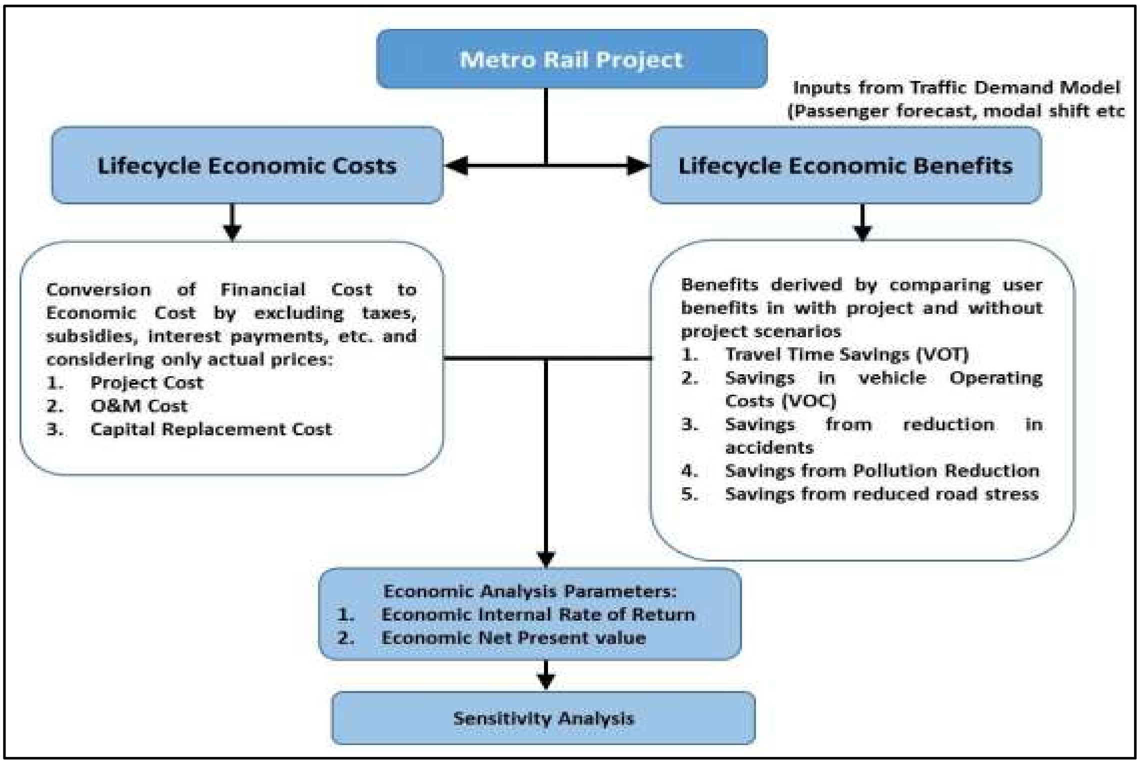
ECONOMIC ANALYSIS

19.1 Framework for Economic Appraisal

The benefits that the metro projects provide are more important from the state government's economic and social point of view compared to the financial benefits that accrue from implementing the project. The proposed system will provide a variety of benefits to the city and society, viz. savings in fuel consumption, vehicle operating costs, travel time, reduction in road accidents and air pollution etc. These economic benefits would overweigh the financial benefits and hence assessing the same would also be of more significance.

The economic analysis for KR Puram to Kempegowda International Airport Line has been carried out within the broad framework of EIRR (Economic Internal Rate of Return) based on Appraisal Guidelines for metro rail projects taken from website of Ministry of Housing & urban affairs.

Figure 19.1 Framework for Economic Analysis; "Appraisal Guidelines for Metro Rail Project Proposals, Ministry of Housing and Urban Affairs GoI"

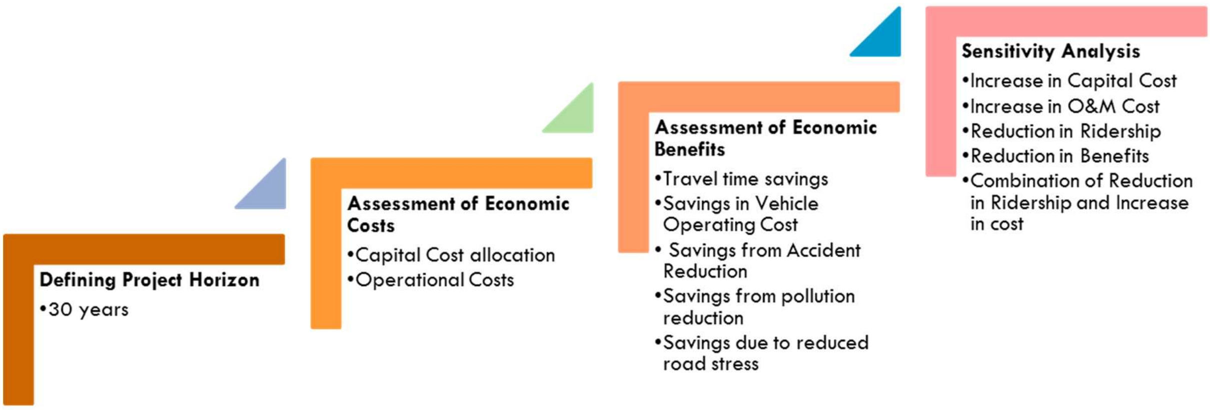


The Economic Analysis is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the various Sensitivity Scenarios. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values computed by converting the market prices using appropriate factors. The annual streams of project costs and benefits have been compared over the entire analysis period to estimate the net cost/ benefit and to calculate the economic viability of the project in terms of EIRR. Effectively 30 years of operations from the start of services from the year 2023-24 has been considered for economic evaluation for the project.

19.2 Approach & Methodology for Economic Appraisal

The approach adopted for carrying out the Economic Assessment of the Project is as shown in **Figure 19.1.**

Figure 19.2: Approach for Economic Analysis



Project horizon comprises of the construction and operation period of the metro rail project. During the project horizon, the cost and benefits associated with project are estimated. The horizon period for the purpose of economic analysis is taken as 33 years including three years of Construction Period.

Economic Cost comprises of Capital Expenditures incurred during the Construction period and the Operation & Maintenance cost during the Project Operation period.

Economic Benefits - Year wise project benefits is estimated during the project operation period. The "Most Likely" scenario is compared with the other factors through Sensitivity assessment

Sensitivity Analysis is undertaken within the range of 5% to 15% of the critical factors which impacts the Economic Assessment.

19.2.1 Methodology

<u>Project Horizon</u>

The analysis period of the project is taken as 33 years from the base year 2020-21 as follows:

- Base Year – 2020-21
- Construction period – 2020-21 to 2022-23
- Project opening for traffic – 2023-24
- End of the analysis period –2052-53
- No. of operating years, considered for economic analysis – 30 years

Thus, 30 years of operation, in effect, from the start of operation i.e. 2023-24 has been considered for economic evaluation for the project.

19.2.2 Assessment of Economic Costs

Table 19.1: Assessment of Economic Costs

Economic Cost of the Project	The economic costs of the capital works and annual operation and maintenance costs are calculated from the financial cost estimates based on: 1. **Price contingencies/price escalations** are excluded but physical contingencies are included because they represent real consumption of resources; 2. **Import duties and taxes** are excluded because they represent transfer payments. For this the shadow exchange rate factor is used; a. The existence of unemployment and under-employment for unskilled workers within the Indian economy means that the opportunity costs if unskilled labour can be considered to be lower than its wage rate; b. The market wage rate for skilled labour and the acquisition cost of land are considered to represent opportunity costs, as both factors are in demand 3. **Sunk costs** –these are the costs which are already committed or irretrievably made. It does not have any prospective cost benefit analysis. Thus, it is excluded.

	4. **Interest payment, principal payment and interest during construction** period are excluded – these are the financial costs and are hence not included as part of economic costs. The conversion factors to be used for economic analysis are given in Appraisal Guidelines and also mentioned in the section on EIRR computation below.

19.2.3 Assessment of Economic Benefits

The following parameters are considered for evaluating the economic benefits from this proposed metro -

- Modal shift from current options to proposed metro line;
- Fuel saved by the passengers by using the public transport;
- Savings in Operating cost of the Private vehicles;
- Reduced time in travel on increasing the schedules and modal shift;
- Reduction in number of fatal accidents and injuries;
- Reduction in traffic congestion;
- Reduction in Road Infrastructure maintenance cost.

a. Modal shift from private transport to public transport

The ultimate objective of the metro is to enhance the public transportation services and reduce the usage of private transport. Therefore, the modal shifts from cars, auto rickshaws and particularly two-wheeler vehicles shall be assessed for the proposed metro corridor and a percentage of modal shifts from other mode of transport to the metro system is estimated and benefits out of this modal shift is calculated.

b. Economic Benefit from Fuel Savings

When there is modal shift from private transport to public transport there is savings in the consumption of fuel which benefits the end users and with rising fuel cost there can be significant shift to public transport leading to more reduction in fuel consumption. In addition, there is benefit on the fuel savings due to reduced congestion of traffic due to the operation of the metro.

c. Economic Benefit from Reduction in number of accidents

The increase in number of vehicles also attributes to the increase in number of accidents which may be fatal, non-fatal and sometimes causing severe injuries. This may not only lead to loss of lives but also pulls down the economy of the family/person. Availability of public transport such as metro leads to less usage of private transport which ultimately results in less number of accidents thereby reducing the economic loss.

d. Economic Benefit due to reduction in travel time

As metro services provide end-to-end dedicated transport connectivity across the corridor, there is reduction in travel time of the passengers using this metro service when compared to the other modes of public transport or private transport. Even a reduction in travel/waiting time of 2 minutes brings huge benefits which when quantified into economic benefit.

e. Reduction in Road Infrastructure maintenance cost

Introduction of Metro services and the modal shift of the passengers will lessen the number of vehicles on road and thereby may result in increasing the life of the existing roads thereby reducing the maintenance cost. In this section, an attempt has been made to calculate the reduction in road maintenance cost which is in-turn the savings because of the Metro Project.

Based on the above parameters, the cost-benefit analysis is made in order to ascertain the economic returns that the metro on this proposed corridor would provide over the project period. Suitable sensitivity analysis is also carried out on the economic benefits that would accrue from this project.

Attempt has been made to ensure that the economic analysis for this proposed metro corridor adheres to the Appraisal Guidelines for Metro Projects Proposals issued by Ministry of Housing and Urban Affairs, Government of India.

19.3 Estimation of Economic Project Cost and Benefits

19.3.1 Economic Project Cost

The project cost stream comprises capital cost, operation and maintenance cost. Cost components considered for the purpose of this exercise include:

- Capital cost of infrastructure
- Operation and Maintenance cost of the system

The capital cost for economic analysis is taken as Rs. 9934.58 Crores. The Operation & Maintenance Cost (O & M cost) is as worked out in the respective Chapter.

The components of the Total project cost are presented in **Table 19.2.**

Table 19.2: The components of the Total project cost

Sl.No	Components	Value
1	Land cost	2171.39
2	Civil & System Works	4141.26
3	Rolling Stock	1008.00
4	Taxes	697.53
5	Contingency	175.40
6	Escalation & D&G Charges	1244.84
7	Interest During Construction	496.16
8	**TOTAL COSTS**	**9,934.58**

Economic Project Benefits

The Economic Benefits has been quantified across the five primary parameters as prescribed by the Appraisal Guidelines. The computation for each of the parameter and the resultant values are detailed below –

i. Economic Benefit due to Savings in Time

The methodology adopted for the computation of benefit for this parameter is as stated below -

- **Step 1** - Based on the Modal Share and No. of Trips by Metro as calculated in the previous sections of this DPR, the estimated trips saved from different Modes of Transport i.e. Cars, 2-Wheelers & 3-Wheelers and Buses is determined;
- **Step 2** - Based on the Modal Shift percentages as provided in DPR and the values as arrived at from Step (I) above, the number of Commuter Trips was determined that might have taken place by Road for different modes of transport if Metro is not in place
- **Step 3** - Time saving for commuters by metro is determined by multiplying the estimated per person per trip time saved (30 minutes) with the total metro trips (as provided in DPR)
- **Step 4** - Time saving for commuters on road is determined by multiplying the time saved for On-Road Commuter trip and the On-Road commuter trips which were as follows –
  - Time saved for On Road commuter trip –Assumed at ~3 min for the first year of operation as per Uber study undertaken for an already established metro corridor in Bengaluru.
  - No. of On-Road commuter trips – Difference between Estimated Commuter trips without metro and No. of Commuter trips shifted to metro.

- **Step 5** - Total Time saved is summation of values determined at Step 3 and Step 4 above
- **Step 6** - Per hour per capita income is considered at Rs. 120.47/hour for 2024.
- The Product of Step 5 and Step 6 have given the Value of Time savings owing to Metro.

Assumptions – For the computation of benefits, certain assumptions have been considered as carried forward from the previous sections of this DPR. The assumptions and the assumed values are shown in **Table 19.3**.

Table 19.3: Assumptions for the computation of benefits

Assumption	Value	Data Source
No. of Passenger Trips daily	4,09,383 (from 2023-24) Additional 73,768 (from 2033-34 onwards)	DPR
Trips Growth Rate	4.18% for the year 2024 to 2030 2.63% for the year 2031 to 2040 and 2.18% for the year 2041 onwards	DPR
Number of days of Operation in a Year	360	DPR
Modal Share for each mode of transport (As per RITES report)	Cars (7%), 2W + 3W (43.5%) and Buses (49.5%)	DPR and Study Report by RITES titled Traffic Demand Forecast and identification of Phase-III corridors of Bangalore Metro dated August 2016
Modal shift within the proposed corridor	Cars (50%), 2W + 3W (10%) and Buses (40%)	DPR
Time saving for passengers travelling by metro	30 min	DPR
Time saving for commuters of other modes of transport	3 min	As per study undertaken by Uber after the completion of Phase-I Metro Corridor of Bengaluru
Per Capita Income Per Hour (2024)	Rs. 120	Derived from the Economic Survey Report of Govt. of Karnataka for the Bengaluru Urban segment.
Per Capital Income Growth during the Operational Period	@7%	As per Economic Suvey Report of GoK, Bengaluru Urban segment has grown by more than 15% in the last 7 years (2010-11 – 2017-18. However, assuming a conservative number, the growth percent have been considered @ 7%.

