

# **DETAILED PROJECT REPORT**

## **Bangalore Metro Phase – II**

### **GOTTIGERE – IIMB – NAGAVARA CORRIDOR**

#### **Final DPR with BMRCL Comments**

**Client : Bangalore Metro Rail Corporation Ltd.**



**Prepared by Delhi Metro Rail Corporation Ltd.**

**SEPTEMBER 2011**





## **FOREWORD**

Delhi Metro Rail Corporation Ltd. (DMRC), a Joint Venture Company owned 50% by the Government of India and 50% by Delhi Government was entrusted with planning, design, implementation and operation of the Delhi Metro Project. Phase I and II of Delhi Metro Rail Project covering approximate length of 190 Kms has already been commissioned up to February 2011. This length of 190 Kms includes the Airport Link Express of 23 Kms also.

The Government of Karnataka availed the DMRC's expertise for the planning, investigation and preparation of a Detailed Project Report (DPR) for two metro lines in Bangalore City, one in the East West direction and the other in the North South direction for Phase – I of Bangalore Metro Rail and the DPR for the same was prepared and submitted by DMRC in May 2003. Subsequently the DPR for extension of N-S line on both the ends was submitted in the year 2007. The implementation of the phase-I comprising of about 42 kms is in progress by Bangalore Metro Rail Corporation Limited (BMRCL). The BMRCL requested DMRC to take up the DPR work for the Phase – II of Bangalore Metro Rail vide Agreement dt.15-12-2008.

DMRC took up the field studies and Submitted DPR for extension of R V Road Terminal Station of N-S line of Phase-I on southern side to Electronic City in May 2010 as a part of Phase-II but for implementation as Extension of Phase – I work itself. However, the same has recently been revised with the provision of extension upto Bommasandra and submitted to BMRCL in May 2011. The draft DPR for extensions of Phase-I N-S line and E-W line on both sides i.e. four extensions as a part of Phase-II has also been submitted in November 2010 and final DPR in July 2011. The draft DPR for the 2<sup>nd</sup> N-S line of Phase-II was prepared and submitted in May 2011 and the Final DPR is submitted now.

DMRC carried out the topographical survey work by engaging M/s Prime Meridian Surveys, Chennai. The detailed geo-technical studies and

Environmental studies were got done through M/s SECON Pvt. Ltd, Bangalore. The detailed traffic study was got done by M/s Wilbur Smith Associates, Bangalore.

During the preparation of the Detailed Project Report there were constant interaction with BMRCL and various Governmental and City Agencies. We wish to place on record particularly the assistance rendered by BMRCL, who had made available some of the previous studies and relevant information needed for preparing this Report.

We also wish to place on record the valuable assistance received from M/s Prime Meridian Surveys Pvt Ltd, M/s SECON Pvt Ltd and M/s Wilbur Smith Associates in compiling this Report.

This report is a compendium of study results carried out by DMRC with our unique background, experience and with considerable effort. The technical solutions recommended herein are the sole property of DMRC. These cannot be copied or made use of by any other agency or person except for the sole use of Bangalore city, without the consent of DMRC.

New Delhi  
Sep 2011

**(E. Sreedharan)**  
Managing Director  
Delhi Metro Rail Corporation

# BANGALORE METRO PHASE-II (Gottigere –IIMB – Nagavara line)

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**SALIENT FEATURES**

## SALIENT FEATURES

1. Gauge Standard Gauge (1435 mm)

2. Route Length

Phase – II N-S line (Gottigere - IIMB - Nagavara)

	Option1 (Hulimavu)	Option 2 (Kothanur)
With Depot at		
Elevated	06.98 km	08.18 km
Underground	13.79 km	13.79 km
Ramps	<u>00.48km</u>	<u>00.48 km</u>
Total	21.25 km	22.45 km

3. Number of stations 18 stations  
(06 elevated, 12 underground)

4. Traffic Forecast

Year	Peak Hour Sectional loading	Number of passengers (Lakhs/day)	Passenger KM (Lakhs)	Mean trip length
2016	11935	2.62	24.37	9.30
2021	16381	4.03	38.20	9.50
2031	22806	5.58	52.69	9.50
2041	25315	6.19	58.81	9.50

5. Train operation

2 <sup>nd</sup> N-S line Gottigere – IIMB - Nagavara Corridor				
YEAR	2016	2021	2031	2041
Cars/trains	3	3	3/6	3/6
Head way (Minutes)	4	3	3	3
Max. PHPDT Demand	11935	16381	22806	25315
PHPDT Capacity Available	11490	15320	23420	23420
Requirement of Coaches	69	93	141	141

6. a) Design speed 80 kmph  
 b) Average Speed 34 kmph



**7. Traction Power Supply for 2<sup>nd</sup> N-S line (Gottigere – IIMB – Nagavara)**

a)	Traction system voltage	25 KV AC
b)	Current Collection	OHE
c)	Power supply source	66 KV AC
d)	No. of receiving Sub stations	2
e)	No. of traction Sub stations	2
f)	SCADA system	provided

**8. Rolling Stock**

a)	2.88 m wide modern rolling stock with stainless steel body Standard Gauge.	
b)	Axle load	- 16 t
c)	Seating arrangement	- Longitudinal
d)	Capacity of 3 Coach unit	- 766 Passengers (with 6 Pas/Sqm)
e)	Class of accommodation	- One

**9. Maintenance Facilities:**

Maintenance Depot	Hulimavu (Option 1) / Kothanur (Option 2)
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**10. Signalling, Telecommunication & Train Control**

a)	Type of Signalling	Cab signalling and continuous automatic train control with Automatic Train Protection (ATP)
b)	Telecommunication	<ul style="list-style-type: none"> <li>i) Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc.</li> <li>ii) Train information system, Control telephones and Centralised Clock System.</li> </ul>

**11. Fare Collection**

Automatic Fare collection system with POM and Smart card etc.

## 12. Construction Methodology

- a) Elevated viaduct consisting of prestressed concrete “U” shaped Girders on Single pier/Portal with pile/Open foundations.
- b) Underground by tunneling through TBM/NATM, Stations by Cut & Cover.

13. Total estimated cost (at January 2011 prices w/o taxes)   Rs.6537 Crores  
(Option 1)
- Total estimated cost (at January 2011 prices w/o taxes)   Rs.7077 Crores  
(Option 2)
- Total estimated cost (at January 2011 prices with taxes)   Rs.7634 Crores  
(Option 1)
- Total estimated cost (at January 2011 prices with taxes)   Rs.8188 Crores  
(Option 2)

## 14. Financial Indices of MRTS Phase-I Network with this corridor

- a)    FIRR                                   0.40% (with PD from 20 Ha) {Option 1}
- FIRR                                   (-)0.20% (with PD from 20 Ha) {Option 2}
- b)    EIRR                                   13.2%

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## **EXECUTIVE SUMMARY**



## EXECUTIVE SUMMARY

### 0.1 BACKGROUND

The DPR for the Phase-I of Bangalore Metro Rail Project was prepared by DMRC and submitted to BMRCL (erstwhile BMRTL) during May 2003 and DPR for extension of N-S line of Phase-I from Yeshwanthpur to Hesaraghatta Cross & R V Road Terminal to Puttenahalli Cross was submitted during October 2007 & June 2008 respectively. The project has been sanctioned and is under implementation. The Phase I Now comprises of two corridors.

- (i) East-West Corridor from Baiyappanahalli Terminal to Mysore Road Terminal – 18.10 km.
- (ii) North-South Corridor from Hesaraghatta Cross Station to Puttenahalli Cross – 24.20 km.

Out of a total of 42.30 km system about 8.80 km is underground section and balance about 33.50 km is elevated. Total 40 stations are planned out of which 7 stations underground, 2 at grade and 31 are elevated. On East West corridor a maintenance depot with full workshop facilities is being constructed at Baiyapanhalli and for North – South Corridor a maintenance depot with full workshop facilities is being constructed at Peenya.

The Metro system is being implemented with 750 V DC Third Rail Traction System, Cab signaling with CATC, SCADA, and AFC.

Provision for extension of corridors in all four directions had been kept.

The BMRCL requested DMRC to take up the DPR work for Ph-II Metro Rail Project as follows.

#### 1. North –South Alignment:

- a) Electronic City to Jayanagar: via Begur, Jigani, Bannerghatta Road via IIMB, via Jayadeva flyover, 45<sup>th</sup> Cross Jayanagar, R V Road Terminal.
- b) Bannerghatta to Yelahanka: Jayadeva underpass on Bannerghatta Road, Hosur road, Brigade road, M G road junction;

a) Kamaraj road, Tannery road, Nagavara Junction (along Outer Ring Road), Sahakara Nagar, Vidyaranyapura to Yelahanka

OR

b) Jayamahal Extension, R T Nagar, Nagavara Junction (along Outer Ring Road), Sahakara Nagar to Yelahanka.

The Metro Alignment may have to go underground after Jayadeva flyover (along Bannerghatta road) up to Nagavara junction (along Outer Ring Road). The remaining portion may have to be elevated. However, final decision may be taken by the consultants after the survey.

1 – A. North – South Alignment would be extended from Puttenahalli Cross to NICE Road on Kanakapura Road which would also be elevated.

**2 East – West Alignment:**

Kathriguppe, Chamarajpet, City Market, Richmond Circle and after that;

a) Richmond road, Airport Road, ITPL, Whitefield

OR

b) From Baiyyappanahalli to Whitefield via K R Puram.

The decision whether the Metro Alignment will be elevated or underground may be taken by the consultants after the survey.

2 – A. East – West Metro Alignment would be extended from Mysore road Terminal to Kengeri which would also be elevated.

The required surveys including Reconnaissance/Topographical survey, Traffic & Transportation Studies, Geo-tech investigations, Environment Studies etc were carried out along the above proposed routes. During the meeting between BMRCL and DMRC on 28-08-2009 after going through the Traffic Survey figures as also all the connected details/surveys and elaborate interaction and discussions on various alternatives, the BMRCL decided on the Phase-II Metro Rail for which the DPR is to be framed and submitted.

Sl. No.	Items	Length in 'Kms'
1	R V Road Terminal to Electronic City via Silk Board junction (with proposal for further extension to Bommasandra Industrial Area)	14.50 (03.60)



2	Baiyyappanahalli to Whitefield	15.50
3	South – North line from IIMB/Meenakshi Temple on Bannerghatta Road to Nagavara via Jayadeva Hospital, Dairy Circle, Vellara Junction, St. Marks Road, Shivaji Nagar, Tannery road.	19.80
4	Extension of Phase-I North – South line from Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC) on Tumkur road	04.00
5	Extension of Metro Phase-I East-West Alignment from Mysore road Terminal to Kengeri on Mysore Road	06.10
6	Extension of North – South Alignment of Phase-I from Puttenahalli Cross to NICE Road Crossing on Kanakapura Road	06.00
7	Phase – II West-East line from Kathriguppe to Baiyyappanahalli via Kathriguppe 80' road, Bull Temple road, Kalasipalyam (City Market Metro Station of Phase-I), Corporation Office, Vellara junction (Interchange of Phase-II E-W and N-S line), Old Airport, Suranjandas road.	22.00
<b>TOTAL</b>		<b>87.90 (91.50)</b>

The High Power Committee (HPC) approved the R V Road – Electronic City – Bommasandra Industrial Area Metro Rail line in the meeting held on 6<sup>th</sup> May 2010. The Final DPR for this line (R V Road-Electronic City-Bommasandra line) was submitted on 14<sup>th</sup> May 2011.

The HPC also cleared the proposal for DPRs in respect of following lines on 25<sup>th</sup> March 2010.

Sl. No.	Alignment	Length of the line in 'Kms'
1	Extension of E-W line – Mysore road Terminal to Kengeri	06.10
2	Extension of E-W line – Baiyyappanahalli to ITPL - Whitefield	15.50
3	Extension of N-S line – Hesaraghatta Cross to	04.00

	Bangalore International Exhibition Centre (BIEC).	
4	Extension of N-S line – Puttenahalli Cross to Anjanapura Township (Up to NICE Road)	06.00
5	New line – N-S – Indian Institute of Management, Bangalore (Meenakshi Temple on Bannerghatta road) to Nagavara	19.80

Final DPR for above four extensions was submitted on 26<sup>th</sup> July 2011.

Now in this DPR for Phase-II N-S line (a 2<sup>nd</sup> N-S line), the corridor proposed is from Gottigere on Bannerghatta Road on the south to Nagavara on the north. Starting from Gottigere this 2<sup>nd</sup> N-S line passes through Hulimavu, IIMB (Indian Institute of Management), J P Nagar-IV Phase, Jayadeva Hospital, Swagath Road Cross, Dairy Circle, MICO Industries on Bannerghatta road, Langford Town, Vellara on Hosur Road, Brigade road, Kamaraj road, Shivaji Nagar Bus stand area, Bangalore Cantonment Railway Station, Millers road, Benson Town, Pottery Town, Tannery road on to Nagavara after crossing the Outer Ring Road.

The stretch between Gottigere to short of Dairy Circle is elevated and beyond from short of Dairy Circle to Nagavara is underground.

## 0.2 TRAFFIC FORECAST

The detailed traffic study was got done by M/s WilburSmith Associates, Bengaluru and the study report is in separate Volume. Based on the detailed household surveys and traffic surveys carried out during DPR study in 2002 - 2003 and Subsequent DPR's for extension of N-S line in October & December 2007 and the latest survey done now as a part of this study, the Transport Demand Model was developed. The N-S Phase-II have been developed from the primary database and used in the transport Demand Model. The traffic demand on this new corridor between IIM (B) and Nagavara has been projected considering that the proposed R V Road – Electronic City – Bommasandra corridor and the four extensions of Ph-I are in place.

### 0.2.1 TRAFFIC DEMAND

The entire study area has been delineated into 182 zones as shown in the Traffic Chapter. Among them 172 are the internal zones and the remaining zones (10 zones) are external zones.

Summary of population projection and employment projections is presented in the **Table 0.1**.

**Table 0.1 Population and Employment projection**

	Base year (2009)	2011	2021	2031
Population(in lakhs)	73.99	80.15	99.67	123.11
Employment(in lakhs)	26.63	29.25	37.87	48.01

These figures are based on the Census (2001) and projected for future.

### Trip Information

The trip information obtained from the survey has been analyzed with respect to distribution of total trips by mode. The daily trips by various modes are presented in **Table 0.2**.

**Table 0.2 Distribution of Motorized Trips**

Sl. No	Mode	Internal Trips	External Trips	Total Trips
1	Two-wheeler	1829858	84083	1913941
2	Car	826909	90360	917269
3	Auto rickshaw	927371	14760	942131
4	Public Transit	3519338	672120	4191458
	Total	7103475	861323	7964798

### Travel Demand Forecast

Four-stage transport demand forecasting method was used to carryout the transport demand forecasts. Land-use parameters used for the purpose are:

- Base year population 2001 and employment and their distribution have been taken from the 2001 census.
- Future population and employment for the horizon years 2016, 2021, 2026 and 2031 have been worked out in consultation with BDA at city level.
- Distribution of future population and employment at zonal level are based on land use plan in consultation with BDA.

### Trip End Models

Taking into consideration the past trends and possibility of accelerated growth rate when the mobility level in the city will increase due to introduction of MRTS, the Per Capita Trip Rate (PCTR) for the horizon years have been assessed as follows:

**Table 0.3 Adopted PCTR (Vehicular) Value**

Year	PCTR Value
Base year	0.96
2011 (Forecast)	0.99
2021 (Forecast)	1.09
2031 (Forecast)	1.21

The above-mentioned PCTRs have been used for development of trip generation and projection.

### Trip Assignment

Capacity restrained assignment technique was used for traffic assignment on the transport network. Distribution of the public transport trips between bus and rail has been determined at the assignment stage by considering a combined public transport network and assigning time penalties for various interchanges with other modes.

Traffic assignment was carried out on the East - West and North - South Metro corridors including proposed four extensions, proposed R. V. Road - Electronic City-Bommasandra corridor and proposed Phase-II 2<sup>nd</sup> North - South Corridor between Gottigere - IIM (B) - Nagavara corridor with total transport network of the city. Based on the final assignment of traffic on the total network, loading on the proposed Phase-II N-S line are as follows:

**Table 0.4 Summary of transport demand projections**

Year	Corridor	Length In km	Peak Hour Sectional loading	Number of passengers (Lakhs/day)	Passenger KM (Lakhs)	Mean trip length
2016	Phase-II N-S line (Gottigere - IIMB - Nagavara)	21.255	11154	2.43	22.08	9.10
2021	Phase-II N-S line (Gottigere - IIMB - Nagavara)	21.255	14965	3.71	34.50	9.30
2031	Phase-II N-S line (Gottigere - IIMB - Nagavara)	21.255	21337	5.13	47.71	9.30
2041	Phase-II N-S line (Gottigere - IIMB - Nagavara)	21.255	23569	5.67	52.75	9.30

The phpdt (peak hour peak direction trips) on this Phase-II N-S line by 2016 will be 11154 and will increase to 23569 by 2041.

### **0.3 PLANNING AND DESIGN PARAMETERS**

DMRC has already implemented Phase I & II of Delhi Metro project and now implementing Phase-III. Various design norms and parameters have been firmed up by DMRC after detailed studies of norms followed by Metro systems in various countries. However a similar system is proposed for adoption for Bangalore city. Certain modifications to the design norms have been recommended keeping in view the specific needs of Bangalore city and with an idea of standardization of parameters for other metropolitan and major cities in the country.

For the elevated section of Bangalore Metro a box shaped deck as adopted for Delhi Metro has been recommended with overall top width of 9.84 m (track center 3.7 on straight alignment) and 10.04 m (track center 4.0 on 120 m radius) to carry both the tracks in the portion where the viaduct is proposed on the single pillar. The section has a walkway at the floor level of the coach for emergency evacuation of passengers. 16 t axle load has been proposed for this corridor.

Bangalore Metro system will have modern, lightweight rolling stock made of stainless steel. Trains are proposed to be air-conditioned, consisting of 3 coaches initially and 6 coaches in future. Maximum acceleration ( $1.0 \text{ m/sec}^2$ ) and maximum deceleration ( $1.1 \text{ m/sec}^2$ ) parameters are similar to that of Delhi Metro system.

The system is proposed to have Standard Gauge (1435 mm) tracks as this will facilitate provision of sharp curves with radii up to 120 m. Other geometrical parameters are similar to that of Bangalore Metro Phase-I.

The Phase-I which is under implementation, Proposed R V Road – Electronic City/Bommasandra line and the proposed four extensions to the Phase-I are with 750 V dc, third rail traction system. However, this 2<sup>nd</sup> N-S line is being proposed with 25 KV traction systems which is more efficient and also economical if compared with 750 v. dc. third rail traction. The other systems like Signaling with Automatic Train Control and Protection system, Automatic Fare Collection system and tunnel ventilation, etc. are more or less similar to that of Phase-I of Bangalore Metro which is in progress.



### 0.3.1 ROUTE ALIGNMENT

Starting from Gottigere between Jigini area and IIMB as an Elevated Metro Rail, the 2<sup>nd</sup> N-S line passes through Hulimavu Station and traverses on the median of Bannerghatta road in front of IIMB where IIMB Metro Station is located. This serves the vast area around which has been developed and is further developing with a number of world class Hospitals and Institutions with High rise apartments. From IIMB the line traverses mostly on Bannerghatta road median enveloping the J P Nagar, BTM Layouts and a large number of IT/BT centers and Trade Centres. Continuing as Elevated Metro Rail the alignment has to cross the road flyover on Marenahalli (South End) Road at higher level in the vicinity of Jayadeva Hospital where Jayadeva Hospital Metro Station is located. Here the alignment crosses the proposed R V Road – Electronic City-Bommasandra Metro Line at a higher level and continues on the median of Bannerghatta road on to Swagath Road Cross Metro Rail Station and further proceeds towards Dairy Circle flyover. Short of this flyover the alignment is taken to the underground on a ramp from the Fire Brigade area on the left side of Bannerghatta road. The Dairy Circle flyover is crossed in the underground suitably and then the Metro alignment continues further on, as underground line only in the entire stretch up to the end at Nagavara. Dairy Circle Station is located opposite to the Bangalore Dairy as an underground Station after crossing the Dairy Circle flyover. The underground alignment continues grazing the side of MICO Industries and crossing the big drain and on a curve taken on to the right turn followed by left turn and grazing the grave yard and reaches to the under side of Hosur road between the Military area and built up area of Missionaries and Schools/Colleges. From here the alignment traverses almost below the Hosur road crossing Richmond road at Vellara. After this the alignment traverses below Brigade road, the Commercial hub and crosses the M G Road underneath the Phase-I East-West Metro Rail line where a 50 M span is available on the Phase-I E-W line to reach Kamaraj road. Here the underground M.G. Road Integrated Station is planned which is about 50M from the Platform edge of existing Elevated M G Road Station of BM Phase-I and is connected through Escalators & Stairs. The proposed City Airport Terminal (CAT) of HSRL at Police Grounds which is about 650M from this proposed Station at M.G. Road station can be connected through round the clock shuttle Bus service. After M.G. Road station, the underground alignment crosses Cubbon road and takes a smooth oblique left turn & traverses below barracks & buildings of Defence land and by the side of Infantry road and turns right to reach the Shivaji Nagar Bus-stand area. Here the Shivaji Nagar Metro Station is planned in the open ground (Shivaji Nagar Stadium) behind the existing Shivaji Nagar Bus-stand and is integrated with it. Further the alignment traverses below the built up areas by the side of Queens Road and cuts across the Queens Road and then turns right to reach the front side car parking area of Bangalore Cantonment Railway Station. Here the Cantonment Railway Metro Station is

planned. This station is integrated with the Bangalore Cantonment Railway Station. From here the alignment crosses below the Cantonment Railway Station area on to the Millers road, Nandi Durg road and traverses below Benson Town area and reach Pottery Town open ground area. Here the Pottery Town underground Station is planned (This station will be connected to the Netaji road through suitable under pass below the SWR line to provide access to the surrounding Frazer town areas). From here the underground alignment turns left to reach below the Tannery road and continues almost below the Tannery road and crosses the Salem Railway line and then Outer Ring Road (ORR) to reach the last Station of this line namely Nagavara, which is located immediately after the crossing of the ORR. The route length is 21.255 km (up to dead end) and there are 18 (06 Elevated + 12 Underground) Stations in this 2<sup>nd</sup> N-S line of Phase-II. Provision has been kept to extend the line later beyond Nagavara as Elevated line to which ever side it is required as the city is growing in these parts.

#### **0.4 CIVIL ENGINEERING WORKS**

The alignment of this line from Gottigere to short of Dairy Circle on Bannerghatta road is elevated, where as the underground is from short of Dairy Circle on Bannerghatta road to the end, i.e. Nagavara is underground. As the work on the Phase-I of the project viz., all the elevated stretches and the E-W underground line have been already started, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc are finalized and it is proposed to continue with the same for this Gottigere - IIMB - Nagavara line, except for the traction system which is proposed as 25 KV OHE system instead of third rail.

18 stations (06 Elevated & 12 U/G) are planned this Phase – II 2<sup>nd</sup> N-S line. Index Plan Showing the alignment is given in **Fig 0.1**.

#### **Geo Technical Investigation**

Geo- technical Investigation has been carried out along the Phase-II N-S line at 67 locations up to a depth of 30 m in soil or up to a depth of minimum 3 m in Hard rock strata.

Generally the top layer of soil is reddish/yellowish/grayish/brownish silty sand with clay. The layer is medium dense. Below this, are a layer of soft rock and a layer of hard rock.

For the elevated section on soft rock and pile foundation up to 1.2 m dia are recommended. The bearing capacity of soil is not likely to cause any problem for the foundations. The complete geo-technical Investigation report containing

bore log details, test results and bearing capacity recommendations has been submitted separately.

Utilities : - The elevated Corridor of Phase-II N-S alignment is passing along the centre/side of the road and the stations of underground corridors are mostly on the roads.

The utility services viz. telephone cables, electric poles, traffic signals etc are existing along the proposed alignments. Details of the existing utility services along the proposed alignments have been collected from the concerned authorities, i.e. BWSSB, BBMP, BSNL, Bangalore Electric Supply and Distribution authorities, Reliance and Tata Telecom, etc. The affected portions of the services with reference to the proposed alignments have been identified.

The following major utility of 220/66/11 KV KV OHE lines are required to be shifted. These utilities may either be taken underground or their height may be increased so as to provide the required clearance to the elevated Metro system.

**Phase-II N-S (Gottigere - IIMB – Nagavara) line**

Sl. No	Chainage	Voltage	Remarks
1	5760	H T line (66 KV)	Near Minichinnappa Kalyana Mantapa
2	19182	H T line (25 KV)	Railway level Crossing
3	22000	H T line (66 KV)	Maruthi Saw Mill, Thanisandra Road

**Land Requirement**

Since land is a scarce commodity especially in metropolitan areas, every effort has been made to keep land requirement to the barest minimum and acquisition of private property has been kept minimal. Land is mainly required for route alignment, station buildings, platforms, entry/exit structures, traffic integration, power sub-stations, temporary construction depots / work sites and sick line facilities etc.

