EXECUTIVE SUMMARY

0.1. PROFILE OF THE CITY

Bengaluru city was built in 1537 by Kempegowda. During the British Raj, Bangalore developed as a centre for colonial rule in South India. The establishment of the Bangalore Cantonment brought in large numbers of migrant workers from Tamil Nadu, Andhra Pradesh and North Indian states for developing and maintaining the infrastructure of the cantonment. The cantonment area covers nearly dozen revenue villages, which included Binnamangala, Domlur, Neelasandra and Ulsoor to name a few.

The city which was originally developed as a Garden City over the years, slowly transformed into an industrial and software hub of India. Bengaluru is known as the 'IT Capital of India' and 'Silicon Valley of India' because of its role as the nation's leading information technology (IT) exporter. Emergence of IT sector has overshadowed other areas of development and has metamorphosed the city into a global hub. Indian technological organizations viz. ISRO, Infosys and Wipro are headquartered in the city. It is home to many educational and research institutions in India, such as Indian Institute of Science (IISc), Indian Institute of Management (IIMB), National Law School of India University (NLSIU), National Institute of Mental Health and Neurosciences (NIMHANS). Numerous state-owned aerospace and defense, such as Bharat Electronics, Hindustan Aeronautics and National Aerospace Laboratories are located.

Bengaluru has become a commercial, administrative and military center for the Region because of its salubrious climate and cosmopolitan nature of people. It was also known as pensioner's paradise with well-developed residential areas, roads with well grown trees, good commercial establishments, shopping malls etc. Despite such growth it is trying to maintain its character of garden city. The city continues to attract India's best and brightest human capital, given its undisputed status as the knowledge capital of India.

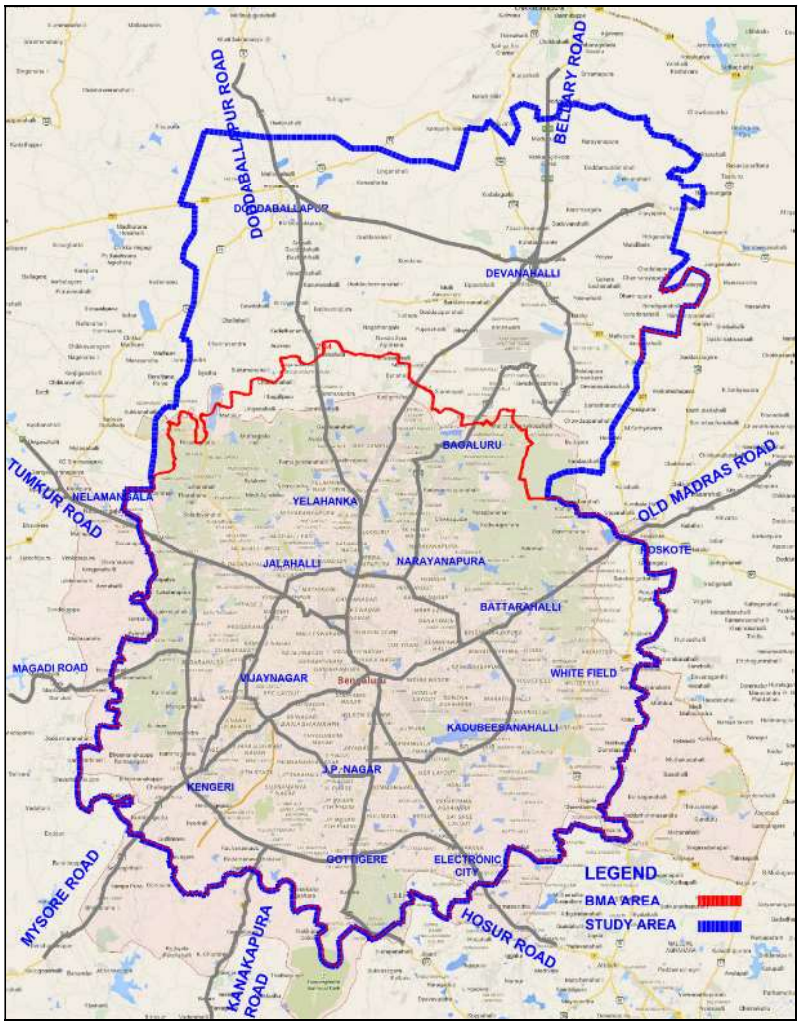
Access points to the City creates centralization of majority of the trips through Central business District (CBD) area, leading to traffic snarls. Travel demand has been increased resulting in increased movement between the city center and suburbs. The road network of the city consists of narrow roads which are not sufficient to cater to increased vehicles and traffic.

Comprehensive Mobility Plan for Bengaluru was prepared in 2020 which identified the major travel corridors including the corridors where mass rapid transit system for Phase 3 of Bangalore Metro has been recommended.

In view of above, Bangalore Metro Rail Corporation Ltd. (BMRCL) intends to prepare Detailed Project Report for Phase 3 corridors of Bangalore Metro for implementation. For this purpose, BMRCL has engaged RITES for preparation of Detailed Project Report for two Corridors of Bengaluru Metro Phase 3 from JP Nagar IV Phase to Kempapura along ORR West and from Hosahalli Metro station to Kadabagere on Magadi Road'.

Study area includes the Bangalore Metropolitan Area (BMA area) i.e. 1306 Sqkm including part BMICAPA area and adjoining areas around Bangalore International Airport Area Planning Authority (BIAAPA). The study area map is shown in **FIGURE 0.1**.

FIGURE 0.1: STUDY AREA



0.2. EXISTING TRANSPORTATION SYSTEM IN THE CITY

The total registered vehicular in Bangalore Metropolitan Region are 100.1 lakh vehicles as on March, 2021 wherein two wheelers constitute the highest of vehicular registration every year. It can be seen that number of vehicles registration in Bengaluru has increased from 61.1 lakh to 100.1 lakh from year 2015 to 2021 with CAGR of 8.5%.

Road network inventory within the study area was carried out as a part of the study for primary and secondary roads. It is observed that about 44.9% of roads have ROW less than 20 m. This indicates the limitation of widening for most of the roads. It is also observed that about 73.8% of surveyed road network length have carriageway width upto 2 lane and about 20% of road network 4 lane and more.

The traffic counts both in terms of numbers of vehicles have been computed for the total daily (24 hour) traffic at various screen line locations and presented. It is observed that the traffic at different locations varies from 56348 Vehicle Hosahalli Road (ROB) to 164930 Vehicle Yeshwantpur Tumkur Road throughout a normal working day.

Road accident causes injuries, fatalities, disabilities and hospitalization with severe socio economic costs. As per the road accidents statistics (2009 – 2020 (Oct)), It can be observed that the number of accidents has been continuously decreased from the past. The overall decrease in road accidents indicates the better resultant of the public awareness programs and strict enforcement of traffic rules by the state authorities.

Mass rapid transit system 'Namma Metro' is being built in various stages in Bengaluru. At present, Phase 1 covering a length of 43 km on two lines i.e. Kengeri to Baiyyappanahalli and Silk Institute to Nagasandra. Both the lines are under operation. The Phase 2, 2A & 2B are under implementation and Phase 3 is under planning.

0.3. TRAVEL CHARACTERISTICS AND DEMAND ESTIMATES

The entire study area has been divided into 198 internal urban & 17 zones of Bangalore International Airport Area Planning Authority and 10 external traffic zones.

Classified traffic volume count surveys have been conducted at 8 mid blocks for 24-hour period on a typical fair weather working day. It is observed that the traffic at different locations varies from 66,443 PCU's (86034 Vehicle) ORR-B.T.M. Layout

(near Water Tank) to 1,28,995 PCU's (1,46,724 Vehicle) ORR (near Hebbal).

Origin – Destination survey of vehicles entering the study area was conducted at 10 outer cordon locations. It seen that about 47.7% of the trips are work and business-based trips, social trips contribute about 26.5% and shopping/recreation trips has about 19.6%.

The PT Stop survey was carried out at 25 bus stops (both sides) to assess the maximum boarding and alighting of passengers at different stops. It is observed that Anjananagara bus stop caters to the 5986 passengers followed by Hebbal bus stop with 5984 passengers.

The pedestrian volume counts were carried at 13 locations in the study area. The maximum daily pedestrian volume of 20,112 is observed at Magadi Main Road Kamakshi Palaya with least of 3,490 observed at Bellery Road outer Ring Road Hebbal.

Parking surveys was conducted at 10 locations identified at on-street parking stretches and off-street parking lots for 16 hours on fair weather working day. The maximum parking demand over the day is observed to be 713 ECS at Appoorva Layout followed by 304 ECS at Kottige Palya.

Household Interview Survey on a sample basis was carried out as a part of the study to get the information spread over the study area. It is observed from the table that about 72% of the trips are performed for work and business purpose together, whereas 13% trips are education and about 16% trips which includes shopping, social, health and recreation.