Following the above method and taking into considerations the above assumptions, the value of savings for the 30 years period is as below –

Table 19.4 Value of Savings for 30 years' Period due to savings in Time

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Trips Annually by Metro users (in crore)	13.41	17.14	22.01	25.07	28.10	31.51	33.74
Total time (in hours) saved for trips by Metro users (in crore)	6.70	8.57	11.00	12.54	14.05	15.75	16.87
Trips Annually by Non-Metro users (in crore)	63.37	72.95	82.04	92.26	103.75	116.67	125.18
Time saved (in hours) on trips by Non-Metro user (in crore)	3.16	3.16	3.14	3.14	3.13	3.12	3.11
Total time (in hours) saved Annually (crore)	9.87	11.37	14.15	15.67	17.18	18.87	19.98
Per Capita Income Per Hour (Rs. Per hour)	120	181	254	356	499	700	857
Value of Time Saving (Rs. Crore)	**1189.55**	**2120.91**	**3589.43**	**5575.92**	**8572.61**	**13206.75**	**17131.83**

ii. Economic Benefit due to Savings in Vehicle Operating Cost

The methodology adopted for the computation of benefit for this parameter is as stated below –

- The manual on IRC provides the per km vehicle operating cost for different category of vehicles;
- Based on the Study Report by RITES titled "Traffic Demand Forecast and identification of Phase-III corridors of Bangalore Metro" dated August 2016 and the DPR for Phase 2B, the total number of vehicle kilometres that could be saved in the proposed corridor is estimated;
- The number of vehicles in the proposed corridor is estimated by using occupancy factor from the Study Report by RITES titled "Traffic Demand Forecast and identification of Phase-III corridors of Bangalore Metro" dated August 2016 and the number of trips from the ridership details as provided in the previous sections of the DPR.
- Savings is computed for both Metro and Non-Metro Users. For Metro users, savings is computed considering the vehicles kilometres reduced owing to modal shift in the passengers opting for Metro services; whereas, for Non-Metro Users, the savings is computed based on the reduced congestion on road thereby enabling smooth ride on road.

Assumptions – The Assumption for the computation of this parameter are taken from the IRC manual and information is taken from RITES report. Other assumptions considered are –

Table 19.5 Assumptions for Savings in Vehicle Operating Cost

Assumption	Value	Data Source
Increase in Vehicle Operating Cost	@5%	As per Appraisal Guideline
Congestion Index	0.45	Report of Department of Urban & Land Transport titled, "Bangalore mobility indicators 2010-11"

owing the above method and taking into considerations the above assumptions, the value of savings for the 30 years period is as below –

Savings on account of Vehicle Users shifting to Metro

Table 19.6 **Vehicle Kilometer saved for different modes after the Metro Project (as per DPR)**

Modes	Kilometer saving	
Cars	1,25,712	Vehicle Kms
Two-wheelers + Auto	8,63,704	VKm
Bus	53,371	VKm
	10,42,787	

Table 19.7 **Vehicle Operating Cost (INR / km)**

Modes	Average Operating cost		
Cars	9	INR / Km	From IRC
Two Wheeler	3	INR / Km	From IRC
Bus	36	INR / Km	From IRC
Average VOC per Km Saved	**5.78**		

Table 19.8 **Value of Vehicle Operating Cost Savings (Daily)**

Modes	VOC Savings	
Cars	11,89,237	INR
Two Wheeler	28,93,407	INR
Bus	19,47,511	INR
Total	**60,30,154**	

Table 19.9 Value of Savings for 30 years in Vehicle Operating Cost after Shifting to Metro

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Savings in Vehicle Operating Cost (Rs. Crore)	**217**	**291**	**371**	**474**	**605**	**772**	**894**

Savings on account of Vehicle Users NOT shifting to Metro

Table 19.10 **Vehicles ON-ROAD with Metro (Daily)**	
Modes	**No. of Vehicles.**
Cars	2,56,931
Two-wheelers + Auto	30,89,170
Bus	1,42,722
	34,88,823

Table 19.11 **Vehicle Operating Cost (INR / km)**			
Modes	**Average Operating cost**		
Cars	9	INR / Km	From IRC
Two Wheeler	3	INR / Km	From IRC
Bus	36	INR / Km	From IRC
Average VOC per Km Saved	**5.78**		

Table 19.12 Value of Savings of Vehicles on Road applying Congestion Index

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Factor for additional distance travelled otherwise in case of No Metro (km)	1.105	0.96	0.85	0.75	0.67	0.59	0.55
Savings on account of vehicles on-road after applying the congestion index (Rs. Crore)	361.15	312.65	277.24	245.84	218.00	193.32	179.87

Total Savings on account of Vehicle Operating Cost is –

Table 19.13 Value of Savings for 30 years on account of Vehicle Operating Cost

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Savings on account of Vehicle Operating Cost	**578**	**604**	**649**	**720**	**823**	**965**	**1073**

iii. Economic Benefit due to reduction in Number of Accidents

The methodology adopted for the computation of benefit for this parameter is as stated below –

- **Step 1** - Proportion determined for the Trips in the Corridor without metro to the Total Trips in Bengaluru for 2024;
- **Step 2** - Above proportion applied on the Average Annual accident cases to estimate the cases of accident happening in the proposed Phase-2B corridor;
- **Step 3** - The estimated cases of accidents in the Corridor are classified across different modes by applying the Modal Proportion;
- **Step 4 -** Reduction in accident cases for different modes is determined by applying the proportion of Modal Shift to the Number of accidents for different modes as determined in Step 3 above
- **Step 5** – Considering the reduced number of accident cases and the compensations for each type of case, the monetary savings were determined for different aspects which are –
    - Compensation in case of death
    - Compensation in case of fatal accident
    - Compensation for vehicular damages considering the occupancy factor of vehicles and the accident numbers
- **Step 6** - Further, having calculated the Transport Mode wise compensation for the base year, the Average compensation per person and average compensation per vehicle was determined.

  For the projection of the number of accident cases reduced Y-o-Y, the same proportion was applied as equivalent to the increase in the Metro trips Y-o-Y which is provided in the above section.

Assumptions – The Assumption for the computation of this parameter are taken from the IRC manual and information is taken from Study Report by RITES titled “Traffic Demand Forecast and identification of Phase-III corridors of Bangalore Metro” dated August 2016.

Table 19.14 Data of accident cases

Assumption	Value	Data Source
Average Number of accident cases in a year resulting in death or fatal damages	**Killed cases** – 801 **Fatal cases** – 771	Bengaluru Traffic Police Department
Increase in compensation values Y-o-Y	**@5%**	Appraisal Guidelines
Monetary Compensation as per the Appraisal Guidelines (as per 2004 Rates)		

Particular	Accident Cost (Rs)
Cost of fatal accident (person killed)	4,37,342
Cost of major accident (person Injured)	64256
Cost of damage to Two wheelers	2286
Cost of damage to Car	9763
Cost of damage to buses in road accidents	32818

Source: Toolkit on Finance and Financial Analysis, 2013 by MoHUA

Following the above method and taking into considerations the above assumptions, the value of savings for the 30 years period is as below –

Table 19.15 Value of Savings due to reduction in Accident Cases

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Accidental Cases reduced during the year	53	64	75	88	103	121	133
Average compensation value for person	6,42,783	8,61,390	10,99,377	14,03,114	17,90,769	22,85,525	26,45,781
Average Compensation value for Vehicle	4,680	6,272	8,004	10,216	13,038	16,641	19,264
Total Savings for Year (in Rs. Crore)	**3.44**	**5.57**	**8.34**	**12.48**	**18.67**	**27.93**	**35.57**

iv. Economic Benefit due to Reduction in Pollution

The methodology adopted for the computation of benefit for this parameter is as stated below –

- The Saved Vehicle Kilometre as determined for calculating Vehicle Operating Cost is used for this calculation
- Further calculation is done as per the Pollutant content estimates per kilometre and the treatment cost as provided by MoHUA Appraisal Guidelines.

Assumption -

- Pollutant details assumed and monetary value for the treatment of Pollutants is assumed as per MoHUA Appraisal Guidelines.

Table 19.16 Details of Pollutants from Vehicles

Vehicle Type/ Pollutant	CO	HC	NOX	PM	CO_2
2-wheeler	1.4	0.7	0.3	0.05	28.58
3-wheeler	2.45	0.75	0.12	0.08	77.89
Cars (incl. cabs)	1.39	0.15	0.12	0.02	139.52
Bus (incl. BRT)	3.72	0.16	6.53	0.24	787.72
Treatment Cost (Rs. /ton)	1,00,000	1,00,000	1,00,000	1,00,000	500

- It is to be noted that the above treatment costs is considered w.r.t. the Current Year (2017-18) and extrapolated for the Project Commencement Year which is 2023-24.
- Increase in Treatment cost Y-o-Y assumed at 5%

Following the above method and taking into considerations the above assumptions, the value of savings for the 30 years period is as below –

Table 19.17 Value of Savings for 30 years due to reduction in Pollution

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Vehicle Kilometre Saved Annually (in crore)	37.54	44.82	51.96	60.24	69.83	80.95	88.46
Average Ton of Pollutant per kilometre saved annually	0.0001016	0.0001016	0.0001016	0.0001016	0.0001016	0.0001016	0.0001016
Tons of Pollutants Saved (Annually)	38,132	45,532	52,784	61,191	70,938	82,236	89,862
Average Treatment Cost Per Ton	4,922	6,596	8,419	10,745	13,714	17,502	20,261
Total Cost Saved (in Rs. Crore)	**19**	**30**	**44**	**66**	**97**	**144**	**182**

v. Economic Benefit due to Reduction in Road Infrastructure Maintenance Cost

The methodology adopted for the computation of benefit for this parameter is as stated below –

- **Step 1** - Determined the Average maintenance cost per trip per year without metro. The cost is determined by collating information on the expenditures incurred on Road Maintenance works by Bruhat Bangalore Mahanagara Palike (BBMP) over the last 3-5 years in the proposed stretch of the Phase-2B metro corridor;

- **Step 2** – Considering that the number of trips on Road after the roll-out of Metro is already calculated, the proportionate cost of maintenance was determined for post Metro scenario.

- Difference between the above values provided for the savings in the Road Maintenance Cost.

Assumption -

- Obtained ward wise Road works Maintenance expenditure from BBMP database for the year 2013-14 to 2016-2017
- Derived the Average maintenance expenditure for each year by applying an inflationary factor of 5% Y-o-Y.

Following the above method and taking into considerations the above assumptions, the value of savings for the 30 years period is as below –

Table 19.18 Value of Savings for 30 years due to reduction in RI Maintenance Cost

	2024…	2030…	2035…	2040…	2045…	2050…	2053
Total Cost Saved (in Rs. Crore)	**2.14**	**2.87**	**3.66**	**4.67**	**5.96**	**7.61**	**8.81**

19.4 EIRR for 30 Years

When the financial values are converted into economic values, they need to be adjusted for taxes, subsidies, inefficient land or wage markets, and other transfer payments, before performing the economic analysis. The conversion factors for different categories to be used are given as in **Table 19.19**.

Table 19.19 Conversion Factor = Economic Price / Financial Price

S.No.	Component	Economic Factor
1	Capital Cost	83%
2	Operating Cost	87%
3	Time cost savings	100%
4	Vehicle Operating cost savings	90%
5	Emission saving cost	100%
6	Accident reduction saving	90%
7	Infrastructure Maintenance cost savings	87%

Economic Internal Rate of Return (EIRR) of **22.11%** has been arrived at based on above assumptions and detailed EIRR computation is tabulated below in table 19.20

19.20 EIRR calculation

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		22.11%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													**2022**	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													**2023**	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**	**2024**	0	0	2024	-277.8	-241.71	2024	1491.98
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**	**2025**	0	0	2025	-298.1	-259.39	2025	1597.40
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**	**2026**	0	0	2026	-320.0	-278.42	2026	1714.76
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**	**2027**	0	0	2027	-343.6	-298.92	2027	1845.33
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**	**2028**	0	0	2028	-369.0	-321.00	2028	1990.53
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**	**2029**	0	0	2029	-396.3	-344.78	2029	2151.92
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**	**2030**	0	0	2030	-425.8	-370.42	2030	2331.25
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**	**2031**	0	0	2031	-490.5	-426.73	2031	2476.24
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**	**2032**	0	0	2032	-526.4	-457.95	2032	2665.08
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**	**2033**	0	0	2033	-565.0	-491.59	2033	2872.00
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**	**2034**	0	0	2034	-606.7	-527.82	2034	3385.00
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**	**2035**	0	0	2035	-651.6	-566.87	2035	3661.37
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**	**2036**	0	0	2036	-700.0	-608.96	2036	3964.08
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**	**2037**	0	0	2037	-752.1	-654.35	2037	4295.62
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**	**2038**	0	0	2038	-808.4	-703.30	2038	4658.70
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**	**2039**	0	0	2039	-869.1	-756.10	2039	5056.28
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**	**2040**	0	0	2040	-934.6	-813.09	2040	5491.62
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**	**2041**	0	0	2041	-1034.5	-900.03	2041	5927.10
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**	**2042**	0	0	2042	-1112.3	-967.71	2042	6428.96
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6976.79
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**	**2044**	0	0	2044	-1286.9	-1119.63	2044	7574.81
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**	**2045**	0	0	2045	-1384.8	-1204.80	2045	8227.60
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8940.16
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**	**2047**	0	0	2047	-1604.9	-1396.23	2047	9717.99
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**	**2048**	0	0	2048	-1728.4	-1503.69	2048	10567.04
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**	**2049**	0	0	2049	-1861.9	-1619.87	2049	11493.88
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**	**2050**	0	0	2050	-2006.3	-1745.50	2050	12505.62
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**	**2051**	0	0	2051	-2162.5	-1881.40	2051	13610.09
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**	**2052**	0	0	2052	-2331.5	-2028.44	2052	14815.80
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**	**2053**	0	0	2053	-2514.5	-2187.59	2053	16132.07

19.5 Sensitivity Analysis Outcomes

Adhering to the Appraisal Guidelines for the Metro Rail Project Proposals, the Sensitivity Assessment has been undertaken for the following scenarios –

Table 19.21 Sensitivity Assessment for Different Scenarios

Factor	Change in Value
Increase in Capital Cost	+5%, +10%, +15%
Increase in Operation & Maintenance Cost	+5%, +10%, +15%
Reduction in Ridership	-15%, -10%, -5%
Reduction in Monetary Benefits (overall)	-15%, -10%, -5%
Combination of Increase in Capital cost and Reduction in Monetary Benefits	5% Change, 10% Change and 15% Change

Based on the above considerations, the Economic IRR values for different scenarios are computed as follows –

Table 19.22 EIRR Values for Different Scenarios

Factors	**5% Change**	**10% Change**	**15% Change**
Increase in Capital Cost	21.48%	20.90%	20.35%
Increase in Operation & Maintenance Cost	22.00%	21.90%	21.79%
Reduction in Ridership	21.45%	20.77%	20.08%
Reduction in Monetary Benefits (overall)	21.47%	20.70%	19.97%
Combination of Increase in Capital cost and Reduction in Monetary Benefits	20.80%	19.57%	18.39%