The total land requirement for Phase-II N-S line works out to:

**Option 1 (With Hulimavu Depot)** = 48.26 ha, out of which 33.10ha is Pvt land and 15.16ha is Govt land.

**Option 2 (With Kothanur Depot)** = 50.26 ha, out of which 49.46ha is Pvt land and 0.80ha is Govt land.

The land cost for the Phase-II N-S alignment & stations:

**Option 1 (With Hulimavu Depot)** = Rs. 264.16 Crores

**Option 2 (With Kothanur Depot) = Rs. 695.07 Crores**

#### Rehabilitation & Resettlement

Sl. No.	Commercial Property	Residential Property	Religious Property	Others	Total
1	196	83	18	121	418

The project involves displacement of about 418 properties out of which 196 are commercial, 83 residential, 18 religious and 121 others.

The displaced persons are to be relocated in nearby areas, in the manner as done for phase-I.

#### Environmental Impact Assessment/Environmental Management Plan

The EIA/EMP Studies were entrusted to M/s SECON Pvt Ltd, Bangalore and the detailed Environmental Impact Assessment and Management Plan Report is enclosed as a separate volume. However, the numbers of trees affected due to Gottigere - IIMB - Nagavara line are enumerated. Total 204 nos. of trees are to be cut and 44 trees are to be trimmed. Ten times the number of trees affected are going to be planted and nourished.

#### 0.5 STATION PLANNING AND TRAFFIC INTEGRATION

The basic planning for stations, as proposed in the DPR of East - West and North - South Corridors of Phase-I, May 2003 and for four extensions of Phase-I lines has been used to plan all the 18 stations of this Phase-II 2<sup>nd</sup> N-S line. Out of the total 18 stations, 6 stations are elevated and the balance 12 stations are underground. The proposed stations along the Phase-II 2<sup>nd</sup> N-S line are as follows:

**Table 0.5 – Stations**

S.N	Name of Stations	Chainage	Inter - Station Distance	Type of Station	Rail Lvl (m)
		(in m)	(in m)	(Elevated/U/G)	
	Dead End	0	-		
1	Gottigere	411	411	Elevated	933.9
2	Hulimavu	1484.5	1073.5	Elevated	915.5
3	IIMB	3204	1719.5	Elevated	907.7
4	J P Nagar-IV Phase	4575	1371	Elevated	914.1
5	Jayadeva Hospital (Integration with R. V. Road - Bommasandra Line )	5414	839	Elevated	918.4
6	Swagath Road Cross	6777	1363	Elevated	905.8
7	Dairy Circle	7929	1152	Underground	878.4

8	MICO Industries	8961	1032	Underground	871.8
9	Langford Town	9880.4	919.4	Underground	883.5
10	Vellara	10884	1003.6	Underground	893.0
11	M. G. Road (Integration with Kengeri – Whitefield (East –West) Line	12020	1136	Underground	896.4
12	Shivaji Nagar	13241	1221	Underground	891.8
13	Cantonment Railway Station	14405	1164	Underground	894.2
14	Pottery Town	16023	1618	Underground	887.9
15	Tannery Road	17182	1159	Underground	901.8
16	Venkateshpura	18168	986	Underground	894.2
17	Arabic College	19592	1424	Underground	871.9
18	Nagavara	20995	1403	Underground	867.3
	Dead End	21255	260		

The stations have been divided into two distinct areas, namely public and non-public (technical) areas. The public area is further sub divided into unpaid and paid areas. Provision for escalators is made at all the stations in paid area from concourse to Platform and in unpaid area from Ground to concourse. Lifts for disabled passengers are provided at all stations.

Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate parking areas for various modes likely to come to important stations including feeder buses/mini buses.

Traffic integration facilities are proposed to be provided at Gottigere, Jayadeva, Bangalore Cantonment and Nagavara Stations.

## 0.6 TRAIN OPERATION PLAN AND MAINTENANCE DEPOT

### Operation Philosophy

The underlying operation philosophy is to make the Bangalore Metro 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.
- A short train consists of 3 coaches with high frequency service which can be increased to 6 Coaches to meet future requirements.



- Multi-tasking of train operation and maintenance staff.

**For Rolling Stock, following two options are proposed:**

**(a) Option – 1 (Recommended)**

In this option, 25 KV AC traction has been proposed resulting in increase in the weight of the car and thus the axle load (axle load increased to 16T as against 15T axle load of existing Bangalore Metro Stock). All other parameters including passenger capacity remain the same as in existing Bangalore Metro Stock.

**(b) Option -2**

Existing Bangalore Metro Rolling Stock with 750V DC traction has been proposed. The Rolling Stock parameters have been updated based on BMRCL's advice received as a part of their comments on Phase-II DPR.

The Train Operation Plan is common for both the above two options as the passenger capacity and performance parameters are the same.

In view of above, based on the projected PHPDT demand, train operation has been planned for Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) for the year 2016, 2021, 2031 and 2041 as detailed below

All infrastructure and maintenance facilities should be planned for 6-car trains.

The PHPDT capacity provided on the three sections in different years of operation is tabulated below:

**Table 0.6 Capacity Provided for Gottigere – IIMB- Nagavara Corridor**

LINE	YEAR			
	2016	2021	2031	2041
Gottigere – IIMB- Nagavara				
<b>Cars/trains</b>	3	3	Alternate 3car /6-car train	Alternate 3car /6- car train
<b>Head way (Minutes)</b>	4	3	3	3
<b>Max. PHPDT Demand</b>	11935	16381	22806	25315
<b>PHPDT Capacity Available @ 6 persons per sqm of standee area</b>	11490 (14625*)	15320 (19500*)	23420 (29790*)	23420 (29790*)

\* @ 8 persons per square meter of standee area

**Train frequency**

The train operation of Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) provides for the following train frequency:

**Table o.7 Train frequency**

Name of Corridor	2016		2021		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	Peak Hour h/w	Lean Hour h/w
<b>Gottigere – IIMB- Nagavara Corridor</b>	4 min	6 to 15 min	3 min	5 to 15 min	3 min	5 to 15 min	3min	5 to 15 min

\*No services are proposed between 00.00 hrs to 5.00 hrs, which

**0.7 ROLLING STOCK**

Rolling stock for 2<sup>nd</sup> Phase-II N-S line of Bangalore 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.

As these run along with the Phase-I lines and in their extensions the Rolling Stock should merge with look and colour of Phase-I coaches already ordered.

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.

Keeping the above features in mind, 2.88 m wide stainless steel light weight coaches are proposed for the Phase-II N-S line of Bangalore 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 3 coach train is 64.1 m while that of 6 –

coach train is 128 m. The Axle load is 16T instead of 15 T that is taken for Phase-I lines for which the structures are to be designed.

## 0.8 POWER SUPPLY, SYSTEM OF TRACTION AND POWER TARIFF

### 0.8.1 Power Supply System

Electricity is the only source of energy for operation of Metro system – for running trains, for station services, workshops, depots & other maintenance infrastructure. Broad estimation of auxiliary and traction power demand has been made based on the following requirements:-

- ◆ Specific energy consumption of rolling stock – 70KWh/1000 GTKM
- ◆ Regeneration by rolling stock – 20%
- ◆ Elevated/at –grade station load – initially 250KW and finally 300 KW in the year 2021
- ◆ Depot auxiliary load – initially 2000KW and finally 2500 KW in the year 2021
- ◆ System of Traction: 25 KV a.c. traction system is proposed for this n Phase-II 2<sup>nd</sup> N-S line.

Keeping in view of the train operation plan and demand of auxiliary and traction power, power requirements projected for the year 2016, 2021 , 2031 and 2041 are summarized in table 8.1 below:-

**Table 8.8 Power Demand Estimation (MVA)**

Corridor		Year			
		2016	2021	2031	2041
Corridor – 2 Gottigere – IIMB -Nagavara [21.25 kms & 18 Stns. (12 U/G)].	Traction	9.0	11.2	19.1	20.2
	Auxiliary	34.2	34.2	39.3	45.1
	Total	43.2	45.4	58.4	65.3

### 0.8.2 Sources of Power Supply

The high voltage power supply network of Bengaluru has 220kV and 66kV network to cater to various types of demand in vicinity of the proposed corridor. 220 KV sub-stations are generally located at outskirts of the city. 66 kV sub stations are located to the alignment of Corridors. Keeping in view the reliability requirements, two input sources of 66 kV Voltage level are normally considered for each corridor. Therefore, to achieve the desired reliability, two Receiving Sub Stations (66 / 33 / 25 kV) are proposed to be set up for Corridor – 2. Based on the discussions with Director/KPTCL, it is

proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations at 66kV voltage through cable feeders.

**Table 0.9 Sources of Power Supply**

Corridor	Grid sub-station (with Input voltage)	Location of RSS of Metro Authority	Approx. length of cables
Gottigere – IIMB – Nagavara.	Nimhans GSS (220 / 66 KV) or Two number 66 KV bays from Audugodi Sub- station	Hulimavu / Kothanur Depot or depending upon simulation study and availability of land (66 / 33/25 KV)	7 km, 66 KV * (Double Circuit Cables).
	East Division GIS GSS (220/66 KV)	Pottery Town (66 / 33/25 KV)	3 km, 66 KV (Double Circuit Cables).

### 0.8.3 Tunnel Ventilation Systems (TVS)

The TVS is provided in a Subway system essentially to carry out the following functions:

- Provide a tenable environment along the path of egress from a fire incident in enclosed stations and enclosed train ways.
- Produce airflow rates sufficient to prevent back layering of smoke in the path of egress within enclosed trainways.
- Be capable of reaching full operational mode within 180 seconds.
- Accommodate the maximum number of trains that could be between ventilation shafts during an emergency.

### 0.8.4 Space Requirement for Tunnel Ventilation System

The tunnel ventilation equipment plant rooms are normally located at each end of the concourse for the two level stations. The approximate area for tunnel ventilation fan room would be 600 sq. m. respectively at each end of the station. The tunnel vent shafts of approximately 20 sq. m. area will be constructed at each end of the stations. There shall be supply shaft and exhaust shafts of similar dimensions at the stations.

The inter – station separation between Cantonment Railway Station underground station and Pottery Town underground station is beyond 1.5 km as per the final alignment plan hence mid section ventilation shafts is required for which additional fund provisions to the tune of Rs. 5.0 Crores

for Electrical and Mechanical works (Ventilation, E&M, BMS, ASS, etc) and Rs.20.0 crores for civil works can be met out of contingency.

## **0.9 SIGNALLING & TRAIN CONTROL**

Train Control and Signalling System has been designed to meet design headway of 150 sec. and shall comprise Continuous Automatic Train Control system with CAB-Signalling. Line side signals will be provided at all stations with points and crossings, which shall be used for the purpose of back up Signalling. The system shall be 'Distance-to-Target' based on fixed block type using coded Audio Frequency Track Circuits. All the stations with points and crossings shall be provided with independent SSI with facility to operate these points and crossings locally as well as being Centrally Controlled from the OCC. The CAB-borne and wayside Computerized equipment shall be designed with sufficient redundancy so as to meet the desired reliability and availability requirements. The mimic panel for these extensions shall be housed in the OCC at Majestic. The Depot shall be provided with an independent SSI.

## **0.10 TELECOMUNICATION AND FARE COLLECTION SYSTEM**

Telecommunication System shall comprise various sub-systems namely Fiber Optic transmission system (FOTS), Telephone, Radio, Public address, Close Circuit TV and Public Information display system etc. The FOTS shall have armoured optical fiber cable with path diversity. The equipment proposed shall be of synchronous digital hierarchy (SDH) in 1+1 configuration with add/drop multiplexer at enroute stations to provide reliable backbone link. It is proposed to provide ISDN – EPABX system to be integrated with other telephone systems with access to PSTN and interface to radio system. The proposed radio system shall support both train radio and hand held portable sets for communication with central control. Microprocessor-based Network Management System covering radio / optical fiber based communication and telephone exchange system shall be provided.

For trouble free and efficient ticketing and passenger control, Computerized Automatic Fare Collection (AFC) System has been proposed. The base AFC system shall make use of "Contactless Smart Card Tickets" for multiple journeys and contact less smart token for single journey, working with multiple operators. The AFC system shall have equipment located at OCC and stations.

The ticket gates are proposed to have a handling capacity of 45 passengers per minute and can be reversible type.

Initially booking office operated machines (BOMs) are proposed but provision for Passenger operated machines (POMs) has been kept at stations.

## **0.11 TRAIN MAINTENANCE DEPOT**

### **Maintenance Depot**

**Option 1:** A Car maintenance depot at Hulimavu is proposed to cater for the rolling stocks of this Phase-II 2<sup>nd</sup> N-S line.

**OR**

**Option 2:** A Car maintenance depot at Kothanur is proposed to cater for the rolling stocks of this Phase-II 2<sup>nd</sup> N-S line.

In the Draft DPR submitted, the proposed depot was in the Hulimavu area. BMRCL vide letter dt.02-09-11 & 20-09-11 had insisted to change the depot area stating that the Hulimavu area is on tank bed. However, no suitable Govt land could be identified for locating this depot and a private land could only be located for this purpose which will be costlier by more than Rs.550 Crores as compared to Option 1. It is seen that the Govt Order regarding Hulimavu tank bed i.e. No.PWD 82 IMB 85 dt 11-02-1988 recommended for "Foreshore Planting, water sheet to be retained" by forest department. However, in spite of this order, nothing has happened since 1988. As of now there are sizable unauthorized encroachments in this tank bed area and is dirty and has become a breeding space for mosquitoes and hence health hazard. If this area is developed as a depot, the whole area will get a face lift with proper landscaping and open area in this locality. In addition the extra cost of more than Rs.550 Crores for acquisition of Pvt lands will be saved. Therefore it is recommended that the depot of Hulimavu area is confirmed after getting proper Governments clearance.

**Note by BMRCL:**

**It is decided to go for option-II, as it is not possible to acquire tank bed land in Hulimavu**

## **0.12 COST ESTIMATES**

The Cost Estimates for the Ph-II 2<sup>nd</sup> N-S line have been prepared at January 2011 prices and works out to as follows:

**Option 1 (With Depot at Hulimavu):** Rs.6537 Crores including land, but excluding taxes & duties. The total cost including taxes works out to Rs.7634 Crores. The same is summarized as below.

OR

**Option 2 (With Depot at Kothanur):** Rs.7077 Crores including land, but excluding taxes & duties. The total cost including taxes works out to Rs.8188 Crores. The same is summarized as below.

**Note by BMRCL :**

**The cost estimate as per due diligence study would be Rs.7526.00 crores and the total cost including taxes and duties comes to Rs.8730.00 crores**

**Option 1 (With Depot at Hulimavu):**

**Abstract Cost Estimate of Ph-II N-S line Gottigere - IIMB - Nagavara**

**Total length = 21.255 km,**

**Under Ground Length= 13.79 km**

**Elevated length= 06.98 km**

**Ramp length= 0.48 km**

**Total Station = 18nos ( UG = 12 , Elv = 06 )**

**(Cost Without Taxes & Duties)**

S. No.	Item	Unit	Rate as per Price level Jan 2011 ( . In Crores)	Qty.	Amount (Rs in Cr.)
<b>1.0</b>	<b>Land</b>				
1.1	Private land	Hect.	16.13	4.100	66.13
1.2	Govt.Land	Hect.	5.00	15.16	75.80
1.4	Temporary land for casting yard, working spaces etc.	Hect.	3.87	29.000	112.23
1.6	Cost of land for rehabilitation ( to be identified)	LS			10.00
	<b>Sub Total (1)</b>				<b>264.16</b>
<b>2.0</b>	<b>Alignment and Formation</b>				
2.1	Underground section by Cut & Cover excluding Station length	R. km.	101.16	0.000	0.00
2.1	Tunneling by TBM	R. km.	144.31	10.910	1574.42
2.2	Ramp (Underground)	R. km.	0.24	44.670	10.72
2.3	Elevated viaduct section	R. km.	29.87	6.980	208.49

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2.4.1	Special Spans	R. km.	41.90	0.500	20.95
2.5	Ramp (Elevated)	R. km.	18.33	0.240	4.40
2.6	Civil work for Mid Section Ventilation Shaft	each	2.00	1.000	2.00
	<b>Sub Total (2)</b>				<b>1820.98</b>
<b>3</b>	<b>Station Buildings</b>				
3.1	Underground Station	Each	120.75	12.000	1449.00
3.2	Elevated stations (including finishes)				
a	Type (A) way side	Each	20.59	4.000	82.36
b	Type (B) Way side with signaling	Each	22.02	1.000	22.02
c	Type (C), Terminal station	Each	23.44	1.000	23.44
3.3	Interchange facilities at interchange stations	Each	5.25	2.000	10.50
	<b>Sub total (3)</b>				<b>1587.32</b>
<b>4</b>	<b>E&amp;M Works</b>				
4.1	Underground station (E&M ,Lifts ,Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	12.000	618.36
4.2	Elevated station (E&M ,Lifts ,Escalators, DG sets etc.)	Each	6.53	6.000	39.18
4.3	Mid Section Ventilation Shaft	Each	5.00	1.000	5.00
	<b>Sub total (4)</b>				<b>662.54</b>
<b>5.0</b>	<b>Depot</b>				
5.1	Depot at Hulimavu (i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			175.00
5.2	Stabling and inspection facilities at Nagavara side ( i/c Civil works, E &M, P&M, Track work, OHE etc.)	LS			40.00
	<b>Sub total (5)</b>				<b>215.00</b>
<b>6.0</b>	<b>Permanent Way</b>				
6.1	Ballastless track for elevated , underground and at grade alignment	R. km.	6.48	21.255	137.73
6.2	Ballasted track for sidings etc in depots	R. km.	2.08	3.000	6.24
	<b>Sub total (6)</b>				<b>143.97</b>
<b>7</b>	<b>Traction &amp; power</b>				



<b>7.1</b>	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>				
7.1.1	Under Ground Section	R. km.	12.74	13.790	175.68
7.1.2	Elevated & at grade section	R. km.	8.56	6.980	59.75
	<b>Sub total (7)</b>				<b>235.43</b>
<b>8.0</b>	<b>Signalling and Telecom.</b>				
8.1	Signalling	R. km.	9.73	21.255	206.81
8.2	Telecom	Each Stn.	4.36	18.000	78.48
8.3	Automatic fare collection				
8.3.1	Underground stations	Each	2.96	12.000	35.52
8.3.2	Elevated stations	Each	2.96	6.000	17.76
	<b>Sub Total (8)</b>				<b>338.57</b>
<b>9.0</b>	<b>R &amp; R incl. Hutments and road restoration etc.</b>	LS			50.00
	<b>Sub Total (9)</b>				<b>50.00</b>
<b>10.1</b>	<b>Misc. Utilities, other civil works such as median, road signages etc.</b>	R. km.	3.15	21.255	66.95
10.2	Electrical Utilities	LS			60.00
10.3	Telecom Utilities	LS			14.00
	<b>Sub Total (10)</b>				<b>140.95</b>
<b>11</b>	<b>Rolling Stock (SG)</b>	Each	8.40	69.000	579.60
	<b>Sub Total (11)</b>				<b>579.60</b>
<b>12.1</b>	<b>Barracks for CISF including security equipments</b>	LS			5.58
<b>12.2</b>	<b>Staff Quarters for O&amp;M</b>	LS			13.00
	<b>Sub Total (12)</b>				<b>18.58</b>
<b>13</b>	<b>Total of all items except Land</b>				<b>5792.94</b>
<b>14</b>	<b>General Charges incl. Design charge @ 5% on all items except land</b>				<b>289.65</b>
<b>15</b>	<b>Total of all items including General charges</b>				<b>6082.59</b>
<b>16</b>	<b>Total of cost inclusive land cost</b>				<b>6346.75</b>
<b>17</b>	<b>Contingencies @ 3 %</b>				<b>190.40</b>
<b>18</b>	<b>Gross Total</b>				<b>6537.15</b>

**Option 2 (With Depot at Kothanur):****Abstract Cost Estimate of Ph-II N-S line Gottigere - IIMB – Nagavara (Option 2)**

Total length = 22.455 km,

Under Ground Length= 13.79 km

Elevated length= 8.18 km

Ramp length= 0.48 km

Total Station = 18nos ( UG = 12 , Elv = 06 )

(Cost Without Taxes &amp; Duties) Rs. In crores

Sl. No.	Item	Unit	As per DPR			As per BMRCL		
			Rate as per Price level Jan 2011	Qty.	Amount (Rs in Cr.)	Rate	Qty.	Amount (Rs in Cr.)
<b>1.0</b>	<b>Land</b>							
1.1	Private land – for station building & viaduct	Hect.	24.84	20.460	508.23	30.00	4.10	123.00
	Private land for Depot					15.00	15.16	227.40
1.2	Govt. Land	Hect.	5.00	0.800	4.00	5.00	0.80	4.00
1.3	Temporary land for casting yard, working spaces etc.	Hect.	5.96	29.000	172.84	5.96	29.00	172.84
1.4	Cost of land for rehabilitation ( to be identified)	LS			10.00			10.00
	<b>Sub Total (1)</b>				<b>695.07</b>			<b>537.24</b>
<b>2.0</b>	<b>Alignment and Formation</b>							
2.1	Underground section by Cut & Cover excluding Station length	R. km.	101.16	0.000	0.00	100.00	0.00	0.00
2.2	Tunneling by TBM	R. km.	144.31	10.910	1574.42	150.00	10.910	1636.50
2.3	Ramp (Underground)	R. km.	44.67	0.240	10.72	45.00	0.48	21.60
2.4.1	Elevated viaduct section – Main line	R. km.	29.87	8.180	244.34	31.50	6.980	219.87
	Elevated viaduct section – Single line to Depot					22.05	1.20	26.46
2.4.2	Special Spans	R. km.	41.90	0.500	20.95	41.90	0.500	20.95
2.5	Ramp (Elevated)	R. km.	18.33	0.480	8.80	18.33	0.240	4.40
2.6	Civil work for Mid Section Ventilation Shaft	each	2.00	1.000	2.00	2.00	1.00	2.00
	<b>Sub Total (2)</b>				<b>1861.23</b>			<b>1931.78</b>
<b>3</b>	<b>Station Buildings</b>							
3.1	Underground Station	Each	120.75	12.000	1449.00	135.00	12.00	1620.00
3.2	Elevated stations (including finishes)							
a	Type (A) way side	Each	20.59	4.000	82.36	30.60	4.00	122.40
b	Type (B) Way side with signaling	Each	22.02	1.000	22.02	32.40	1.00	32.40

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c	Type (C), Terminal station	Each	23.44	1.000	23.44	34.20	1.00	34.20
3.3	Interchange facilities at interchange stations	Each	5.25	2.000	10.50	5.25	2.00	10.50
	<b>Sub total (3)</b>				<b>1587.32</b>			<b>1819.50</b>
<b>4</b>	<b>E&amp;M Works</b>							
4.1	Underground station (E&M, Lifts, Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	12.000	618.36	51.53	12.00	618.36
4.2	Elevated station (E&M, Lifts, Escalators, DG sets etc.)	Each	6.53	6.000	39.18	6.53	6.00	39.18
4.3	Mid Section Ventilation Shaft	Each	5.00	1.000	5.00	5.00	1.00	5.00
	<b>Sub total (4)</b>				<b>662.54</b>			<b>662.54</b>
<b>5.0</b>	<b>Depot</b>							
5.1	Depot at Hulimavu (i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			175.00			238.00
5.2	Stabling and inspection facilities at Nagavara side( i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			40.00			50.00
	<b>Sub total (5)</b>				<b>215.00</b>			<b>288.00</b>
<b>6.0</b>	<b>Permanent Way</b>							
6.1	Ballastless track for elevated , underground and at grade alignment	R. km.	6.48	22.455	145.51	6.42	21.255	136.46
6.2	Ballasted track for sidings etc in depots	R. km.	2.08	3.000	6.24	2.08	3.00	6.24
	<b>Sub total (6)</b>				<b>151.75</b>			<b>142.70</b>
<b>7</b>	<b>Traction &amp; power</b>							
<b>7.1</b>	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>							
7.1.1	Under Ground Section	R. km.	12.74	13.790	175.68	12.74	13.79	175.68
7.1.2	Elevated & at grade section	R. km.	8.56	8.180	70.02	8.56	9.38	80.29
	<b>Sub total (7)</b>				<b>245.70</b>			<b>255.97</b>
<b>8.0</b>	<b>Signalling and Telecom.</b>							
8.1	Signalling	R. km.	9.73	22.455	218.49	11.37	22.455	255.31
8.2	Telecom	Each Stn.	4.36	18.000	78.48	5.04	19.00	95.76
8.3	Automatic fare collection							
8.3.1	Underground stations	Each	2.96	12.000	35.52	2.50	12.00	30.00
8.3.2	Elevated stations	Each	2.96	6.000	17.76	2.50	6.00	15.00
	<b>Sub Total (8)</b>				<b>350.25</b>			<b>396.07</b>