The projected population, employment in the years 2021, 2031, 2041 and 2051 is presented in the **Table 0.1.**

TABLE 0.1: PROJECTED LANDUSE PARAMETERS FOR STUDY AREA (IN LAKH)

Year	Population	Employment	Student Enrolment
2021	143.5	61.7	31.6
2031	208.5	92.1	45.8
2041	266.0	117.9	58.5
2051	332.3	148.7	73.1

A four stage travel demand model has been used for transport demand forecasting. The maximum peak hour peak direction trips (PHPDT) are shown in the **TABLE 0.2**.

TABLE 0.2: MAXIMUM PHPDT ON CORRIDOR 1 & 2

Corridor	Max. PHPDT			
	2028	2031	2041	2051
JP Nagar 4th Phase to Kempapura	23303	25173	29930	33061
Hosahalli to Kadabagere	18227	19679	23272	25707

Total daily boardings on the study corridors for the years 2028, 2031, 2041 and 2051 is expected to be 7.86 lakh, 8.37 lakh, 10.2 lakh and 11.5 lakh respectively and presented in **Table 0.3.**

TABLE 0.3: DAILY PASSENGER BOARDINGS

Corridor	Daily Boarding (in Lakh)			
	2028	2031	2041	2051
JP Nagar 4th Phase to Kempapura	5.86	6.25	7.69	8.67
Hosahalli to Kadabagere	1.99	2.12	2.51	2.83
Total	**7.86**	**8.37**	**10.20**	**11.50**

Total daily trips on the study corridors for the years 2028, 2031, 2041 and 2051 is expected to be 6.35 lakh, 6.7 lakh, 8.1 lakh and 9.12 lakh respectively and presented in **TABLE 0.4**.

TABLE 0.4: DAILY PASSENGER TRIPS

Corridor	Daily Trips (in Lakh)			
	2028	2031	2041	2051
JP Nagar 4th Phase to Kempapura	4.63	4.89	5.91	6.66
Hosahalli to Kadabagere	1.72	1.81	2.18	2.46
Total	**6.35**	**6.70**	**8.10**	**9.12**

0.4. SYSTEM & TECHNOLOGY SELECTION

Considering the city specific characteristics, traffic demand, availability of right of way, Medium Metro rail system, which can cater to design PHPDT is proposed to be adopted for Bangalore Metro Phase-3 corridors. The system specifications are tabulated below:

Parameters		System Specification
Traffic Handling capacity (PHPDT)		60,000 with 6 car trains (Considering peak period headway of 2 minutes)
Alignment and Gauge	**Minimum radius of curvature**	Min. for elevated = 120m Min. for UG = 200m
	Gradient	4%
	Gauge	Standard gauge (1435 mm)
Traction System		750 V DC Third Rail

Parameters		System Specification
Signaling System		Communication Based Train Control (CBTC) System
Telecommunication System		GE (Gigabit Ethernet) based system
Rolling Stock	**Coach Width**	2.88 m wide coaches
	Train Composition	6 car – DMC-TC-MC-MC-TC-DMC Capable of GoA4 operation Every coach should be fully interchangeable with any other coach of same type.
	Coach construction	Light weight stainless steel body
	Axle load	≤15 T
	Braking System	Regenerative Braking
	Propulsion system	3 phase drive system with VVVF control
	Performance Characteristics	Max. Design speed: 90 kmph Max. Operating Speed: 80 kmph Average Acceleration rate from 0-30 kmph: 1.0 m/s^2 ± 5% Average Deceleration from 80 kmph to 0 kmph: 0.95 m/s^2 ± 5% Instantaneous full service deceleration: 1.1 m/s^2 (>1.3m/sec^2 during emergency)

0.5. CIVIL ENGINEERING & ALIGNMENT DETAILS

0.5.1. Geometric Design Parameters

TABLE 0.5: DESIGN CRITERIA

SN	Criteria	Dimension
1	Gauge	1435 mm
2	Design Speed	90 Kmph
3	Maximum Axle Load	≤15 T
4	Electric Power Collection	3rd Rail, 750 V D.C.

TABLE 0.6: HORIZONTAL CURVE PARAMETERS

Description	Elevated Section
Minimum radius on main running lines other than stations	120 m with check rail*
Minimum curve radius at Depot & other lines	100m
Minimum curve radius at passenger stations	1000 m
Maximum permissible cant (Ca)	110 mm
Maximum cant deficiency (Cd)	100 mm
* Check rails are to be provided on circular curves of less than 190m radius including their transition curves	

TABLE 0.7: TRACK CENTRE AND HEIGHT IN ELEVATED SECTION

Parameter	Minimum Track Centre	Minimum Rail Level above Ground Level
Mid-Section	4.20 m*	7.50 m**
Station	4.20 m	12.50 m

Note:
***** Track centre in elevated section can be modified as per the choice of girder/super structure. For Double U-girder minimum 4.85 m track centre will be provided.
****** For I-girder and Box-girder, Minimum Rail Level above Ground Level shall be 8.50 m

TABLE 0.8 : GRADIENT PARAMETERS

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

TABLE 0.9: VERTICAL CURVE PARAMETERS

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

0.5.2. Engineering Survey

Topographical Surveys for the corridor were conducted based on differential GPS.

0.5.3. Geotechnical Investigations

A total of 36 boreholes were drilled along this proposed corridor, 26 borings along the proposed alignment for Corridor 1 and the remaining 10 borings along the proposed alignment for Corridor 2. Bore Holes have been drilled upto a maximum 30.00 m depth each for all along the length of proposed Metro alignment.

0.5.4. Alignment Description

Two corridors have been finalized for implementation in Phase – III of Bangalore Metro network and are given as under:

i. Corridor-1: JP Nagar 4th Phase to Kempapura

ii. Corridor-2: Hosahalli to Kadabagere

Corridor-1: JP Nagar 4th Phase to Kempapura

Considering centre line of JP Nagar 4th Phase Station as 42.00m, this corridor is 32.15km long starting from Ch: (-)330m and running up to Ch: 31820m. At Kempapura Station, track Integration with under construction Phase-2B corridor is

planned. Provision already exists in the station and track layout of Phase-2B corridor. The corridor is proposed completely elevated. Total of 22 stations have been proposed on the corridor. The corridor is summarized as shown in **TABLE 0.10**.

TABLE 0.10: SUMMARY OF SECTIONS FOR CORRIDOR-1

S. No.	Corridor Section	Length (km)	Stations
1	JP Nagar 4th Phase to Mysore Road	10.93	8
2	Mysore Road to Sumanahalli Cross	7.30	5
3	Sumanahalli Cross to Peenya	5.10	4
4	Peenya to Kempapura	8.82	5
	Total	**32.15**	**22**

Corridor-2: Hosahalli to Kadabagere

Considering centre line of Hosahalli as 0.00m, this corridor is 12.50 km long starting from (-)450m and running up to 12050m. The corridor is proposed completely elevated. Total of 9 stations have been proposed along corridor. A common Maintenance depot has been proposed for both the corridors at Sunkadakatte in Govt. state land with an area of about 30 Ha. The corridor is summarized as shown in **TABLE 0.11**.

TABLE 0.11: SUMMARY OF SECTIONS FOR CORRIDOR-2

S. No.	Corridor Section	Length (km)	Stations
1	Hosahalli to Sumanahalli Cross	5.15	4
2	Sumanahalli Cross to Kadabagere	7.35	5
	Total	**12.50**	**9**

TABLE 0.12: ABSTRACT OF HORIZONTAL CURVES FOR CORRIDOR-1

S. No.	Curve Radius	No. of Occurrences	Length	Percentage
1	≤150	13	2019	14.28
2	>150 ≤300	45	4909	34.72
3	>300 ≤ 500	15	1517	10.73
4	>500 ≤ 800	22	2369	16.76
5	>800 ≤ 1000	12	1181	8.35
6	>1000	26	2142	15.15
	Total	**133**	**14137**	**100.00**

TABLE 0.13: ABSTRACT OF HORIZONTAL CURVES FOR CORRIDOR-2

S. No.	Curve Radius	No. of Occurrences	Length	Percentage
1	≤150	10	1695	26.6
2	>150 ≤300	5	701	11.0
3	>300 ≤ 500	10	1589	24.9
4	>500 ≤ 800	3	525	8.2
5	>800 ≤ 1000	7	945	14.8
6	>1000	10	928	14.5
	Total	**45**	**6384**	**100.0**

TABLE 0.14: ABSTRACT OF GRADIENTS FOR CORRIDOR-1

S. No.	Description	No's of Occurrences	Length (m)	Percentage
1	Level (0%)	28	9262	28.81
2	>0% to 1%	18	5206	16.19
3	>1% to 2%	26	6810	21.18
4	>2% to 3%	14	4526	14.08
5	>3%	19	6346	19.74
	TOTAL	**105**	**32150**	**100.00**

TABLE 0.15: ABSTRACT OF GRADIENTS FOR CORRIDOR-2

S. No.	Description	No's of Occurrences	Length (m)	Percentage
1	Level (0%)	11	4002	32.02
2	>0% to 1%	7	2098	16.78
3	>1% to 2%	9	2345	18.76
4	>2% to 3%	4	1277	10.21
5	>3%	7	2778	22.22
	TOTAL	**38**	**12500**	**100.00**

0.5.6 Land Requirement

Land will be required for the following main components:

- MRTS Structure - Viaduct (including Route Alignment)
- Station Building, Entry/Exit Structures, Parking, Multimodal Integration Facilities
- Maintenance Depot
- Receiving/Traction Sub-stations
- Property Development (PD)
- Temporary casting yard and work sites.