Scenario 1.1 – Increase in Capital Cost by 5%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		21.48%
2020													2020		0	2020		0.00	2020	0.00
2021													2021	(3,935.13)	-3266.16	2021		0.00	2021	-3266.16
2022													2022	(3,579.11)	-2970.66	2022		0.00	2022	-2970.66
2023													2023	(2,917.07)	-2421.17	2023		0.00	2023	-2421.17
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**	2024	0	0	2024	-277.8	-241.71	2024	1491.98
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**	2025	0	0	2025	-298.1	-259.39	2025	1597.40
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**	2026	0	0	2026	-320.0	-278.42	2026	1714.76
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**	2027	0	0	2027	-343.6	-298.92	2027	1845.33
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**	2028	0	0	2028	-369.0	-321.00	2028	1990.53
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**	2029	0	0	2029	-396.3	-344.78	2029	2151.92
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**	2030	0	0	2030	-425.8	-370.42	2030	2331.25
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**	2031	0	0	2031	-490.5	-426.73	2031	2476.24
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**	2032	0	0	2032	-526.4	-457.95	2032	2665.08
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**	2033	0	0	2033	-565.0	-491.59	2033	2872.00
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**	2034	0	0	2034	-606.7	-527.82	2034	3385.00
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**	2035	0	0	2035	-651.6	-566.87	2035	3661.37
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**	2036	0	0	2036	-700.0	-608.96	2036	3964.08
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**	2037	0	0	2037	-752.1	-654.35	2037	4295.62
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**	2038	0	0	2038	-808.4	-703.30	2038	4658.70
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**	2039	0	0	2039	-869.1	-756.10	2039	5056.28
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**	2040	0	0	2040	-934.6	-813.09	2040	5491.62
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**	2041	0	0	2041	-1034.5	-900.03	2041	5927.10
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**	2042	0	0	2042	-1112.3	-967.71	2042	6428.96
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**	2043	0	0	2043	-1196.3	-1040.76	2043	6976.79
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**	2044	0	0	2044	-1286.9	-1119.63	2044	7574.81
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**	2045	0	0	2045	-1384.8	-1204.80	2045	8227.60
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**	2046	0	0	2046	-1490.6	-1296.81	2046	8940.16
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**	2047	0	0	2047	-1604.9	-1396.23	2047	9717.99
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**	2048	0	0	2048	-1728.4	-1503.69	2048	10567.04
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**	2049	0	0	2049	-1861.9	-1619.87	2049	11493.88
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**	2050	0	0	2050	-2006.3	-1745.50	2050	12505.62
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**	2051	0	0	2051	-2162.5	-1881.40	2051	13610.09
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**	2052	0	0	2052	-2331.5	-2028.44	2052	14815.80
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**	2053	0	0	2053	-2514.5	-2187.59	2053	16132.07

Scenario 1.2 – Increase in Capital Cost by 10%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		20.90%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(4,122.52)	-3421.69	2021		0.00	2021	-3421.69
2022													**2022**	(3,749.55)	-3112.12	2022		0.00	2022	-3112.12
2023													**2023**	(3,055.98)	-2536.46	2023		0.00	2023	-2536.46
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**	**2024**	0	0	2024	-277.8	-241.71	2024	1491.98
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**	**2025**	0	0	2025	-298.1	-259.39	2025	1597.40
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**	**2026**	0	0	2026	-320.0	-278.42	2026	1714.76
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**	**2027**	0	0	2027	-343.6	-298.92	2027	1845.33
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**	**2028**	0	0	2028	-369.0	-321.00	2028	1990.53
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**	**2029**	0	0	2029	-396.3	-344.78	2029	2151.92
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**	**2030**	0	0	2030	-425.8	-370.42	2030	2331.25
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**	**2031**	0	0	2031	-490.5	-426.73	2031	2476.24
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**	**2032**	0	0	2032	-526.4	-457.95	2032	2665.08
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**	**2033**	0	0	2033	-565.0	-491.59	2033	2872.00
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**	**2034**	0	0	2034	-606.7	-527.82	2034	3385.00
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**	**2035**	0	0	2035	-651.6	-566.87	2035	3661.37
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**	**2036**	0	0	2036	-700.0	-608.96	2036	3964.08
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**	**2037**	0	0	2037	-752.1	-654.35	2037	4295.62
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**	**2038**	0	0	2038	-808.4	-703.30	2038	4658.70
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**	**2039**	0	0	2039	-869.1	-756.10	2039	5056.28
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**	**2040**	0	0	2040	-934.6	-813.09	2040	5491.62
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**	**2041**	0	0	2041	-1034.5	-900.03	2041	5927.10
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**	**2042**	0	0	2042	-1112.3	-967.71	2042	6428.96
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6976.79
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**	**2044**	0	0	2044	-1286.9	-1119.63	2044	7574.81
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**	**2045**	0	0	2045	-1384.8	-1204.80	2045	8227.60
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8940.16
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**	**2047**	0	0	2047	-1604.9	-1396.23	2047	9717.99
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**	**2048**	0	0	2048	-1728.4	-1503.69	2048	10567.04
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**	**2049**	0	0	2049	-1861.9	-1619.87	2049	11493.88
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**	**2050**	0	0	2050	-2006.3	-1745.50	2050	12505.62
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**	**2051**	0	0	2051	-2162.5	-1881.40	2051	13610.09
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**	**2052**	0	0	2052	-2331.5	-2028.44	2052	14815.80
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**	**2053**	0	0	2053	-2514.5	-2187.59	2053	16132.07

Scenario 1.3 – Increase in Capital Cost by 15%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		20.35%
2020													2020		0	2020		0.00	2020	0.00
2021													2021	(4,309.90)	-3577.22	2021		0.00	2021	-3577.22
2022													2022	(3,919.98)	-3253.58	2022		0.00	2022	-3253.58
2023													2023	(3,194.89)	-2651.75	2023		0.00	2023	-2651.75
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**	**2024**	0	0	2024	-277.8	-241.71	2024	1491.98
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**	**2025**	0	0	2025	-298.1	-259.39	2025	1597.40
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**	**2026**	0	0	2026	-320.0	-278.42	2026	1714.76
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**	**2027**	0	0	2027	-343.6	-298.92	2027	1845.33
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**	**2028**	0	0	2028	-369.0	-321.00	2028	1990.53
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**	**2029**	0	0	2029	-396.3	-344.78	2029	2151.92
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**	**2030**	0	0	2030	-425.8	-370.42	2030	2331.25
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**	**2031**	0	0	2031	-490.5	-426.73	2031	2476.24
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**	**2032**	0	0	2032	-526.4	-457.95	2032	2665.08
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**	**2033**	0	0	2033	-565.0	-491.59	2033	2872.00
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**	**2034**	0	0	2034	-606.7	-527.82	2034	3385.00
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**	**2035**	0	0	2035	-651.6	-566.87	2035	3661.37
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**	**2036**	0	0	2036	-700.0	-608.96	2036	3964.08
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**	**2037**	0	0	2037	-752.1	-654.35	2037	4295.62
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**	**2038**	0	0	2038	-808.4	-703.30	2038	4658.70
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**	**2039**	0	0	2039	-869.1	-756.10	2039	5056.28
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**	**2040**	0	0	2040	-934.6	-813.09	2040	5491.62
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**	**2041**	0	0	2041	-1034.5	-900.03	2041	5927.10
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**	**2042**	0	0	2042	-1112.3	-967.71	2042	6428.96
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6976.79
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**	**2044**	0	0	2044	-1286.9	-1119.63	2044	7574.81
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**	**2045**	0	0	2045	-1384.8	-1204.80	2045	8227.60
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8940.16
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**	**2047**	0	0	2047	-1604.9	-1396.23	2047	9717.99
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**	**2048**	0	0	2048	-1728.4	-1503.69	2048	10567.04
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**	**2049**	0	0	2049	-1861.9	-1619.87	2049	11493.88
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**	**2050**	0	0	2050	-2006.3	-1745.50	2050	12505.62
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**	**2051**	0	0	2051	-2162.5	-1881.40	2051	13610.09
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**	**2052**	0	0	2052	-2331.5	-2028.44	2052	14815.80
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**	**2053**	0	0	2053	-2514.5	-2187.59	2053	16132.07

Scenario 2.1 – Increase in Operational Cost every year by 5%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		22.00%
2020													2020		0	2020		0.00	2020	0.00
2021													2021	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													2022	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													2023	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**	**2024**	0	0	2024	-291.7	-253.80	2024	1479.89
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**	**2025**	0	0	2025	-313.1	-272.36	2025	1584.43
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**	**2026**	0	0	2026	-336.0	-292.34	2026	1700.84
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**	**2027**	0	0	2027	-360.8	-313.87	2027	1830.39
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**	**2028**	0	0	2028	-387.4	-337.05	2028	1974.48
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**	**2029**	0	0	2029	-416.1	-362.02	2029	2134.68
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**	**2030**	0	0	2030	-447.1	-388.94	2030	2312.73
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**	**2031**	0	0	2031	-515.0	-448.07	2031	2454.90
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**	**2032**	0	0	2032	-552.7	-480.85	2032	2642.19
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**	**2033**	0	0	2033	-593.3	-516.16	2033	2847.42
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**	**2034**	0	0	2034	-637.0	-554.21	2034	3358.61
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**	**2035**	0	0	2035	-684.2	-595.21	2035	3633.02
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**	**2036**	0	0	2036	-735.0	-639.41	2036	3933.63
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**	**2037**	0	0	2037	-789.7	-687.07	2037	4262.90
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**	**2038**	0	0	2038	-848.8	-738.46	2038	4623.53
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**	**2039**	0	0	2039	-912.5	-793.91	2039	5018.47
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**	**2040**	0	0	2040	-981.3	-853.74	2040	5450.96
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**	**2041**	0	0	2041	-1086.2	-945.03	2041	5882.10
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**	**2042**	0	0	2042	-1167.9	-1016.09	2042	6380.57
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**	**2043**	0	0	2043	-1256.1	-1092.80	2043	6924.75
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**	**2044**	0	0	2044	-1351.3	-1175.61	2044	7518.83
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**	**2045**	0	0	2045	-1454.1	-1265.04	2045	8167.36
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**	**2046**	0	0	2046	-1565.1	-1361.65	2046	8875.32
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**	**2047**	0	0	2047	-1685.1	-1466.04	2047	9648.17
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**	**2048**	0	0	2048	-1814.8	-1578.88	2048	10491.86
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**	**2049**	0	0	2049	-1955.0	-1700.86	2049	11412.88
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**	**2050**	0	0	2050	-2106.6	-1832.78	2050	12418.35
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**	**2051**	0	0	2051	-2270.7	-1975.47	2051	13516.02
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**	**2052**	0	0	2052	-2448.1	-2129.87	2052	14714.37
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**	**2053**	0	0	2053	-2640.2	-2296.97	2053	16022.69

Scenario 2.2 – Increase in Operational Cost every year by 10%

ECONOMIC SAVINGS (in Rs. Crore)												
	As per Calculations						For EIRR Computation (Ratio as per Guidelines)					
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings
Factor							100%	90%	90%	100%	87%	
2020												
2021												
2022												
2023												
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**

CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
Most Likely						Most Likely	
Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
		83%			87%		21.90%
2020		0	2020		0.00	2020	0.00
2021	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	0	0	2024	-305.6	-265.88	2024	1467.81
2025	0	0	2025	-328.0	-285.33	2025	1571.46
2026	0	0	2026	-352.0	-306.27	2026	1686.92
2027	0	0	2027	-377.9	-328.81	2027	1815.44
2028	0	0	2028	-405.9	-353.10	2028	1958.43
2029	0	0	2029	-435.9	-379.26	2029	2117.44
2030	0	0	2030	-468.3	-407.46	2030	2294.20
2031	0	0	2031	-539.5	-469.40	2031	2433.56
2032	0	0	2032	-579.0	-503.75	2032	2619.29
2033	0	0	2033	-621.5	-540.74	2033	2822.84
2034	0	0	2034	-667.4	-580.60	2034	3332.22
2035	0	0	2035	-716.7	-623.56	2035	3604.68
2036	0	0	2036	-770.0	-669.86	2036	3903.19
2037	0	0	2037	-827.3	-719.78	2037	4230.19
2038	0	0	2038	-889.2	-773.63	2038	4588.37
2039	0	0	2039	-956.0	-831.72	2039	4980.67
2040	0	0	2040	-1028.0	-894.40	2040	5410.31
2041	0	0	2041	-1138.0	-990.04	2041	5837.10
2042	0	0	2042	-1223.5	-1064.48	2042	6332.19
2043	0	0	2043	-1315.9	-1144.83	2043	6872.72
2044	0	0	2044	-1415.6	-1231.59	2044	7462.85
2045	0	0	2045	-1523.3	-1325.28	2045	8107.12
2046	0	0	2046	-1639.6	-1426.49	2046	8810.48
2047	0	0	2047	-1765.4	-1535.86	2047	9578.36
2048	0	0	2048	-1901.2	-1654.06	2048	10416.67
2049	0	0	2049	-2048.1	-1781.85	2049	11331.89
2050	0	0	2050	-2207.0	-1920.05	2050	12331.07
2051	0	0	2051	-2378.8	-2069.54	2051	13421.95
2052	0	0	2052	-2564.7	-2231.29	2052	14612.95
2053	0	0	2053	-2765.9	-2406.35	2053	15913.31