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9.0	R & R incl. Hutments and road restoration etc.	LS			52.00			50.00
	<b>Sub Total (9)</b>				<b>52.00</b>			<b>50.00</b>
10.1	Misc. Utilities, other civil works such as median, road signages etc.	R. km.	3.15	22.455	70.73	3.12	22.455	70.06
10.2	Electrical Utilities	LS			60.00			60.00
10.3	Telecom Utilities	LS			15.00			15.00
	<b>Sub Total (10)</b>				<b>145.73</b>			<b>145.06</b>
11	Rolling Stock (SG)	Each	8.40	69.000	579.60	10.00	69.00	690.00
	<b>Sub Total (11)</b>				<b>579.60</b>			<b>690.00</b>
12.1	Barracks for CISF including security equipments	LS			5.58			5.58
12.2	Staff Quarters for O&M	LS			24.55			60.00
	<b>Sub Total (12)</b>				<b>30.13</b>			<b>65.58</b>
13	Total of all items except Land				5881.25			6447.20
14	General Charges incl. Design charge @ 5% on all items except land				294.06			322.36
15	Total of all items including General charges				6175.31			6769.56
16	Total of cost inclusive land cost				6870.38			7306.80
17	Contingencies @ 3%				206.11			219.20
18	Gross Total				7076.49			7526.00

Phase II N-S line Gottigere - IIMB – Nagavara (Option 1, With Depot at Hulimavu)						
Details of Taxes and Duties						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1587.14	99.73	80.10	107.23	<b>287.06</b>
	Elevated, at grade & entry to Depot	233.84		16.86	22.57	<b>39.43</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1464.75	92.04	73.93	98.96	<b>264.93</b>

	b) Underground station-EM works	623.36	65.29	27.29	36.53	<b>129.10</b>
	c) Elevated station - civil works	159.32		11.49	15.38	<b>26.86</b>
	d) Elevated station-EM works	39.18	1.64	2.74	3.67	<b>8.06</b>
<b>5</b>	<b>Depot</b>					
	Civil works	86.00	5.40	4.34	5.81	<b>15.55</b>
	EM works	129.00	5.40	9.04	12.09	<b>26.53</b>
<b>6</b>	<b>P-Way</b>	143.97	24.13	2.52	3.37	<b>30.02</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	235.43	19.73	12.37	16.55	<b>48.65</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	285.29	47.81	5.88	7.87	<b>61.55</b>
	AFC	53.28	8.37	1.37	1.84	<b>11.58</b>
<b>9</b>	<b>R &amp; R hutments</b>	50.00			3.13	<b>3.13</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	66.95		4.83	6.46	<b>11.29</b>
	EM works	74.00		6.48	8.67	<b>15.15</b>
<b>11</b>	<b>Rolling stock</b>	579.60	106.84	4.66	6.23	<b>117.73</b>
	<b>Total</b>	<b>5812.11</b>	<b>476.38</b>	<b>263.97</b>	<b>356.47</b>	<b>1096.62</b>
	<b>Total taxes &amp; Duties</b>					<b>1097</b>

**Phase II N-S line Gottigere - IIMB – Nagavara (Option 2, with Kothanur Depot) As per DPR**

<b>Details of Taxes and Duties</b>						
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1587.14	99.73	80.10	107.23	<b>287.06</b>
	Elevated, at grade & entry to Depot	274.09		19.76	26.45	<b>46.22</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1464.75	92.04	73.93	98.96	<b>264.93</b>
	b) Underground station-EM works	623.36	65.29	27.29	36.53	<b>129.10</b>

Executive Summary

	c) Elevated station - civil works	159.32		11.49	15.38	<b>26.86</b>
	d) Elevated station-EM works	39.18	1.64	2.74	3.67	<b>8.06</b>
<b>5</b>	<b>Depot</b>					
	Civil works	86.00	5.40	4.34	5.81	<b>15.55</b>
	EM works	129.00	5.40	9.04	12.09	<b>26.53</b>
<b>6</b>	<b>P-Way</b>	151.75	25.43	2.66	3.56	<b>31.64</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	245.70	20.59	12.91	17.28	<b>50.77</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	296.97	49.76	6.12	8.19	<b>64.07</b>
	AFC	53.28	8.37	1.37	1.84	<b>11.58</b>
<b>9</b>	<b>R &amp; R hutments</b>	52.00			3.25	<b>3.25</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	70.73		5.10	6.83	<b>11.93</b>
	EM works	75.00		6.57	8.79	<b>15.36</b>
<b>11</b>	<b>Rolling stock</b>	579.60	106.84	4.66	6.23	<b>117.73</b>
	<b>Total</b>	<b>5887.87</b>	<b>480.50</b>	<b>268.06</b>	<b>362.07</b>	<b>1110.63</b>
	<b>Total taxes &amp; Duties</b>					<b>1111</b>

**Phase II N-S line Gottigere - IIMB – Nagavara (Option 2, with Kothanur Depot)  
As per BMRCL**

<b>Details of Taxes and Duties</b>						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1636.50	102.84	82.59	110.56	<b>295.99</b>
	Elevated, at grade & entry to Depot	295.28		21.29	28.50	<b>49.79</b>

<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1620.00	101.80	81.76	109.45	<b>293.01</b>
	b) Underground station-EM works	618.36	64.76	27.07	36.23	<b>128.06</b>
	c) Elevated station - civil works	199.50		14.38	19.25	<b>33.64</b>
	d) Elevated station-EM works	44.18	1.85	3.09	4.14	<b>9.09</b>
<b>5</b>	<b>Depot</b>					
	Civil works	120.00	7.54	6.06	8.11	<b>21.70</b>
	EM works	118.00	4.94	8.26	11.06	<b>24.27</b>
<b>6</b>	<b>P-Way</b>	142.70	23.91	2.50	3.34	<b>29.76</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	255.97	21.45	13.45	18.00	<b>52.89</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	396.07	66.37	8.16	10.92	<b>85.45</b>
	AFC	45.00	7.07	1.16	1.55	<b>9.78</b>
<b>9</b>	<b>R &amp; R hutments</b>	50.00			3.13	<b>3.13</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	70.06		5.05	6.76	<b>11.81</b>
	EM works	75.00		6.57	8.79	<b>15.36</b>
<b>11</b>	<b>Rolling stock</b>	690.00	127.19	5.54	7.42	<b>140.15</b>
	<b>Total</b>	<b>6376.62</b>	<b>529.72</b>	<b>286.94</b>	<b>387.22</b>	<b>1203.87</b>
	<b>Total taxes &amp; Duties</b>					<b>1204</b>

### 0.13 FINANCIAL ANALYSIS AND FINANCING PLAN

**Option 1:** The completion cost including central taxes for the Phase-II N-S line of 21.255 km has been assessed at Rs.8815 Crores.

OR

**Option 2:** The completion cost including central taxes for the Phase-II N-S line of 22.455 km has been assessed at Rs.9385 Crores.

#### Financing Plan: -

The N-S line for Bangalore Metro Phase-II should be basically funded on the same pattern as Phase-I of Bangalore Metro. Accordingly, the funding mode as recommended is tabulated as under: -

**DMRC/BMRC/CMRL pattern of Financing:** - A Special Purpose Vehicle (SPV) is set up for the implementation of the project and for its subsequent Operation & Maintenance. Under this arrangement Government of India and Government of Karnataka shall make equal equity contribution and run SPV as a commercial enterprise. As per the prevalent practice, Central Government may be willing to contribute 20% of the project cost as their equity contribution. An equal amount can be contributed by Government of Karnataka aggregating the total equity to 40%. With the equal ownership of the SPV, both the governments nominate their representatives as members of the Board of Directors, which in turn select functional directors. Such a SPV has a benefit of independent management under the aegis of Indian Companies Act, 1956. DMRC, BMRC, CMRL are the shining examples of success of such a SPV. For the balance 60% funding requirement, options available are as follows: -

**Table 0.11**  
**Funding pattern under DMRC model (with central taxes) For Option 1**

Particulars	Government of India		Government of Karnataka		Total	
	%	Rs/Crore	%	Rs/Crore	%	Rs/Crore
Equity by GOI & GO Karnataka	20%	1764.00	20%	1764.00	40%	3528.00
SD for land cost by GO Karnataka	0%	0.00	3%	272.00	3%	272.00
Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	8%	717.00	2%	179.00	10%	895.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	47%	4120.00	0%	0.00	47%	4120.00
<b>Total</b>	<b>75.00%</b>	<b>6617.00</b>	<b>25.00%</b>	<b>2215.00</b>	<b>100.00%</b>	<b>8815.00</b>

Based on proposed fare structure and considering the land of 48.26 ha for alignment, Stations, FIRR for the project works out as 0.40 %.

**OR**

**Funding pattern under DMRC model (with central taxes) For Option 2**

Particulars	Government of India		Government of Karnataka		Total	
	%	Rs/Crore	%	Rs/Crore	%	Rs/Crore
Equity by GOI & GO Karnataka	20%	1878.00	20%	1878.00	40%	3756.00
SD for land cost by GO Karnataka	0%	0.00	8%	716.00	8%	716.00



Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	8%	718.00	2%	1180.00	10%	898.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	42%	4016.00	0%	0.00	42%	4015.00
<b>Total</b>	<b>75.00%</b>	<b>6612.00</b>	<b>30.00%</b>	<b>2774.00</b>	<b>100.00%</b>	<b>9385.00</b>

Based on proposed fare structure and considering the land of 50.26 ha for alignment, Stations, FIRR for the project works out as (-)0.20% %.

**Recommendations: -**

**Option 1:**

The FIRR of subject metro with taxes is 0.40% & the cumulative cash balance at the end of 30 years (including construction period) is positive to the extent of Rs.4281 crore with JICA loan and with market borrowing @11% per annum is Rs.32 crore after meeting all the operational expenses, interest payment and repayment of loan. Hence, the corridors are recommended for implementation.

The total contribution of GOI & Government of Karnataka under the SPV model excluding PTA to be repaid latter is Rs.4696 Crore only (excluding state taxes to be exempted of Rs.356 Crore at Jan-2011 level) as against Rs. 7340 crore under BOT model. Since the Bangaluru Metro is primarily a social project and the total contribution of funds to be made by GOI and Karnataka Government is less under SPV model, it is recommended that it should be implemented by the existing SPV.

**OR**

**Option 2:**

The FIRR of subject metro with taxes is (-)0.20% & the cumulative cash balance at the end of 30 years (including construction period) is positive to the extent of Rs.4044 crore with JICA loan and with market borrowing @11% per annum is Rs.(-)25 crore after meeting all the operational expenses, interest payment and repayment of loan.

The total contribution of GOI & Government of Karnataka under the SPV model excluding PTA to be repaid latter is Rs.5370 Crore only (excluding state taxes to be exempted of Rs.362 Crore at Jan-2011 level) as against Rs. 8050 crore under BOT model. Since the Bangaluru Metro is primarily a social project and the total contribution of funds to be made by GOI and

Karnataka Government is less under SPV model, it is recommended that it should be implemented by the existing SPV.

Therefore, option-I with FIRR 0.40% is recommended for implementation i.e. the depot to be constructed on tank bed at Hulimavu (Govt land).

#### **0.14 ECONOMIC ANALYSIS**

Implementation of the proposed Phase-II N-S line will result in reduction of busses, vehicles on roads and increase in the journey speed of road based vehicles. The Economic Internal Rate of Return for the project has been worked out and given in the table below.

Parameter	Value
EIRR (%)	13.2 %

#### **0.15 IMPLEMENTATION STRATEGY AND PROJECT IMPLEMENTATION**

The project is to be implemented as Phase-II for Bangalore Metro in the extended time frame i.e. by March 2017. However these sections get priority as these are the busy areas of Bannerghatta road, Tannery road and CBD areas like Brigade road, Shivaji Nagar etc of Central Bangalore.

The civil works for the corridor can be implemented through 1 contract package for the Viaduct and 2 contract packages for six elevated stations. The contracts are recommended to be finalized on design and build basis. The underground corridor including 12 stations can be implemented through two Design & Build contract.

The systems contracts may also be finalized as recommended in other systems chapters.

#### **0.16 CONCLUSIONS AND RECOMMENDATIONS**

For successful implementation of any metro project, which by its very nature is highly technical and complex, huge in size and to be executed in difficult urban environments, political will and commitment is necessary. Decisions are to be taken fast and the implementing agency must have the required work culture, commitment to targets, safety, quality and cost consciousness.

Executive Summary

The implementation of the two corridors of Bangalore Metro is already in progress by BMRCL. Detailed Implementation programme for this line may be drawn so as to commission this line by March 2017. This may necessitate to even start the work on this line in parallel to Phase-I corridors presently under implementation.

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**CHAPTER-1**  
**INTRODUCTION**

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## CHAPTER -1

### INTRODUCTION

#### 1.0 INTRODUCTION

#### 1.1 Phase-I Corridors

1.1.1 Detailed Project Report (DPR) of Bangalore Metro (Phase - I) was prepared by DMRC and submitted to BMRCL in May 2003. The Metro Network comprised of two corridors:

- (i) East – West corridor from Mysore Road Terminal to Baiyapanhalli Terminal -18.10 km.
- (ii) North – South corridor from Yeshwantpur to R V Road terminal -14.90 km.

1.1.2 DPR for extension of North – South Corridor at north end from Yeshwantpur to Hesarghatta Cross for a length of 5.60 kms known as Peenya extension was submitted in October 2007. A maintenance depot with full workshop facilities has been planned at Peenya.

1.1.3 DPR for extension of N – S Corridor at south end from R V Road terminal to Puttenahalli cross was submitted on 14<sup>th</sup> June 2008.

1.1.4 The details of North-South line presently under implementation are given in table 1.1 and 1.2 .

Table 1.1

**DETAILS OF NORTH – SOUTH CORRIDOR IN PHASE- I**  
(Presently under implementation)

S.No.	Section	Length (in km)	No. of Stations
1.	Hesarghatta Cross to Yashwantpur (excl)	05.600	06 (all elevated)
2.	Yashwantpur to R V Road	14.900	15 (12 elevated & 3 underground)
3.	R V Road (excl) to Puttenahalli Cross	03.665	03 (all elevated)
	<b>TOTAL</b>	<b>24.165</b>	<b>24 (21 elevated &amp; 3 underground)</b>



**Table 1.2**  
**LIST OF STATIONS ON NORTH-SOUTH CORRIDOR IN PH-I**  
(Presently under implementation)

S. No	NAME	C/L Chainage of station (in m)	Inter Station Distance (in m)
1	Hesarghatta Cross	-5400	-
2	T. Dasarahalli	-4497	903
3	Jalahalli	-3747	750
4	Peenya Ind Area	-3021	726
5	Peenya	-1950	1071
6	Outer Ring Road	-1138	812
7	Yeshwantapur	0	1138
8	Soap Factory	1103	1103
9	Mahalakshmi	2102	999
10	Rajaji Nagar	3069	967
11	Kuvempu Road	3975	906
12	Malleswaram	4728	753
13	Swastik	5864	1136
14	Majestic	7540	1676
15	Chickpete	8559	1019
16	City Market	9235	676
17	K R Road	10427	1192
18	Lal Bagh	11431	1004
19	South End Circle	12386	955
20	Jayanagar	13288	902
21	R V Road	14180	892
22	Banashankari	15540	1360
23	J.P.Nagar	16413	873
24	Puttenahalli Cross	17798	1385

**Table 1.3**  
**LIST OF STATIONS ON EAST-WEST CORRIDOR IN PHASE-I**  
(Presently under implementation)

S. No	NAME	C/L Chainage of station (in m)	Inter Station Distance (in m)
1	Mysore Road Terminal	0	-
2	Deepanjali Nagar	1117	1117
3	Vijaya Nagar	2345	1228
4	Hosahalli	3446	1101
5	Toll Gate	4448	1002
6	Magadi Road	5600	1152



7	City Railway Station	6755	1155
8	Majestic	7503	748
9	Central College	8697	1194
10	Vidhan Soudha	9318	621
11	Cricket Stadium	10643	1325
12	M G Road	11380	737
13	Trinity Circle	12522	1142
14	Ulsoor	13725	1203
15	Indira Nagar	14610	885
16	Old Madras Road	16419	1809
17	Baippanahalli	17374	955

## 1.2 Phase-II Corridors

The BMRCL requested DMRC to take up the DPR work for Ph-II Metro Rail Project as follows.

### 1. North –South Alignment:

- a) Electronic City to Jayanagar: via Begur, Jigani, Bannerghatta Road via IIMB, via Jayadeva flyover, 45<sup>th</sup> Cross Jayanagar, R V Road Terminal.
- b) Bannerghatta to Yelahanka: Jayadeva underpass on Bannerghatta Road, Hosur road, Brigade road, M G road junction;
  - i) Kamaraj road, Tannery road, Nagavara Junction (along Outer Ring Road), Sahakara Nagar, Vidyaranyapura to Yelahanka  
OR
  - ii) Jayamahar Extension, R T Nagar, Nagavara Junction (along Outer Ring Road), Sahakara Nagar to Yelahanka.

The Metro Alignment may have to go underground after Jayadeva flyover (along Bannerghatta road) up to Nagavara junction (along Outer Ring Road). The remaining portion may have to be elevated. However, final decision may be taken by the consultants after the survey.

1 –(A). North – South Alignment would be extended from Puttenahalli Cross to NICE Road on Kanakapura Road which would also be elevated.

### 2 East – West Alignment:

Kathriguppe, Chamarajpet, City Market, Richmond Circle and after that;

- a) Richmond Road, Airport Road, ITPL, Whitefield



OR

b) From Baiyyappanahalli to Whitefield via K R Puram.

The decision whether the Metro Alignment will be elevated or underground may be taken by the consultants after the survey.

**3-(A)** East – West Metro Alignment would be extended from Mysore road Terminal to Kengeri which would also be elevated.

The required surveys including Reconnaissance/Topographical survey, Traffic & Transportation Studies, Geo-technical investigations, Environment Studies etc were carried out along the above proposed routes. During the meeting between BMRC and DMRC on 28-08-2009, after going through the Traffic Survey figures as also all the connected details/surveys and elaborate interaction and discussions on various alternatives, the BMRC decided on the Phase-II Metro Rail for which the DPR is to be framed and submitted.

Sl. No.	Items	Length in 'Kms'
1	R V Road Terminal to Electronic City via Silk Board junction (with proposal for further extension to Bommasandra Industrial Area)	14.50 (03.60)
2	Baiyyappanahalli to Whitefield	15.50
3	South – North line from IIMB/Meenakshi Temple on Bannerghatta Road to Nagavara via Jayadeva Hospital, Dairy Circle, Vellara Junction, St. Marks Road, Shivaji Nagar, Tannery road.	19.80
4	Extension of Phase-I North – South line from Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC) on Tumkur road	04.00
5	Extension of Metro Phase-I East-West Alignment from Mysore road Terminal to Kengeri on Mysore Road	06.10
6	Extension of North – South Alignment of Phase-I from Puttenahalli Cross to NICE Road Crossing on Kanakapura Road	06.00
7	Phase – II West-East line from Kathriguppe to Baiyyappanahalli via Kathriguppe 80' road, Bull Temple road, Kalasipalyam (City Market Metro Station of Phase-I), Corporation Office, Vellara junction (Interchange of Phase-II E-W and N-S line), Old Airport, Suranjandas road.	22.00
<b>TOTAL</b>		<b>87.90 (91.50)</b>





The High Power Committee (HPC) approved the R V Road – Electronic City – Bommasandra Industrial Area Metro Rail line in the meeting held on 6<sup>th</sup> May 2010. The Final DPR for this line (R V Road-Electronic City-Bommasandra line) was submitted on 14<sup>th</sup> May 2011.

The HPC also cleared the proposal for DPRs in respect of following lines on 25<sup>th</sup> March 2010.

Sl. No.	Alignment	Length of the line in 'Kms'
1	Extension of E-W line – Mysore road Terminal to Kengeri	06.10
2	Extension of E-W line – Baiyyappanahalli to ITPL - Whitefield	15.50
3	Extension of N-S line – Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC)	04.00
4	Extension of N-S line – Puttenahalli Cross to Anjanapura Township (Up to NICE Road)	06.00
5	North South line – Indian Institute of Management, Bangalore (Meenakshi Temple on Bannerghatta road) to Nagavara	19.80

Final DPR for above four extensions (Sl. No 1 to 4) was submitted on 26<sup>th</sup> July 2011.

Phase-I Metro Corridors and proposed Phase-II Corridors of Bangalore Metro are shown in Fig 1.1.

### 1.3 North – South line IIM (B) to Nagavara

	Option 1 (With Hulimavu Depot)	Option 2 (With Kothanur Depot)
Elevated: from Ch.0 to Ch.6980	= 06.98 km	08.18 km
Underground from Ch.7465 to Ch.21255	= 13.79 km	13.79 km
Ramps from Ch.6980 to 7465	= 00.48 km	00.48 km
Total length	= 21.25 km	22.45 km

The busy Bannerghatta road from Gottigere to the Hosur Road junction covering Hulimavu, IIMB, J P Nagar-IV Phase, Jayadeva Hospital (interchange with 'R V Road-Electronic City- Bommasandra' line), Dairy Circle (near NIMHANS Hospital), MICO Layout, the Hosur Road, Vellara junction and Brigade road (the commercial hub) are covered by this line. This line further crosses the East West Metro Corridor at M G road and traverses on Kamaraj road. Integration between proposed M.G. Road station (underground) with elevated M G Road metro Station presently under implementation is planned. Incidentally, the proposed City Airport Terminal



(CAT) at Police Grounds of the High Speed Rail Link to Bangalore International Airport about 650 m away from this station will be catering for the Air passengers generating from the southern part of the city where the IT hub 'Electronic City' of the Silicon City is situated. The line further traverses almost below Infantry road after traversing below Defense area. It then traverses by the side of Shivaji Nagar Bus-stand, where the Shivaji Nagar Metro underground station is planned in the part of open ground. This Shivaji Nagar, the busy CBD area which handles the east Bangalore traffic will be served by this Ph-II N-S line. Further the Cantonment Railway Station area will also be connected by this line. The Pottery Town, Nagavara and other prominent places and thickly populated areas like HBR layout, Kushal Nagar, on Tannery road will be connected by metro. Index Plan showing the proposed alignment is shown in **Fig 1.1**

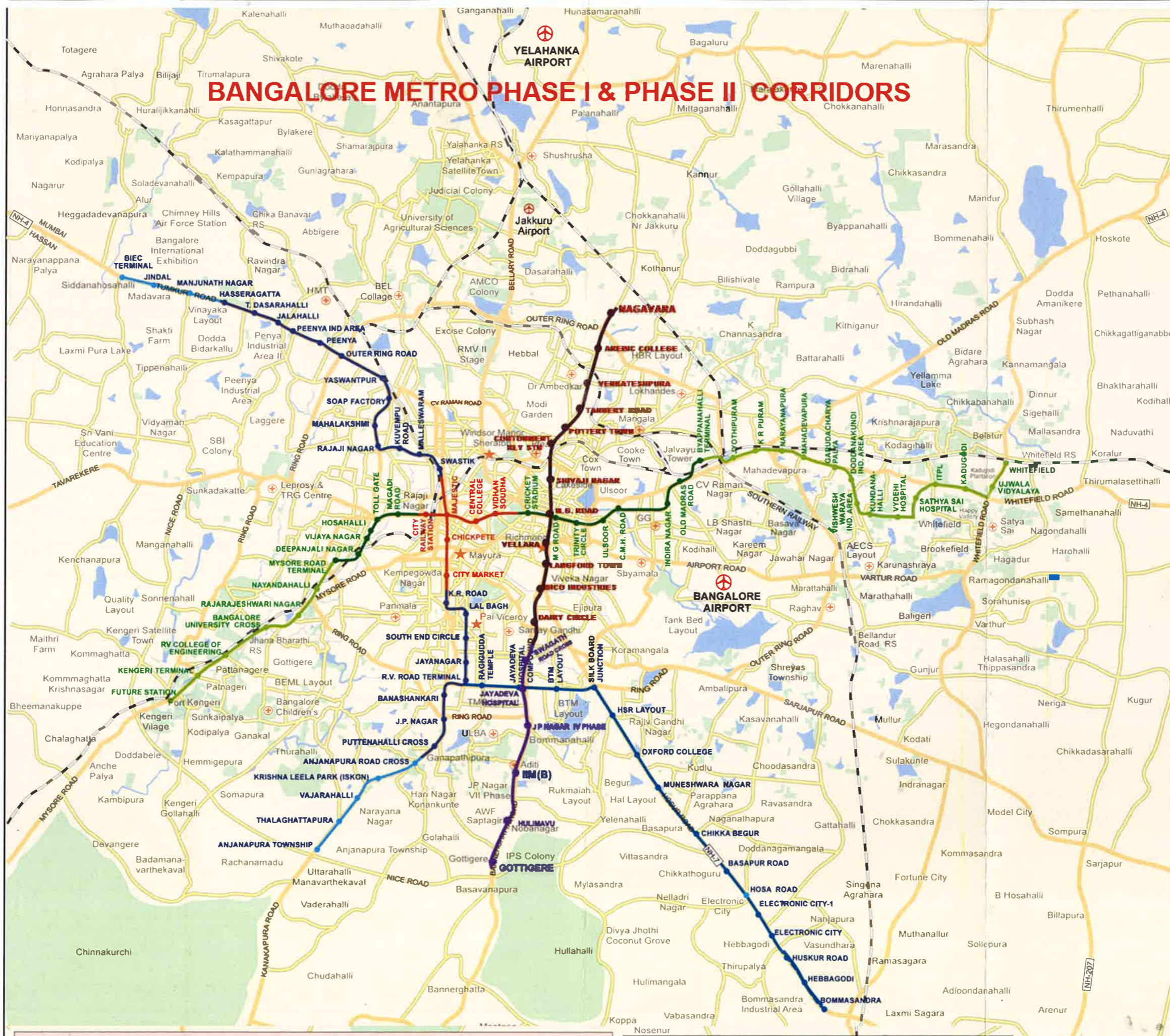
This Report is structured in 17 Chapters as below:

Chapter - 1	INTRODUCTION
Chapter - 2	TRAFFIC DEMAND ANALYSIS
Chapter - 3	PLANNING & DESIGN PARAMETERS
Chapter - 4	CIVIL ENGINEERING WORKS
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Chapter - 9	SIGNALLING SYSTEM
Chapter - 10	TELECOMMUNICATION & AUTOMTIC FARE COLLECTION SYSTEM
Chapter - 11	TRAIN MAINTENANCE DEPOT
Chapter - 12	ENVIRONMENTAL IMPACT ASSESSMENT
Chapter - 13	COST ESTIMATES
Chapter - 14	FINANCIAL VIABILITY, FARE STRUCTURE & FINANCING OPTIONS
Chapter - 15	ECONOMICAL ANALYSIS
Chapter - 16	IMPLEMENTATION PLAN
Chapter - 17	CONCLUSIONS AND RECOMMENDATIONS

The gist of the chapters is provided in Executive Summary and Salient Features placed in the beginning of report.