Abstract of land requirements for different components of corridors are given in **Table 0.16 & Table 0.17**.

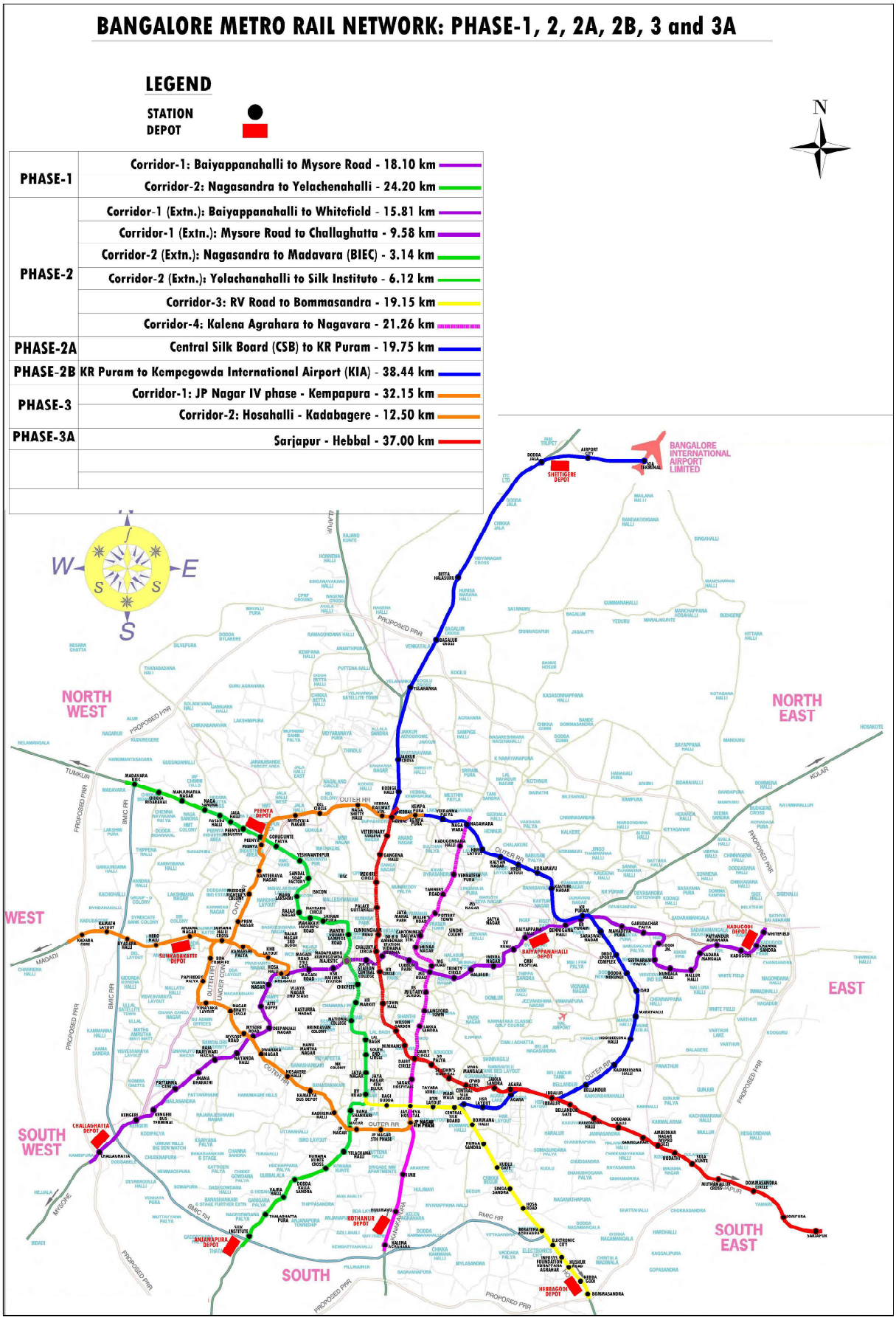
TABLE 0.16: LAND & STRUCTURES REQUIREMENT FOR CORRIDOR-1

Ownership	Purpose	Permanent Land (Sqm)	Structures (Floor Area in Sqm)
Govt. (Central)	Running Section (Viaduct)	13032	89
	Station Building, Entry/Exit and Ancillary facilities	1048	0
	MMI	2200	0
	Stabling Line - Entry	3691	0
	Pier	243	0
	Total	**20214**	**89**
Govt. (State)	Running Section (Viaduct)	16293	3061
	Station Building, Entry/Exit and Ancillary facilities	2320	0
	Parking and Property Development (P.D.)	17500	460
	RSS/TSS	6400	0
	MMI	819	0
	Road Widening	1236	1589
	Pier	443	0
	Total	**45011**	**5110**
Private	Running Section (Viaduct)	22529	30729
	Station Building, Entry/Exit and Ancillary facilities	10936	13629
	Parking	9630	224
	MMI	1079	581
	Road Widening	12997	47946
	Pier	2814	11428
	Total	**59985**	**104537**
Grand Total		**125210**	**109736**

TABLE 0.17: LAND & STRUCTURES REQUIREMENT FOR CORRIDOR-2

Ownership	Purpose	Permanent Land (Sqm)	Structures (Floor Area in Sqm)
Govt. (Central)	Running Section (Viaduct)	0	0
	Station Building, Entry/Exit and Ancillary facilities	0	0
	Total	**0**	**0**
Govt. (State)	Running Section (Viaduct)	4712	98
	Station Building, Entry/Exit and Ancillary facilities	639	0
	Parking	0	0
	Property Development (P.D.)	0	0
	RSS/TSS	3200	0
	Maintenance Depot	300000	0
	Depot Entry (Corridor-1 to Corridor-2)	3696	0
	Total	**312247**	**98**
Private	Running Section (Viaduct)	4247	12997
	Station Building, Entry/Exit and Ancillary facilities	7012	8903
	Parking	6050	3390
	Property Development (P.D.)	0	0
	Depot Entry (Corridor-1 to Corridor-2)	2830	5808
	Total	**20139**	**31098**
Grand Total		**332386**	**31196**

FIGURE 0.2: PROPOSED CORRIDORS OF PHASE-3



0.6. STATION PLANNING

0.6.1. Station Planning

The stations have been planned based on the basis of following parameters:

a. Station planning is dependent on the peak hour traffic load for each station in the design year.

b. The station is planned for 6 cars train.

c. The total evacuation time for the movement of all passengers in an emergency from platform level to the landing at the next level does not exceed 5.5 minutes in elevated stations considering that the stations are open and the risk is much less.

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

e. Six typical designs have been suggested for various station (**TABLE 0.18**) and these will form basis for planning of all the stations (**TABLE 0.19**).

TABLE 0.18: TYPICAL DESIGNS

Sr. No.	Proposed Type	Remarks
1	Type A	135 m x 20.50 m (Typical Station)
2	Type B	135m x 22.30 m (Station with common concourse & having connectivity with both corridors, corridor 1 crossing at first level & corridor 2 at second level) i.e., Sumanahalli Cross Station
3	Type C	135 m x 20.50 m (Station on triple height due to proposed flyover at station location & connectivity through paid concourse) i.e., J P Nagar Metro Station
4	Type D	135 m x 20.50 m (Station with PD area at three different floor level below concourse & connectivity through Paid Concourse area) i.e., Mysore Road Metro Station
5	Type E	135 m x 37.75 m (Common station with Phase 2 Metro, having two side & one island platform) i.e., J P Nagar 4th Phase Station
6	Type F	135 m x 20.50m (Station having three PD levels below concourse & connectivity through paid concourse) i.e., Peenya Station
7	Type G	77.20m x 30.30m (Station having one side & one island platform with four tracks & Depot connectivity) i.e., Sunkadakatte Station