Scenario 2.3 – Increase in Operational Cost every year by 15%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		21.79%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													**2022**	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													**2023**	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,190	578	3	19	2.14	**1,792**	1,189.55	520.41	3.09	18.77	1.86	**1,734**	**2024**	0	0	2024	-319.5	-277.97	2024	1455.72
2025	1,309	581	4	20	2.25	**1,916**	1,308.72	522.46	3.35	20.30	1.96	**1,857**	**2025**	0	0	2025	-342.9	-298.30	2025	1558.49
2026	1,440	584	4	22	2.36	**2,052**	1,440.36	525.18	3.63	21.95	2.05	**1,993**	**2026**	0	0	2026	-368.0	-320.19	2026	1673.00
2027	1,586	587	4	24	2.48	**2,204**	1,585.82	528.60	3.94	23.74	2.16	**2,144**	**2027**	0	0	2027	-395.1	-343.76	2027	1800.49
2028	1,747	592	5	26	2.60	**2,372**	1,746.59	532.72	4.27	25.68	2.26	**2,312**	**2028**	0	0	2028	-424.3	-369.15	2028	1942.38
2029	1,924	597	5	28	2.73	**2,557**	1,924.34	537.58	4.63	27.77	2.38	**2,497**	**2029**	0	0	2029	-455.7	-396.50	2029	2100.20
2030	2,121	604	6	30	2.87	**2,763**	2,120.91	543.21	5.01	30.04	2.50	**2,702**	**2030**	0	0	2030	-489.6	-425.98	2030	2275.68
2031	2,313	611	6	32	3.01	**2,965**	2,312.81	549.61	5.44	32.48	2.62	**2,903**	**2031**	0	0	2031	-564.1	-490.74	2031	2412.23
2032	2,522	619	7	35	3.16	**3,186**	2,522.43	556.84	5.89	35.13	2.75	**3,123**	**2032**	0	0	2032	-605.3	-526.65	2032	2596.39
2033	2,751	628	7	38	3.32	**3,427**	2,751.41	564.90	6.39	37.99	2.89	**3,364**	**2033**	0	0	2033	-649.8	-565.32	2033	2798.26
2034	3,288	638	8	41	3.49	**3,978**	3,287.94	573.84	6.92	41.09	3.03	**3,913**	**2034**	0	0	2034	-697.7	-606.99	2034	3305.83
2035	3,589	649	8	44	3.66	**4,294**	3,589.43	583.68	7.50	44.44	3.19	**4,228**	**2035**	0	0	2035	-749.3	-651.90	2035	3576.34
2036	3,919	661	9	48	3.84	**4,640**	3,919.05	594.46	8.13	48.06	3.34	**4,573**	**2036**	0	0	2036	-804.9	-700.31	2036	3872.74
2037	4,279	674	10	52	4.04	**5,019**	4,279.45	606.22	8.82	51.98	3.51	**4,950**	**2037**	0	0	2037	-864.9	-752.50	2037	4197.47
2038	4,674	688	11	56	4.24	**5,432**	4,673.55	618.99	9.56	56.21	3.69	**5,362**	**2038**	0	0	2038	-929.6	-808.79	2038	4553.20
2039	5,105	703	12	61	4.45	**5,884**	5,104.54	632.82	10.36	60.80	3.87	**5,812**	**2039**	0	0	2039	-999.4	-869.52	2039	4942.86
2040	5,576	720	12	66	4.67	**6,379**	5,575.92	647.74	11.23	65.75	4.07	**6,305**	**2040**	0	0	2040	-1074.8	-935.05	2040	5369.65
2041	6,076	738	14	71	4.91	**6,903**	6,075.78	663.81	12.17	71.11	4.27	**6,827**	**2041**	0	0	2041	-1189.7	-1035.04	2041	5792.10
2042	6,621	757	15	77	5.15	**7,474**	6,621.02	681.07	13.19	76.90	4.48	**7,397**	**2042**	0	0	2042	-1279.2	-1112.87	2042	6283.80
2043	7,216	777	16	83	5.41	**8,098**	7,215.80	699.57	14.30	83.17	4.71	**8,018**	**2043**	0	0	2043	-1375.7	-1196.87	2043	6820.68
2044	7,865	799	17	90	5.68	**8,777**	7,864.68	719.37	15.50	89.95	4.94	**8,694**	**2044**	0	0	2044	-1480.0	-1287.57	2044	7406.87
2045	8,573	823	19	97	5.96	**9,517**	8,572.61	740.52	16.80	97.28	5.19	**9,432**	**2045**	0	0	2045	-1592.6	-1385.52	2045	8046.88
2046	9,345	848	20	105	6.26	**10,325**	9,345.03	763.07	18.21	105.21	5.45	**10,237**	**2046**	0	0	2046	-1714.2	-1491.33	2046	8745.64
2047	#####	875	22	114	6.58	**11,205**	10,187.87	787.10	19.74	113.78	5.72	**11,114**	**2047**	0	0	2047	-1845.6	-1605.67	2047	9508.55
2048	#####	903	24	123	6.90	**12,164**	11,107.61	812.66	21.40	123.06	6.01	**12,071**	**2048**	0	0	2048	-1987.6	-1729.24	2048	10341.49
2049	#####	933	26	133	7.25	**13,211**	12,111.32	839.83	23.19	133.09	6.31	**13,114**	**2049**	0	0	2049	-2141.2	-1862.85	2049	11250.90
2050	#####	965	28	144	7.61	**14,351**	13,206.75	868.68	25.14	143.93	6.62	**14,251**	**2050**	0	0	2050	-2307.3	-2007.33	2050	12243.80
2051	#####	999	30	156	7.99	**15,595**	14,402.34	899.28	27.25	155.66	6.95	**15,491**	**2051**	0	0	2051	-2486.9	-2163.61	2051	13327.88
2052	#####	1,035	33	168	8.39	**16,952**	15,707.33	931.72	29.54	168.35	7.30	**16,844**	**2052**	0	0	2052	-2681.3	-2332.71	2052	14511.53
2053	#####	1,073	36	182	8.81	**18,432**	17,131.83	966.08	32.02	182.07	7.67	**18,320**	**2053**	0	0	2053	-2891.6	-2515.72	2053	15803.93

Scenario 3.1 – Reduction in Ridership of First year of operation by 5%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		21.45%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													**2022**	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													**2023**	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,130	568	3	18	2.14	**1,721**	1,130.07	511.21	2.94	17.83	1.86	**1,664**	**2024**	0	0	2024	-277.8	-241.71	2024	1422.21
2025	1,243	570	4	19	2.25	**1,838**	1,243.28	512.76	3.18	19.29	1.96	**1,780**	**2025**	0	0	2025	-298.1	-259.39	2025	1521.08
2026	1,368	572	4	21	2.36	**1,968**	1,368.34	514.95	3.45	20.86	2.05	**1,910**	**2026**	0	0	2026	-320.0	-278.42	2026	1631.24
2027	1,507	575	4	23	2.48	**2,111**	1,506.53	517.82	3.74	22.56	2.16	**2,053**	**2027**	0	0	2027	-343.6	-298.92	2027	1753.88
2028	1,659	579	5	24	2.60	**2,270**	1,659.26	521.36	4.06	24.39	2.26	**2,211**	**2028**	0	0	2028	-369.0	-321.00	2028	1890.35
2029	1,828	584	5	26	2.73	**2,446**	1,828.12	525.62	4.40	26.38	2.38	**2,387**	**2029**	0	0	2029	-396.3	-344.78	2029	2042.12
2030	2,015	590	5	29	2.87	**2,641**	2,014.87	530.61	4.77	28.53	2.50	**2,581**	**2030**	0	0	2030	-425.8	-370.42	2030	2210.86
2031	2,197	596	6	31	3.01	**2,833**	2,197.17	536.35	5.17	30.86	2.62	**2,772**	**2031**	0	0	2031	-490.5	-426.73	2031	2345.44
2032	2,396	603	6	33	3.16	**3,042**	2,396.31	542.87	5.61	33.37	2.75	**2,981**	**2032**	0	0	2032	-526.4	-457.95	2032	2522.96
2033	2,614	611	7	36	3.32	**3,271**	2,613.84	550.20	6.08	36.09	2.89	**3,209**	**2033**	0	0	2033	-565.0	-491.59	2033	2717.52
2034	3,138	620	7	39	3.49	**3,808**	3,137.86	558.37	6.59	39.04	3.03	**3,745**	**2034**	0	0	2034	-606.7	-527.82	2034	3217.07
2035	3,426	630	8	42	3.66	**4,110**	3,425.68	567.41	7.15	42.22	3.19	**4,046**	**2035**	0	0	2035	-651.6	-566.87	2035	3478.77
2036	3,740	641	9	46	3.84	**4,440**	3,740.36	577.34	7.75	45.66	3.34	**4,374**	**2036**	0	0	2036	-700.0	-608.96	2036	3765.49
2037	4,084	654	9	49	4.04	**4,801**	4,084.44	588.21	8.40	49.38	3.51	**4,734**	**2037**	0	0	2037	-752.1	-654.35	2037	4079.59
2038	4,461	667	10	53	4.24	**5,195**	4,460.70	600.05	9.11	53.40	3.69	**5,127**	**2038**	0	0	2038	-808.4	-703.30	2038	4423.65
2039	4,872	681	11	58	4.45	**5,626**	4,872.19	612.90	9.87	57.76	3.87	**5,557**	**2039**	0	0	2039	-869.1	-756.10	2039	4800.49
2040	5,322	696	12	62	4.67	**6,098**	5,322.25	626.81	10.70	62.46	4.07	**6,026**	**2040**	0	0	2040	-934.6	-813.09	2040	5213.20
2041	5,799	713	13	68	4.91	**6,598**	5,799.49	641.80	11.60	67.55	4.27	**6,525**	**2041**	0	0	2041	-1034.5	-900.03	2041	5624.68
2042	6,320	731	14	73	5.15	**7,143**	6,320.07	657.93	12.58	73.06	4.48	**7,068**	**2042**	0	0	2042	-1112.3	-967.71	2042	6100.42
2043	6,888	750	15	79	5.41	**7,738**	6,887.97	675.25	13.64	79.01	4.71	**7,661**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6619.82
2044	7,508	771	16	85	5.68	**8,386**	7,507.52	693.80	14.79	85.45	4.94	**8,307**	**2044**	0	0	2044	-1286.9	-1119.63	2044	7186.88
2045	8,183	793	18	92	5.96	**9,093**	8,183.48	713.64	16.03	92.42	5.19	**9,011**	**2045**	0	0	2045	-1384.8	-1204.80	2045	7805.96
2046	8,921	816	19	100	6.26	**9,863**	8,921.02	734.83	17.38	99.95	5.45	**9,779**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8481.82
2047	9,726	842	21	108	6.58	**10,703**	9,725.82	757.42	18.84	108.09	5.72	**10,616**	**2047**	0	0	2047	-1604.9	-1396.23	2047	9219.66
2048	#####	868	23	117	6.90	**11,619**	10,604.05	781.48	20.43	116.90	6.01	**11,529**	**2048**	0	0	2048	-1728.4	-1503.69	2048	10025.18
2049	#####	897	25	126	7.25	**12,618**	11,562.48	807.06	22.15	126.43	6.31	**12,524**	**2049**	0	0	2049	-1861.9	-1619.87	2049	10904.57
2050	#####	927	27	137	7.61	**13,706**	12,608.51	834.25	24.01	136.74	6.62	**13,610**	**2050**	0	0	2050	-2006.3	-1745.50	2050	11864.63
2051	#####	959	29	148	7.99	**14,894**	13,750.20	863.11	26.04	147.88	6.95	**14,794**	**2051**	0	0	2051	-2162.5	-1881.40	2051	12912.78
2052	#####	993	31	160	8.39	**16,189**	14,996.38	893.72	28.23	159.93	7.30	**16,086**	**2052**	0	0	2052	-2331.5	-2028.44	2052	14057.12
2053	#####	1,029	34	173	8.81	**17,602**	16,356.70	926.15	30.60	172.97	7.67	**17,494**	**2053**	0	0	2053	-2514.5	-2187.59	2053	15306.50

Scenario 3.2 – Reduction in Ridership of First year of operation by 10%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		20.77%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													**2022**	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													**2023**	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,071	558	3	17	2.14	**1,651**	1,070.60	502.01	2.78	16.89	1.86	**1,594**	**2024**	0	0	2024	-277.8	-241.71	2024	1352.44
2025	1,178	559	3	18	2.25	**1,761**	1,177.85	503.06	3.02	18.27	1.96	**1,704**	**2025**	0	0	2025	-298.1	-259.39	2025	1444.76
2026	1,296	561	4	20	2.36	**1,883**	1,296.32	504.73	3.27	19.76	2.05	**1,826**	**2026**	0	0	2026	-320.0	-278.42	2026	1547.71
2027	1,427	563	4	21	2.48	**2,018**	1,427.24	507.04	3.55	21.37	2.16	**1,961**	**2027**	0	0	2027	-343.6	-298.92	2027	1662.43
2028	1,572	567	4	23	2.60	**2,169**	1,571.93	510.01	3.85	23.11	2.26	**2,111**	**2028**	0	0	2028	-369.0	-321.00	2028	1790.16
2029	1,732	571	5	25	2.73	**2,335**	1,731.91	513.66	4.17	24.99	2.38	**2,277**	**2029**	0	0	2029	-396.3	-344.78	2029	1932.32
2030	1,909	576	5	27	2.87	**2,519**	1,908.82	518.01	4.53	27.03	2.50	**2,461**	**2030**	0	0	2030	-425.8	-370.42	2030	2090.46
2031	2,082	581	5	29	3.01	**2,700**	2,081.53	523.08	4.91	29.23	2.62	**2,641**	**2031**	0	0	2031	-490.5	-426.73	2031	2214.65
2032	2,270	588	6	32	3.16	**2,899**	2,270.19	528.91	5.32	31.62	2.75	**2,839**	**2032**	0	0	2032	-526.4	-457.95	2032	2380.83
2033	2,476	595	6	34	3.32	**3,115**	2,476.27	535.50	5.77	34.19	2.89	**3,055**	**2033**	0	0	2033	-565.0	-491.59	2033	2563.05
2034	2,988	603	7	37	3.49	**3,638**	2,987.78	542.90	6.26	36.98	3.03	**3,577**	**2034**	0	0	2034	-606.7	-527.82	2034	3049.14
2035	3,262	612	8	40	3.66	**3,926**	3,261.93	551.13	6.79	39.99	3.19	**3,863**	**2035**	0	0	2035	-651.6	-566.87	2035	3296.17
2036	3,562	622	8	43	3.84	**4,239**	3,561.68	560.22	7.36	43.25	3.34	**4,176**	**2036**	0	0	2036	-700.0	-608.96	2036	3566.90
2037	3,889	634	9	47	4.04	**4,583**	3,889.43	570.21	7.98	46.78	3.51	**4,518**	**2037**	0	0	2037	-752.1	-654.35	2037	3863.57
2038	4,248	646	10	51	4.24	**4,958**	4,247.85	581.12	8.66	50.59	3.69	**4,892**	**2038**	0	0	2038	-808.4	-703.30	2038	4188.61
2039	4,640	659	10	55	4.45	**5,368**	4,639.84	592.99	9.39	54.72	3.87	**5,301**	**2039**	0	0	2039	-869.1	-756.10	2039	4544.70
2040	5,069	673	11	59	4.67	**5,817**	5,068.57	605.87	10.18	59.17	4.07	**5,748**	**2040**	0	0	2040	-934.6	-813.09	2040	4934.77
2041	5,523	689	12	64	4.91	**6,293**	5,523.20	619.79	11.04	64.00	4.27	**6,222**	**2041**	0	0	2041	-1034.5	-900.03	2041	5322.26
2042	6,019	705	13	69	5.15	**6,812**	6,019.13	634.79	11.97	69.21	4.48	**6,740**	**2042**	0	0	2042	-1112.3	-967.71	2042	5771.87
2043	6,560	723	14	75	5.41	**7,378**	6,560.14	650.92	12.98	74.85	4.71	**7,304**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6262.84
2044	7,150	742	16	81	5.68	**7,995**	7,150.37	668.23	14.08	80.95	4.94	**7,919**	**2044**	0	0	2044	-1286.9	-1119.63	2044	6798.95
2045	7,794	763	17	88	5.96	**8,668**	7,794.35	686.77	15.26	87.55	5.19	**8,589**	**2045**	0	0	2045	-1384.8	-1204.80	2045	7384.32
2046	8,497	785	18	95	6.26	**9,401**	8,497.01	706.59	16.55	94.69	5.45	**9,320**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8023.48
2047	9,264	809	20	102	6.58	**10,201**	9,263.76	727.74	17.95	102.41	5.72	**10,118**	**2047**	0	0	2047	-1604.9	-1396.23	2047	8721.34
2048	#####	834	22	111	6.90	**11,073**	10,100.49	750.29	19.46	110.75	6.01	**10,987**	**2048**	0	0	2048	-1728.4	-1503.69	2048	9483.31
2049	#####	860	23	120	7.25	**12,024**	11,013.64	774.29	21.11	119.78	6.31	**11,935**	**2049**	0	0	2049	-1861.9	-1619.87	2049	10315.26
2050	#####	889	25	130	7.61	**13,062**	12,010.27	799.82	22.89	129.54	6.62	**12,969**	**2050**	0	0	2050	-2006.3	-1745.50	2050	11223.64
2051	#####	919	28	140	7.99	**14,193**	13,098.07	826.93	24.82	140.10	6.95	**14,097**	**2051**	0	0	2051	-2162.5	-1881.40	2051	12215.47
2052	#####	951	30	152	8.39	**15,426**	14,285.44	855.71	26.92	151.51	7.30	**15,327**	**2052**	0	0	2052	-2331.5	-2028.44	2052	13298.44
2053	#####	985	32	164	8.81	**16,771**	15,581.58	886.22	29.19	163.86	7.67	**16,669**	**2053**	0	0	2053	-2514.5	-2187.59	2053	14480.94