# BANGALORE METRO PHASE I & PHASE II CORRIDORS



LEGEND			
	Phase-1 UNDERGROUND SECTION		Phase-2 ELEVATED SECTION (N-S LINE)
	Phase-1 ELEVATED SECTION (N-S LINE)		Phase-2 ELEVATED SECTION (E--W LINE)
	Phase-1 ELEVATED SECTION (E--W LINE)		ELEVATED Phase2 2nd NORTH SOUTH LINE
	Extension of Phase-1 ELEVATED SECTION		METRO STATIONS

Fig 1.1



**CHAPTER-2**

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**TRAFFIC FORECAST**



## CHAPTER 2

### TRAFFIC FORECAST

#### 2.0 TRANSPORT DEMAND FORECAST

#### 2.1 Travel Characteristics

##### 2.1.1. General

Bangalore Metro Rail Corporation limited has been implementing the Bangalore Metro for the city of Bangalore. It is currently implementing the Phase 1 of the Bangalore Metro. A DPR has been prepared and submitted to supplement the Phase-1 with a proposed line from R.V road terminal (of Phase 1) to Electronic City – Bommasandra Industrial Area for a total length of about 18.10 kms and for Four Extensions of Ph-I lines on all the four ends. Now this DPR is being prepared for the proposed Gottigere – IIMB – Nagavara (2<sup>nd</sup> N-S) line of about 21.25 kms.

This Chapter covers the transport demand projections for the 2<sup>nd</sup> N-S line (Gottigere – IIMB – Nagavara) with length as 21.25 Kms and section and station loadings for the same.

##### 2.1.2. TRANSPORT DEMAND MODELLING

###### Data Base

Detailed Household surveys and various traffic surveys were carried out during the DPR study. Results of the surveys are presented in a volume titled “Interim Data Report”. The Transport Demand model was developed and the future OD-Matrices based on the projected Population and employment was developed.



The Network for the proposed Gottigere – IIMB - Nagavara alignment has been developed from the same primary database and used in the Transport Demand Model

The Four Stage Transport Demand Model involving trip generation, Trip distribution, Modal Split and Assignment has been used.

The basic functions included in the transportation study process are:

- Trip-end prediction or trip generation and attractions – i.e., the determination of the number of person trips leaving a zone irrespective of destination and the number of trips attracted to a zone, irrespective of origin.
- Trip distribution – the linking of the trip origins (generation) with their destinations (attraction).
- Modal split – the division of trips between public transport modes and different private modes
- Assignment – the allocation of trips between a pair of zones to the most likely route(s) on the network.
- Evaluation – assessing the effectiveness of the network in meeting the transport demand.

The details of the planning process as adopted for this study is shown in **Figure 2.1**.

### 2.1.3 ZONING

The entire study area has been delineated into 182 zones as shown in **Figure 2.2**. Among them 172 are the internal zones and the remaining zones (10 zones) are external zones. Detailed list of all these zones is given in the **Annexure 2.1**.

Summary of population projection and employment projections is presented in the **Table 2.1**.

**Table 2.1 Population and Employment projection**

	<b>Base year</b>	<b>2011</b>	<b>2021</b>	<b>2031</b>
Population(in lakhs)	73.99	80.15	99.67	123.11
Employment(in lakhs)	26.63	29.25	37.87	48.01

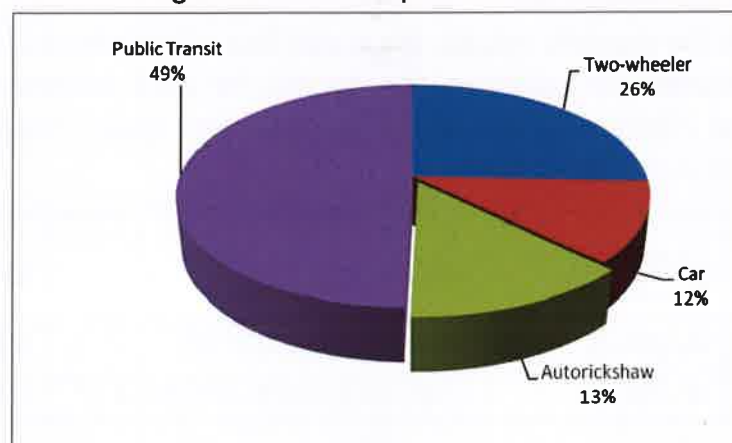
These figures are based on the Census (2001) and projected for future in consultation with the city development authorities.

#### 2.1.4 Trip Information

The trip information obtained from the survey has been analyzed with respect to distribution of total trips by mode. The daily trips by various modes are presented in **Table 2.2** and **Fig. 2.1**.

**Table 2.2 Distribution of Motorised Trips**

<b>Sl. No</b>	<b>Mode</b>	<b>Internal Trips</b>	<b>External Trips</b>	<b>Total Trips</b>
1	Two-wheeler	1829858	84083	1913941
2	Car	826909	90360	917269
3	Auto rickshaw	927371	14760	942131
4	Public Transit	3519338	672120	4191458
	Total	7103475	861323	7964798

**Figure 2.1 Mode Split – Motorized**



Bus trips constitute about 49% of the total trips while Two-wheeler trips are 26 %, Auto trips 13% and Car trips constitutes 12%.

## 2.2 TRANSPORT DEMAND MODEL AND PARAMETERS

### 2.2.1 Model Description

As stated earlier, standard four stage Model i.e. Trip generation, trip Distribution, Modal split and Assignment is used. Extensive Household surveys and traffic surveys were carried out and the four stage model was developed. The horizon year Origin Destination (O – D) Matrices for private and public modes were also developed using the Gravity Model. The parameters obtained from the Model have been used for the transport demand projections for extension of Electronic City corridor.

### 2.2.2 CAPACITY OF THE ROAD SYSTEM

The types of roads and their capacities are given in **Table 2.3**

**TABLE 2.3 TYPES OF ROADS AND THEIR CAPACITIES**

Link Type	Functional Characteristics	Directional capacity
3	2L-1W-UD	6000
7	4L-1W-UD	12000
8	4L-2W-UD	3800
9	4L-2W-D	4500
11	6L-2W-D	6700

(Note: l: Lanes, 1w- One Way ,UD- Undivided, D- Divided,2W- Two way )

### 2.2.3 Speed Flow Relationship

In addition to the capacity values, the speed flow relationships of the four types of links are required for modifying the speeds for each incremental loading. A Mathematical model was developed for each link type. These mathematical models are shown in table 2.4:

S.NO	Lane Details	Equation	R <sup>2</sup>
1	6L-2W-D	$49.97-0.000001 X^2$	0.99
2	4L-2W-D	$43.03-0.001X-.0000014 X^2$	0.98



3	3L-2W-UD	38.45-0.008X	0.90
4	2L-2W-UD	35.11-0.011X	0.82

**Table 2.4: Speed Flow Relations**

The initial free flow speeds taken for the assignment of public and private modes are summarized in **Table 2.5**.

**Table 2.5 Free flow Speeds**

Mode	Free Flow Speed in kmph*		
	2-lane	4-lane	6-lane
All modes	36	40	49

#### 2.2.4 TRIP CATEGORIZATION

The passenger transport demand in terms of daily passenger trips has been broadly categorized as intra-city and inter-city trips. The inter-zonal trips are the most important, so far as transport system development is concerned. The trips were classified by different motorized modes including private, hired and public motorized vehicles.

#### 2.2.5 TRIP GENERATION

The first of the sub-models in the study process is that which predicts the number of trips starting and finishing in each zone. The techniques developed attempt to utilize the observed relationships between travel characteristics and the urban environment and are based on the assumption that 'trip making' is a function of three basic factors:

- Land use pattern and development in the study area,
- Socio-economic characteristics of the trip-making population of the study area, and
- Nature, extent and capabilities of the transportation system in the study area

Mathematically, trip generation can be expressed as:

Trips Generated = Function (socio-economic, location etc. variables)



Various techniques for developing the trip generation sub-models are available and notable among them are:

- Regression Analysis
- Category Analysis or Cross Classification Analysis

A typical regression analysis for trip generation model is

$$G = A_0 + \sum_{i=1}^k a_{ij} x_i$$

Where

G	=	No. Of trips (produced/attracted) in a zone for a specific purpose.
A <sub>0</sub>	=	Constant term to be calibrated.
a <sub>0</sub> , a <sub>1</sub> ..... a <sub>k</sub>	=	Coefficients to be determined by the regression analysis
X <sub>1</sub> , x <sub>2</sub> .	=	Zonal planning input factor (independent) variable)

The significance of the regression equation is tested on the basis of R<sup>2</sup> value and the t-statistics value (for each of the coefficients).

Typical inputs for trip generation sub-models are population, employment, vehicle ownership, household income, residential density, etc. These models are developed using standard computer programs.

Population is a major influencing factor for trip generation. As it is one of the major variables in the trip end models used for obtaining the future trip ends, it has an influence in the overall trip productions / attractions.

For the generation of trip generation sub-models, analysis has been carried out at zonal level utilizing regression analysis technique. The generalized form of the trip generation equation to be developed is as under: -

$$Y=A+BX$$

Where Y=Trips produced or attracted

A=Constant term

B=Trip rate to be determined from least square Analysis

X=Independent variable e.g., population, employment, Vehicle ownership



The results of calibration of different models are given in **Table 2.6**

**Table 2.6 Generation for Total Trips**

	<b>Co-off.</b>
Intercept	1653
X Variable	0.037

By using the above table the value of  $R^2$  was found to be 0.55 (**Assuming Population in zones as the variable**).

**Table 2.7 Trip attraction for total trips**

	<b>Co-off.</b>
Intercept	1312
X Variable	0.126

By using above expression the value of  $R^2$  was found to be 0.81 (**Assuming Employment in zone as variable**).

The population and employment projection for the horizon years is presented in **Table 2.8** below:

**Table 2.8 Population and employment projections**

<b>Year</b>	<b>Population(Lakhs)</b>	<b>Employment(Lakhs)</b>
Base year	73.99	26.63
2011	80.15	29.25
2021	99.67	37.87
2031	123.11	48.01

### **2.2.6 PER CAPITA TRIP RATE (PCTR)**

Adopted Per Capita Trip Rate for base and horizon years i.e., 2011, 2016 and 2021 and 2031 are as given in the **Table 2.9**.



**Table 2.9 Adopted PCTR (Vehicular) Value**

Year	PCTR Value
Base year	0.96
2011	0.99
2021	1.09
2031	1.21

**2.2.7 TRIP DISTRIBUTION AND MODE CHOICE**

A regular four stage transport model distributes the trip ends to the zones initially and then selects the choice of the mode. Trip distribution normally is carried out using the traditional gravity function. Many methods are available for mode choice including diversion curve, utility based logit model etc. The present study combines the trip distribution and mode choice to form a combined Trip Distribution and Modal Split phase using a conventional doubly constrained gravity model of the form:

**$T_{ijm} = r_i G_i s_j A_j F_{ijm}$**

Where T= number of inter zonal trips between zone i & j and 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)

Fijm= Deterrence function for mode m

**$F_{ijm} = K m e^{-\beta C_{ijm}} C_{ijm}^\alpha$  ----- Eqn 1**

Where K= Constant Factor

C=Generalized Cost

$\beta$ = Calibration Constant –Exponential function

$\alpha$ =Calibration Constant- Power function

Double Constraints are imposed by ensuring that



$$\sum_{Jm} T_{ij} = G_i \quad \text{and} \quad \sum_{Im} T_{ij} = A_i$$

The calibration includes estimation of parameters of the deterrence function in the form of Gamma (Refer Eqn 1). The calibration process for combined trip distribution and mode choice is explained in flowchart as shown in **Figure 2.4**.

The cost of travel (C- generalized cost) between the zones has been estimated based on skims from the Highway and Public Transport assignment. The estimation of generalized cost for the base year is explained in the following section.

### 2.2.8 Deterrence functions

Calibrated parameters for the Deterrence function by mode is given in Table 2.10

**Table 2.10 Calibrated Deterrence Functions for Morning peak hour**

Mode	Morning Peak		
	K	ALPHA	BETA
Two wheeler	0.147	-0.5	0.1
Car	11.8	1.0	8.8
Auto Rickshaw	1.1	0.4	3.2
Public Transport	2.54	1.73E-13	22.0

### 2.2.9 TRIP ASSIGNMENT

**2.2.9.1** Trip assignment is the process of allocating a given set of trip interchanges to a specific transportation system and is generally used to estimate the volume of travel on various links of the system to simulate present conditions for validation purposes and to use the same for horizon years for developing forecast scenarios. The process requires as input, a complete description of either the proposed or existing transportation system, and a matrix of inter-zonal trip movements. The output of the process is an estimate of the trips on each link of the transportation system, although the more sophisticated assignment techniques also include directional turning movements at intersections.

The purposes of trip assignment are:



1. To assess the deficiencies of the existing transportation system by assigning estimated future trips to the existing system – **Do Nothing Scenario**.
2. To evaluate the effects of limited improvements and extensions to the existing transportation system by assigning estimated trips to the network which included these improvements.
3. To develop system development priorities by assigning estimated future trips for intermediate years to the transportation system proposed for these years.
4. To test alternative transportation system proposals by systematic and readily acceptable procedures.
5. To provide design hours volumes and turning movements.

#### **2.2.9.2 Assignment Procedure Adopted**

The observed highway and public transport matrices were assigned on the network to check the validation across the screen lines. The assigned traffic volume has been compared with the observed traffic counts. The assignment is carried out in two stages with the assignment of Transit trips following the Highway PCU Assignment. The highway assignment is the assignment of vehicles on Roads and this is carried out also in stages with commercial vehicles and buses taken as pre loads. The transit assignment is the assignment of commuters on a Public Transit Network which comprises of buses, metros etc which are linked on to the zonal system via walk links. This methodology is presented in **Figure 2.5**.

#### **2.2.9.3 PCU Conversion Factor**

The results from the trip assignment, which is in terms of person trips, have to be converted to PCU trips for updating the link speeds. As the occupancy levels of the private modes are quite different from the road-based public transport modes, separate passenger to PCU conversion factors were derived for the two types of travel. The factors used for the study area are given in **Table 2.11**

Goods vehicles and other slow moving vehicles use the roads simultaneously. Thus the capacity comparison and speed modifications must take movement of these vehicles in mixed traffic conditions into account. Thus, after the person trips are converted to vehicles trips in terms of PCUs, the goods traffic factor is added to boost up the value to incorporate the mixed flow conditions because of goods vehicles and the slow moving vehicles.



TABLE 2.11 PCU CONVERSION FACTORS

Private Vehicles & IPT	Modes	PCE Values
	Two wheeler	0.50
	Auto rickshaw	0.50
	Car	0.80
Commercial Vehicles	Modes	PCU Values
	Truck	3.7
	MAV	4.0
	LCV	1.4

## 2.3 TRANSPORT DEMAND PROJECTIONS

2.3.1 The proposed stations on the Gottigere – IIMB – Nagavara line is given in Table 2.12

Table 2.12 – Interstation distances

Station no	Name of Station	Inter Station Distance (M)
1	Gottigere	-
2	Hulimavu	1073.50
3	Indian Institute of Management, Bangalore (IIMB)	1719.50
4	J P Nagar IV Phase	1371
5	Jayadeva Hospital	839
6	Swagath Road Cross	1363
7	Dairy Circle	1152
8	MICO Industries	1032
9	Langford Town	919.40
10	Vellara	1003.60
11	M G Road	1134
12	Shivaji Nagar	1195
13	Cantonment Railway Station	1172
14	Pottery Town	1626
15	Tannery Road	1159



Station no	Name of Station	Inter Station Distance (M)
16	Venkateshpura	986
17	Arabic College	1424
18	Nagavara	1403

The alignment is 21.255 km in length with 18 proposed stations (06 elevated + 12 U/G) up to Nagavara. It may be noted that station spacing along the alignment varies from 0.839 km to 1.72 km.

### 2.3.2 Section Loading

The traffic assignment was carried out on the Gottigere – IIMB – Nagavara line with the phase 1 lines, its four extensions and R.V Road terminal - Electronic City – Bommasandra Industrial Area line in place. The loading on the proposed Gottigere – IIMB – Nagavara line is presented in **Table 2.13**

**Table 2.13 Summary of Transport demand projections**

Year	Peak Hour Sectional loading	Number of passengers (Lakhs/day)	Passenger KM(Lakhs)	Mean trip length
2016	11,935	2.62	24.37	9.3
2021	16,381	4.03	38.20	9.5
2031	22,806	5.58	52.89	9.5
2041	25,315	6.19	58.81	9.5

The total ridership in the proposed line in the year 2016, 2021, 2031 and 2041 will be 2.62, 4.03, 5.58 and 6.19 lakhs passengers per day respectively. Based on traffic volume counts, peak hour factor of 9 has been arrived for the city.

The PHPDT on this extension in 2016 will be 11,935 and by 2041 it is likely to be of the order of 25,315. The section wise loading and PHPDT is presented in **Annexure 2.2**.

### 2.3.3 Station loading

The daily station loading (two way boardings) of Gottigere – IIMB – Nagavara (2<sup>nd</sup> N-S) corridor is presented in **Table 2.14**.





**Table 2.14 Daily Station Loading for Gottigere – IIMB – Nagavara (2<sup>nd</sup> N-S) line**

Station Name	2016	2021	2031	2041
Gottigere	31682	53860	74328	82504
Hulimavu	13578	23083	31856	35360
Indian Institute of Management, Bangalore (IIMB)	8838	14942	20624	22888
J P Nagar IV Phase	9492	15923	21968	24384
Jayadeva Hospital	75688	119833	165368	183560
Swagath Road Cross	7921	13244	18280	20288
Dairy Circle	4623	7563	12032	13360
MICO Industries	2532	4193	5784	6416
Langford Town	9860	15434	21304	23640
Vellara	4213	6726	9280	10304
M G Road	18825	21322	29432	32656
Shivaji Nagar	7546	11717	16168	17952
Cantonment Railway Station	2844	4440	6128	6800
Pottery Town	4201	6543	9024	10024
Tannery Road	3174	4922	6792	7536
Venkateshpura	12147	18757	25880	28728
Arabic College	15744	24246	33456	37136
Nagavara	29125	36848	50848	56440

(Note: Numbers are total Boardings with both directions (Up and Down) put together)

#### 2.3.4 Trip length frequency distribution

#### 2.3.5

The trip length frequency distribution of the Metro trips is presented in **Annexure 2.3** it can be observed that the average trip length for the years 2016 and 2041 are and km respectively.