TABLE 0.19: LIST OF STATIONS

SN	Station Name	Chainages	Inter-station Distance (m)	Size (All Elevated Station)	Existing Ground Level (GL) (m)	Proposed Rail Level (RL) (m)
Corridor 1: JP NAGAR 4th PHASE TO KEMPAPURA						
1	JP Nagar 4th Phase	42	-	135m x 37.75m (including Phase-2 R6 Station platform)	900.018	913.184
2	JP Nagar 5th Phase	1789	1747	135m x 20.50m	900.354	917.500
3	JP Nagar	3089	1300	135m x 20.50m	900.698	924.500
4	Kadirenahalli	4261	1172	135m x 20.50m	903.464	918.000
5	Kamakya Junction	6247	1986	135m x 20.50m	867.670	897.500
6	Hosakerehalli	7472	1225	135m x 20.50m	872.062	892.000
7	Dwaraka Nagar	8658	1186	135m x 20.50m	838.247	860.000
8	Mysore Road	10162	1504	135m x 20.50m	813.002	839.500
9	Nagarbhavi Circle	11651	1489	135m x 20.50m	844.815	858.500
10	Vinayaka Layout	13091	1440	135m x 20.50m	839.528	858.000
11	Papireddy Palya	14381	1290	135m x 20.50m	867.982	882.000
12	BDA Complex Nagarbhavi	15711	1330	135m x 20.50m	888.577	904.000
13	Sumanahalli Cross	17290	1579	135m x 22.30m	858.940	879.000
14	Chowdeshwari Nagar	18576	1286	135m x 20.50m	863.616	878.000
15	Freedom Fighter's Colony	19675	1099	135m x 20.50m	883.368	903.000
16	Kanteerva Nagar	21067	1392	135m x 20.50m	896.720	910.000
17	Peenya	22797	1730	135m x 20.50m	910.787	940.000
18	Muthyala Nagar	25064	2267	135m x 20.50m	909.976	924.000
19	Bel Circle	26302	1238	135m x 20.50m	904.323	924.000
20	Nagashetty Halli	27722	1420	135m x 20.50m	897.781	911.000
21	Hebbal Railway Station	30149	2427	135m x 20.50m	894.316	907.500
22	Kempapura	31581	1432	135m x 29.50m (including Phase 2B Station platforms)	888.126	902.500
Corridor 2: Hosahalli to Kadabagere						
1	Hosahalli	0	-	135m x 20.50m	877.172	896.500
2	KHB Colony	1648	1648	135m x 20.50m	895.114	909.000
3	Kamakshipalya	2971	1323	135m x 20.50m	880.003	900.000
4	Sumanahalli Cross	3907	936	135m x 22.30m	858.985	886.500
5	Sunkadakatte	5660	1753	135m x 30.30m (including two additional tracks of depot entry)	906.949	920.000
6	Herohalli	6981	1321	135m x 20.50m	883.399	897.500
7	Byadarahalli	8562	1581	135m x 20.50m	868.691	881.500
8	Kamath Layout	10006	1444	135m x 20.50m	874.050	887.000
9	Kadabagere	11590	1584	135m x 20.50m	867.254	880.000

*As suggested by MoHUA, eight stations of corridor-2 will be constructed for 3 car train having size of 77.20mx20.50m. Platforms will be extended to accommodate 6 car trains as and when required in future.

0.6.2. NMV and Pedestrian Facilities

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

0.6.3. Accessibility for Differently-abled

The proposed Metro Rail system should be user-friendly ensuring accessibility to persons with disabilities, people travelling with small children or are carrying luggage, as well as people with temporary mobility problems and the elderly persons. The standards are extracted from ‘Guidelines for Pedestrian Facilities' and ‘NBC 2016 Guidelines’, ‘Space Standards for Barrier Free Built Environment for differently-abled and Elderly Persons' and other standards. Standard for differently-abled facilities within station areas will be provided for seamless movement around metro stations.

0.7. INTERMODAL INTEGRATION

0.7.1 Intermodal Integration with Existing Modes

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

- Minimizing pedestrian/vehicle conflicts and effective passenger interchange with feeder modes.
- Facilitating passenger interchange with other transit systems
- Circulation area with designated space for embarking and disembarking for vehicular traffic and NMT.
- Availability of total carriageway and footpath widths required to cater to the proposed traffic volumes and relocation of vendors/hawkers

0.7.2 Feeder Bus System

The feeder buses have been proposed of high quality, ultra-modern and customer oriented that can deliver fast, comfortable and cost-effective urban mobility. Easy-to-board (low floor), attractive and environmentally friendly buses with air conditioning having capacity of 35 (Mini-buses) are proposed for feeder system.

The facilities of feeder buses have been estimated for peak hours of various horizon years. The total number of buses required are 256, 262, 346 and 416 in the year

2028, 2031, 2041 and 2051 respectively. Public bicycle sharing is provided for the passengers for about 2 km of the metro stations influence area.

Some of the essential features of an integrated multi-modal urban transport system are the physical integration of public transport services, fares, ticketing, infrastructure provision, management, pricing, and integration of transport authorities.

0.8. TRAIN OPERATIONS PLAN

The train operation plan for the proposed corridor will be based on the following salient features:

- Operation from Bangalore Metro phase-3 (Corridor-1: JP Nagar 4th Phase to Kempapura and Corridor-2: Hosahalli to Kadabagere) Running of services for 19 hours of a day (5:00 hrs to 24:00 hrs) with a station dwell time of 20-30 seconds.
- Scheduled speed of 34 kmph.
- Make up time of 5% with 8% coasting.
- Adequate services to ensure comfortable journey for commuters even during peak periods.

The train operation plan is envisaged for Bangalore Metro phase-3 with 6 car rake composition for Corridor-1 and 3 car composition for Corridor-2 during the initial years of operation. The infrastructure and train operation plan for the corridor is proposed to be designed accordingly for the design year.

Based on the traffic demand, the details of the proposed train operation plan for Bangalore Metro phase-3 are given in **TABLE 0.20.**

TABLE 0.20: TRAIN OPERATION PLAN WITH AW4 LOADING

Horizon Years		2028	2031	2041	2051
Corridor 1 : JP Nagar 4th Phase to Kempapura	Cars/ Train	6	6	6	6
	Headway in minutes	5.0	4.5	4.0	3.5
	Trains Per Hour	12	13	15	17
	Capacity Achieved @ 6 person per sqm	18888	20462	23610	26758
	Capacity Provided @ 8 person per sqm	24048	26052	30060	34068
	PHPDT	23303	25173	29930	33061
Corridor 2 : Hosahalli to Kadabagere	Cars/ Train	3	3	3 & 6	6
	Headway in minutes	3.0	3.0	3.0	4.0

Horizon Years		2028	2031	2041	2051
	Trains Per Hour	20	20	20 (16 trips of 3 car trains & 4 trips of 6 car train)	15
	Capacity Achieved @ 6 person per sqm	15280	15280	18520	23610
	Capacity Provided @ 8 person per sqm	19500	19500	23616	30060
	PHPDT	18227	19679	23272	25707

**Headway has been considered either in nearest whole number or as nearest multiples of 0.5.*

The above train operation and headway for different horizon years is proposed to meet the Peak hour peak direction traffic demand (PHPDT) with standees @6 passengers/ m2 in most of the sections, except in few sections where traffic demand is met with standees @ 8 passengers/ m2. This arrangement will optimize the rolling stock requirement. Rolling Stock requirement for different horizon years for Bangalore Metro phase-III is given in **TABLE 0.21.**

TABLE 0.21: ROLLING STOCK REQUIREMENT FOR DIFFERENT HORIZON YEARS

TRAIN OPERATION/ CORRIDOR	TIME HORIZON YEAR	RAKE CONFIGURATION	HEADWAY IN MINUTES	SECTION LENGTH KM	BARE RAKE REQMT	TRAFFIC SPARE @5%	MAINT. SPARE @10%	TOTAL RAKE REQMT	TOTAL COACH REQMT
CORRIDOR 1: JP NAGAR PH 4TH TO KEMPAPURA	2028	6 CAR	5.0	31.52	24.0	2	3	29	174
	2031	6 CAR	4.5	31.52	27.0	2	3	32	192
	2041	6 CAR	4.0	31.52	30.0	2	4	36	216
	2051	6 CAR	3.5	31.52	35.0	2	4	41	246
CORRIDOR 2: HOSAHALLI TO KADABAGERE	2028	3 CAR	3.0	11.6	17.0	1	2	20	60
	2031	3 CAR	3.0	11.6	17.0	1	2	20	60
	2041	3 CAR & 6 CAR	3.0	11.6	17.0	1	2	20 (14 NOS. OF 3-CAR TRAINS + 6 NOS. OF 6-CAR TRAINS)	78
	2051	6 CAR	4.0	11.6	13.0	1	2	16	96

0.9. SIGNALING AND TELECOMMUNICATION

0.9.1. Signaling System

The Communication based Train Control (CBTC) Signaling system provides adequate safety level of CENELEC SIL-4 (Safety Integrity Level) and permits an operational

headway of 90 seconds with continuous automatic train control. The CBTC Technology is suitable for UTO (Unattended Train Operation) / DTO (Driverless Train Operation). Considering the above, CBTC system is recommended for Bangalore Metro Phase-3.