Scenario 3.3 – Reduction in Ridership of First year of operation by 15%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		20.08%
2020													2020		0	2020		0.00	2020	0.00
2021													2021	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													2022	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													2023	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,011	548	3	16	2.14	**1,580**	1,011.12	492.81	2.63	15.95	1.86	**1,524**	**2024**	0	0	2024	-277.8	-241.71	2024	1282.66
2025	1,112	548	3	17	2.25	**1,683**	1,112.41	493.35	2.85	17.26	1.96	**1,628**	**2025**	0	0	2025	-298.1	-259.39	2025	1368.44
2026	1,224	549	3	19	2.36	**1,798**	1,224.31	494.50	3.09	18.66	2.05	**1,743**	**2026**	0	0	2026	-320.0	-278.42	2026	1464.19
2027	1,348	551	4	20	2.48	**1,926**	1,347.95	496.25	3.35	20.18	2.16	**1,870**	**2027**	0	0	2027	-343.6	-298.92	2027	1570.97
2028	1,485	554	4	22	2.60	**2,067**	1,484.60	498.65	3.64	21.83	2.26	**2,011**	**2028**	0	0	2028	-369.0	-321.00	2028	1689.98
2029	1,636	557	4	24	2.73	**2,224**	1,635.69	501.69	3.95	23.61	2.38	**2,167**	**2029**	0	0	2029	-396.3	-344.78	2029	1822.53
2030	1,803	562	5	26	2.87	**2,397**	1,802.78	505.41	4.28	25.53	2.50	**2,340**	**2030**	0	0	2030	-425.8	-370.42	2030	1970.07
2031	1,966	566	5	28	3.01	**2,568**	1,965.89	509.82	4.64	27.61	2.62	**2,511**	**2031**	0	0	2031	-490.5	-426.73	2031	2083.85
2032	2,144	572	6	30	3.16	**2,755**	2,144.06	514.94	5.04	29.86	2.75	**2,697**	**2032**	0	0	2032	-526.4	-457.95	2032	2238.70
2033	2,339	579	6	32	3.32	**2,959**	2,338.70	520.81	5.46	32.29	2.89	**2,900**	**2033**	0	0	2033	-565.0	-491.59	2033	2408.57
2034	2,838	586	7	35	3.49	**3,469**	2,837.70	527.44	5.93	34.93	3.03	**3,409**	**2034**	0	0	2034	-606.7	-527.82	2034	2881.21
2035	3,098	594	7	38	3.66	**3,741**	3,098.19	534.86	6.43	37.77	3.19	**3,680**	**2035**	0	0	2035	-651.6	-566.87	2035	3113.57
2036	3,383	603	8	41	3.84	**4,039**	3,383.00	543.11	6.97	40.85	3.34	**3,977**	**2036**	0	0	2036	-700.0	-608.96	2036	3368.31
2037	3,694	614	8	44	4.04	**4,365**	3,694.43	552.20	7.56	44.18	3.51	**4,302**	**2037**	0	0	2037	-752.1	-654.35	2037	3647.54
2038	4,035	625	9	48	4.24	**4,721**	4,035.00	562.18	8.20	47.78	3.69	**4,657**	**2038**	0	0	2038	-808.4	-703.30	2038	3953.56
2039	4,407	637	10	52	4.45	**5,110**	4,407.48	573.08	8.90	51.68	3.87	**5,045**	**2039**	0	0	2039	-869.1	-756.10	2039	4288.91
2040	4,815	650	11	56	4.67	**5,536**	4,814.90	584.93	9.65	55.89	4.07	**5,469**	**2040**	0	0	2040	-934.6	-813.09	2040	4656.35
2041	5,247	664	12	60	4.91	**5,988**	5,246.92	597.77	10.47	60.44	4.27	**5,920**	**2041**	0	0	2041	-1034.5	-900.03	2041	5019.84
2042	5,718	680	13	65	5.15	**6,481**	5,718.19	611.65	11.36	65.37	4.48	**6,411**	**2042**	0	0	2042	-1112.3	-967.71	2042	5443.33
2043	6,232	696	14	71	5.41	**7,018**	6,232.31	626.60	12.32	70.70	4.71	**6,947**	**2043**	0	0	2043	-1196.3	-1040.76	2043	5905.86
2044	6,793	714	15	76	5.68	**7,604**	6,793.22	642.66	13.36	76.46	4.94	**7,531**	**2044**	0	0	2044	-1286.9	-1119.63	2044	6411.01
2045	7,405	733	16	83	5.96	**8,243**	7,405.21	659.90	14.49	82.69	5.19	**8,167**	**2045**	0	0	2045	-1384.8	-1204.80	2045	6962.68
2046	8,073	754	17	89	6.26	**8,940**	8,073.00	678.35	15.72	89.43	5.45	**8,862**	**2046**	0	0	2046	-1490.6	-1296.81	2046	7565.13
2047	8,802	776	19	97	6.58	**9,700**	8,801.70	698.06	17.05	96.72	5.72	**9,619**	**2047**	0	0	2047	-1604.9	-1396.23	2047	8223.02
2048	9,597	799	21	105	6.90	**10,528**	9,596.92	719.10	18.49	104.60	6.01	**10,445**	**2048**	0	0	2048	-1728.4	-1503.69	2048	8941.44
2049	#####	824	22	113	7.25	**11,431**	10,464.80	741.52	20.06	113.12	6.31	**11,346**	**2049**	0	0	2049	-1861.9	-1619.87	2049	9725.95
2050	#####	850	24	122	7.61	**12,417**	11,412.03	765.39	21.76	122.34	6.62	**12,328**	**2050**	0	0	2050	-2006.3	-1745.50	2050	10582.64
2051	#####	879	26	132	7.99	**13,491**	12,445.93	790.76	23.60	132.31	6.95	**13,400**	**2051**	0	0	2051	-2162.5	-1881.40	2051	11518.16
2052	#####	909	28	143	8.39	**14,663**	13,574.49	817.70	25.60	143.10	7.30	**14,568**	**2052**	0	0	2052	-2331.5	-2028.44	2052	12539.75
2053	#####	940	31	155	8.81	**15,941**	14,806.46	846.30	27.77	154.76	7.67	**15,843**	**2053**	0	0	2053	-2514.5	-2187.59	2053	13655.36

Scenario 4.1 – Reduction in overall monetary benefits by 5%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		21.41%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													**2022**	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													**2023**	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,130	560	3	18	2.03	**1,713**	1,130.07	504.16	2.94	17.83	1.77	**1,657**	**2024**	0	0	2024	-277.8	-241.71	2024	1415.06
2025	1,243	563	4	19	2.14	**1,831**	1,243.28	506.60	3.18	19.29	1.86	**1,774**	**2025**	0	0	2025	-298.1	-259.39	2025	1514.82
2026	1,368	566	4	21	2.24	**1,962**	1,368.34	509.69	3.45	20.86	1.95	**1,904**	**2026**	0	0	2026	-320.0	-278.42	2026	1625.87
2027	1,507	571	4	23	2.35	**2,106**	1,506.53	513.47	3.74	22.56	2.05	**2,048**	**2027**	0	0	2027	-343.6	-298.92	2027	1749.43
2028	1,659	576	5	24	2.47	**2,266**	1,659.26	517.96	4.05	24.39	2.15	**2,208**	**2028**	0	0	2028	-369.0	-321.00	2028	1886.82
2029	1,828	581	5	26	2.60	**2,443**	1,828.12	523.17	4.39	26.38	2.26	**2,384**	**2029**	0	0	2029	-396.3	-344.78	2029	2039.55
2030	2,015	588	5	29	2.73	**2,639**	2,014.87	529.14	4.76	28.53	2.37	**2,580**	**2030**	0	0	2030	-425.8	-370.42	2030	2209.25
2031	2,197	595	6	31	2.86	**2,832**	2,197.17	535.88	5.16	30.86	2.49	**2,772**	**2031**	0	0	2031	-490.5	-426.73	2031	2344.83
2032	2,396	604	6	33	3.00	**3,043**	2,396.31	543.43	5.60	33.37	2.61	**2,981**	**2032**	0	0	2032	-526.4	-457.95	2032	2523.37
2033	2,614	613	7	36	3.16	**3,273**	2,613.84	551.81	6.07	36.09	2.74	**3,211**	**2033**	0	0	2033	-565.0	-491.59	2033	2718.97
2034	3,124	623	7	39	3.31	**3,797**	3,123.54	561.06	6.58	39.04	2.88	**3,733**	**2034**	0	0	2034	-606.7	-527.82	2034	3205.27
2035	3,410	635	8	42	3.48	**4,098**	3,409.96	571.20	7.13	42.22	3.03	**4,034**	**2035**	0	0	2035	-651.6	-566.87	2035	3466.66
2036	3,723	647	9	46	3.65	**4,428**	3,723.09	582.28	7.73	45.66	3.18	**4,362**	**2036**	0	0	2036	-700.0	-608.96	2036	3752.97
2037	4,065	660	9	49	3.84	**4,788**	4,065.47	594.33	8.38	49.38	3.34	**4,721**	**2037**	0	0	2037	-752.1	-654.35	2037	4066.54
2038	4,440	675	10	53	4.03	**5,182**	4,439.87	607.38	9.08	53.40	3.50	**5,113**	**2038**	0	0	2038	-808.4	-703.30	2038	4409.94
2039	4,849	691	11	58	4.23	**5,613**	4,849.31	621.49	9.84	57.76	3.68	**5,542**	**2039**	0	0	2039	-869.1	-756.10	2039	4785.97
2040	5,297	707	12	62	4.44	**6,083**	5,297.12	636.68	10.67	62.46	3.86	**6,011**	**2040**	0	0	2040	-934.6	-813.09	2040	5197.71
2041	5,772	726	13	68	4.66	**6,583**	5,771.99	653.01	11.56	67.55	4.06	**6,508**	**2041**	0	0	2041	-1034.5	-900.03	2041	5608.14
2042	6,290	745	14	73	4.89	**7,127**	6,289.97	670.53	12.53	73.06	4.26	**7,050**	**2042**	0	0	2042	-1112.3	-967.71	2042	6082.63
2043	6,855	766	15	79	5.14	**7,720**	6,855.01	689.28	13.58	79.01	4.47	**7,641**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6600.60
2044	7,471	788	16	85	5.40	**8,367**	7,471.44	709.32	14.72	85.45	4.69	**8,286**	**2044**	0	0	2044	-1286.9	-1119.63	2044	7166.01
2045	8,144	812	18	92	5.67	**9,072**	8,143.98	730.71	15.96	92.42	4.93	**8,988**	**2045**	0	0	2045	-1384.8	-1204.80	2045	7783.19
2046	8,878	837	19	100	5.95	**9,840**	8,877.78	753.49	17.30	99.95	5.18	**9,754**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8456.89
2047	9,678	864	21	108	6.25	**10,678**	9,678.48	777.75	18.75	108.09	5.43	**10,589**	**2047**	0	0	2047	-1604.9	-1396.23	2047	9192.28
2048	#####	893	23	117	6.56	**11,591**	10,552.23	803.54	20.33	116.90	5.71	**11,499**	**2048**	0	0	2048	-1728.4	-1503.69	2048	9995.01
2049	#####	923	24	126	6.89	**12,587**	11,505.76	830.92	22.03	126.43	5.99	**12,491**	**2049**	0	0	2049	-1861.9	-1619.87	2049	10871.27
2050	#####	956	27	137	7.23	**13,672**	12,546.41	859.98	23.88	136.74	6.29	**13,573**	**2050**	0	0	2050	-2006.3	-1745.50	2050	11827.80
2051	#####	990	29	148	7.59	**14,856**	13,682.22	890.79	25.89	147.88	6.61	**14,753**	**2051**	0	0	2051	-2162.5	-1881.40	2051	12871.98
2052	#####	1,026	31	160	7.97	**16,147**	14,921.96	923.43	28.06	159.93	6.94	**16,040**	**2052**	0	0	2052	-2331.5	-2028.44	2052	14011.88
2053	#####	1,064	34	173	8.37	**17,555**	16,275.23	957.98	30.42	172.97	7.28	**17,444**	**2053**	0	0	2053	-2514.5	-2187.59	2053	15256.30