Figure 2.2: Modeling approach

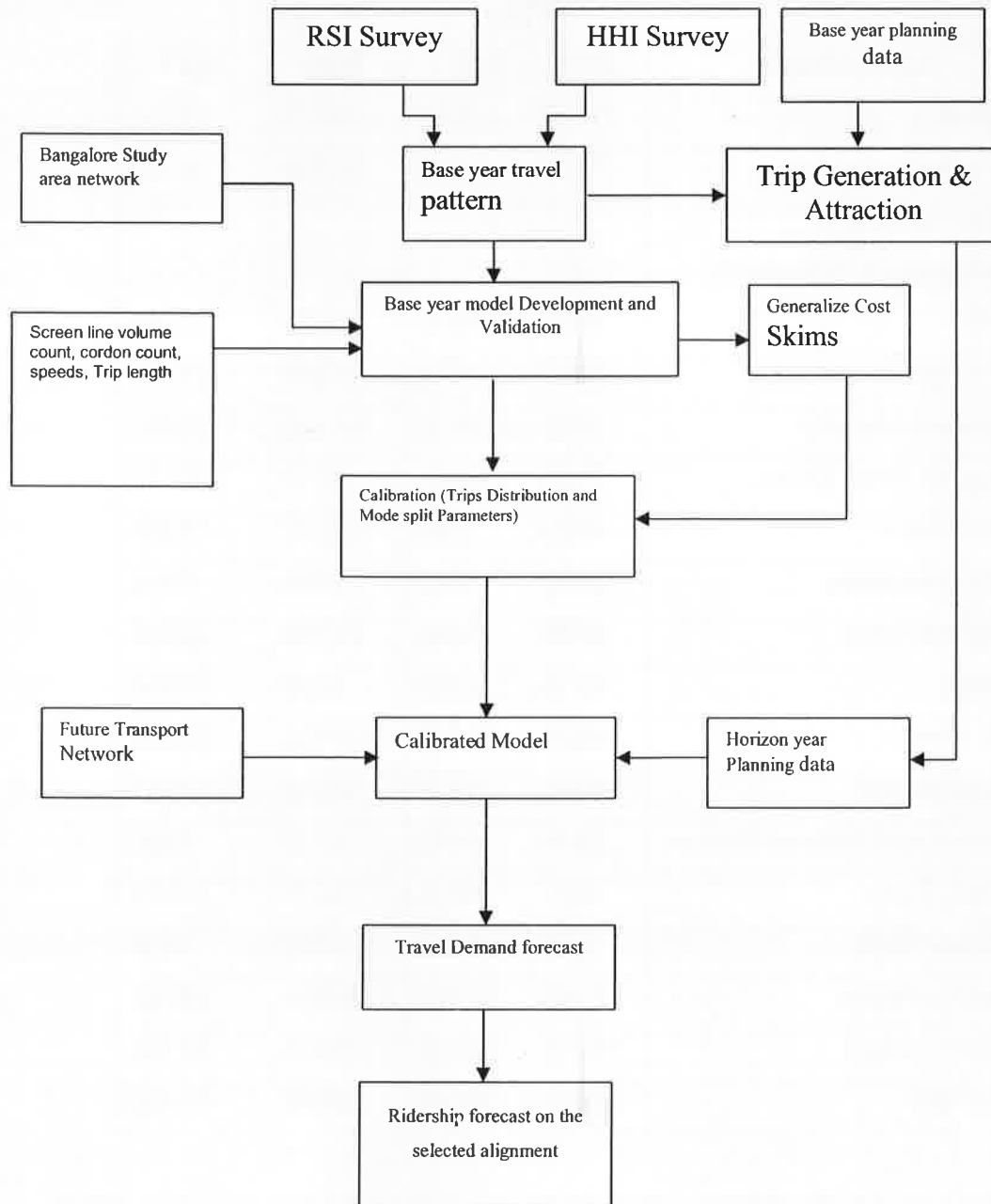




Figure 2.3: Zoning system

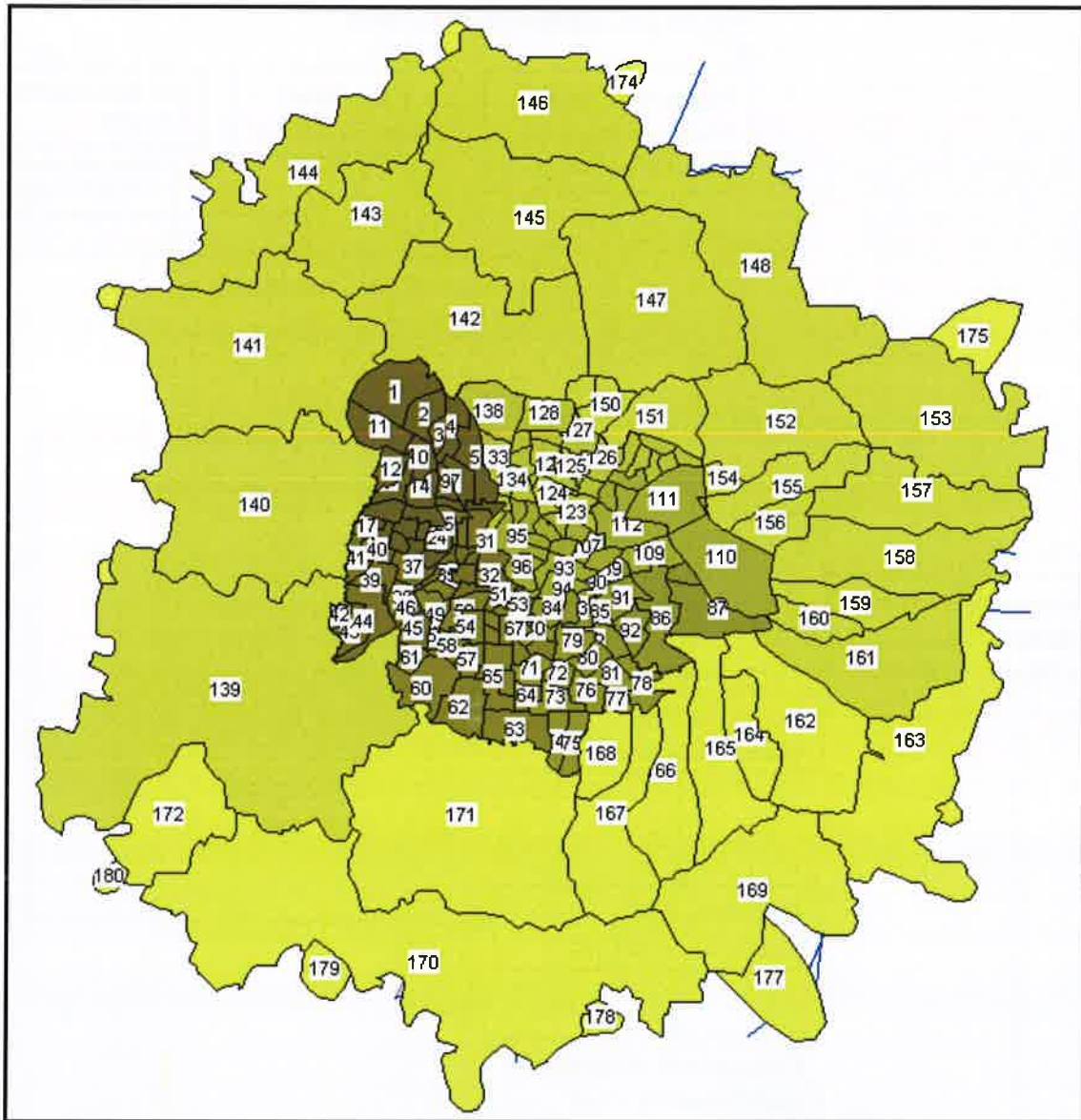




Figure 2.4: Calibration process

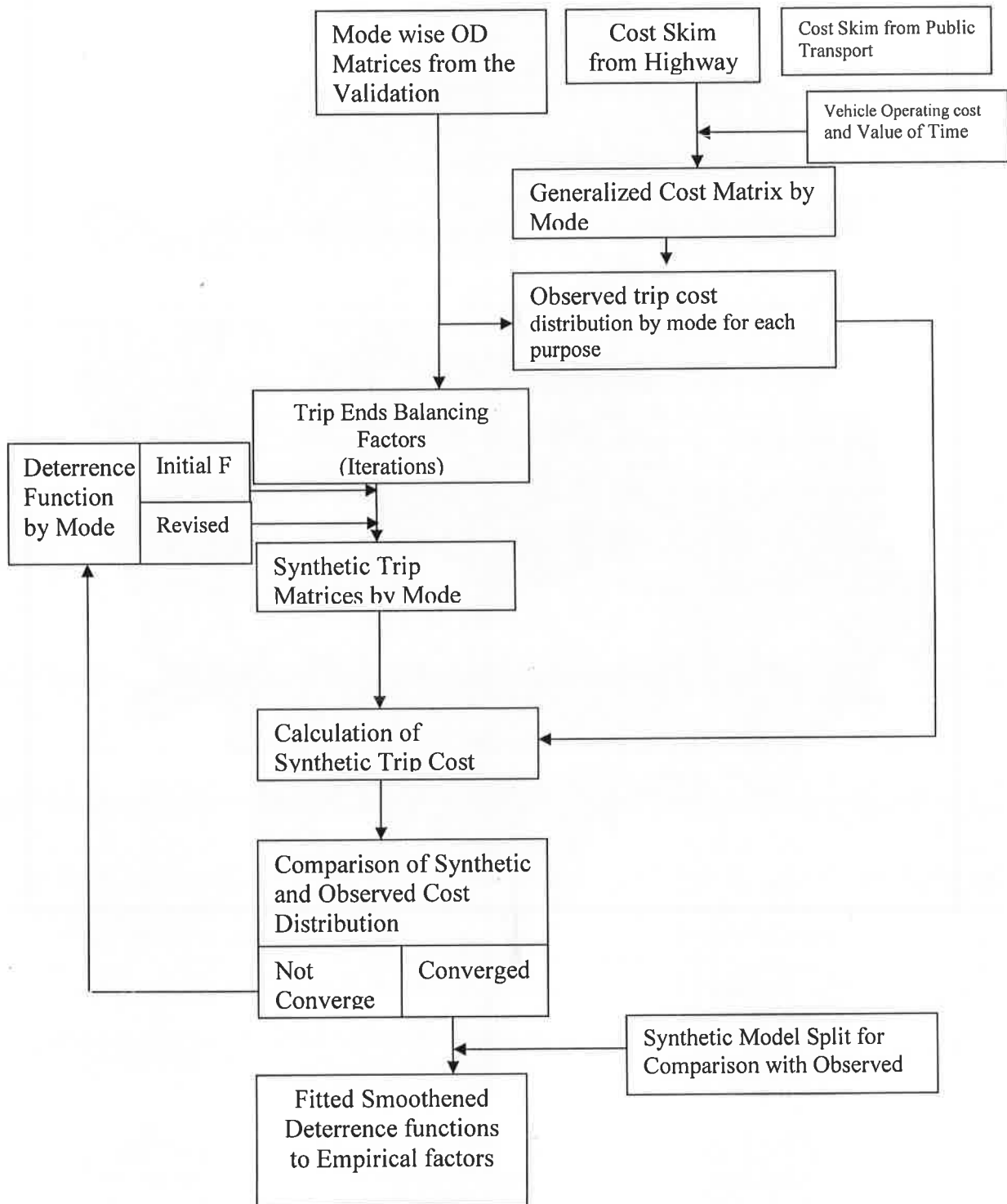
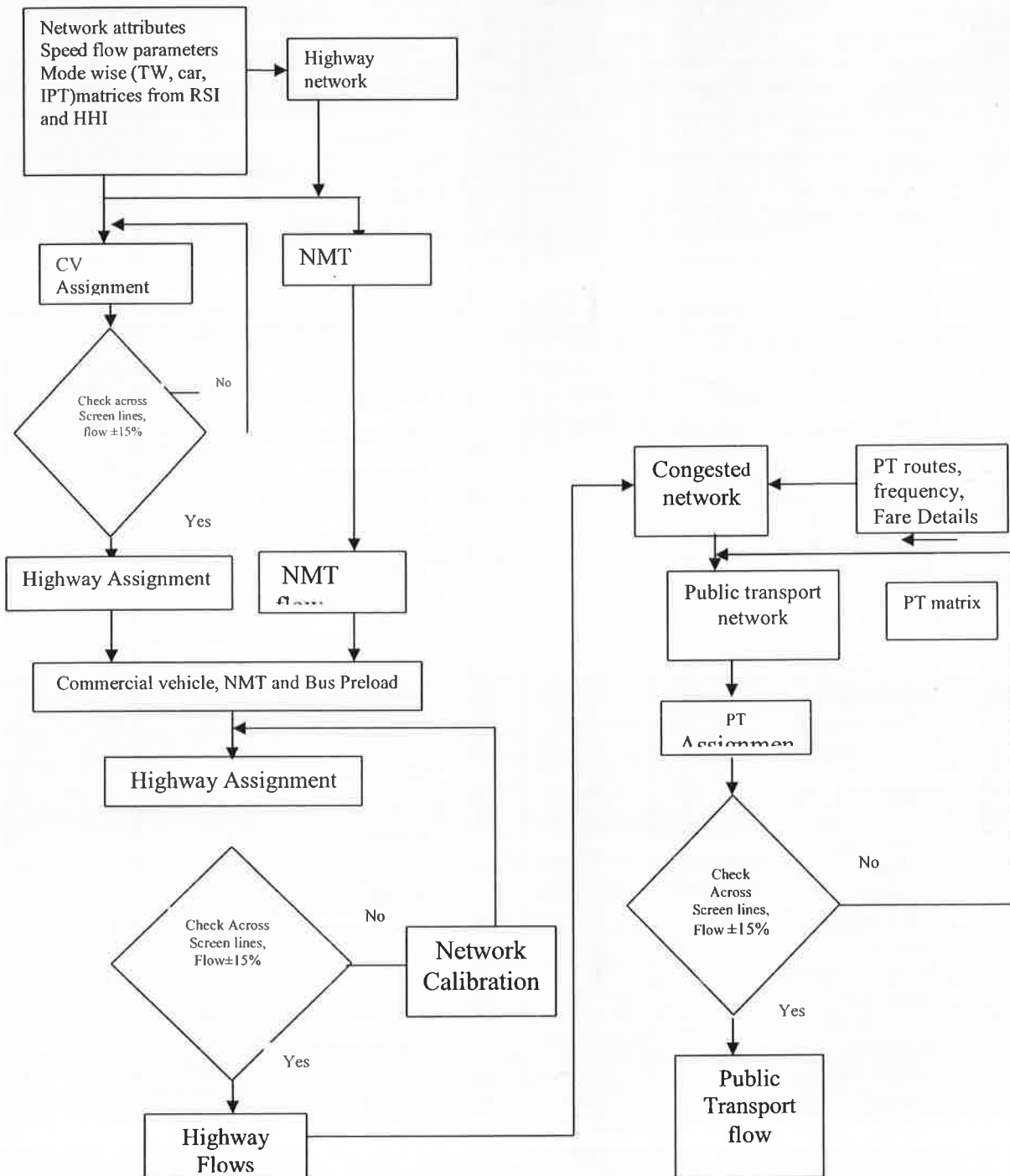




Figure 2.5. Trip Assignment





## ANNEXURE -2.1

## ZONE NUMBERS AND ZONE NAMES

Zone No.	Zone Name
1	HMT
2	Jalahalli
3	Yeshwanthapura
4	Mathikere
5	Kodandarampura
6	Dattatreya Temple
7	Malleshwaram
8	Gayathrinagar
9	Subramanyanagar
10	Mahalakshmipuram
11	Peenya Industrial Area
12	Nandini Layout
13	Geleyarabalaga Extension
14	Nagapura
15	Rajajinagar
16	Kamalanagar
17	Vrishabavathi Nagara
18	Kamakshipalya
19	Basaweshwaranagar
20	Shivanagar
21	
22	Industrial Town
23	
24	Sri Ram Mandir
25	Prakashnagar
26	Bashyamanagara
27	Ramachandrapuram
28	
29	Sevashrama
30	
31	Gandhi Nagar
32	Chickpet
33	Cottonpet
34	Sri K.R.Market
35	Binny Pet
36	Kempapura Agrahara
37	Vijayanagar
38	R.P.C. Layout
39	Marenahalli
40	Govindarajanagar
41	Amarjyothi Nagar

Zone No.	Zone Name
42	Mudala Palya
43	Chandra Layout
44	Attiguppe
45	Gali Anjaneya Temple
46	Bapuji Nagar
47	Padarayanapura
48	Jagajeevanaram Nagar
49	Azad Nagar
50	Chamrajpet
51	Dharmarayaswamy Temple
52	
53	Sudhamanagara
54	Kempegowdanagar
55	
56	Vishweshwarapuram
57	Basavanagudi
58	Hanumantha Nagar
59	Srinagar
60	Srinivasanagar
61	Padhmanabhanagar
62	Ganesha Mandir
63	JP Nagar
64	Jayanagar
65	Yediyur
66	Pattabiramnagar
67	Mavalli
68	
69	Hombegowdanagar
70	
71	Lakkasandara
72	
73	Gurappanapalya
74	B.T.M. Layout
75	
76	Madivala
77	
78	
79	
80	Koramangala
81	
82	Ejipura



Zone No.	Zone Name
83	Neelasandra
84	Sahnthinagar
85	Austin Town
86	Domlur
87	Airport
88	Jeevanbhimanagar
89	Jougupalya
90	
91	
92	
93	Richmond Town
94	
95	Sampangiramanagara
96	
97	
98	
99	
100	Vasanthanagara
101	
102	
103	
104	Shivajinagar
105	Bharathinagar
106	
107	Ulsoor
108	Hoysala Nagara
109	
110	Sir C.V. Raman Nagara
111	Bennigana Nagar
112	Sarvagna Nagara
113	Maruthi Sevanagar
114	
115	Lingarajpur
116	Banasvadi
117	
118	
119	
120	Kacharakanahalli
121	
122	Sagayapuram
123	Pulikesy Nagar
124	Jayamahall
125	Devarajeevanahalli
126	Kadugondanahalli
127	Kaval Byrasandra
128	Hebbal

Zone No.	Zone Name
129	J.C. Nagar
130	Ganga Nagar
131	
132	
133	Aramane Nagar
134	
135	
136	
137	
138	Sanjayanagar
139	Kengeri
140	Herohalli
141	Makali
142	Byatarayanapura
143	Bavalakere
144	Hesarghatta
145	Yelahanka
146	Bettaalasuru
147	Tanisandra
148	Bagaluru
149	Horamavu
150	
151	
152	Avalahalli
153	
154	K.R.Puram
155	
156	Sadar Mangala
157	
158	
159	Whitefield
160	
161	Varthur
162	
163	Dommasandra
164	Begur
165	
166	
167	
168	
169	Electronic City
170	Bannerghatta
171	Anjanapura
172	Kumbalagoda
173	Towards Doddaballapur
174	Towards Hyderabad



Zone No.	Zone Name
175	Towards Kolar
176	Towards Sarjapur
177	Towards Hosur
178	Towards Bannerghatta
179	Towards Kanakpura
180	Towards Mysore
181	Towards Magadi
182	Towards Tumkur





## ANNEXURE 2.2

PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2016- METRO PHASE  
II GOTTIGERE – IIMB – NAGAVARA LINE

Station no	Station Name	Boarding	Alight ing	Sectional loading	Station no	Station Name	Boarding	Alight ing	Sectional loading
1	Gottigere	3960	0	3960	18	Nagavara	3641	0	3641
2	Hulimavu	1697	0	5658	17	Arabic College	1968	10	5599
3	Indian Institute of Management, Bangalore (IIMB)	1026	210	6474	16	Venkateshpura	1479	14	7064
4	J P Nagar IV Phase	981	225	7230	15	Tannery Road	370	23	7410
5	Jayadeva Hospital	6348	4406	9172	14	Pottery Town	467	34	7843
6	Swagath Road Cross	776	444	9504	13	Cantonment Railway Station	308	24	8128
7	Dairy Circle	293	406	9391	12	Shivaji Nagar	869	68	8929
8	MICO Industries	210	64	9537	11	M G Road	2094	269	10754
9	Langford Town	195	494	9238	10	Vellara	340	144	10950
10	Vellara	187	311	9113	9	Langford Town	1038	135	11852
11	M G Road	259	2229	7143	8	MICO Industries	107	233	11726
12	Shivaji Nagar	75	1014	6203	7	Dairy Circle	285	75	11935
13	Cantonment Railway Station	47	274	5976	6	Swagath Road Cross	214	604	11545
14	Pottery Town	58	629	5405	5	Jayadeva Hospital	3113	9167	5491
15	Tannery Road	27	446	4985	4	J P Nagar IV Phase	206	508	5188
16	Venkateshpura	39	1037	3987	3	Indian Institute of Management (IIMB)	79	613	4654
17	Arabic College	0	1710	2278	2	Hulimavu	0	2792	1862
18	Nagavara	0	2278	0	1	Gottigere	0	1862	0

**PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2021- METRO PHASE  
II GOTTIGERE – IIMB – NAGAVARA LINE**

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading
1	Gottigere	6732	0	6732	18	Nagavara	4606	0	4606
2	Hulimavu	2885	0	9618	17	Arabic College	3030	15	7622
3	Indian Institute of Management, Bangalore (IIMB)	1744	357	11005	16	Venkateshpura	2278	22	9878
4	J P Nagar IV Phase	1668	382	12291	15	Tannery Road	570	36	10412
5	Jayadeva Hospital	1079	7491	15592	14	Pottery Town	719	52	11078
6	Swagath Road Cross	1320	754	16157	13	Cantonment Railway Station	475	37	11516
7	Dairy Circle	499	691	15965	12	Shivaji Nagar	1338	104	12750
8	MICO Industries	357	109	16213	11	M G Road	2225	414	14561
9	Langford Town	331	839	15704	10	Vellara	524	222	14862
10	Vellara	317	529	15492	9	Langford Town	1598	208	16252
11	M G Road	440	3790	12143	8	MICO Industries	167	366	16053
12	Shivaji Nagar	127	1724	10545	7	Dairy Circle	447	118	16381
13	Cantonment Railway Station	80	466	10159	6	Swagath Road Cross	336	948	15769
14	Pottery Town	99	1069	9188	5	Jayadeva Hospital	4187	12392	7564
15	Tannery Road	45	759	8475	4	J P Nagar IV Phase	323	798	7089
16	Venkateshpura	67	1763	6779	3	Indian Institute of Management (IIMB)	124	962	6251
17	Arabic College	0	2907	3872	2	Hulimavu	0	4384	1867
18	Nagavara	0	3872	0	1	Gottigere	0	1867	0

**PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2031- METRO PHASE  
II GOTTIGERE – IIMB – NAGAVARA LINE**

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading
1	Gottigere	9291	0	9291	18	Nagavara	6356	0	6356
2	Hulimavu	3982	0	13273	17	Arabic College	4182	20	10518
3	Indian Institute of Management, Bangalore (IIMB)	2407	492	15187	16	Venkateshpura	3143	30	13631
4	J P Nagar IV Phase	2301	527	16961	15	Tannery Road	786	49	14368
5	Jayadeva Hospital	14893	10337	21517	14	Pottery Town	992	72	15288
6	Swagath Road Cross	1821	1041	22297	13	Cantonment Railway Station	655	51	15892
7	Dairy Circle	688	953	22032	12	Shivaji Nagar	1846	144	17595
8	MICO Industries	492	151	22373	11	M G Road	3071	571	20094
9	Langford Town	457	1158	21672	10	Vellara	722	307	20510
10	Vellara	438	730	21380	9	Langford Town	2206	288	22428
11	M G Road	608	5230	16757	8	MICO Industries	231	506	22153
12	Shivaji Nagar	175	2380	14552	7	Dairy Circle	816	163	22806
13	Cantonment Railway Station	111	644	14019	6	Swagath Road Cross	464	1308	21961
14	Pottery Town	136	1476	12680	5	Jayadeva Hospital	5778	17101	10638
15	Tannery Road	63	1047	11696	4	J P Nagar IV Phase	445	1101	9983
16	Venkateshpura	92	2433	9354	3	Indian Institute of Management (IIMB)	171	1328	8825
17	Arabic College	0	4012	5343	2	Hulimavu	0	6049	2776
18	Nagavara	0	5343	0	1	Gottigere	0	2776	0

**PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2041- METRO PHASE  
II GOTTIGERE – IIMB – NAGAVARA LINE**

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading
1	Gottigere	10313	0	10313	18	Nagavara	7055	0	7055
2	Hulimavu	4420	0	14733	17	Arabic College	4642	23	11675
3	Indian Institute of Management, Bangalore (IIMB)	2671	546	16857	16	Venkateshpura	3489	34	15130
4	J P Nagar IV Phase	2554	585	18827	15	Tannery Road	873	55	15949
5	Jayadeva Hospital	16531	11475	23884	14	Pottery Town	1102	80	16970
6	Swagath Road Cross	2021	1155	24750	13	Cantonment Railway Station	727	57	17641
7	Dairy Circle	764	1058	24456	12	Shivaji Nagar	2049	160	19530
8	MICO Industries	546	167	24835	11	M G Road	3408	634	22305
9	Langford Town	507	1285	24056	10	Vellara	802	341	22766
10	Vellara	486	811	23731	9	Langford Town	2448	319	24895
11	M G Road	674	5806	18600	8	MICO Industries	256	561	24590
12	Shivaji Nagar	195	2641	16153	7	Dairy Circle	906	181	25315
13	Cantonment Railway Station	123	714	15562	6	Swagath Road Cross	515	1452	24377
14	Pottery Town	151	1638	14075	5	Jayadeva Hospital	6414	18982	11809
15	Tannery Road	69	1162	12982	4	J P Nagar IV Phase	494	1222	11081
16	Venkateshpura	102	2701	10383	3	Indian Institute of Management (IIMB)	190	1474	9796
17	Arabic College	0	4453	5930	2	Hulimavu	0	6715	3081
18	Nagavara	0	5930	0	1	Gottigere	0	3081	0



## Annexure 2.3.

**Trip length distribution –  
Bangalore Metro PHASE II GOTTIGERE – IIMB – NAGAVARA LINE  
Year – 2016**

Distance in kms.	Percent distribution	Metro Fare (Rs.)
0-2	7.00%	9.00
2-4	7.00%	12.00
4-6	8.00%	14.00
6-9	9.00%	18.00
9-12	16.00%	19.00
12-15	24.00%	21.00
15-18	12.00%	23.00
18-21	6.00%	25.00
21-24	4.00%	26.00
24-27	3.00%	27.00
27-31	1.00%	30.00
31-35	1.00%	32.00
35-39	1.00%	33.00
39-44	0.50%	34.00
>44	0.50%	36.00
Total	100.00%	

**CHAPTER-3**

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**PLANNING & DESIGN PARAMETERS**



## CHAPTER 3

### PLANNING AND DESIGN PARAMETRES

#### 3.0 GEOMETRIC 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.

#### 3.1 HORIZONTAL CURVES

On consideration of maximum allowable cant of 110 mm and cant deficiency of 85 mm on Metro tracks, the safe speed on curves of radii of 400 m or more is 80 km/h. On elevated section use of curves with minimum radius of 200 m, having speed of 55 km/h shall be adopted. There are, however, exceptional situations where due to site constraints; use of sharper curves is unavoidable. Under such situations sharp curves up to 120 m radius (safe speed of 40 km/h) have been adopted. However provision for restraining rails will have to be made to avoid derailment where curves of 120 m radius and sharper are unavoidable in the eventuality of exceeding desirable speed.

Indian Permanent Way Manual recommends the check rail on the curves as under:

- (a) Broad Gauge tracks radius sharper than 218.75 M ( $8^\circ$ )
- (b) On Meter Gauge tracks radius sharper than 125 M ( $14^\circ$ )

The check rail clearance recommended is 44 mm for Broad Gauge and 41 mm for Meter Gauge.

With the above clearances on Broad Gauge the back of the inner wheel will always come in contact of check rail and hence there will be wearing of outer rail as well as check rail and also back of the wheel. On review of literature available on Internet, it is found that no check rails on curves are recommended irrespective of radius. However, some of Railways have gone for restraining rail which is almost like check rail but with gap of more than 65 mm .which to be



calculated exactly based on gauge widening, allowable lateral rail wear and wheel flange wear. Even a book on derailments published by Indian Railway Institute for Civil Engineers, Pune provides for the restraining rails on sharp curves. Hence it is recommended for provision of restraining rail on curves 120 m radius and sharper.

For maximum permissible speed on curve with various radii table 3.1 may be referred.