0.9.2. Telecommunication System

The telecommunication system acts as communication backbone for signaling and other systems and provides telecommunication services to meet operational and administrative requirements of metro network.

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

- GE (Gigabit Ethernet) based Transmission System
- Telephone Exchange
- Mobile Radio Communication System
- Public Address System (PAS)
- Centralized Clock System
- Passenger Information Display System (PIDS)
- Close Circuit Television (CCTV)
- Central Digital Recording System (CDRS)
- Central Communication Fault Reporting System (CCFRS)

0.10. FARE COLLECTION SYSTEM

Mass Rapid Transit Systems which is proposed in Banglore Metro Phase-3 corridors handle a 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, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. Automatic fare collection system meets these requirements.

0.11. ROLLING STOCK

Rolling Stock proposed for the Bangalore Metro phase-3 corridors will be similar to Bangalore Metro Phase 2A and 2B. The broad features of Rolling Stock are presented in **Table 0.22.**

TABLE 0.22: BROAD FEATURES OF ROLLING STOCK

SN	Parameter	Details
1.	**Gauge**	1435 mm
2.	**Traction System**	
	Voltage	750V DC
	Method of Current Collection	Third Rail Bottom Current Collection System
3	**Train Composition**	
	6 Car Train	DMC-TC-MC-MC-TC-DMC with 67% motorization
	3 Car Train	DMC-TC-DMC with 67% motorization
4	**Coach Body**	Stainless Steel
5	**Coach Dimensions**	
(a)	Height	3.848 m
(b)	Width	2.88 m
6	Length over body (approx.)	
(a)	Driving Motor Car (DMC)	21.05 m
(b)	Trailer Car (TC)	20.88 m
(c)	Motor Car (MC)	20.88 m
7	**Design Passenger Loading**	
(a)	Design of Propulsion equipment	Full seating + standee passengers @ 8 Passengers/ m^2
(b)	Design of Mechanical systems	Full seating + standee passengers @ 10 Passengers/ m^2
8	**Carrying Capacity - @ Full seating + 8 standee passengers per sq. m**	
(a)	Coach Carrying Capacity	
	DMC	316 (seating – 43; standing – 273)
	TC	343 (seating – 50; standing – 293)
	MC	343 (seating – 50; standing – 293)
(b)	Train Carrying Capacity	3 Car – 975 (seating 136, standing- 839) 6 Car - 2004 (seating – 286; standing – 1718)
9	**Axle Load**	$\leq$ 15 Tonne
10	**Propulsion System**	3 phase drive system with VVVF control
11	**Braking System**	Regenerative Braking
12	**Performance Characteristics**	
(a)	Maximum Design speed :	90 kmph
(b)	Maximum Operating Speed :	80 kmph
(c)	Average Acceleration rate from 0-30 kmph	1.0 $m/s^2 \pm 5\%$
(d)	Average Deceleration from 80 kmph to 0 kmph	0.95 $m/s^2 \pm 5\%$
(e)	Instantaneous full service deceleration	1.1 m/s^2 (>1.3m/sec^2 during emergency)

0.12. POWER SUPPLY AND TRACTION

0.12.1. 750 V DC Third Rail traction system is proposed for Bangalore Metro phase-3 corridors. The power requirements of a metro system are determined by peak-hour power demand for traction and auxiliary applications. The ultimate (design) power

requirement for this corridor will be conceptualized considering following norms, directives/ guidelines:

- Train operation with 6 car trains during the design year
- Peak period headway of 3.5 minutes for Corridor 1: JP Nagar 4th Phase to Kempapura and 4.0 minutes for Corridor 2: Hosahalli to Kadabagere during the design year i.e 2051.
- Specific energy consumption of rolling stock – 75 KWh/ 1000 GTKM
- Regeneration @ 20%
- At grade / Elev. station load – initially 200kW, ultimate design 300kW.
- Depot auxiliary load- initially 1500 KW, ultimate design 2250KW.
- Depot traction Load- initially 1000 KW, ultimate design 1750 KW.
- Power factor of load – 0.9
- Transmission losses @ 5%

Keeping in view of the above norms, power demand estimation for the corridor is given in **Table 0.23.**

TABLE 0.23: POWER DEMAND ESTIMATION (MVA)

Corridor	Horizon Year	2028	2031	2041	2051
Corridor-1: JP Nagar 4th Phase to Kempapura	Traction	18.76	20.32	23.45	26.57
	Auxiliary	5.13	6.42	7.06	7.70
	Total	**23.89**	**26.74**	**30.51**	**34.27**
Corridor-2: Hosahalli to Kadabagere	Traction	6.86	7.15	8.61	10.67
	Auxiliary	3.85	4.67	5.22	5.78
	Total	**10.71**	**11.82**	**13.83**	**16.45**

0.12.2. Sources of Power Supply

Bangalore city has 66kV & 220kV power transmission and distribution network to cater to various types of demand in the vicinity of the proposed Corridors. Keeping in view of the reliability requirements and considering the complete length of Corridors, three (03) Receiving Sub Stations are proposed to avail power supply for traction as well as auxiliary services. Each Receiving Sub Station avail power supply from Two (02) different Grid Sub Stations of Power Supply Authority (PSA) i.e., Karnataka Power Transmission Corporation Limited (KPTCL) at 66kV (Upto 20 MVA) or 220kV (above 20 MVA) voltage level through underground cable feeders for the proposed Bangalore Metro Phase-3 i.e., Corridor 1 and Corridor 2. The Grid Substations which have been identified near the alignment are given in **Table 0.24.**

TABLE 0.24: SOURCES OF POWER SUPPLY

Corridors	Location of RSS of Metro Authority	Grid Sub-Station	Approx. Dist. GSS to RSS	Feeding Zone
Corridor-1: JP Nagar 4th Phase to Kempapura	RSS 1: Nagarbhavi Circle RSS (66/33 kV)	Existing 220/66kV Vrishabhavathi Valley GSS & Proposed 220/66kV from Nagarabhavi GSS	6.5 km from Vrishabhavathi Valley GSS. & 3.0 km from Nagarbhavi GSS	JP Nagar 4th Phase to Vinayaka layout
	RSS 2: BEL Circle RSS (66/33 kV)	Proposed 220/66kV Mathikere GSS & Existing 220/66kV Sahakarinagar GSS	3.0 km from Mathikere GSS. & 6.5 km from Sahakarinagar GSS	Vinayaka layout to kempapura
Corridor-2: Hosahalli to Kadabagere	RSS 3: KHB Colony RSS (66/33 kV)	Existing 220/66kV NRS GSS & Existing 66/11kV Chandra layout GSS OR Existing 66/11kV Vijayanagar GSS	4.5 km from NRS GSS & 4.0 km from Chandra Layout /Vijayanagar	Hosahalli to Kadabagere

0.12.3. Auxiliary Supply Arrangements and Standby Power Supply

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

Each elevated station shall be provided with an Auxiliary Substation with two nos. 33kV/415V, 3-phase, 500 kVA dry type cast resin transformers and the associated HT & LT switchgear. In addition, provision shall be made for one DG set of adequate capacity at interchange and Signaling Interlock/Cross Over stations. All stations shall be provided with UPS of 2 hours backup to cater for station emergency lighting.

Apart from stations, separate ASS is required at each depot with 2X2000 kVA auxiliary transformers to cater to depot cum workshop load.

0.12.4. Solar Energy Harnessing System

Considering the futuristic technology and potential for solar power generation, need for development of solar power, provision of a grid connected solar

photovoltaic power plant utilizing all possible areas viz. roof top of stations/ sheds and buildings is proposed for Bangalore Metro Phase-3 MRTS.

Based on the solar radiation intensity in the city of Bangalore, the peak solar power generation in the corridor is expected to be about 200 kWp for each elevated station and 500kWp for Depot.

0.13. VENTILATION AND AIR-CONDITIONING SYSTEM

The proposed corridors of Bangalore Metro Phase-3 has been planned as completely elevated. The air conditioning and ventilation requirement in the elevated stations of the corridors is mainly for the ancillary spaces such as staff room, equipment rooms etc. It is essential to maintain an acceptable environment for the operating and maintenance personnel, to prolong the life of equipment by proper control of temperature, pressure, and humidity, and to mitigate possible gas accumulation.

0.14. MAINTENANCE DEPOT

The Common maintenance depot facility is proposed for Corridor-1 and Corridor-2 of Phase-3 Project at Sunkadakatte in 30 Hectares of land. According to operation plan for the year 2051 Corridor-1 will require 41 rakes and Corridor-2 will be require 16 Rakes. Hence, Rolling stock maintenance facilities have to be created for total 57 rakes of both corridors. To facilitate seamless operation from either end of the corridors, it is proposed to house stabling facility for 40 rakes at Sunkadakatte depot and 8 rakes at Peenya. The balance 9 rakes will be stabled at terminal stations. Details are provided in the subsequent section.