Scenario 4.2 – Reduction in overall monetary benefits by 10%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		20.70%
2020													2020		0	2020		0.00	2020	0.00
2021													2021	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													2022	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													2023	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,071	542	3	17	1.93	**1,635**	1,070.60	487.91	2.78	16.89	1.68	**1,580**	2024	0	0	2024	-277.8	-241.71	2024	1338.15
2025	1,178	545	3	18	2.02	**1,747**	1,177.85	490.73	3.02	18.27	1.76	**1,692**	2025	0	0	2025	-298.1	-259.39	2025	1432.24
2026	1,296	549	4	20	2.12	**1,871**	1,296.32	494.20	3.27	19.76	1.85	**1,815**	2026	0	0	2026	-320.0	-278.42	2026	1536.98
2027	1,427	554	4	21	2.23	**2,008**	1,427.24	498.35	3.54	21.37	1.94	**1,952**	2027	0	0	2027	-343.6	-298.92	2027	1653.52
2028	1,572	559	4	23	2.34	**2,161**	1,571.93	503.20	3.84	23.11	2.04	**2,104**	2028	0	0	2028	-369.0	-321.00	2028	1783.12
2029	1,732	565	5	25	2.46	**2,329**	1,731.91	508.76	4.16	24.99	2.14	**2,272**	2029	0	0	2029	-396.3	-344.78	2029	1927.18
2030	1,909	572	5	27	2.58	**2,516**	1,908.82	515.07	4.51	27.03	2.25	**2,458**	2030	0	0	2030	-425.8	-370.42	2030	2087.26
2031	2,082	580	5	29	2.71	**2,699**	2,081.53	522.14	4.89	29.23	2.36	**2,640**	2031	0	0	2031	-490.5	-426.73	2031	2213.43
2032	2,270	589	6	32	2.85	**2,899**	2,270.19	530.02	5.30	31.62	2.48	**2,840**	2032	0	0	2032	-526.4	-457.95	2032	2381.65
2033	2,476	599	6	34	2.99	**3,118**	2,476.27	538.72	5.75	34.19	2.60	**3,058**	2033	0	0	2033	-565.0	-491.59	2033	2565.95
2034	2,959	609	7	37	3.14	**3,615**	2,959.14	548.28	6.23	36.98	2.73	**3,553**	2034	0	0	2034	-606.7	-527.82	2034	3025.54
2035	3,230	621	8	40	3.30	**3,902**	3,230.49	558.73	6.75	39.99	2.87	**3,839**	2035	0	0	2035	-651.6	-566.87	2035	3271.96
2036	3,527	633	8	43	3.46	**4,215**	3,527.14	570.10	7.32	43.25	3.01	**4,151**	2036	0	0	2036	-700.0	-608.96	2036	3541.86
2037	3,852	647	9	47	3.63	**4,558**	3,851.50	582.44	7.93	46.78	3.16	**4,492**	2037	0	0	2037	-752.1	-654.35	2037	3837.47
2038	4,206	662	10	51	3.81	**4,932**	4,206.19	595.77	8.60	50.59	3.32	**4,864**	2038	0	0	2038	-808.4	-703.30	2038	4161.18
2039	4,594	678	10	55	4.01	**5,341**	4,594.09	610.15	9.32	54.72	3.48	**5,272**	2039	0	0	2039	-869.1	-756.10	2039	4515.66
2040	5,018	695	11	59	4.21	**5,788**	5,018.33	625.62	10.10	59.17	3.66	**5,717**	2040	0	0	2040	-934.6	-813.09	2040	4903.80
2041	5,468	714	12	64	4.42	**6,262**	5,468.20	642.21	10.95	64.00	3.84	**6,189**	2041	0	0	2041	-1034.5	-900.03	2041	5289.17
2042	5,959	733	13	69	4.64	**6,779**	5,958.91	659.99	11.87	69.21	4.03	**6,704**	2042	0	0	2042	-1112.3	-967.71	2042	5736.31
2043	6,494	754	14	75	4.87	**7,343**	6,494.22	678.99	12.87	74.85	4.24	**7,265**	2043	0	0	2043	-1196.3	-1040.76	2043	6224.41
2044	7,078	777	15	81	5.11	**7,957**	7,078.21	699.27	13.95	80.95	4.45	**7,877**	2044	0	0	2044	-1286.9	-1119.63	2044	6757.21
2045	7,715	801	17	88	5.37	**8,626**	7,715.35	720.90	15.12	87.55	4.67	**8,544**	2045	0	0	2045	-1384.8	-1204.80	2045	7338.79
2046	8,411	827	18	95	5.64	**9,356**	8,410.53	743.92	16.39	94.69	4.90	**9,270**	2046	0	0	2046	-1490.6	-1296.81	2046	7973.62
2047	9,169	854	20	102	5.92	**10,151**	9,169.09	768.40	17.77	102.41	5.15	**10,063**	2047	0	0	2047	-1604.9	-1396.23	2047	8666.57
2048	9,997	883	21	111	6.21	**11,018**	9,996.85	794.41	19.26	110.75	5.41	**10,927**	2048	0	0	2048	-1728.4	-1503.69	2048	9422.98
2049	#####	913	23	120	6.52	**11,963**	10,900.19	822.01	20.87	119.78	5.68	**11,869**	2049	0	0	2049	-1861.9	-1619.87	2049	10248.66
2050	#####	946	25	130	6.85	**12,993**	11,886.07	851.28	22.63	129.54	5.96	**12,895**	2050	0	0	2050	-2006.3	-1745.50	2050	11149.98
2051	#####	980	27	140	7.19	**14,117**	12,962.10	882.30	24.53	140.10	6.26	**14,015**	2051	0	0	2051	-2162.5	-1881.40	2051	12133.88
2052	#####	1,017	30	152	7.55	**15,342**	14,136.60	915.14	26.58	151.51	6.57	**15,236**	2052	0	0	2052	-2331.5	-2028.44	2052	13207.96
2053	#####	1,055	32	164	7.93	**16,678**	15,418.64	949.89	28.82	163.86	6.90	**16,568**	2053	0	0	2053	-2514.5	-2187.59	2053	14380.52

Scenario 4.3 – Reduction in overall monetary benefits by 15%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		19.97%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,747.74)	-3110.63	2021		0.00	2021	-3110.63
2022													**2022**	(3,408.68)	-2829.20	2022		0.00	2022	-2829.20
2023													**2023**	(2,778.16)	-2305.87	2023		0.00	2023	-2305.87
2024	1,011	524	3	16	1.82	**1,556**	1,011.12	471.66	2.63	15.95	1.58	**1,503**	**2024**	0	0	2024	-277.8	-241.71	2024	1261.23
2025	1,112	528	3	17	1.91	**1,662**	1,112.41	474.86	2.85	17.26	1.66	**1,609**	**2025**	0	0	2025	-298.1	-259.39	2025	1349.65
2026	1,224	532	3	19	2.01	**1,780**	1,224.31	478.72	3.09	18.66	1.75	**1,727**	**2026**	0	0	2026	-320.0	-278.42	2026	1448.09
2027	1,348	537	4	20	2.11	**1,911**	1,347.95	483.23	3.35	20.18	1.83	**1,857**	**2027**	0	0	2027	-343.6	-298.92	2027	1557.62
2028	1,485	543	4	22	2.21	**2,055**	1,484.60	488.44	3.63	21.83	1.92	**2,000**	**2028**	0	0	2028	-369.0	-321.00	2028	1679.42
2029	1,636	549	4	24	2.32	**2,215**	1,635.69	494.35	3.93	23.61	2.02	**2,160**	**2029**	0	0	2029	-396.3	-344.78	2029	1814.81
2030	1,803	557	5	26	2.44	**2,392**	1,802.78	501.00	4.26	25.53	2.12	**2,336**	**2030**	0	0	2030	-425.8	-370.42	2030	1965.27
2031	1,966	565	5	28	2.56	**2,566**	1,965.89	508.41	4.62	27.61	2.23	**2,509**	**2031**	0	0	2031	-490.5	-426.73	2031	2082.03
2032	2,144	574	6	30	2.69	**2,756**	2,144.06	516.61	5.01	29.86	2.34	**2,698**	**2032**	0	0	2032	-526.4	-457.95	2032	2239.93
2033	2,339	584	6	32	2.82	**2,964**	2,338.70	525.63	5.43	32.29	2.46	**2,905**	**2033**	0	0	2033	-565.0	-491.59	2033	2412.92
2034	2,795	595	7	35	2.96	**3,434**	2,794.75	535.50	5.88	34.93	2.58	**3,374**	**2034**	0	0	2034	-606.7	-527.82	2034	2845.81
2035	3,051	607	7	38	3.11	**3,706**	3,051.01	546.25	6.38	37.77	2.71	**3,644**	**2035**	0	0	2035	-651.6	-566.87	2035	3077.25
2036	3,331	620	8	41	3.27	**4,003**	3,331.19	557.92	6.91	40.85	2.84	**3,940**	**2036**	0	0	2036	-700.0	-608.96	2036	3330.76
2037	3,638	634	8	44	3.43	**4,327**	3,637.53	570.55	7.49	44.18	2.99	**4,263**	**2037**	0	0	2037	-752.1	-654.35	2037	3608.39
2038	3,973	649	9	48	3.60	**4,682**	3,972.52	584.17	8.12	47.78	3.13	**4,616**	**2038**	0	0	2038	-808.4	-703.30	2038	3912.42
2039	4,339	665	10	52	3.78	**5,069**	4,338.86	598.82	8.80	51.68	3.29	**5,001**	**2039**	0	0	2039	-869.1	-756.10	2039	4245.35
2040	4,740	683	11	56	3.97	**5,493**	4,739.53	614.55	9.54	55.89	3.46	**5,423**	**2040**	0	0	2040	-934.6	-813.09	2040	4609.88
2041	5,164	702	11	60	4.17	**5,942**	5,164.41	631.41	10.34	60.44	3.63	**5,870**	**2041**	0	0	2041	-1034.5	-900.03	2041	4970.20
2042	5,628	722	12	65	4.38	**6,432**	5,627.86	649.44	11.21	65.37	3.81	**6,358**	**2042**	0	0	2042	-1112.3	-967.71	2042	5389.99
2043	6,133	743	14	71	4.60	**6,965**	6,133.43	668.69	12.15	70.70	4.00	**6,889**	**2043**	0	0	2043	-1196.3	-1040.76	2043	5848.22
2044	6,685	766	15	76	4.83	**7,547**	6,684.97	689.22	13.17	76.46	4.20	**7,468**	**2044**	0	0	2044	-1286.9	-1119.63	2044	6348.40
2045	7,287	790	16	83	5.07	**8,180**	7,286.72	711.09	14.28	82.69	4.41	**8,099**	**2045**	0	0	2045	-1384.8	-1204.80	2045	6894.38
2046	7,943	816	17	89	5.32	**8,871**	7,943.28	734.34	15.48	89.43	4.63	**8,787**	**2046**	0	0	2046	-1490.6	-1296.81	2046	7490.35
2047	8,660	843	19	97	5.59	**9,624**	8,659.69	759.05	16.78	96.72	4.86	**9,537**	**2047**	0	0	2047	-1604.9	-1396.23	2047	8140.87
2048	9,441	873	20	105	5.87	**10,445**	9,441.47	785.28	18.19	104.60	5.11	**10,355**	**2048**	0	0	2048	-1728.4	-1503.69	2048	8850.95
2049	#####	903	22	113	6.16	**11,339**	10,294.62	813.10	19.71	113.12	5.36	**11,246**	**2049**	0	0	2049	-1861.9	-1619.87	2049	9626.06
2050	#####	936	24	122	6.47	**12,314**	11,225.74	842.58	21.37	122.34	5.63	**12,218**	**2050**	0	0	2050	-2006.3	-1745.50	2050	10472.16
2051	#####	971	26	132	6.79	**13,378**	12,241.99	873.81	23.16	132.31	5.91	**13,277**	**2051**	0	0	2051	-2162.5	-1881.40	2051	11395.78
2052	#####	1,008	28	143	7.13	**14,537**	13,351.23	906.85	25.11	143.10	6.21	**14,432**	**2052**	0	0	2052	-2331.5	-2028.44	2052	12404.05
2053	#####	1,046	30	155	7.49	**15,801**	14,562.05	941.80	27.21	154.76	6.52	**15,692**	**2053**	0	0	2053	-2514.5	-2187.59	2053	13504.75