Curve radius in mid section:

Under Ground Section

Minimum	:	300 m
Absolute Minimum	:	200 m

Elevated Section

Minimum	:	200 m
Absolute minimum	:	122.50 m

Minimum curve radius at stations	:	1000 m
Maximum permissible cant (Ca)	:	125 mm
Desirable Maximum cant (Ca)	:	110 mm
Maximum cant deficiency (Cd)	:	85 mm

### Transition curves

Due to undulating terrain of Bengaluru city it is necessary to provide frequent vertical curves along the alignment. The existing roads also have frequent curves. These constraints may lead to reduced lengths of transition curves. However for safety and comfort of passengers, the transition curves have to be designed with certain minimum parameters.

- Minimum length of Transitions of

Horizontal curves (m) : 0.44 times actual cant or cant deficiency (in mm), which ever is higher.

- Desirable : 0.72 times actual cant or cant deficiency, (in mm) which ever is higher

- No overlap is allowed between transition curves and vertical curves.

- Minimum straight between two

Transition curves : either 25 m or NIL.





- Minimum curve length between two transition curves : 25 m

## 3.2 VERTICAL ALIGNMENT

### 3.2.1 Elevated Sections

Track supporting structures on Elevated sections are to permit a vertical clearance of 5.5 m above road level. For meeting this requirement with the 'box girder' design the rail level shall be at least 9.8 m above the road level. With elevated concourse the rail level at stations shall be 12.5 m.

The track center on the elevated section is 3.7 m on straight stretches and increased on curves with a maximum of 4.2 m for curves with a radii of 120 m.

**Note by BMRCL:**

***The track center will have a uniform width of 4.20m for the entire stretch.***

### 3.2.2 Underground sections

Rail level at midsection in tunneling portion shall be kept at least 12.0 m below the ground level. At stations, the desirable depth of rail below ground level is 13.3 m, so that station concourse can be located above the platforms. This requirement has been kept in view while designing the vertical profile.

### 3.2.3 Gradients

Normally the stations shall be on level stretch. In limiting cases station may be on a grade of 0.1 %. Between stations, generally the grades may not be steeper than 2.0 %. However, there are a few situations, where steeper grades are unavoidable. These are:

- (i) Switch over ramp between underground and elevated sections where a grade up to 4% is adopted to minimise the length of ramp.
- (ii) Where existing road gradients are steeper than 2 % as the elevated section is kept parallel to road surface to minimise rail level (to reduce the pier heights).
  - Maximum gradient at stations : 0.1 %
  - Desirable gradient at stations : level



- Maximum gradient in mid section:

Normal	:	2.0 %
Exceptional	:	4.0 %

### 3.2.4 Vertical Curves

Vertical curves are to be provided when change in gradient exceeds 0.4%. However it is recommended to provide vertical curves at every change of gradient.

Minimum radius of vertical curves:

- On main line : 2500 m
- Other Locations : 1500 m
- Minimum length of vertical curve : 20 m

### 3.3 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.

**Table 3.1**  
**Cant, Permitted speed and Minimum Transition length for curves**

Radius	Speed	Actual Cant	Cant Deficiency	Permitted Speed	Minimum Transition
(m)	(km/h)	(mm)	(mm)	(kmph)	(m)
3000	80	15	10.36	80	10
2000	80	20	18.04	80	10
1000	80	40	36.03	80	20
800	80	50	45.12	80	25
500	80	80	72.19	80	40
400	80	110	85	80	50
300	80	110	85	70	50
200	80	110	85	55	50
150	80	110	85	45	50
120	80	110	85	40	50



### 3.4 PERMANENT WAY

#### 3.4.1 TRACK STRUCTURE

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

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.

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

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

#### 3.4.2 Rail Section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1080 Head Hardened as per IRS-T- 12-96. As these rails are not manufactured in India at present, these are to be imported. For the Depot lines, the grade of rails should be 880, which can be easily manufactured indigenously.

#### 3.4.3 Ballastless Track on Viaducts

On the viaducts, it is proposed to adopt plinth type ballastless track structure with RCC derailment guards integrated with the plinths (shown in **Fig. 3.1**). Further, it is proposed to adopt 336 Fastenings System (shown in **Fig. 3.2**) or any other



suitable system on both types of ballastless track structures, with a base-plate to base-plate spacing of generally 70 cm on viaducts and to be firmed up in detailed design stage, complying to the performance criterion laid down vide Railway board's letter No. 2009/Proj/MAS/9/2, dated 02.05.2010.

#### 3.4.4 Ballast less Track in Depot

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

- Discretely supported on concrete/steel pedestal for inspection lines.
- Embedded rail type inside the Workshop.
- Plinth type for Washing Plant line.
- Normal Ballast less (as on viaduct) for Washing lines, Stabling and other running lines.

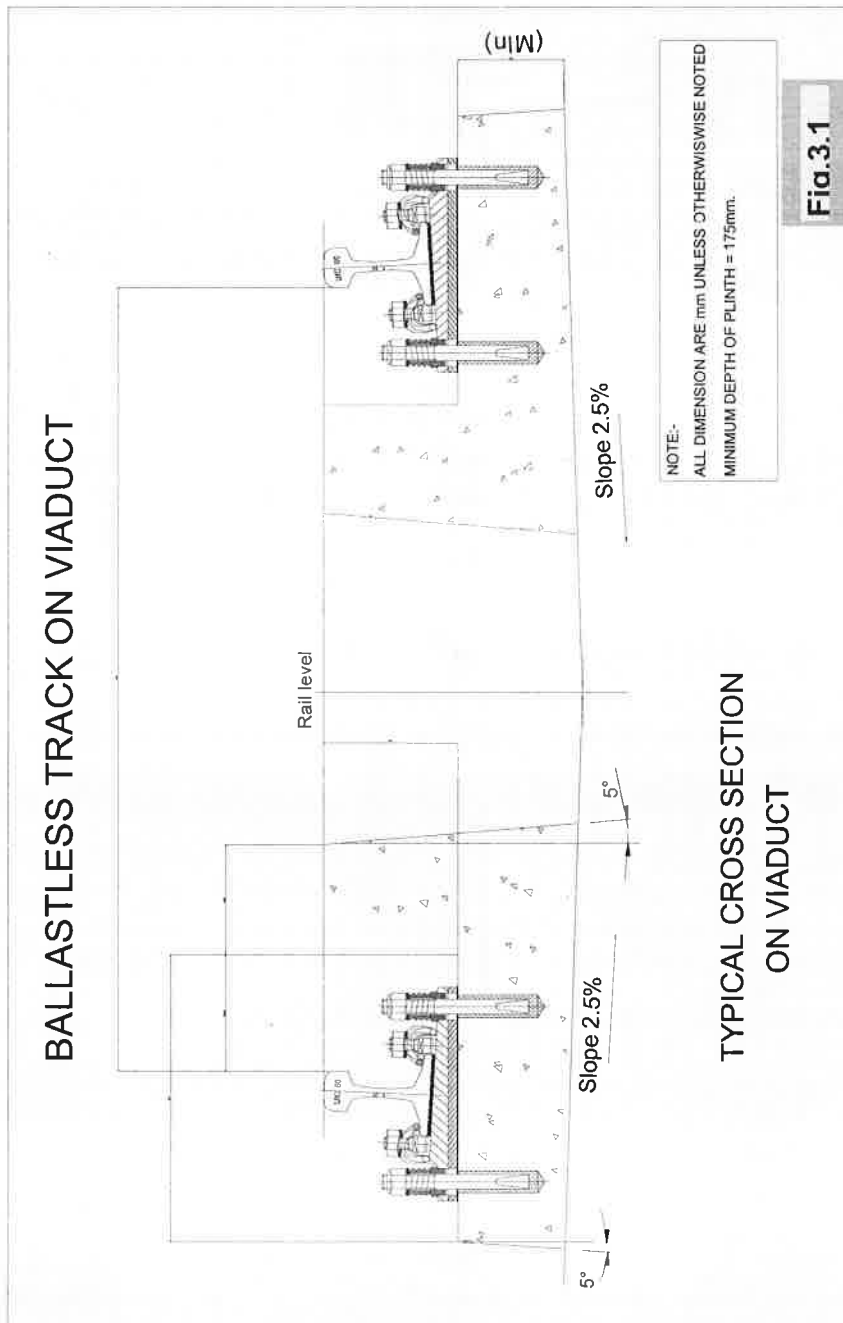
#### 3.4.5 Turnouts

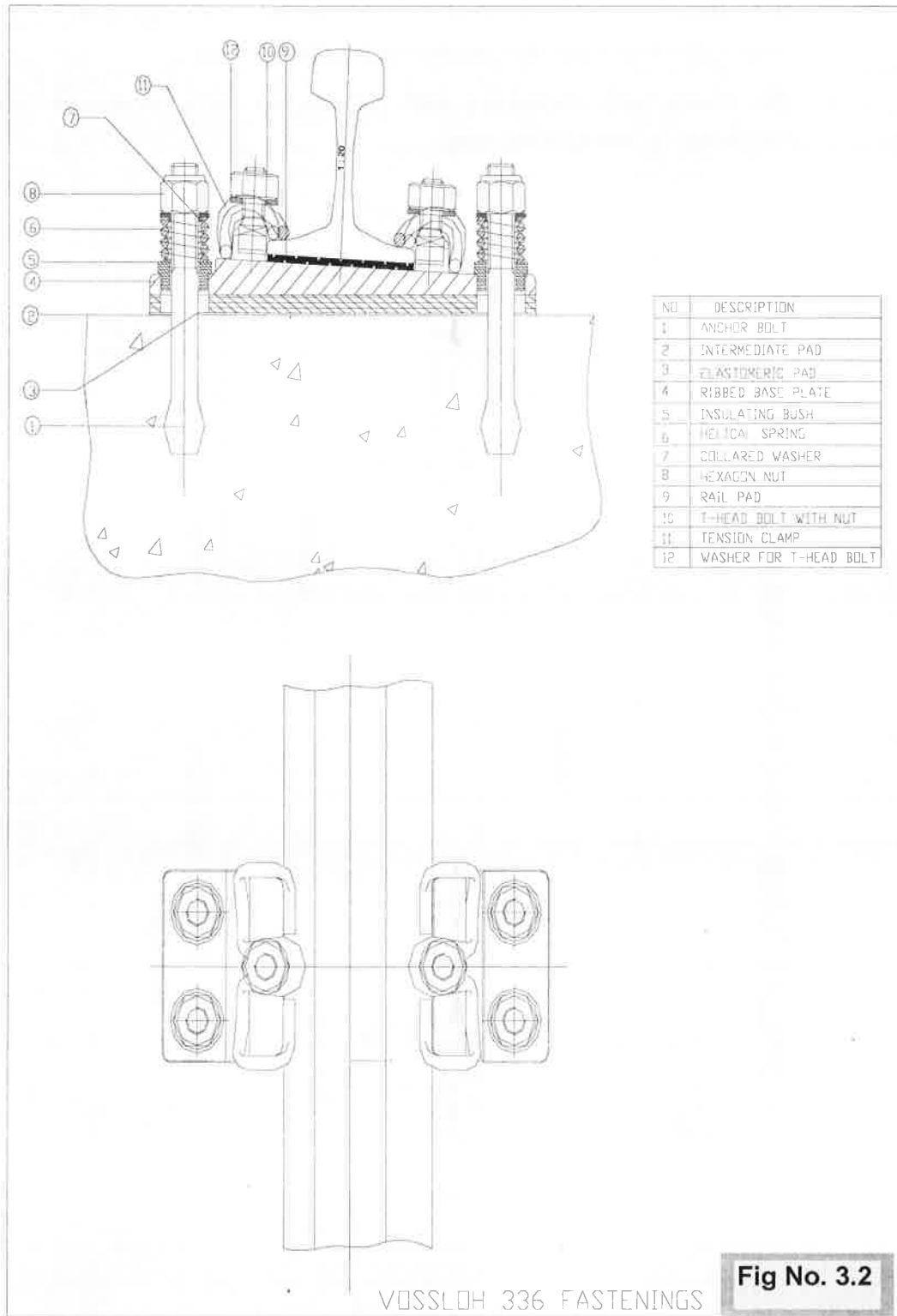
- From considerations of maintainability and riding comfort, it is proposed to lay the turnouts also with 1 in 20 cant. Further, it is proposed to adopt the following two types of turnouts:
  - i) On main lines, 1 in 9 type turnout with a lead radius of 300 metres and permissible speed on divergent track as 40 km/h (shown in **Fig.3.3**).
  - ii) On Depot lines, 1 in 7 type turnout with a lead radius of 140 metres and permissible speed on divergent track as 25 km/h (shown in **Fig.3.4**). However, at design stage radius of 190 meters with speed of 40 km/h may be examined.
- The Scissors cross-overs on Main Lines (1 in 9 type) will be with a minimum track centre of 4.5 m (shown in **Fig.3.5**).
- The proposed specifications for turnouts are given below: -
  - i) The turnouts should have fan-shaped layout throughout the turnout so as to have same sleepers/base-plates and slide chairs for both LH and RH turnouts.
  - ii) The switches and crossings should be interchangeable between ballasted and ballastless turnouts (if required).
- The switch rail should be with thick web sections, having forged end near heel of switch for easy connection with lead rails, behind the heel of switch. The



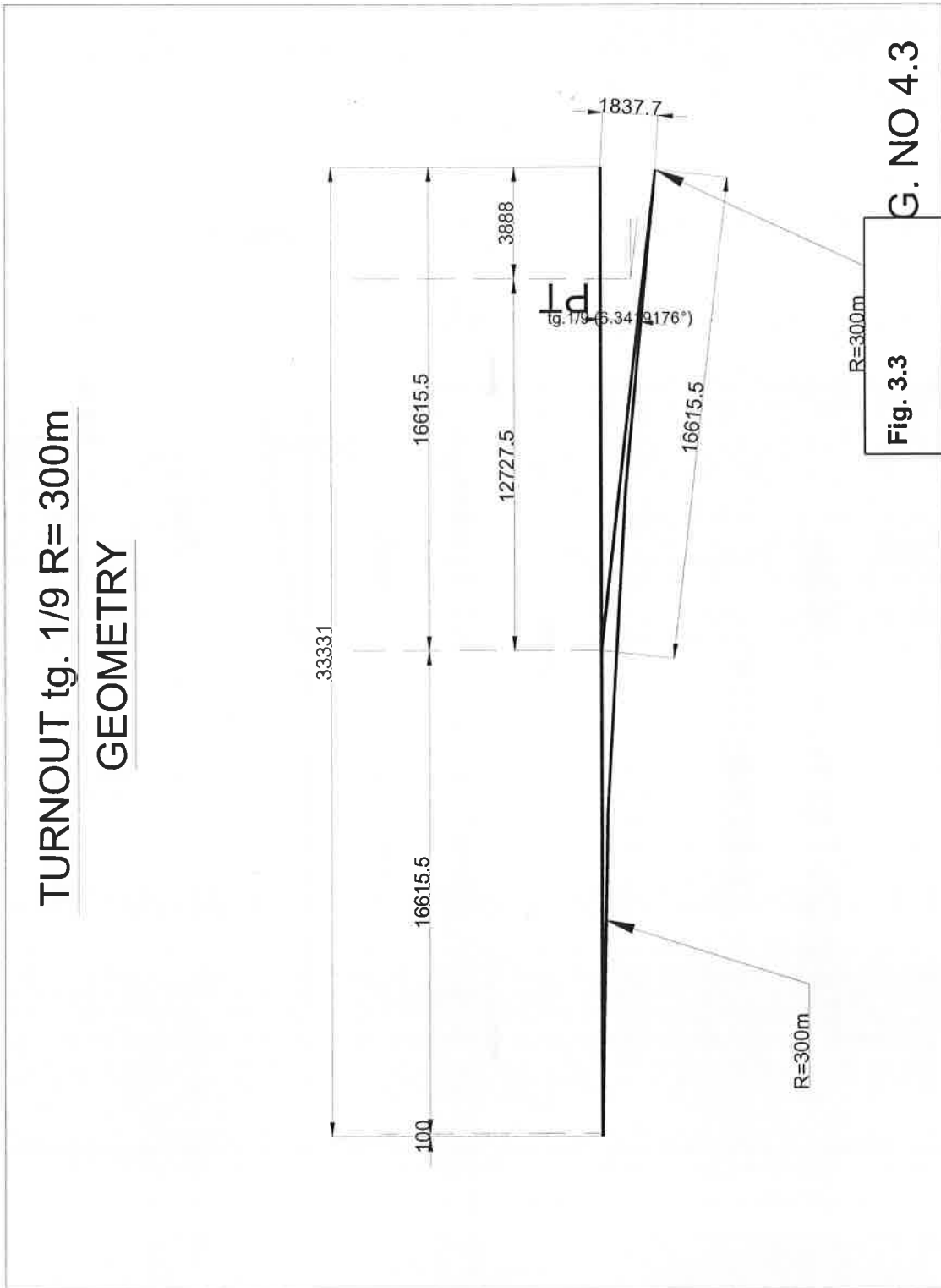
switches should have anti creep device at heel of switch for minimizing the additional LWR forces transmitted from tongue rail to stock rail.

- The crossings should be made of cast manganese steel and with welded leg extensions. These crossings should be explosive hardened type for main lines and without surface hardening for Depot lines.
- The check rails should be with UIC-33 rail section without being directly connected to the running rails.





**Fig No. 3.2**





TURNOUT tg 140 m = 400m

GEOMETRY

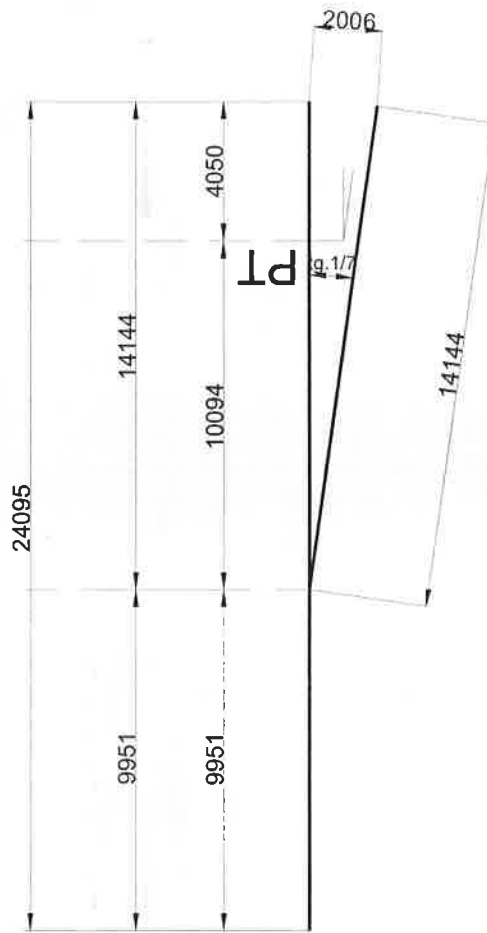


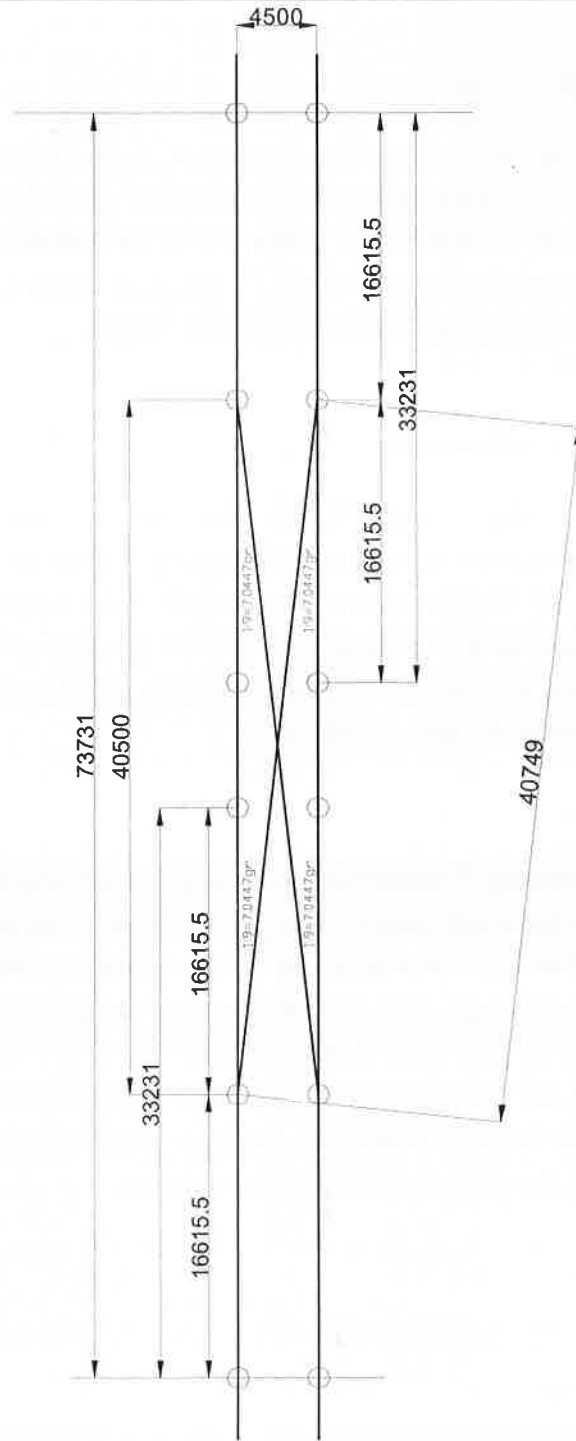
Fig No. 3.4





**DOUBLE CROSSOVER tg. 1/9 R= 300m C.L. 4500**

**AXLE SCHEME**



**Fig No.3.5**



### 3.4.6 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.

### 3.4.7 Rail Structure Interaction

For continuing the LWR/CWR on Viaducts, the elevated structures are to be adequately designed for the additional longitudinal forces likely to be transmitted as a result of Rail-Structure interaction. Rail structure interaction study will determine the need and locations of Rail Expansion Joints (REJ) also. REJ in ballasted track will be for a maximum gap of 120 mm, whereas on ballastless track for a maximum gap of 180 mm.

### 3.4.8 Welding

Flash Butt Welding Technique is to be used for welding of rails. Aluminothermy 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. For special track layouts such as turnouts and scissors cross overs, use of frozen rail joints are recommended to facilitate replacement and to avoid cutting of prefabricated specials in case of weld failures.

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**CHAPTER-4**

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**CIVIL ENGINEERING WORKS**



## CHAPTER 4

# CIVIL ENGINEERING WORKS

### 4.1 DESCRIPTION OF ALIGNMENT:

The proposed line starts from Gottigere in south and will be upto Nagavara in North. The Corridor traverses via Hulimavu, IIMB, J P Nagar-IV Phase, Jayadeva Hospital, Swagath Road Cross, Dairy Circle, MICO Industries on Bannerghatta road, Langford Town, Vellara on Hosur road, Brigade road, Kamaraj road, Infantry road, Central Street, Shivaji Nagar, Cantonment Railway Station, Millers road, Pottery Town, Tannery road and terminates at Nagavara. The length from Gottigere to short of Dairy Circle is Elevated and the stretch beyond, that is, from short of Dairy Circle to Nagavara is underground.