The maintenance depot will have infrastructure to maintain the rakes with necessary facilities viz stabling lines, scheduled inspection lines, workshop for overhaul, unscheduled maintenance including major repairs, wheel profiling, heavy interior/ under frame/ roof cleaning etc. for the rolling stock operational on the corridor as well as maintenance facilities for Civil – track, buildings, water supply; Electrical – Traction, E&M; Signaling & Telecommunication; Automatic Fare Collection etc.

In broad terms, based on the planned rolling stock requirements, this chapter covers the conceptual design of the following aspects of the Depots.

- Conceptual design and layout of Servicing Shed and Workshop to provide maintenance facilities and stabling facilities for Rolling Stock.
- Operational and functional safety requirements.
- Ancillary buildings for other maintenance facilities.
- Electrical & Mechanical Services, power supply and distribution system.

- Water Supplies, Drainage & Sewerage.
- Signal and Telecommunication Services
- Water Supplies, Drainage & Sewerage.
- Roof Top and Solar System on Sheds and Buildings

The details of the depot are provided on conceptual design basis and will work as a guideline for detailed design and planning and project stage based on actual traffic needs. Common maintenance facilities being housed in single depot Automatic Train Control (ATC) will need to be designed accordingly.

The proposed arrangement for stabling and maintenance facilities for Depot is given below in **Table 0.25.**

TABLE 0.25: MAINTENANCE DEPOT

Location	Infrastructure	Depot
Sunkadakatte	Stabling Lines	40 lines of 6 car rake
	Inspection Lines	5 lines of 6 car each
	Workshop Lines	4 lines of 6 car each
Peenya	Stabling Lines	8 lines of 6 car rake

0.15. ENVIRONMENT AND SOCIAL IMPACT ASSESSMENT

0.15.1. Environmental Impact Assessment

- **Environmental Baseline:** Land use along the corridor is Built-up area and vegetation. The elevation of the city varies from 850 to 950 m amsl and the city is located in Seismic Zone II. The Bangalore city has tropical savanna climate with distinct wet and dry seasons. Maximum rainfall occurs between June to November. As per Air Quality Monitoring data by KSPCB, PM10 and PM2.5 are exceeding the permissible limits.

- **Environmental Impacts:** During the period of construction, manpower will be needed for various project activities. In post-construction phase, about 1540 people will be employed for operation and maintenance of the system. The project will yield benefits in terms of better accessibility, savings in fuel consumption, reduction in vehicle operating costs, savings in travel time, improvement in quality of life and reduction in road accidents.

- Approximately 11137 trees are likely to be cut /transplanted during construction along the proposed corridors and depot. The dust will be produced due to excavation, loading & unloading, transportation of construction materials,

vehicular & construction equipment, and emission from the DG sets.

- **Mitigation Measures, Environmental Management Plan And Monitoring Plan:** Mitigation measures and management plan for Water and Energy management, Compensatory afforestation, Management of construction material and waste, Energy efficiency, Construction Safety Management, Labour Camp and Workplace facilities, Air Pollution Control, Noise pollution and Vibration control, Rain Water Harvesting, Management Plan for Depot, Solid Waste Disposal, Training to engineers and managers from the Implementing Agency. Environmental Monitoring is proposed during construction and operation phases of the project. Environmental Management Cell will supervise and coordinate monitoring and implementation of EMP. The cost of Environmental Management Plan and Environmental Monitoring Plan is estimated as **Rs. 3349.62 Lakh** for corridor-1 and **Rs. 1009.49 Lakh** for Corridor-2.

0.15.2. Social Impact Assessment

- The SIA has been prepared in accordance with the Compensation and Resettlement Package (CRP) 2019, based on the Government Order No. UDD 91 PRJ 2019, dated 10.7.2019 adopted by BMRCL.

- On the basis of proposed alignment plan about 376 structures and 703 families have been identified to be affected across both the corridors. Majority of structures are likely to be affected in corridor-1 whereas majority of families are likely to be affected in corridor-2. The Compensation and Resettlement Package has been formulated based on the guiding principles followed by BMRCL for Phase 1 and Phase 2.

- The BMRCL has a Project Implementation Unit in place for implementation of the project headed by the Director, Projects and Planning. The Land Acquisition office is headed by the General Manager Land Acquisition, who reports directly to the Managing director and is responsible for the implementation of the rehabilitation activities and disbursement of payments. The cost of R&R implementation plan is estimated as **Rs. 3528.32 Lakh** for corridor-1 and **Rs. 2090.49 Lakh** for Corridor-2. Cost of compensation for land and structures has been considered in DPR.

0.16. DISASTER MANAGEMENT & SECURITY MEASURES

0.16.1. Disaster Management Measures

Disaster is a crisis that results in massive damage to life and property, uproots the physical and psychological fabric of the affected communities and outstrips the capacity of the local community to cope with the situation. Disasters are those situations which cause acute distress to passengers, employees and outsiders and may even be caused by external factors. As per the disaster management act, 2005 "disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results insubstantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.

0.16.2. Security Measures

Metro Rail System has emerged as the most reliable mode of urban transportation system in India. The inherent characteristics of metro system make it an ideal target for terrorists and miscreants. Metro systems are typically open and dynamic systems which carry thousands of commuters. Moreover, high cost of infrastructure, its economic impacts to the society, being the life line of city with high news value pose greater threat to its security. Security is a relatively new challenge in the context of public transport. It addresses problems caused intentionally and differs from safety which addresses problems caused accidentally. Security problems or threats are caused by people whose actions aim to undermine or disturb the public transport system and/or to harm passengers or staff. These threats range from daily operational security problems such as disorder, vandalism and terror threat.

The public transportation system is increasingly becoming important for urban areas to prosper in the face of challenges such as reduction in congestion and pollution. Therefore, security system for public transportation like metro rail plays an important role in helping the system to become the preferred mode choice for commuters. Therefore, provision of an excellent and reliable security system is a prerequisite for metro system for increasing its market share. Metro railway administration must ensure that security model keep pace with the rapid expansion of the metro and changing security scenario.

0.17. DETAILED PROJECT COST ESTIMATES

0.17.1. Capital Cost Estimate

Cost estimate for Corridor-1: JP Nagar 4th Phase to Kempapura and Corridor-2: Hosahalli to Kadabagere of Bangalore Metro phase-3 from has been prepared

covering civil, electrical, signaling and telecommunications works, rolling stock, environmental protection, rehabilitation, etc. at March'2023 price level is presented in **Table 0.26.**

Basic cost is exclusive of taxes and duties. i.e. GST and Custom duty. Taxes and duties mainly comprising of latest prevalent GST & Custom duty are worked out for each corridor. Current rates of Taxes have been taken into consideration.

The rates of items other than land has been finalized on the basis of benchmarking exercise undertaken by MoHUA in February'2019 for Medium Metro. An escalation of 5% per annum has been considered to bring the rates to March'2023 price level. Rates for certain items which are not included in the benchmarking rates has been taken from the approved/awarded rates of Bangalore Metro Phase-2A and Phase-2B corridor.

TABLE 0.26: ABSTRACT OF COST ESTIMATE

at March'2023 Price Level

S. No.	Item	Amount (Rs. in Crore)		Total Amount (Rs. in Crore)
		Corridor-1	Corridor-2	
1	Land and R&R	1837.59	565.97	2403.56
2	Alignment and Formation	1990.85	702.16	2693.01
3	Station Buildings	945.62	252.93	1198.55
4	Maintenance Depot	231.00	79.00	310.00
5	P-Way for main line & depot	332.61	129.11	461.73
6	Traction & Power Supply	624.65	272.19	896.84
7	Signalling and Telecommunication	513.78	218.38	732.16
8	Environmental works	33.50	10.10	43.60
9	Miscellaneous Utilities	318.52	124.50	443.02
10	Capital Expenditure on Security	9.89	4.05	13.94
11	Rolling Stock	1392.00	480.00	1872.00
12	Capital Expenditure on Multimodal Integration	76.58	32.82	109.40
13	Total of all items except Land and R&R	**6469.02**	**2305.24**	**8774.25**
14	General Charges incl. Design charges @ 5% on all items except land and R&R	**323.45**	**115.26**	**438.71**
15	Total of all items including G. Charges except land and R&R	**6792.47**	**2420.50**	**9212.96**
16	Contingencies @ 3% on all items except land and R&R	**194.07**	**69.16**	**263.23**
17	**Gross Total Cost excluding Land and R&R**	**6986.54**	**2489.66**	**9476.19**
18	**Gross Total Cost including Land and R&R**	**8824.12**	**3055.63**	**11879.75**
19	Central GST & Customs duty	**735.98**	**263.48**	**999.46**
20	State GST	**621.62**	**221.61**	**843.23**
21	**Total Cost including Taxes & Duties**	**10181.72**	**3540.72**	**13722.44**

0.17.2. O&M Estimate

- **Corridor 1: JP Nagar 4th Phase to Kempapura**

The total O&M cost including additional and replacement cost in the year 2028, 2031, 2041 and 2051 are estimated at Rs. 231.42 Crore, Rs. 282.92 Crore, Rs. 529.76Crore, and Rs. 1002.92 Crore respectively.