Scenario 5.1 – Combination of Increase in Capital cost and Reduction in Monetary Benefits by 5%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		20.80%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(3,935.13)	-3266.16	2021		0.00	2021	-3266.16
2022													**2022**	(3,579.11)	-2970.66	2022		0.00	2022	-2970.66
2023													**2023**	(2,917.07)	-2421.17	2023		0.00	2023	-2421.17
2024	1,130	560	3	18	2.03	**1,713**	1,130.07	504.16	2.94	17.83	1.77	**1,657**	**2024**	0	0	2024	-277.8	-241.71	2024	1415.06
2025	1,243	563	4	19	2.14	**1,831**	1,243.28	506.60	3.18	19.29	1.86	**1,774**	**2025**	0	0	2025	-298.1	-259.39	2025	1514.82
2026	1,368	566	4	21	2.24	**1,962**	1,368.34	509.69	3.45	20.86	1.95	**1,904**	**2026**	0	0	2026	-320.0	-278.42	2026	1625.87
2027	1,507	571	4	23	2.35	**2,106**	1,506.53	513.47	3.74	22.56	2.05	**2,048**	**2027**	0	0	2027	-343.6	-298.92	2027	1749.43
2028	1,659	576	5	24	2.47	**2,266**	1,659.26	517.96	4.05	24.39	2.15	**2,208**	**2028**	0	0	2028	-369.0	-321.00	2028	1886.82
2029	1,828	581	5	26	2.60	**2,443**	1,828.12	523.17	4.39	26.38	2.26	**2,384**	**2029**	0	0	2029	-396.3	-344.78	2029	2039.55
2030	2,015	588	5	29	2.73	**2,639**	2,014.87	529.14	4.76	28.53	2.37	**2,580**	**2030**	0	0	2030	-425.8	-370.42	2030	2209.25
2031	2,197	595	6	31	2.86	**2,832**	2,197.17	535.88	5.16	30.86	2.49	**2,772**	**2031**	0	0	2031	-490.5	-426.73	2031	2344.83
2032	2,396	604	6	33	3.00	**3,043**	2,396.31	543.43	5.60	33.37	2.61	**2,981**	**2032**	0	0	2032	-526.4	-457.95	2032	2523.37
2033	2,614	613	7	36	3.16	**3,273**	2,613.84	551.81	6.07	36.09	2.74	**3,211**	**2033**	0	0	2033	-565.0	-491.59	2033	2718.97
2034	3,124	623	7	39	3.31	**3,797**	3,123.54	561.06	6.58	39.04	2.88	**3,733**	**2034**	0	0	2034	-606.7	-527.82	2034	3205.27
2035	3,410	635	8	42	3.48	**4,098**	3,409.96	571.20	7.13	42.22	3.03	**4,034**	**2035**	0	0	2035	-651.6	-566.87	2035	3466.66
2036	3,723	647	9	46	3.65	**4,428**	3,723.09	582.28	7.73	45.66	3.18	**4,362**	**2036**	0	0	2036	-700.0	-608.96	2036	3752.97
2037	4,065	660	9	49	3.84	**4,788**	4,065.47	594.33	8.38	49.38	3.34	**4,721**	**2037**	0	0	2037	-752.1	-654.35	2037	4066.54
2038	4,440	675	10	53	4.03	**5,182**	4,439.87	607.38	9.08	53.40	3.50	**5,113**	**2038**	0	0	2038	-808.4	-703.30	2038	4409.94
2039	4,849	691	11	58	4.23	**5,613**	4,849.31	621.49	9.84	57.76	3.68	**5,542**	**2039**	0	0	2039	-869.1	-756.10	2039	4785.97
2040	5,297	707	12	62	4.44	**6,083**	5,297.12	636.68	10.67	62.46	3.86	**6,011**	**2040**	0	0	2040	-934.6	-813.09	2040	5197.71
2041	5,772	726	13	68	4.66	**6,583**	5,771.99	653.01	11.56	67.55	4.06	**6,508**	**2041**	0	0	2041	-1034.5	-900.03	2041	5608.14
2042	6,290	745	14	73	4.89	**7,127**	6,289.97	670.53	12.53	73.06	4.26	**7,050**	**2042**	0	0	2042	-1112.3	-967.71	2042	6082.63
2043	6,855	766	15	79	5.14	**7,720**	6,855.01	689.28	13.58	79.01	4.47	**7,641**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6600.60
2044	7,471	788	16	85	5.40	**8,367**	7,471.44	709.32	14.72	85.45	4.69	**8,286**	**2044**	0	0	2044	-1286.9	-1119.63	2044	7166.01
2045	8,144	812	18	92	5.67	**9,072**	8,143.98	730.71	15.96	92.42	4.93	**8,988**	**2045**	0	0	2045	-1384.8	-1204.80	2045	7783.19
2046	8,878	837	19	100	5.95	**9,840**	8,877.78	753.49	17.30	99.95	5.18	**9,754**	**2046**	0	0	2046	-1490.6	-1296.81	2046	8456.89
2047	9,678	864	21	108	6.25	**10,678**	9,678.48	777.75	18.75	108.09	5.43	**10,589**	**2047**	0	0	2047	-1604.9	-1396.23	2047	9192.28
2048	#####	893	23	117	6.56	**11,591**	10,552.23	803.54	20.33	116.90	5.71	**11,499**	**2048**	0	0	2048	-1728.4	-1503.69	2048	9995.01
2049	#####	923	24	126	6.89	**12,587**	11,505.76	830.92	22.03	126.43	5.99	**12,491**	**2049**	0	0	2049	-1861.9	-1619.87	2049	10871.27
2050	#####	956	27	137	7.23	**13,672**	12,546.41	859.98	23.88	136.74	6.29	**13,573**	**2050**	0	0	2050	-2006.3	-1745.50	2050	11827.80
2051	#####	990	29	148	7.59	**14,856**	13,682.22	890.79	25.89	147.88	6.61	**14,753**	**2051**	0	0	2051	-2162.5	-1881.40	2051	12871.98
2052	#####	1,026	31	160	7.97	**16,147**	14,921.96	923.43	28.06	159.93	6.94	**16,040**	**2052**	0	0	2052	-2331.5	-2028.44	2052	14011.88
2053	#####	1,064	34	173	8.37	**17,555**	16,275.23	957.98	30.42	172.97	7.28	**17,444**	**2053**	0	0	2053	-2514.5	-2187.59	2053	15256.30

Scenario 5.2 – Combination of Increase in Capital cost and Reduction in Monetary Benefits by 10%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		19.57%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(4,122.52)	-3421.69	2021		0.00	2021	-3421.69
2022													**2022**	(3,749.55)	-3112.12	2022		0.00	2022	-3112.12
2023													**2023**	(3,055.98)	-2536.46	2023		0.00	2023	-2536.46
2024	1,071	542	3	17	1.93	**1,635**	1,070.60	487.91	2.78	16.89	1.68	**1,580**	**2024**	0	0	2024	-277.8	-241.71	2024	1338.15
2025	1,178	545	3	18	2.02	**1,747**	1,177.85	490.73	3.02	18.27	1.76	**1,692**	**2025**	0	0	2025	-298.1	-259.39	2025	1432.24
2026	1,296	549	4	20	2.12	**1,871**	1,296.32	494.20	3.27	19.76	1.85	**1,815**	**2026**	0	0	2026	-320.0	-278.42	2026	1536.98
2027	1,427	554	4	21	2.23	**2,008**	1,427.24	498.35	3.54	21.37	1.94	**1,952**	**2027**	0	0	2027	-343.6	-298.92	2027	1653.52
2028	1,572	559	4	23	2.34	**2,161**	1,571.93	503.20	3.84	23.11	2.04	**2,104**	**2028**	0	0	2028	-369.0	-321.00	2028	1783.12
2029	1,732	565	5	25	2.46	**2,329**	1,731.91	508.76	4.16	24.99	2.14	**2,272**	**2029**	0	0	2029	-396.3	-344.78	2029	1927.18
2030	1,909	572	5	27	2.58	**2,516**	1,908.82	515.07	4.51	27.03	2.25	**2,458**	**2030**	0	0	2030	-425.8	-370.42	2030	2087.26
2031	2,082	580	5	29	2.71	**2,699**	2,081.53	522.14	4.89	29.23	2.36	**2,640**	**2031**	0	0	2031	-490.5	-426.73	2031	2213.43
2032	2,270	589	6	32	2.85	**2,899**	2,270.19	530.02	5.30	31.62	2.48	**2,840**	**2032**	0	0	2032	-526.4	-457.95	2032	2381.65
2033	2,476	599	6	34	2.99	**3,118**	2,476.27	538.72	5.75	34.19	2.60	**3,058**	**2033**	0	0	2033	-565.0	-491.59	2033	2565.95
2034	2,959	609	7	37	3.14	**3,615**	2,959.14	548.28	6.23	36.98	2.73	**3,553**	**2034**	0	0	2034	-606.7	-527.82	2034	3025.54
2035	3,230	621	8	40	3.30	**3,902**	3,230.49	558.73	6.75	39.99	2.87	**3,839**	**2035**	0	0	2035	-651.6	-566.87	2035	3271.96
2036	3,527	633	8	43	3.46	**4,215**	3,527.14	570.10	7.32	43.25	3.01	**4,151**	**2036**	0	0	2036	-700.0	-608.96	2036	3541.86
2037	3,852	647	9	47	3.63	**4,558**	3,851.50	582.44	7.93	46.78	3.16	**4,492**	**2037**	0	0	2037	-752.1	-654.35	2037	3837.47
2038	4,206	662	10	51	3.81	**4,932**	4,206.19	595.77	8.60	50.59	3.32	**4,864**	**2038**	0	0	2038	-808.4	-703.30	2038	4161.18
2039	4,594	678	10	55	4.01	**5,341**	4,594.09	610.15	9.32	54.72	3.48	**5,272**	**2039**	0	0	2039	-869.1	-756.10	2039	4515.66
2040	5,018	695	11	59	4.21	**5,788**	5,018.33	625.62	10.10	59.17	3.66	**5,717**	**2040**	0	0	2040	-934.6	-813.09	2040	4903.80
2041	5,468	714	12	64	4.42	**6,262**	5,468.20	642.21	10.95	64.00	3.84	**6,189**	**2041**	0	0	2041	-1034.5	-900.03	2041	5289.17
2042	5,959	733	13	69	4.64	**6,779**	5,958.91	659.99	11.87	69.21	4.03	**6,704**	**2042**	0	0	2042	-1112.3	-967.71	2042	5736.31
2043	6,494	754	14	75	4.87	**7,343**	6,494.22	678.99	12.87	74.85	4.24	**7,265**	**2043**	0	0	2043	-1196.3	-1040.76	2043	6224.41
2044	7,078	777	15	81	5.11	**7,957**	7,078.21	699.27	13.95	80.95	4.45	**7,877**	**2044**	0	0	2044	-1286.9	-1119.63	2044	6757.21
2045	7,715	801	17	88	5.37	**8,626**	7,715.35	720.90	15.12	87.55	4.67	**8,544**	**2045**	0	0	2045	-1384.8	-1204.80	2045	7338.79
2046	8,411	827	18	95	5.64	**9,356**	8,410.53	743.92	16.39	94.69	4.90	**9,270**	**2046**	0	0	2046	-1490.6	-1296.81	2046	7973.62
2047	9,169	854	20	102	5.92	**10,151**	9,169.09	768.40	17.77	102.41	5.15	**10,063**	**2047**	0	0	2047	-1604.9	-1396.23	2047	8666.57
2048	9,997	883	21	111	6.21	**11,018**	9,996.85	794.41	19.26	110.75	5.41	**10,927**	**2048**	0	0	2048	-1728.4	-1503.69	2048	9422.98
2049	#####	913	23	120	6.52	**11,963**	10,900.19	822.01	20.87	119.78	5.68	**11,869**	**2049**	0	0	2049	-1861.9	-1619.87	2049	10248.66
2050	#####	946	25	130	6.85	**12,993**	11,886.07	851.28	22.63	129.54	5.96	**12,895**	**2050**	0	0	2050	-2006.3	-1745.50	2050	11149.98
2051	#####	980	27	140	7.19	**14,117**	12,962.10	882.30	24.53	140.10	6.26	**14,015**	**2051**	0	0	2051	-2162.5	-1881.40	2051	12133.88
2052	#####	1,017	30	152	7.55	**15,342**	14,136.60	915.14	26.58	151.51	6.57	**15,236**	**2052**	0	0	2052	-2331.5	-2028.44	2052	13207.96
2053	#####	1,055	32	164	7.93	**16,678**	15,418.64	949.89	28.82	163.86	6.90	**16,568**	**2053**	0	0	2053	-2514.5	-2187.59	2053	14380.52

Scenario 5.3 – Combination of Increase in Capital cost and Reduction in Monetary Benefits by 15%

ECONOMIC SAVINGS (in Rs. Crore)													CAPITAL EXPENDITURE			OPERATING COST			EIRR COMPUTATION	
As per Calculations							For EIRR Computation (Ratio as per Guidelines)						Most Likely						Most Likely	
Year	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	VOT	VOC	Accident Saving	Pollution saving	Infrastructure Cost Saving	Total Economic Savings	Year	Capex Consideration for FIRR	Capex Consideration for EIRR*	Year	Opex Consideration for FIRR	Opex Consideration for EIRR	Year	Net Economic Benefit
Factor							100%	90%	90%	100%	87%				83%			87%		18.39%
2020													**2020**		0	2020		0.00	2020	0.00
2021													**2021**	(4,309.90)	-3577.22	2021		0.00	2021	-3577.22
2022													**2022**	(3,919.98)	-3253.58	2022		0.00	2022	-3253.58
2023													**2023**	(3,194.89)	-2651.75	2023		0.00	2023	-2651.75
2024	1,011	524	3	16	1.82	**1,556**	1,011.12	471.66	2.63	15.95	1.58	**1,503**	**2024**	0	0	2024	-277.8	-241.71	2024	1261.23
2025	1,112	528	3	17	1.91	**1,662**	1,112.41	474.86	2.85	17.26	1.66	**1,609**	**2025**	0	0	2025	-298.1	-259.39	2025	1349.65
2026	1,224	532	3	19	2.01	**1,780**	1,224.31	478.72	3.09	18.66	1.75	**1,727**	**2026**	0	0	2026	-320.0	-278.42	2026	1448.09
2027	1,348	537	4	20	2.11	**1,911**	1,347.95	483.23	3.35	20.18	1.83	**1,857**	**2027**	0	0	2027	-343.6	-298.92	2027	1557.62
2028	1,485	543	4	22	2.21	**2,055**	1,484.60	488.44	3.63	21.83	1.92	**2,000**	**2028**	0	0	2028	-369.0	-321.00	2028	1679.42
2029	1,636	549	4	24	2.32	**2,215**	1,635.69	494.35	3.93	23.61	2.02	**2,160**	**2029**	0	0	2029	-396.3	-344.78	2029	1814.81
2030	1,803	557	5	26	2.44	**2,392**	1,802.78	501.00	4.26	25.53	2.12	**2,336**	**2030**	0	0	2030	-425.8	-370.42	2030	1965.27
2031	1,966	565	5	28	2.56	**2,566**	1,965.89	508.41	4.62	27.61	2.23	**2,509**	**2031**	0	0	2031	-490.5	-426.73	2031	2082.03
2032	2,144	574	6	30	2.69	**2,756**	2,144.06	516.61	5.01	29.86	2.34	**2,698**	**2032**	0	0	2032	-526.4	-457.95	2032	2239.93
2033	2,339	584	6	32	2.82	**2,964**	2,338.70	525.63	5.43	32.29	2.46	**2,905**	**2033**	0	0	2033	-565.0	-491.59	2033	2412.92
2034	2,795	595	7	35	2.96	**3,434**	2,794.75	535.50	5.88	34.93	2.58	**3,374**	**2034**	0	0	2034	-606.7	-527.82	2034	2845.81
2035	3,051	607	7	38	3.11	**3,706**	3,051.01	546.25	6.38	37.77	2.71	**3,644**	**2035**	0	0	2035	-651.6	-566.87	2035	3077.25
2036	3,331	620	8	41	3.27	**4,003**	3,331.19	557.92	6.91	40.85	2.84	**3,940**	**2036**	0	0	2036	-700.0	-608.96	2036	3330.76
2037	3,638	634	8	44	3.43	**4,327**	3,637.53	570.55	7.49	44.18	2.99	**4,263**	**2037**	0	0	2037	-752.1	-654.35	2037	3608.39
2038	3,973	649	9	48	3.60	**4,682**	3,972.52	584.17	8.12	47.78	3.13	**4,616**	**2038**	0	0	2038	-808.4	-703.30	2038	3912.42
2039	4,339	665	10	52	3.78	**5,069**	4,338.86	598.82	8.80	51.68	3.29	**5,001**	**2039**	0	0	2039	-869.1	-756.10	2039	4245.35
2040	4,740	683	11	56	3.97	**5,493**	4,739.53	614.55	9.54	55.89	3.46	**5,423**	**2040**	0	0	2040	-934.6	-813.09	2040	4609.88
2041	5,164	702	11	60	4.17	**5,942**	5,164.41	631.41	10.34	60.44	3.63	**5,870**	**2041**	0	0	2041	-1034.5	-900.03	2041	4970.20
2042	5,628	722	12	65	4.38	**6,432**	5,627.86	649.44	11.21	65.37	3.81	**6,358**	**2042**	0	0	2042	-1112.3	-967.71	2042	5389.99
2043	6,133	743	14	71	4.60	**6,965**	6,133.43	668.69	12.15	70.70	4.00	**6,889**	**2043**	0	0	2043	-1196.3	-1040.76	2043	5848.22
2044	6,685	766	15	76	4.83	**7,547**	6,684.97	689.22	13.17	76.46	4.20	**7,468**	**2044**	0	0	2044	-1286.9	-1119.63	2044	6348.40
2045	7,287	790	16	83	5.07	**8,180**	7,286.72	711.09	14.28	82.69	4.41	**8,099**	**2045**	0	0	2045	-1384.8	-1204.80	2045	6894.38
2046	7,943	816	17	89	5.32	**8,871**	7,943.28	734.34	15.48	89.43	4.63	**8,787**	**2046**	0	0	2046	-1490.6	-1296.81	2046	7490.35
2047	8,660	843	19	97	5.59	**9,624**	8,659.69	759.05	16.78	96.72	4.86	**9,537**	**2047**	0	0	2047	-1604.9	-1396.23	2047	8140.87
2048	9,441	873	20	105	5.87	**10,445**	9,441.47	785.28	18.19	104.60	5.11	**10,355**	**2048**	0	0	2048	-1728.4	-1503.69	2048	8850.95
2049	#####	903	22	113	6.16	**11,339**	10,294.62	813.10	19.71	113.12	5.36	**11,246**	**2049**	0	0	2049	-1861.9	-1619.87	2049	9626.06
2050	#####	936	24	122	6.47	**12,314**	11,225.74	842.58	21.37	122.34	5.63	**12,218**	**2050**	0	0	2050	-2006.3	-1745.50	2050	10472.16
2051	#####	971	26	132	6.79	**13,378**	12,241.99	873.81	23.16	132.31	5.91	**13,277**	**2051**	0	0	2051	-2162.5	-1881.40	2051	11395.78
2052	#####	1,008	28	143	7.13	**14,537**	13,351.23	906.85	25.11	143.10	6.21	**14,432**	**2052**	0	0	2052	-2331.5	-2028.44	2052	12404.05
2053	#####	1,046	30	155	7.49	**15,801**	14,562.05	941.80	27.21	154.76	6.52	**15,692**	**2053**	0	0	2053	-2514.5	-2187.59	2053	13504.75