#### 4.1.1 ROUTE

Starting from Gottigere between Jigini area and IIMB as an Elevated Metro Rail, the 2<sup>nd</sup> N-S line passes through Hulimavu Station and traverses on the median of Bannerghatta road in front of IIMB where IIMB Metro Station is located. This serves the vast area around which has developed and is further developing with a number of world class Hospitals and Institutions with High rise apartments. From IIMB the line traverses mostly on Bannerghatta road median enveloping the J P Nagar, BTM Layouts and a large number of IT/BT centers and Trade Centres. Continuing as Elevated Metro Rail the alignment has to cross the road flyover on Marenahalli (South End) Road at higher level in the vicinity of Jayadeva Hospital where Jayadeva Hospital Metro Station is located. Here the alignment crosses the proposed R V Road – Electronic City – Bommasandra Metro Line at a higher level and continues on the median of Bannerghatta road on to Swagath Road Cross Metro Rail Station and further proceeds towards Dairy Circle flyover. Short of this flyover the alignment is taken to the underground on a ramp from the Fire Brigade area on the left side of Bannerghatta road. The Dairy Circle flyover is crossed in the underground suitably and then the Metro alignment continues further on, as underground line only in the entire stretch up to the end at Nagavara. Dairy Circle Station is located opposite to the Bangalore Dairy as an underground Station after



crossing the Dairy Circle flyover. The underground alignment continues grazing the side of MICO Industries and crossing the big drain and on a curve taken on to the right turn followed by left turn and grazing the grave yard and reaches to the under side of Hosur road between the Military area and built up area of Missionaries and Schools/Colleges. From here the alignment traverses almost below the Hosur road crossing Richmond road at Vellara. After this the alignment traverses below Brigade road and crosses the M G Road underneath the Phase-I East-West Metro Rail line where a 50 M span is available on the Phase-I E-W line to reach Kamaraj road. Here the underground M. G. Road Integrated Station is planned which is about 50M from the Platform edge of existing Elevated M G Road Station of BM Phase-I and is connected through Escalators & Stairs. The proposed City Airport Terminal (CAT) of HSRL at Police Grounds which is about 650M from this proposed M. G. Road Station which can be connected through shuttle Bus service. After M. G. Road station, the underground alignment crosses Cubbon road and takes a swift oblique left turn & traverses below barracks & buildings of Defence land and by the side of Infantry road and turns right to reach the Shivaji Nagar Bus-stand area. Here the Shivaji Nagar Metro Rail Station is planned in the open ground (Shivaji Nagar Stadium) behind the existing Shivaji Nagar Bus-stand and is integrated with it. Further the alignment traverses below the built up areas by the side of Queens Road and cuts across the Queens Road and then turns right to reach the front side car parking area of Bangalore Cantonment Railway Station. Here the Cantonment Railway Metro Station is planned. This station is integrated with the Bangalore Cantonment Railway Station. From here the alignment crosses below the Cantonment Railway Station area on to the Millers road, Nandi Durg road and traverses below Benson Town area and reach Pottery Town open ground area. Here the Pottery Town underground Station is planned (This station will be connected to the Netaji road through suitable under pass below the SWR line to provide access to the surrounding Frazer town areas). From here the underground alignment turns left to reach below the Tannery road and continues almost below the Tannery road and crosses the Salem Railway line and then Outer Ring Road (ORR) to reach the last Station of this line namely Nagavara, which is located immediately after the crossing of the ORR. The route length is 21.255 km (up to dead end) and there are 18 (06 Elevated + 12 Underground) Stations in this 2nd N-S line of Phase-II. Provision has been kept to extend the line later beyond Nagavara as Elevated line to which ever side it is required as the city is growing in these parts.



#### **4.1.2 REFERENCE POINT**

The dead end at Gottigere has been taken as 0.0 km for reckoning of chainage on Gottigere - IIMB - Nagavara line. Chainage increases from Gottigere to Nagavara.

#### **4.1.3 REFERENCE LINE**

Line from Gottigere station to Nagavara Terminal station has been named 'Up Line' and from Nagavara Terminal to Gottigere Station has been named as 'Down Line'.

**4.1.4** Index Plan showing the alignment of Gottigere Metro station to Dead end of Nagavara Terminal Metro station is given at **Figure 4.1**.

#### **4.1.5 ALIGNMENT PLANNING AND DESIGN NORMS**

The alignment of this line from Gottigere to short of Dairy Circle on Bannerghatta road is elevated, where as the underground is from short of Dairy Circle on Bannerghatta road to the end, i.e. Nagavara is underground. As the work on the Phase-I of the project viz., all the elevated stretches and the E-W underground line have been already started, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc are finalized and it is proposed to continue with the same for this Gottigere - IIMB - Nagavara line, except for the traction system which is proposed as 25 KV OHE system instead of third rail. 18 – Stations (06 Elevated & 12 Underground) are planned on this line.

#### **4.1.6 TERMINAL STATION**

It is proposed to plan elevated terminal station at south end that is Gottigere and Underground Terminal Station that is Nagavara, being last stations on this corridor. At the end of these stations, the train reversal facilities are proposed by providing cross-over and dead end. The C/L of the Gottigere station is at chainage 0.411 km, whereas the Dead End is at chainage 0.00km and C/L of Nagavara Station is at Chainage 20.995 km, whereas the Dead End of this phase is at Chainage 21.255 Km.



#### 4.1.7 HORIZONTAL ALIGNMENT

The alignment of this line from Gottigere to short of Dairy Circle (Chainage 6958) on Bannerghatta road is elevated, where as the underground is between Chainage 7465 on Bannerghatta road to Chainage 21255. From Ch.6958 to 7465 ramp has been proposed. As the work on the Phase-I of the project viz., all the elevated stretches and E-W underground line have already been started, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc are finalized and it is proposed to continue with the same, except for the traction system which is proposed as 25 KV OHE systems instead of third rail.

For planning convenience and narrative purpose, the extreme end of the line i.e. about 340M beyond Gottigere Terminal Station has been referred as Gottigere Dead end.

The line starting from Gottigere Terminal Station dead end continues to be on the median of the Bannerghatta road up to short of Jayadeva Hospital junction flyover. At this point the alignment is taken to LHS parallel to LHS retaining wall of the Jayadeva junction underpass/fly over and turns back to the median of the Bannerghatta road after crossing the Jayadeva junction underpass and continues to be on the median of the road till approx chainage 6500. Here it is taken slightly towards left just inside the Fire Brigade compound where the elevated alignment ramps down and becomes fully underground at approx chainage 7465. From here the alignment traverses almost below the Bannerghatta road as underground and turns towards left and traverses below the Hosur road in front of Military area and then onto Vellara junction. The line after crossing vellara junction traverses below the Brigade road and crosses the Phase-I elevated line on M G Road and traverses below the Kamaraj road where the underground integrated station with the BM Phase-I M G Road elevated station is planned. This station also serves as the integrated Station with City Air Terminal (CAT) on Police Grounds of High Speed Rail Link (HSRL) to Bangalore International Airport which is about 650 M away. After M. G. Road station, the underground alignment crosses Cubbon road and takes a swift oblique left turn & traverses below barracks & buildings of Defence land and by the side of Infantry road and turns right to reach the Shivaji Nagar Bus-stand area. Here the Shivaji Nagar Metro Rail Station is planned in the open ground (Shivaji Nagar Stadium) behind the existing Shivaji Nagar Bus-stand and is integrated with it. Further the alignment traverses



below the built up areas by the side of Queens Road and cuts across the Queens Road and then turns right to reach the front side car parking area of Bangalore Cantonment Railway Station. Here the Cantonment Railway Metro Station is planned. This station is integrated with the Bangalore Cantonment Railway Station. From here the alignment crosses below the Cantonment Railway Station area on to the Millers road, Nandi Durg road and traverses below Benson Town area and reach Pottery Town open ground area. Here the Pottery Town underground Station is planned (This station will be connected to the Netaji road through suitable under pass below the SWR line to provide access to the surrounding Frazer town areas). From here the underground alignment turns left to reach below the Tannery road and continues almost below the Tannery road and crosses the Salem Railway line and then Outer Ring Road (ORR) to reach the last Station of this line namely Nagavara, which is located immediately after the crossing of the ORR. The route length is 21.255 km (up to dead end) and there are 18 (06 Elevated + 12 Underground) Stations in this 2<sup>nd</sup> N-S line of Phase-II. Provision has been kept to extend the line later beyond Nagavara as Elevated line to which ever side it is required as the city is growing in these parts.

There are eighteen (18) stations on this Phase – 2<sup>nd</sup> N-S line as follows:-

Gottigere (Ch.411), Hulimavu (Ch.1484.50), IIMB (Indian Institute of Management) [Ch.3204], J P Nagar-IV Phase (Ch.4575), Jayadeva Hospital (interchange with proposed R V Road–Electronic City–Bommasandra line) [Ch.5414], Swagath Road Cross (Ch.6777), Bangalore Dairy (Ch.7929), MICO Industries (Ch.8961), Langford Town (Ch.9880.40), Vellara (Ch.10884), M. G. Road (interchange with M G road elevated Station of BM Ph-I) [Ch.12020], Shivaji Nagar (Ch.13241), Cantonment Railway Station (Ch.14405), Pottery Town (Ch.16023), Tannery road (Ch.17182), Venkateshpura (Ch.18168), Arabic College (Ch.19592 ) and Nagavara (Ch.20995).

This Ph-II N-S line is partly elevated from Gottigere to Swagath Road cross Station. After this Station ramp from elevated to underground is proposed between Ch.6958 to 7465 at the fringe of Fire Brigade & west side carriage way of Bannerghatta road. From Ch.7465 to Ch.21255 the alignment will be fully underground. Again future ramp is planned from Ch.21255 to Ch. 21702 at the end after the Nagavara underground Metro Station.





## 4.1.8 VERTICAL ALIGNMENT

### 4.1.8.1 Elevated Sections

Track supporting structures on Elevated sections are to permit a vertical clearance of 5.5 m above road level. For meeting this requirement with the 'box girder' design the rail level shall be at least 9.8 m above the road level. With elevated concourse the rail level at stations shall be 12.5 m.

The track center on the elevated section is 3.7 m on straight stretches and increased on curves with a maximum of 4.2 m for curves with a radii of 120 m.

### 4.1.8.2 Underground Sections

Rail level at midsection in tunneling portion shall be kept at least 12.0 m below the ground level. At stations, the desirable depth of rail below ground level is 13.3 m, so that station concourse can be located above the platforms. This requirement has been kept in view while designing the vertical profile.

## 4.2 CURVES

Total number of 62 horizontal curves has been provided up to Nagavara. The radius of curves varies from 125m to 8000 m. Hence, the sharpest curve is 125 m. A statement of curves is given at Table 4.1

**TABLE 4.1 STATEMENT OF CURVES**  
2<sup>nd</sup> North – South Phase-II Line (Gottigere - IIMB - Nagavara)

Curve No.	Direction of Curve	Radius (m)	Deflection Angle			Transiti on Length (m)		Circular Curve Length	Total Curve Length (m)	Straight between
			D	M	S	L1	L2			
1	Left	1200	9	42	11	25	25	178.222	228.222	....
2	Right	1800	1	43	8	20	20	33.998	73.998	46.964
3	Left	3000	1	15	8	10	10	55.567	75.567	253.885
4	Right	1200	2	10	49	25	25	20.663	70.663	715.359
5	Right	800	9	14	23	40	40	89.013	169.013	31.246
6	Right	3000	0	49	18	10	10	33.016	53.016	128.847
7	Left	1250	9	52	25	25	25	190.408	240.408	149.566
8	Right	2000	2	21	27	15	15	67.291	97.291	26.204
9	Right	1500	2	24	34	25	25	38.081	88.081	122.677



10	Right	2000	2	20	54	25	25	56.971	106.971	132.407
11	Left	400	12	58	35	55	55	35.592	145.592	92.59
12	Right	700	7	59	3	35	35	62.545	132.545	93.46
13	Left	125	52	52	41	55	55	60.362	170.362	242.192
14	Right	175	34	7	15	55	55	49.217	159.217	107.28
15	Right	6500	0	19	24	10	10	26.681	46.681	454.834
16	Right	900	4	4	3	30	30	33.891	93.891	112.82
17	Right	1000	8	32	42	25	25	124.136	174.136	366.574
18	Left	6500	0	32	54	10	10	52.198	72.198	80.21
19	Left	800	4	27	57	30	30	32.353	92.353	127.693
20	Left	6000	0	32	59	10	10	47.565	67.565	269.075
21	Left	1500	2	56	18	25	25	51.928	101.928	153.919
22	Right	2550	1	9	35	25	25	26.616	76.616	98.08
23	Right	1200	10	51	23	25	25	202.374	252.374	44.363
24	Right	4000	0	33	31	10	10	29.006	49.006	377.102
25	Right	8000	10	47	31	10	10	100.587	120.587	30.567
26	Left	1000	3	44	50	25	25	40.402	90.402	138.065
27	Right	2000	2	22	29	15	15	67.897	97.897	173.547
28	Left	360	13	59	31	55	55	32.913	142.913	73.289
29	Left	578	9	41	29	40	40	57.768	137.768	0.003
30	Right	800	6	54	38	35	35	61.49	131.49	0.301
31	Right	350	25	45	3	55	55	102.302	212.302	34.191
32	Left	1500	2	29	24	25	25	40.19	90.19	105.979
33	Right	540	9	52	16	40	40	53.033	133.033	43.857
34	Left	550	8	2	58	40	40	37.27	117.27	200.292
35	Left	650	9	32	12	35	35	73.191	143.191	27.01
36	Left	1300	8	53	11	20	20	181.629	221.629	638.145
37	Left	1100	8	5	57	20	20	135.491	175.491	27.292
38	Right	1225	22	17	55	25	25	451.748	501.748	197.405
39	Right	1000	3	39	37	25	25	38.884	88.884	361.209
40	Left	250	89	22	15	55	55	334.954	444.954	159.564



41	Right	300	33	59	0	55	55	122.936	232.936	212.912
42	Right	250	54	49	53	55	55	184.247	294.247	982.729
43	Right	500	61	8	31	40	40	493.565	573.565	307.26
44	Left	300	38	44	24	55	55	147.843	257.843	435.454
45	Left	300	37	57	17	55	55	143.73	253.73	530.425
46	Right	300	39	59	52	55	55	154.428	264.428	197.938
47	Left	600	23	45	10	40	40	208.739	288.739	263.853
48	Right	900	4	14	45	30	30	36.695	96.695	70.995
49	Left	900	5	2	42	35	35	44.246	114.246	116.436
50	Left	950	11	40	47	35	35	158.657	228.657	257.569
51	Left	3000	0	51	47	10	10	35.189	55.189	356.795
52	Right	1500	2	32	11	25	25	41.406	91.406	86.447
53	Right	1400	10	23	54	25	25	229.079	279.079	33.097
54	Right	4000	1	6	35	10	10	67.479	87.479	174.198
55	Right	1000	6	14	15	25	25	83.866	133.866	96.918
56	Left	810	14	59	36	35	35	176.963	246.963	129.256
57	Left	800	4	58	32	30	30	39.472	99.472	0.935
58	Right	600	16	35	10	40	40	133.689	213.689	64.504
59	Left	2000	2	29	37	20	20	67.047	107.047	33.84
60	Right	440	22	48	16	55	55	120.125	230.125	263.716
61	Left	550	10	57	34	40	40	65.204	145.204	75.743
62	Left	800	5	21	25	30	30	44.797	104.797	417.738

### 4.3 GRADIENTS

SL.NO	Description	Nos. of occurrence	Length	%age
1	Level (0%)	18	6912.290	29.51%
2	0% $\geq$ 1%	14	4085.000	22.95%
3	> 1.0% to 2.0 %	10	2757.000	16.39%
4	>2% to 3%	11	4210.547	18.03%
5	>3% TO 4%	8	3279.800	13.11%
		61	21244.637	100.00%



The detail statement of gradients of Gottigere - IIMB - Nagavara Corridor is placed in tables 4.2

**Table 4.2**  
**STATEMENT OF GRADIENTS**

S. No.	Chainage		Rail Levels	Gradient		Remarks	
	From	To		From	To		
1	0.000	680.200	680.200	933.900	933.900	0.000%	Level
2	680.200	1260.000	579.800	933.900	916.500	-3.001%	Fall
3	1260.000	1375.000	115.000	916.500	915.500	-0.870%	Fall
4	1375.000	1605.000	230.000	915.500	915.500	0.000%	Level
5	1605.000	2010.000	405.000	915.500	923.300	1.926%	Rise
6	2010.000	2320.000	310.000	923.300	915.100	-2.645%	Fall
7	2320.000	2575.000	255.000	915.100	910.300	-1.882%	Fall
8	2575.000	2875.000	300.000	910.300	907.800	-0.833%	Fall
9	2875.000	3080.000	205.000	907.800	907.700	-0.049%	Fall
10	3080.000	3404.090	324.090	907.700	907.700	0.000%	Level
11	3404.090	3760.000	355.910	907.700	899.300	-2.360%	Fall
12	3760.000	4430.000	670.000	899.300	914.100	2.209%	Rise
13	4430.000	4710.000	280.000	914.100	914.100	0.000%	Level
14	4710.000	5041.000	331.000	914.100	916.300	0.665%	Rise
15	5041.000	5290.000	249.000	916.300	918.400	0.843%	Rise
16	5290.000	5550.000	260.000	918.400	918.400	0.000%	Level
17	5550.000	6075.000	525.000	918.400	903.000	-2.933%	Fall
18	6075.000	6375.000	300.000	903.000	903.600	0.200%	Rise
19	6375.000	6545.000	170.000	903.600	905.800	1.294%	Rise
20	6545.000	6910.000	365.000	905.800	905.800	0.000%	Level
21	6910.000	7400.000	490.000	905.800	889.236	-3.380%	Fall
22	7400.000	7750.000	350.000	889.236	878.400	-3.096%	Fall
23	7750.000	8095.000	345.000	878.400	878.400	0.000%	Level
24	8095.000	8428.000	333.000	878.400	874.500	-1.171%	Fall
25	8428.000	8775.000	347.000	874.500	871.800	-0.778%	Fall
26	8775.000	9185.000	410.000	871.800	871.800	0.000%	Level
27	9185.000	9410.000	225.000	871.800	876.000	1.867%	Rise
28	9410.000	9675.000	265.000	876.000	883.500	2.830%	Rise
29	9675.000	10050.000	375.000	883.500	883.500	0.000%	Level
30	10050.000	10475.000	425.000	883.500	892.200	2.047%	Rise
31	10475.000	10710.000	235.000	892.200	893.000	0.340%	Rise
32	10710.000	11075.000	365.000	893.000	893.000	0.000%	Level



33	11075.000	11410.000	335.000	893.000	882.900	-3.015%	<b>Fall</b>
34	11410.000	11820.000	410.000	882.900	896.400	3.293%	<b>Rise</b>
35	11820.000	12210.000	390.000	896.400	896.400	0.000%	<b>Level</b>
36	12210.000	12460.000	250.000	896.400	895.500	-0.360%	<b>Fall</b>
37	12460.000	12650.000	190.000	895.500	898.500	1.579%	<b>Rise</b>
38	12650.000	12860.000	210.000	898.500	891.500	-3.333%	<b>Fall</b>
39	12860.000	13084.000	224.000	891.500	891.800	0.134%	<b>Rise</b>
40	13084.000	13399.000	315.000	891.800	891.800	0.000%	<b>Level</b>
41	13399.000	13720.000	321.000	891.800	885.900	-1.838%	<b>Fall</b>
42	13720.000	14190.000	470.000	885.900	894.200	1.766%	<b>Rise</b>
43	14190.000	14660.000	470.000	894.200	894.200	0.000%	<b>Level</b>
44	14660.000	14973.000	313.000	894.200	896.014	0.579%	<b>Rise</b>
45	14973.000	15200.000	227.000	896.014	889.500	-2.869%	<b>Fall</b>
46	15200.000	15863.000	663.000	889.500	887.900	-0.241%	<b>Fall</b>
47	15863.000	16340.000	477.000	887.900	887.900	0.000%	<b>Level</b>
48	16340.000	16680.000	340.000	887.900	899.300	3.353%	<b>Rise</b>
49	16680.000	16953.000	273.000	899.300	901.800	0.916%	<b>Rise</b>
50	16953.000	17430.000	477.000	901.800	901.800	0.000%	<b>Level</b>
51	17430.000	17685.000	255.000	901.800	897.700	-1.608%	<b>Fall</b>
52	17685.000	17994.000	309.000	897.700	894.200	-1.133%	<b>Fall</b>
53	17994.000	18368.000	374.000	894.200	894.200	0.000%	<b>Level</b>
54	18368.000	18818.000	450.000	894.200	882.200	-2.667%	<b>Fall</b>
55	18818.000	19074.000	256.000	882.200	875.100	-2.773%	<b>Fall</b>
56	19074.000	19368.000	294.000	875.100	871.900	-1.088%	<b>Fall</b>
57	19368.000	19738.000	370.000	871.900	871.900	0.000%	<b>Level</b>
58	19738.000	20018.000	280.000	871.900	874.300	0.857%	<b>Rise</b>
59	20018.000	20444.000	426.000	874.300	874.100	-0.047%	<b>Fall</b>
60	20444.000	20773.000	329.000	874.100	867.300	-2.067%	<b>Fall</b>
61	20773.000	21178.000	405.000	867.300	867.300	0.000%	<b>Level</b>
62	21178.000	21743.000	565.000	867.300	887.854	3.638%	<b>Rise</b>
63	21743.000	22140.637	397.637	887.854	896.000	2.049%	<b>Rise</b>

4.3.1 Detailed Alignment Plans is given in Drawing No. Phase-II/N-S (Gottigere - IIMB – Nagavara)/AL/GAD line/2010 (Sheet No. 1 – 45).

#### 4.4 LAND

4.4.1 As the Metro alignment has to be planned on set standards and parameters, apart from alignment the various structures like stations, parking facilities, traction sub stations, communication towers, etc. require large plots of land.



The land being scarce, costly and acquisition being complex process, the alignment is so planned that 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
- Radio Towers
- Property Development.

#### 4. 4.2 Break-up of Land requirement

##### Option 1 (With Hulimavu Depot):

The total land requirement is 48.26 Ha, of which 33.10 Ha Private Land and 15.16 Ha Govt land.

##### Option 2 (With Kothanur Depot):

The total land requirement is 50.26 Ha, of which 49.46 Ha Private Land and 0.80 Ha Govt land.

In the Draft DPR submitted, the proposed depot was in the Hulimavu area. BMRCL vide letter dt.02-09-11 & 20-09-11 had insisted to change the depot area stating that the Hulimavu area is on tank bed. However, no suitable Govt land could be identified for locating this depot and a private land could only be located for this purpose which will be costlier by more than Rs.550 Crores as compared to Option 1. It is seen that the Govt Order regarding Hulimavu tank bed i.e. No.PWD 82 IMB 85 dt 11-02-1988 recommended for "Foreshore Planting, water sheet to be retained" by forest department. However, in spite of this order, nothing has happened since 1988. As of now there are sizable unauthorized encroachments in this tank bed area and is dirty and has become a breeding space for mosquitoes and hence health hazard. If this area is developed as a depot, the whole area will get a face lift with proper landscaping and open area in this locality. In addition the extra cost of more than Rs.550 Crores for acquisition of Pvt lands will be saved. Therefore it is recommended that the depot of Hulimavu area is confirmed after getting proper Governments clearance.