- **Corridor 2: Hosahalli to Kadabagere**

The total O&M cost including additional and replacement cost in the year 2028, 2031, 2041 and 2051 are estimated at Rs. 87.92 Crore, Rs. 105.32 Crore, Rs. 198.45 Crore, and Rs. 379.53 Crore respectively.

0.18. TRANSIT ORIENTED DEVELOPMENT PLAN

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

For Bengaluru Metro Ph-3, following sources of Value Capture Finance have been taken:

i. Premium on sale of additional FAR
ii. Betterment levy for areas utilizing the additional FAR
iii. Change in Land Use
iv. Betterment and development cess for the layout/sites coming within the Metro impact zone.

It is proposed that 60% of yearly projected revenue collection will accrue to BMRCL (in same lines with Bengaluru Metro Ph I and II as per TOD policy). The rest 40% share will be distributed among BBMP, BWSSB and BDA. The total revenue share to BMRCL from all the above VCF tools in different years is given in **TABLE 0.27.**

TABLE 0.27: TOTAL REVENUE SHARE TO BMRCL FROM VALUE CAPTURE FINANCE

Year	Revenue from VCF (Rs. In Crores)
	Premium on Additional FAR
2028	215.00
2029	215.00
2030	215.00
2031	215.00
2032	215.00
2033	225.75
2034	225.75
2035	225.75
2036	225.75
2037	225.75

Year	Revenue from VCF (Rs. In Crores)
	Premium on Additional FAR
2038	241.88
2039	241.88
2040	241.88
2041	241.88
2042	241.88
2043	248.76
2044	248.76
2045	248.76
2046	248.76
2047	248.76

The BMRCL parking land along Mysore Road with total 0.87 Ha land has been identified for property development. Out of the total parking area of 24,480 sqm, taken along the proposed metro corridors, 50% area i.e. 12,240 sqm has also been considered for property development. In addition, total 10,455 sqm of area has been taken inside the Mysore Road metro station and Peenya metro station for property development.

Since BMRCL cannot sell residential or commercial Properties to any third party and can only lease the Property, the property development with only leasing of commercial properties has been considered. A total OF 52,335 sqm of property development having Commercial facilities has been proposed.

With the construction of metro, the cost of property/land along the corridor increases manifolds due to improved connectivity. It may be decided to capture the value of real estate along the corridor to fund the project.

0.19. FINANCIAL ANALYSIS AND NON FARE BOX REVENUE ASSESSMENT

0.19.1. Input for Financial Analysis

The cost of land is estimated at Rs. 2347 Crore that includes Rs. 1689 Crore for private land and Rs. 658 Crore for government land. The cost of R&R is estimated to be Rs. 56 Crore. The total cost of project including land and R&R cost but excluding taxes and duties is estimated at Rs. 11,880 Crore. The Central and State GST amount to Rs. 1842 Crore. The capital cost components at March 2023 prices are given in **TABLE 0.28.**

TABLE 0.28: CAPITAL COSTS

Cost Component	Amount (Rs. in crore)
Construction Cost excluding Rolling Stock, Land, R&R and Contingencies	7247
Land Cost and R & R incl. Hutments	2404
Rolling Stock (incl. its GC, Conting.)	2022
Contingencies	207
Construction Cost including land and R&R, contingencies and Rolling Stock	**11,880**
Taxes	**1842**
Central GST & Basic Customs Duty	999
State GST	843
Total Cost including Taxes & Duties	**13,722**

With escalation factor of 5 % p.a. (on all costs except Land and R&R), the Completion Cost of the project including Land and R&R is estimated to be Rs. 15203 Crore (excluding IDC and front end fee). It is proposed to start land acquisition and construction work by Year 2023 and commission the system by Year 2028.

The O&M cost of the metro system is another input for the financial analysis. The total O&M cost in the year 2031 is estimated at Rs. 388 Crore, Rs.728 Crore in the year 2041 and Rs. 1382 Crore in the year 2051. Additional investment of Rs. 144 Crore in the Year 2031, 336 Crore in Year 2041 and Rs. 336 Crore in Year 2051 has been estimated to cater to increased traffic demand.

0.19.2. Means of Finance

The Revenue for Bangalore Metro will mainly consists of fare box collection and revenue from other non-fare box sources such as property development, advertisement, parking, taxes etc. Estimation of revenue from fare box and non-fare box source has been made. The total annual revenue through the fare box and other sources for the study corridors is given in **TABLE 0.29.**

TABLE 0.29 TOTAL REVENUE COLLECTION (Rs. in Crore)

Source of Revenue	2028	2031	2035	2041	2045	2051	2056
Fare Box Revenue	493	1145	1486	2018	2332	3031	3889
Non-Fare Box Revenue	273	294	335	414	458	282	0
Total Revenue	**766**	**1438**	**1821**	**2432**	**2790**	**3313**	**3889**

0.19.3. Operational Viability

The FIRR for the project with capital costs including Central taxes and revenue from fare box and non-fare box sources works out to be **6.54%**. FIRR under various scenarios has been computed and shown in **Table 0.30**. The FIRR is found to be more sensitive to ridership than to capital costs. The FIRR of the project is sensitive to

revenues, and capital costs. The sensitivity of the project with respect to these factors is given **TABLE 0.31**.

TABLE 0.30: FIRR UNDER DIFFERENT SCENARIOS

Scenario	FIRR
FIRR with Farebox, Advt. revenue, PD and TOD revenue ("Base Case")	**6.54%**
FIRR with Farebox, Advt. revenue, TOD revenue but w/o PD revenue	6.32%
FIRR with Farebox, Advt. revenue but w/o PD, TOD revenue	5.20%
FIRR with only Farebox revenue	**4.66%**
FIRR with Farebox, Advt. revenue, PD and TOD revenue and innovative financing model	**6.79%**

TABLE 0.31 FIRR SENSITIVITY

Parameter	+5%	+10%	-5%	-10%
Capital Cost	6.19%	5.85%	6.93%	7.34%
Ridership	7.04%	7.50%	6.02%	5.46%

0.19.4. Alternate Means of Financing

The financing option for metro implementation depends upon selection of the dedicated agency created to implement the project. As per Metro Rail Policy '2017, the prominent models are:

- Equity Sharing Model (Special Purpose Vehicle fully under Government Control
- Built, Operate & Transfer (BOT) or Public Private Partnership (PPP)
- Grant by the Central Government with certain component on Public Private Partnership (PPP)

The total fund contribution of GoI & GoK for the Karnataka Metro corridor under analysis as per above alternatives excluding land and state taxes is tabulated in **Table 0.32.**

TABLE 0.32: COMPARISON OF THREE IMPLEMENTATION MODELS (RS. CRORE)

Particulars	SPV	VGF	Fixed Fee
Contribution by GoI	2369	4065	1184
Contribution by GoK	2369	4065	7106
Sub-Total	**4737**	**8131**	**8290**
Land by GoK	2404	2404	2404
State Taxes by GoK	956	0	956
Total	**8097**	**10534**	**11650**
Present Value @8% of Net Cash Flow to Public Entity	**247**	**-6699**	**-2596**
Equity IRR (pre-tax) to private party	**-**	**18.0%**	**16.0%**
Amount of VGF/Fixed Fee to Private Party (incl. O&M by Pvt.)	**-**	**64% (₹ 8131 Cr)**	**₹ 885 Cr p.a.**

It can be seen from the above table that the contribution of Governments under SPV model is the lowest. Also the present value of operating cash flow to public entity is highest in case of SPV model. Considering the net benefits vis-à-vis contributions by the Govt., it is proposed that the project may be implemented on the SPV Model.

The funding pattern developed under SPV model is placed in **TABLE 0.33**.

TABLE 0.33 FUNDING PATTERN UNDER SPV MODEL

Sources of Funds	Amount (Rs. crore)	% Share
Equity by GoI	1804	15.24%
SD for Central Taxes by GoI	564	4.76%
GoI Share sub total (1)	**2368**	**20.00%**
Equity by GoK	1804	15.24%
SD for Central Taxes by GoK	564	4.76%
GoK Share sub total (2)	**2368**	**20.00%**
Senior Debt in form of external assistance through multilateral/bilateral agencies or commercial loans	**7106**	**60.00%**
Sub Total	**11842**	**100.00%**
SD for Land and R&R by GoK	2404	
SD for State taxes by GoK	956	
Interest during construction (IDC) to borne by GoK	415	
Total Sources	**15618**	

Further based on extant market of the option, SPV model with Upfront Innovative Financing has been explored for Bangalore Metro Phase 3 corridors.