Chapter 20

Implementation Plan

CHAPTER – 20

IMPLEMENTATION PLAN

20.1 Project Implementation Plan

Implementing a Metro project in a congested metropolis is indeed a challenge. In sheer size, magnitude and technical complexity there are no parallels to Metro projects. Airport Metro line as BMRCL Phase 2B with a network length of 38.00 Kms (36.44 Kms from Jyothipuram to KIA Terminals) is to be carried out in difficult urban environment without dislocating city life, while at the same time preserving the environment. The required lands without encumbrances, have to be taken possession of in time. Clearances from the local authorities have to be taken which includes permission to cut/transplant trees, diversion of multiple utilities, management of Road traffic, etc., The project involves integration of a number of complex technical systems and interfacing among the various system contracts to construct a seamless system is a difficult and highly skilled exercise. Side by side, timely and adequate funds have to be mobilized for uninterrupted implementation of the project. These activates require an efficient and competent project implementing agency.

BMRCL, an SPV formed by GoI and GoK with 50:50 ownerships, has the necessary experience and competence to implement the project. The company has implemented Phase 1 of the Metro project with 42.3 Kms network and is currently implementing Phase 2 with network length of 72.1 Kms. The company will however, require to augment its capacity to complete this project within the proposed time limits.

20.2 Way Forward

20.2.1 On receipt of the Detailed Project Report, following actions will be required for implementing the proposed Airport Metro line as Phase 2B between K R Puram to Airport with a network length of 38.00 Kms (36.44 Kms from Jyothipuram to KIA Terminal) of Bangalore Metro Project.

i. Administrative approval of Government of Karnataka for implementation of the project by BMRCL, providing funds for its share of the financing plan, facilitating land acquisition and utility shifting by its agencies and providing policy support as envisaged in the Metro Policy 2017.

ii. Approval of Government of India for taking up of this project as a central sector project, as has been the case of Phase 1 and Phase 2, under equal equity sharing financing mode envisaged in the Metro Policy 2017.

iii. Approval of Government of India for arranging a major part of the senior debt as sovereign loan from multilateral and bilateral development agencies, as has been the case of Phase 1 and Phase 2.

iv. Approval of the Railway Board and NHAI for the alignment crossing the Railway line and National Highway.

v. Approval of the civil agencies (BBMP, BWSSB, BESCOM) and Bengaluru Traffic Police.

vi. Approval of Government of Karnataka for advance action of land acquisition, utility shifting, detailed design.

vii. Preparation of detailed designs for the project components through in-house capabilities or through outsourcing.

viii. Advance approval for Tender documents from multilateral and bilateral development agencies financing the senior debt.

20.3 Specific Features of Project Implementation

a) The area along this corridor is well developed between Jyothipuram (K R Puram) to Jakkur Cross via Hebbal all along outer ring road and National Highway (NH-44). Also, this corridor is further extended towards Whitefield on one Side and electronic city on the other side beyond Jyothipuram (K R Puram) which are identified as IT hubs and Business Centre. NH-44 is the fastest growing area with very heavy vehicular traffic on the existing road. Hebbal is the key junction between International Airport & Bengaluru City Which is the nodal point of vehicular traffic distribution between city & International Airport. Added to it this corridor is linked with Bhaiyappanahalli on East west corridor of Metro Phase-1 next to Kasturi Nagar & further linked with proposed R6 UG line (between Gottigere and Nagawara) at Nagawara. With all the above mentioned criticality, it is certain that the implementation between KR Puram & International Airport via Hebbal will Serve the purpose fully.

b) There are several factors which facilitate speedy construction of Metro line over this alignment. Firstly, very little land acquisition is involved for the Viaduct portion. The existing grade separators at few road junctions could have posed a serious problem, but since all these grade separators were designed as split flyovers and hence the Metro alignment could run in the space between the two legs of the flyover. Even at the existing underpasses, there is enough space between the two Carriageways, where the Viaduct could be accommodated without any major difficulty.

c) Another factor in favour of this alignment is that there are no sharp horizontal or vertical curves as the ORR and National Highway (NH-44) are so designed that sharp curves on the roads were avoided. The construction work can commence soon after award of contracts as no land acquisition is involved for the majority of Viaduct portion on ORR between K R Puram and Hebbal. Dedicated stretch of land is already available along NH-44 corridor between Hebbal and Doddajala. Even for the stations, the work can be commenced for the central portion along the road median and the land requirement can be made available by the land commission by the time other work are in progress for the entry structures on either side.

d) Because of the above favorable factors, it is planned to complete the entire project in a period of 45 months from the time 50% of the Financial Closure for senior debt is done.

20.4 Project Implementation Structure if implemented on PPP model.

Generally, PPP model runs on the logic and criteria that land to be provided by one party and construction and maintenance cost to be borne by other. Finally, the profit generated shall be distributed among two parties reasonably.

Here, the project of metro connectivity to International Airport being taken up by BMRCL, which is service oriented essential public transport facility where the whole responsibility of the project implementation lies with the client i.e., BMRCL. Hence the question of implementation of this project on PPP model is hardly appreciable. If required after commissioning of the project, the service and maintenance could be shared with other agencies on PPP basis. Also, if any private company comes forward during the course of project progress, few of the station can be built on PPP model as executed under Phase-1 of metro project.

In respect of a portion of this project which is to be taken up within Airport boundary on joint cost sharing basis by BMRCL and BIAL, an MoU will be drawn and necessary back end PPP will be dealt as mentioned in chapter 18 (Financial Analysis & Non-Fare Box Revenue Assessment).

20.5 Legal and institutional frame work for implementing the Project.

Implementation of proposed Airport Metro line from K R Puram to Airport can be done under “The Metro Railways (construction of works) Act 1978”, “The Metro Railways (Operations and Maintenance) Act 2002” and “The Metro Railways (Amendment) Act 2009”.

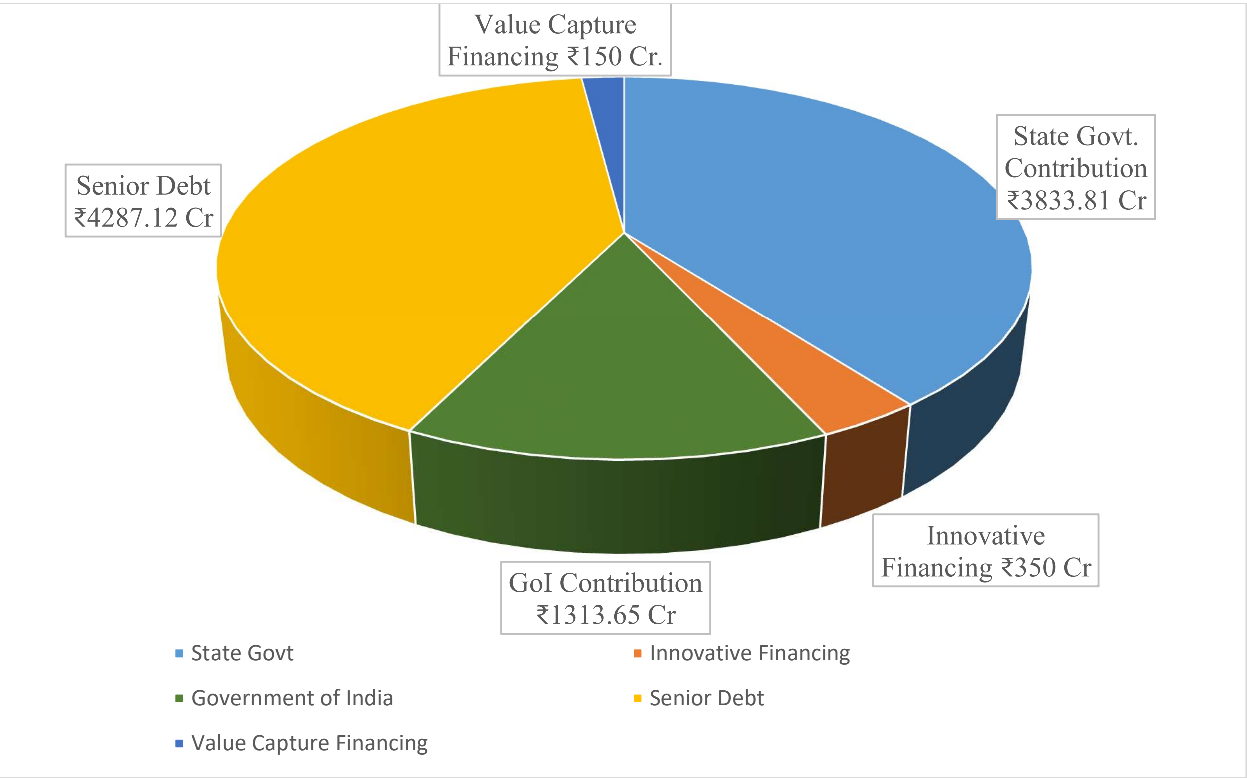
20.6 Funding Pattern for the Project

The financing plan to fund the estimated cost of the Phase 2B as permitted under the Metro Rail Policy 2017 is proposed as in **Table 20.1**. Also, Pie chart on proposed funding pattern is shown in **Figure 20.1**.

Table 20.1 Proposed funding pattern

Sources	Amount (Rs in crore)	(% of Share)
GoI - Equity	1,139.27	11.47%
GoI - Sub-debt	174.38	1.76%
GOI Share sub total (1)	**1,313.65**	**13.22%**
GoK - Equity	1,139.27	11.47%
GoK - Sub-debt	174.38	1.76%
GoK - Sub-debt (Land Cost)	2,171.39	21.86%
Subordinate-debt (State Taxes)	348.76	3.51%
GoK Share sub total (2)	**3,833.81**	**38.59%**
Value Capture Financing (3)	**150.00**	**1.51%**
Innovative Financing (4)	**350.00**	**3.52%**
Senior Debt (Sovereign/Non Sovereign Loans) (5)	**4,287.12**	**43.15%**
Total Sources (1) to (5)	**9,934.58**	**100.00%**

Figure 20.1 Proposed Funding Pattern



20.7 Implementation Plan

a. The proposed duration for completion of important activities are given in **Table 20.2**. The Bar Chart for the same is shown in the **Figure 20.2**.
b. The start month is taken as month of submission of the proposal to GoK i.e., January 2019.
c. Land acquisition process is proposed to be continued with the approval of GoK and will be completed for major part by the time civil works contracts are awarded.
d. It is presumed that approval of GoK and GoI will be received in 6 months period and financial closure for 50% of the senior debt will be achieved in 12 months period. Civil Tenders will have to be invited in advance to save time and to make it possible to award by the time of financial closure.
e. Many of the activities are shown over lapping meaning that different activates will be executed simultaneously.
f. The entire work is planned to be completed in 45 months from Financial Closure (Tying up of 50% of senior debt) i.e., from April 2020 to December 2023.

Table 20.2 Activities showing start, end & duration for Implementing Phase 2B

Activity	Description	Start	End	Duration in Months
Activity 1	Land Acquisition for Viaduct & Stations	0	12	12
Activity 2	Approval by GoK	0	3	3
Activity 3	Approval by GoI	4	6	3
Activity 4	Financial Closure by atleast 50% Senior debt	7	12	6
Activity 5	Award of civil works contract	4	12	8
Activity 6	Piling & Pile cap	15	27	12
Activity 7	Pier & Pier cap	18	30	12
Activity 8	Segment Launching	22	40	18
Activity 9	Station works	15	2	27
Activity 10	Station Finishing works	35	50	15
Activity 11	Track works	35	50	15
Activity 12	System works Completion (Traction, E&M and S&T)	30	54	24
Activity 13	Integrated Testing	54	57	3

Figure 20.2 Bar Chart of Activities showing start, end & duration for Implementing Phase 2B.

ACTIVITIES	Description	0	60	Duration in Months
	Activity 1 (Land Acquisition)	0	12	12
	Activity 2 (Approval by GoK)	0	3	3
	Activity 3 (Approval by GoI)	4	6	3
	Activity 4 (Financial Closure)	7	12	6
	Activity 5 (Award of civil contract)	4	12	8
	Activity 6 (Piling & Pile cap)	15	27	12
	Activity 7 (Peir & Pier cap)	18	30	12
	Activity 8 (Segment Launching)	22	40	18
	Activity 9 (Station works)	15	42	27
	Activity 10 (Station finishing works)	35	50	15
	Activity 11 (Track works)	35	50	15
	Activity 12 (System works)	30	54	24
	Activity 13 (Integrated Testing)	54	57	3