0.19.5. Upfront Innovating Financing

Public Private Partnership with some unbundled component is explored. This is necessary in terms of Metro Rail Policy 2017 for proposals seeking central financial assistance. However, a private player would price the risk associated with the uncertain revenue streams, limited flexibility in setting of fares, uncertainty in ridership, etc. this will increase the cost of private investment and correspondingly its return requirements in an already capital intensive project with high gestation period, public good characteristic and less attractive returns on investment. Therefore, it is essential that the Government leads the funding of the project and on board multilateral banks with suitable debt products. Further the focus on leveraging private resources, expertise in funding the projects by way of unbundling various activities or components or supplementing the project with exploitation of real estate development along stations and transit oriented development.

a) Sale of Additional FAR

By implementing TOD policy and thereby realizing revenues from VCF upon initiation of construction and reasonable progress on the project, GoK would be able to fund the Metro and other infrastructure projects in Karnataka. By sale of additional Floor Area Ratio (FAR)/FSI to developers along the proposed corridor, it is expected that a cumulative **Rs. 400 Crore** can be realized from 4th year onwards from start of construction.

b) Upfront Premium from Property Development

BMRCL can collect premium or revenue share from private developer to whom a land parcel would be leased out for a period of 30/45 years. The private developer would develop a residential, office spaces, commercial or recreational tower like Malls, Theaters, etc. which would fetch him rentals from the property. Based on the product mix, investment and desired return and according to the rent profile in the area, the developer would be able to provide upfront premium which can be mobilized for Metro development. Considering possibility of residential complexes also, it is estimated that **Rs. 50** Crore can be realized by this means.

c) Corporate Naming Rights / Advertising Space

BMRCL has for the Phase 2 projects made use of this method to approach Corporates alongside the Metro corridor and grant them bundle of rights including advertising space, commercial space, Naming Rights and provision of direct access. Appreciating the advantages of an efficient public transport facility, it is expected that the corporates will come forward and be willing to participate in this innovating model of partnership. It is estimated that **Rs 100 Crore** can be realized by this means.

Based on above, the funding pattern under SPV model can be modified with Innovative Finances as provided in **Table 0.34.** Project FIRR under this model is estimated as **6.79%**.

TABLE 0.34: FUNDING PATTERN UNDER SPV WITH INNOVATIVE FINANCES

Sources of Funds	Amount (Rs. crore)	% Share
Equity by GoI	1695	15.00%
SD for Central Taxes by GoI	564	5.00%
GoI Share sub total (1)	**2259**	**20.00%**
Equity by GoK	1695	15.00%
SD for Central Taxes by GoK	564	5.00%
GoK Share sub total (2)	**2259**	**20.00%**
Senior Debt in form of external assistance through multilateral/bilateral agencies or commercial loans	**6775**	**60.00%**

Sources of Funds	Amount (Rs. crore)	% Share
Sub Total	**11293**	**100.00%**
SD for Land and R&R by GoK	2404	
SD for State taxes by GoK	956	
Accruals from Value Capture Financing	400	
Innovative Financing (Private Participation)	150	
Interest during construction (IDC) to borne by GoK	408	
Total Sources	**15611**	

Considering the net benefits vis-à-vis contributions by the Govt., it is proposed that the project may be implemented on the SPV Model and efforts may be made in securing the alternate source of financing means namely Innovating Finances and Value Capture Finances as explored in earlier sections.

As per new Metro Rail Policy 2017, it is essential to explore private participation either for complete provisioning of metro rail or for some unbundled components of operations and maintenance costs of metro rail. Additionally, Government can also involve private party in O&M part of the metro operations i.e. during procurement and operation of Rolling Stock and associated maintenance on PPP basis or some other form of O&M PPP after completion of infrastructure facilities.

0.20. ECONOMIC ANALYSIS

The economic appraisal has been carried out within the broad framework of Social Cost – Benefit Analysis Technique. It is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the "with" and "without" project scenario. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices.

This has been done to iron out distortions due to externalities and anomalies arising in real world pricing systems. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost / benefit and to calculate the economic viability of the project in terms of EIRR & ENPV.

ENPV has been worked at two rates namely social cost of capital @14% and at government security rate @7.03%.

The **EIRR works out to 17.04%.** ENPV@7.03% works out to Rs. 12,769 Crore and @14% it is estimated at Rs. 1,898 Crore. Sensitivity analysis of the EIRR with 5% to

15% cost overrun and reduction in traffic materialization (separately) has been carried out. The EIRRs under these scenarios are given in **TABLE 0.35.**

TABLE 0.35: EIRR AND SENSITIVITY ANALYSIS

S. No.	Factor	Range		
		5%	10%	15%
1	Cost overruns due to delay or other factors	16.43%	15.87%	15.34%
2	Increase in Maintenance Cost	16.98%	16.93%	16.87%
3	Reduction in Ridership	16.66%	16.28%	15.88%
4	Reduction in benefits	16.35%	15.63%	14.88%
5	Combination of reduction in benefits and increase in cost	15.75%	14.51%	13.30%

0.21. IMPLEMENTATION PLAN

0.21.1. Project Implementation Plan

The appointment of DDC and General Consultants may be initiated for project management including preparation of tender documents – as soon as DPR is approved by Government of Karnataka and BMRCL. The possible dates for important milestones are given in **TABLE 0.36.**

TABLE 0.36: PROJECT IMPLEMENTATION SCHEDULE

S.N.	Tasks	Timelines
1	Updated DPR	June'2023
2	Approval of updated DPR by GoK	June'2023
3	Approval by GoI	July'2023 *(S)
4	Appointment of DDC for Civil Works	August'2023 *(S+1 month)
5	Packaging and Invitation of Bids	September'2023 *(S+2 months)
6	Finalization of Bids/Award of Tender	November'2023 *(S+4 months)
7	Commencement of Civil Works	December'2023 *(D = S+5 months)
8	Commencement of Operation	December'2028 *(D+60 months)

**S – Starting Date of Project, D- Commencement of Civil Works*

The construction period from commencement of Civil works will be 4.5 years and 6 months for safety audit and certification. The commercial operation on Phase-3 corridors may start from December 2028.

0.21.2. Implementation Structure

Karnataka has a successful example of metro operation in Bengaluru on SPV model by Bangalore Metro Rail Corporation Limited (BMRCL). Bangalore Metro Rail Phase-1 project is also implemented on SPV model by BMRCL and Phase-2 is also being implemented on SPV model. Similarly, Bangalore Metro Phase-3 project may also be implemented on SPV model. However, some subcomponents of operations & maintenance may be taken up with private sector participation (PPP) model.

The PPP model to be adopted and implementation structure shall be decided at the time of implementation.

0.21.3. Way Forward

On acceptance of the Detailed Project Report by BMRCL, following actions may be initiated for implementing Bangalore Metro Phase-3 project:

- Approval of State Government to the Detailed Project Report
- Issue of notifications for the project and alignment
- DPR to be forwarded to the Ministry of Housing and Urban Affairs, Niti Aayog and Finance Ministry with request for approving the Metro project and for financial participation through equity contribution to the SPV
- Approval from Government of India
- Appointment of Detailed Design Consultants (DDC)
- Packaging and invitation of bids for various contracts
- Land acquisition
- Examination and appraisal of DPR by bilateral/multilateral funding agencies for possible funding
- Stakeholder consultation on environmental and social impact of the project
- Signing of an MOU between Karnataka State Government and Government of India giving all details of the Joint Venture bringing out the financial involvement of each party, liability for the loans raised, the administrative control in the SPV, policy in regard to fare structure etc.
- Agreement between the State and Central Government for financing the debt portion of the project along with the setting up of time frame for completing the Project
- Loan approval
- Providing legal cover for construction as well as O&M stages of the Project.
- Memorandum of Understanding between various service providers to provide seamless integration between various transport modes.

0.22. CYBER SECURITY

Metro Rail faces new security challenges as system has become more interconnected, integrates more and more digital technologies, and increasingly uses data to deliver higher capacity & performance and thus cybersecurity is essential to the safe and reliable operation of modern Metro Rail System. Cyber Security is required to ensure end-to-end information security, not only to prevent and to detect attacks, but also to react rapidly if they occur. Objective of Cyber Security for Metro includes availability, integrity, confidentiality, reliability and safety of information and process of entire Metro Rail Eco-System.

To meet the Cyber Security Threats, a Security Policy and framework is recommended for Bangalore Metro Phase-III to manage the cyber security needs and mitigate the project risks. The Cyber Security System shall be an integral part of the Telecom system.

FIGURE 0.3: SYSTEM ARCHITECTURE