**Note By BMRCL:**



**The proposal to have depot at Hulimavu tank bed is noted and it is found not possible to get Government clearance for this proposal. Hence it is decided to go for the second option and acquire private land measuring 15.16ha and 0.8 ha of Govt. land located behind Meenakshi temple on Bannerghatta road for location of depot.**

Section-wise land requirement is given at table 4.3

**Table 4.3  
LAND REQUIREMENT & OWNERSHIP**

Sl No	Location	Chainage		Area in (Sqm)			
		From	To	Alignment		Station	
				Private (on Permanent Acqn)	Govt (on Permanent Acqn)	Private (on Permanent acqn)	Pvt on Temporary acquisition
<b>Gottigere - IIM (B) - Nagavara</b>							
<b>I</b>	<b>Alignment (excluding Stations)</b>						
1	Alignment	0	1000	54.75	0	-	-
2	Alignment	1000	2000	0	0	-	-
3	Alignment	2000	3000	0	0	-	-
4	Alignment	3000	4000	0	0	-	-
5	Alignment	4000	5000	0	0	-	-
6	Alignment	5000	6000	5744.02	0	-	-
7	Alignment	6000	7000	5645.81	0	-	-
8	Alignment	7000	8000	930.07	0	-	-
9	Alignment	8000	9000	0	0	-	-
10	Alignment	9000	10000	0	0	-	-
11	Alignment	10000	11000	0	0	-	-
12	Alignment	11000	12000	0	0	-	-
13	Alignment	12000	13000	0	0	-	-
14	Alignment	13000	14000	0	0	-	-
15	Alignment	14000	15000	0	0	-	-
16	Alignment	15000	16000	0	0	-	-
17	Alignment	16000	17000	0	0	-	-
18	Alignment	17000	18000	0	0	-	-
19	Alignment	18000	19000	0	0	-	-
20	Alignment	19000	20000	0	0	-	-
21	Alignment	20000	21000	0	0	-	-
22	Alignment	21000	21255	105.20	0	-	-
<b>Total</b>				<b>12479.9</b>	<b>0</b>	<b>-</b>	<b>-</b>
<b>II</b>	<b>Stations</b>						



1	Gottigere			-	-	2539.00	0
2	Hulimavu			-	-	3237.00	0
3	IIMB			-	-	2568.00	0
4	J P Nagar - IV Phase			-	-	1832.00	0
5	Jayadeva Hospital			-	-	3149.00	0
6	Swagath Road Cross			-	-	2766.00	0
7	Dairy Circle			-	-	200.00	5129.21
8	MICO Factory			-	-	200.00	6206.48
9	Langford Town			-	-	200.00	7805.97
10	Vellara			-	-	200.00	6443.11
11	Kamaraj Road			-	-	200.00	4543.06
12	Shivaji Nagar			-	-	200.00	10781.33
13	Cantonment Railway Station			-	-	200.00	11769.88
14	Pottery Town			-	-	200.00	8533.55
15	Tannery Road			-	-	200.00	6893.91
16	Venkateshpura			-	-	200.00	7072.77
17	Arabic College			-	-	200.00	7913.73
18	Nagavara			-	-	200.00	6958.24
	For Construction Depots						200000
	<b>Total</b>			-	-	<b>18491.00</b>	<b>290051.24</b>

Land for Car Maintenance depot = 15.16 Ha (Govt Land) {Option 1}, Hulimavu /  
17.16 Ha {(0.80 Ha Govt + 14.36 Ha Pvt) for depot + 2 Ha Pvt for approach}

Land for RSS = 1.0 Ha

4.4.3 Land Plans will be submitted separately along with DPR.

4.4.4 The important locations and reference points along the corridor is presented in table 4.4 as under :

**TABLE 4.4**

S.No	Chainages		Important Locations / reference points	Locations w.r.t alignment
	From	To		
1	0.0	500	B.K Circle (B T Road)	LHS
			Kammanahalli Main Road	RHS
			B T Road	LHS
2	500	1000	Mud Road (Way to Police Station)	RHS
			Way To Maruthi Dental College	RHS
			Mud Road	RHS





			Mud Road	LHS
3	1000	1500	Mud Road	LHS
			3 <sup>rd</sup> Cross, Thimma Reddy Lyout	LHS
			2 <sup>nd</sup> Cross, Thimma Reddy Lyout	LHS
			1 <sup>st</sup> Cross, Thimma Reddy Lyout	LHS
			Hulimavu Road	RHS
			3 <sup>rd</sup> Main Road	LHS
			2 <sup>nd</sup> Main Road	LHS
			1 <sup>st</sup> Main Road	LHS
			B T Road	LHS
			B T Road	RHS
			B T Road	LHS
			B T Road	LHS
			B T Road	RHS
4	2000	2500	B T Road	LHS
			B T Road	LHS
			Way to Puttana halli	LHS
			Way to Arakere	RHS
			B T Road	LHS
5	2500	3000	Way to Vijaya Bank Employees Housing Society	RHS
			B T Road	LHS
			B T Road	LHS
6	3000	3500	B T Road	LHS
			B T Road	LHS
			Mud Road	LHS
			B T Road	RHS
			B T Road	LHS
			B T Road	RHS
			B T Road	RHS
			B T Road	LHS
			B T Road	RHS
7	3500	4000	B T Road	LHS
			B T Road	LHS
			B T Road	RHS
			B T Road	LHS
			Way to Poorva Heights Apptts	RHS
			B T Road	RHS
8	4000	4500	B T Road	RHS
			B T Road	RHS
			Outer Ring Road	LHS
			B T Road	RHS
9	4500	5000	B T Road	RHS
			J P Nagar 9 <sup>th</sup> Main Road	LHS
			4 <sup>th</sup> Main Road	LHS



10	5000	5500	2 <sup>nd</sup> Main Road	RHS
			Marenahalli (south end) Road)	LHS
			Outer Ring Road	RHS
11	5500	6000	B T Road	LHS
			Old Gurappanapalya Main Road	RHS
12	6000	6500	9th Block Road	LHS
			Jala Bhawan Road	LHS
			Bismilla Nagar 3 <sup>rd</sup> Main Rod	RHS
13	6500	7000	Swagath Road	LHS
			Krishnappa Garden 1 <sup>st</sup> Main Road	LHS
14	7000	7500	-	-
15	7500	8000	Marigowda Road	LHS, RHS
			Way to Sri Matha Om Shakti Temple	RHS
16	8000	8500	New MICO Road	RHS
17	8500	9000	1 <sup>st</sup> Main Road	LHS, RHS
18	9000	9500	1 <sup>st</sup> Main road	RHS
			1 <sup>st</sup> Main Road	RHS
19	9500	10000	K H Road	LHS
			Kadidal Manjappa Road	LHS
20	10000	10500	-	-
21	10500	11000	Agha Abdulla Street	LHS
			Leonard Road	LHS
			Campbell Road	RHS
			General Thimmaiah Road	LHS
			B T Road	RHS
22	11000	11500	Wood Street (B T Road)	RHS
			Brigade Road – Museum Road Junction	LHS
			Castle Street	RHS
			Markham Road	RHS
			Magara Road	RHS
			F M cariappa Road	LHS
23	11500	12000	Residency Road	RHS
			Brigade Cross Road	LHS
			Church Street	LHS
			M G Road	LHS, RHS
24	12000	12500	Cubbon Road	LHS, RHS
			Main Guard Cross Road	LHS, RHS
25	12500	13000	Lady Curzon Road	LHS, RHS
26	13000	13500	Hospital Road	LHS, RHS
			Venkataswamy Naidu Rod	LHS
			Meenakshi Koil Street	RHS
27	13500	14000	Old Cemetery Road	LHS, RHS
			B T Road	LHS, RHS



			Queens Road	LHS, RHS
28	14000	14500	B T Road	LHS, RHS
			Thimmaiaha Road	LHS, RHS
			Station Road	LHS, RHS
29	14500	15000	Millers Road	LHS, RHS
			Nandi Durg Road	LHS, RHS
30	15000	15500	Benson Cross Road	LHS, RHS
31	15500	16000	Harris Road	LHS, RHS
			Williams Road	LHS
32	16000	16500	Church Road	LHS
			Masjid Road	LHS, RHS
33	16500	17000	B T Road	LHS, RHS
			Viviyani Road	RHS
			Giddappa Block Road	RHS
34	17000	17500	D I Halli Main Road	LHS
			Pillanna Garden Road	LHS
			Venkateshpura Cross Road	LHS
35	17500	18000	9 <sup>th</sup> Main Road	RHS
			P & T Colony Road	LHS
			Doddanna 2 <sup>nd</sup> Main Road	LHS
			Telecom Street	RHS
			Shastri Street	LHS
36	18000	18500	Nehru Street	LHS
			Kitoor Chennamma Street	LHS
			1 <sup>st</sup> Main Road	LHS
			Vinobha Nagar Main Road	RHS
37	18500	19000	B T Road	LHS
			Maria Street	LHS
			Ganesh Temple Street	RHS
			G M Main Road	LHS
			Way to Bharat English School	RHS
38	19000	19500	No.1 Chuna lane	RHS
			Railway Line Crossing (L C)	LHS, RHS
			80' 1 <sup>st</sup> Main Road	RHS
39	19500	20000	1 <sup>st</sup> Main Road	LHS
			Way to St. Frazer High School	LHS
			Haneefa Masjid Road	LHS
			Sri Mutthu Mariamma Circle	-
			Govindapura Main Road	LHS
40	20000	20500	1 <sup>st</sup> Main Umar Nagar	LHS
			Way to SJM Public School	LHS
			Way to M A M Primary School	RHS
			Way to Chaitanya Play School	RHS
			Rashid Road	LHS
41	20500	21000	B T Road	LHS



			B T Road	RHS
			B T Road	LHS
			B T Road	LHS
			Outer Ring Road	LHS, RHS
42	21000	21500	-	-

#### 4.5 STATION PLANNING

Gottigere - IIMB - Nagavara alignment covers 21.255 km and consists of the following 18 stations:

1. Gottigere Ch.411
2. Hulimavu Ch.1484.50
3. IIMB (Indian Institute of Management) Ch.3204
4. J P Nagar-IV Phase Ch.4575
5. Jayadeva Hospital Ch.5414
6. Swagath Road Cross Ch.6777
7. Dairy Circle Ch.7929
8. MICO Industries Ch.8961
9. Langford Town Ch.9880.40
10. Vellara Ch.10884
11. M.G. Road Ch.12020
12. Shivaji Nagar Ch.13241
13. Cantonment Railway Station Ch.14405
14. Pottery Town Ch.16023
15. Tannery road Ch.17182
16. Venkateshpura Ch.18168
17. Arabic College Ch.19592
18. Nagavara Ch.20995

The inter-station Distance and Rail levels at Stations are given in Table 4.5.:

Table 4.5 inter station Distance and Rail levels at Stations

S.N	Name of Stations	Chainage	Inter - Station Distance	Type of Station	Rail Lvl (m)
		(in m)	(in m)	(Elevated/U/G)	
	Dead End	0	-		
1	Gottigere	411	411	Elevated	933.9
2	Hulimavu	1484.5	1073.5	Elevated	915.5
3	IIMB	3204	1719.5	Elevated	907.7
4	J P Nagar-IV Phase	4575	1371	Elevated	914.1



5	Jayadeva Hospital (Integration with Jayadeva Hospital Station of R. V. Road – Bommasandra Line )	5414	839	Elevated	918.4
6	Swagath Road Cross	6777	1363	Elevated	905.8
7	Dairy Circle	7929	1152	Underground	878.4
8	MICO Industries	8961	1032	Underground	871.8
9	Langford Town	9880.4	919.4	Underground	883.5
10	Vellara	10884	1003.6	Underground	893.0
11	M. G. Road (Integration with M G Road Station of Kengeri – Whitefield (East –West) Line	12020	1136	Underground	896.4
12	Shivaji Nagar	13241	1221	Underground	891.8
13	Cantonment Railway Station	14405	1164	Underground	894.2
14	Pottery Town	16023	1618	Underground	887.9
15	Tannery Road	17182	1159	Underground	901.8
16	Venkateshpura	18168	986	Underground	894.2
17	Arabic College	19592	1424	Underground	871.9
18	Nagavara	20995	1403	Underground	867.3
	Dead End	21255	260		

#### 4.5.1 Station Design

As per the configuration of alignment, first six stations would be elevated of which the 'Jayadeva Hospital' station is an interchange station with the 'Jayadeva Hospital' station of proposed R V road–Electronic City–Bommasandra line. The balance twelve stations are underground stations of which the M G Road underground station is an interchange station with elevated M G Road Station of Ph-I and with City Airport Terminal (CAT) of proposed High Speed Rail Link (HSRL) to the Bangalore International Airport (through round the clock shuttle services).

#### 4.5.2 PLATFORMS

Elevated Stations have been planned with side platforms to avoid the viaduct structure from flaring in and out at stations, which obstructs the road traffic below. Care has been taken to locate stations on straight alignment. However,



in some stations, site constraints have become the deciding criteria and a curve of 1000 m radius has been introduced. Underground Stations have been planned with island platforms.

#### **4.5.3 Station Facilities**

The elevated alignment passes on the middle of the road and the station is also proposed on the middle of the road. The commuter can directly approach to the unpaid concourse at higher level, through staircases and escalators, from either side, without crossing the road. The operational area is proposed in the paid concourse.

The ground level has been proposed for parking/ ancillary structures and space for movement of commuters.

Ticket / token counters, information has been proposed in the unpaid area of concourse.

Automatic Fare Collection machines have been proposed between paid & unpaid concourse. The commuter after purchasing tickets / tokens enters into the paid concourse.

A conflict free circulation system is proposed for commuters and operational staff.

The proposed elevated stations will have two side platforms & Underground Stations will have island platforms. The access to the platforms is through staircases and escalators, housed in the paid area of concourse.

Elevators have been proposed for elderly and physically challenged persons from ground to concourse and concourse to the platforms. There will be a special dedicated path with tactile flooring for visually impaired persons.

Plaza has been proposed in front of the station for pedestrian movement, facilities for parking for private vehicles and public transport.

Public Conveniences in the form of paid toilets have also been proposed at the station, outside the station building.

#### **4.5.4 Station Locations**



### 1. **Gottigere Station**

Gottigere Station is the first station on Gottigere-IIMB – Nagavara line. It serves the surrounding residential areas & Apartments and for the entire traffic generated south of Gottigere. The elevated station has been proposed on the middle of Bannerghatta Road. The chainage of the station is 411. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on RHS.

### 2. **Hulimavu Station**

Hulimavu Station is the second station on IIMB – Nagavara line. It serves for the entire traffic of Hulimavu and surrounding areas. The elevated station has been proposed on the middle of Bannerghatta Road. The chainage of the station is 1484.50. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on RHS.

### 3. **Indian Institute of Management, Bangalore (IIMB) Station**

This is the elevated station, on the middle of the Bannerghatta road. The elevated station is located on the middle of Bannerghatta road. It serves the traffic of IIMB and surrounding areas. The chainage of the station is 3204. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on RHS.

### 4. **J P Nagar–IV Phase Station**

This is the elevated station on IIMB - Nagavara line. The elevated station has been proposed on the middle of Bannerghatta Road. It serves for the traffic of J P Nagar IV Phase and its surrounding areas. The station is located on the middle of Bannerghatta road. The chainage of the station is 4575. The accesses to the station are proposed across the road. Ancillary Structures required for operational activities have been housed in part of the open area on RHS.

### 5. **Jayadeva Hospital Station**

This is the elevated station on IIMB - Nagavara line. The elevated station has been proposed on the left side of Jayadeva Hospital underpass/flyover on



Bannerghatta Road and is planned as the combined & interchange station along with Jayadeva Hospital Station of proposed 'R V road-Electronic City - Bommasandra line'. The chainage of the station is 5414. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in Jayadeva hospital area on LHS.

#### **6. Swagath Road Cross Station**

This is the last elevated station on IIMB - Nagavara line. The elevated station has been proposed on the LHS of Bannerghatta Road. The chainage of the station is 6777. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed on LHS.

#### **7. Dairy Circle Station**

This is the first underground station on IIMB - Nagavara line. The underground station has been proposed on the middle of Bannerghatta Road. It serves the traffic around Dairy Circle & nearby NIMHANS as well as Rajiv Gandhi Hospitals. The chainage of the station is 7929. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

#### **8. MICO Industries Station**

This is an underground station. The underground station has been proposed under the middle of Bannerghatta Road. It serves the surrounding traffic of this area. The chainage of the station is 8961. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

#### **9. Langford Town Station**

This is an underground station. The underground station has been proposed under the middle of Hosur Road. The chainage of the station is 9880.40. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.





### **10. Vellara Station**

This is an underground station. The underground station has been proposed under the middle & LHS of Hosur Road. The chainage of the station is 10884. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

### **11. M. G. Road Station**

This is an underground station proposed near elevated M G Road station of Ph-I. It is an integrated station. The underground station has been proposed on the middle of Kamaraj road. The chainage of the station is 12020. This station also serves as the integrated Station with City Air Terminal (CAT) on Police Grounds of High Speed Rail Link (HSRL) to Bangalore International Airport which is about 650 M distance through round the clock shuttle bus services. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

### **12. Shivaji Nagar Station**

This is an underground station proposed below the part of Corporation P V College ground by the side of Shivaji Nagar Bus Terminal and it is an integrated station with the Shivaji Nagar Bus Terminal. This station serves the traffic around Shivaji Nagar as well as the traffic from east Bangalore. The chainage of the station is 13241. Ancillary Structures required for operational activities have been housed within the station box.

### **13. Cantonment Railway Station**

This is an underground station proposed in front of the Cantonment Railway station and it is an integrated station with the Cantonment Railway Station. The chainage of the station is 14405. Ancillary Structures required for operational activities have been housed within the station box.

### **14. Pottery Town Station**

This is an underground station in the open land and below the road. The chainage of the station is 16023. It serves the traffic of surrounding Benson Town & also Frazer Town areas through underpasses below the SWR line.



Ancillary Structures required for operational activities have been housed within the station box.

#### **15. Tannery Road Station**

This is an underground station proposed under the Tannery Road. It serves for the traffic of Tannery road & its adjoining areas. The chainage of the station is 17182. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

#### **16. Venkateshpura Station**

This is an underground station proposed under the Tannery Road. The chainage of the station is 18168. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed on LHS.

#### **17. Arabic College Station**

This is an elevated station proposed under the Tannery Road. The chainage of the station is 19592. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

#### **18. Nagavara Station**

This is the last underground station on Gottigere - IIMB - Nagavara line. The underground station has been proposed after the crossing of Outer Ring Road, under the Thanisandra Road. It serves for the traffic generated beyond Nagavara like Thanisandra, Hegade Nagar etc. The chainage of the station is 20995. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed within the station box.

### **4.5.5 Architectural Finishes**

A light weight and sleek steel structures have been envisaged for roof of stations with translucent fabric sheeting for ambient day lighting within the stations. Glass walls with granite floor and stainless steel and glass 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.

#### 4.5.6 Passenger Facilities

The proposed station will have the following facilities for the information of the passenger:

- Passenger Information Display System
- Public Address System
- Clocks
- Signage.

#### 4.6 UTILITIES AND SERVICES

The proposed alignment of Gottigere - IIMB - Nagavara is traversing along the Bannerghatta Road, Hosur road, Brigade road, Infantry road, Central Street, Millers tank bund area, Millers road, Bore Bank road and Tannery road. Number of sub-surface, surface and over head utility services viz. sewers, water supply lines, storm water drains, telephone cables, overhead electrical transmission lines, electric poles, traffic signals etc. are existing along the proposed alignment. These utility services are essential and have to be maintained in working order during different stages of construction by temporary / permanent diversions or by supporting in position. As such, these may affect construction and project implementation time schedule / costs, for which necessary planning / action needs to be initiated in advance.

Organisations / Departments responsible for concerned utility services are provided in **Table 4.6**.

**Table 4.6**  
**ORGANISATION RESPONSIBLE FOR UTILITIES AND SERVICES**

S. No.	Organisation / Department	Utility services
1	Bangalore Water Supply & Sewerage Board (BWSSB)	i) Sewerage and drainage conduits ii) Water mains, their service lines, Including hydrants and fountains etc. water treatment plants, pumping stations etc.
2	Bruhat Bangalore Mahanagara Palike (BBMP)	Roads, surface water drains, nallahs etc.
3	Karnataka Power	H.T. Lines with Pylons, Power cables



	Transmission Corporation Limited (KPTCL)	and their appurtenances
4	Bangalore Electricity Supply Company (BESCOM)	L.T. lines, their electric Light posts, pole mounted transformers etc.
5	Bharat Sanchar Nigam Limited (BSNL)	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
6	Bangalore Traffic Police	Traffic signal posts, junction boxes and cable connections etc.
7	Reliance Industries Limited	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
8	Tata Telecommunication Limited	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.
9	Bharti Telecommunications	Telecommunication cables, junction boxes, telephone posts, O.H. lines etc.

#### 4.6.1 Diversion of Utilities

While planning for diversion of utility services e.g. sewer lines, water pipe lines, cables etc., during construction of Metro alignment, the following guidelines have been adopted:

- i) 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.
- ii) 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 planning 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.

#### 4.6.2 Major Utility Diversion

The list of major electrical wires crossing is furnished in Table 4.7 below. These are to be replaced by underground cabling.

Table 4.7 List of major electrical line crossing



S. No.	Chainage	Voltage	Remark
1	5760	H T line (66 KV)	Near Minichinnappa Kalyana Mantapa
2	19182	H T line (25 KV)	Railway level Crossing
3	22000	H T line (66 KV)	Maruthi Saw Mill, Thanisandra Road

#### 4.7 ENVIRONMENTAL IMPACT ASSESSMENT/ENVIRONMENTAL MANAGEMENT PLAN

The EIA/EMP Studies were entrusted to M/s SECON Pvt Ltd, Bangalore and the detailed Environmental Impact Assessment and Management Plan Report is enclosed as a separate volume. However, the numbers of trees affected due to Gottigere - IIMB - Nagavara line are enumerated. Total 204 nos. of trees are to be cut and 44 trees are to be trimmed. Ten times the number of trees affected are going to be planted and nourished. The Environmental Impact Evaluation is given below.

The impact evaluation for Phase II North - South alignment 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.

$$EIU = \sum_{i=1}^n EQ_{ij} \cdot PIU_i$$

EIU = Environmental Impact Unit

$EQ_{ij}$  = Environmental Quality Relative Scale value for  $i^{\text{th}}$  factor of  $j^{\text{th}}$  alternative

$PIU_i$  = Parameter Importance Unit for  $i^{\text{th}}$  factor

Environmental parameters have been identified under three categories viz Physical Environment, Biological Environment and Socio Economic Environment. The changes in EIU have been calculated for baseline (as on date) as well as environmental status with EMP after the project implementation is presented in Table 4.9

Table 4.9: Evaluation of the Environmental Quality and Benefits



Environmental Aspect and Components	PIU Assigned (Ideal)	EIU without Project (As on 2009 baseline)	EIU with Project (With EMP)	EIU Change due to project (With EMP)
<b>i. Physical</b>				
Air Quality	345	182	244	+62
Water Quality	114	111	113	+2
Land	65	62	61	-1
<b>ii. Biological</b>				
Terrestrial Ecosystem	205	187	200	+13
Aquatic Ecosystem	22	21	22	+1
<b>iii. Socio economic</b>				
Traffic Congestion, Fossil Fuels, Quality of life, Comforts etc	249	42	221	+179
<b>Total EIU</b>	<b>1000</b>	<b>605</b>	<b>861</b>	<b>+256</b>

It is observed that the initiation of Phase II North - South alignment would be beneficial against an ideal of 1000 units. Currently, the EIU stands at 605 units in Phase II North - South alignment with the absence of Metro while there is an increase up to 861 units following the introduction of Metro rail with comprehensive Environmental Management Plan. Therefore, a net gain of +256 (42.31 % gain) EIU units with respect to baseline (2009) is observed which demonstrates a positive benefit to the surrounding community.

Incidentally, the prevailing baseline EIU value of 605 units in Phase II North - South alignment (as on 2009) is likely to degrade over the next 7 years (up to 2016), till the Metro inception due to persistent growth of vehicles. The predicated value of EIU for the year 2016 is around 535 from the present 605 units. The overall benefits in EIU due to Metro will be =  $861 - 535 = 326$  with reference to predicted EIU value of 535 after 7 years, i.e. the improvement of 61 % gives clear positive indication of Metro benefits.

#### 4.8 GEOTECHNICAL INVESTIGATIONS

The main purpose of the Geotechnical Investigations undertaken is to have an insight into the geological conditions along the proposed Phase-II N-S corridor (Gottigere - IIMB – Nagavara line), so as to arrive at the type of foundations to be adopted for elevated corridors and to design the tunneling for the underground routes with appropriate technology.



The geotechnical investigations were carried out by M/s. SECON Private Limited, Bangalore, ISO 9001:2008 certified, one of the leading GIS based Civil Engineering Consultancy organization, having accreditation to their laboratory under NABL (National Accreditation Board of testing Laboratories).

#### 4.8.1 General Description of the Area and Geology

Bangalore or Bengaluru, the Capital City of Karnataka State is its Principal Financial and Administrative Center. The City is situated on a latitude of 12° 58' N and longitude of 77° 36' E. Bangalore is popularly called as "Garden City/Silicon Valley" of India and is India's fifth largest City. Bangalore is well known and acclaimed for its extensively developed Electronics, Software, Aeronautical and Defence Research and Development Industries. In addition, City houses educational Institutions of international repute in Humanities, Commerce, Science, Management and Engineering.

Bangalore City and the District enjoy a pleasant and salubrious climate which is neither too humid nor too dry. The District experiences an annual rainfall of approximately 760 mm.

Bangalore is situated at an elevation of about 900 m above Mean Sea Level on a gently sloping rolling topography, sloping gently from North to South. Terrain wise, while the Western portion of the district is covered by a chain of small-disconnected hillocks. Northern, Eastern and Central parts of the district is almost plain with undulating topography.

Geology wise, Bangalore 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 Young 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.

#### 4.8.2 FIELD INVESTIGATION

Field investigation consisted of 67 number of borehole exploration up to a maximum depth of 30 m. If rock was encountered within 30 m, drilling was carried up to a depth of 3 m in intact hard rock. Boreholes were generally located at about 500 m intervals in elevated portion and 250 m in underground portions along the alignment.

Borehole exploration was carried out by rotary drilling method using heavy duty rotary drilling rigs. At one point of time, 15 rotary drilling rigs were deployed at site to complete the work on schedule. 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 100 mm diameter, 450 mm long as per IS 2132, in cohesive soil strata. Both SPT 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.

For determining field permeability in rock, pumping in tests were carried out as per IS 5529 (Part 2) in selected boreholes in the underground portion. Single packer method was used to seal the top of the test section. The permeability value of hard rock varies from 0.3 to 0.59 Lugeons indicating 'Water tight' condition of bed rock.





The depth of ground water table in the boreholes was monitored after 24 hours of completion of drilling operation and depth of water level was recorded after it was stabilized.

The details of stratification, SPT values, Ground Water Table etc., are indicated in the Sub-Soil Profiles enclosed (05 sheets).

#### **4.8.3 LABORATORY TESTING**

The following laboratory tests were conducted on soil, water and rock samples collected from the boreholes.

##### **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

##### **Tests on Rock samples:**

- Specific Gravity, Water Absorption and Porosity of rock
- Hardness
- Uniaxial compressive strength
- Point Load Index strength
- Modulus of Elasticity
- Abrasion test

##### **Chemical Tests on Soil and Water Samples:**

- pH
- Chloride
- Sulphates
- Organic matter

#### **4.8.4 GENERAL STRATIFICATION**

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 reddish / greyish sandy silt with clay or clayey sand/silt. This layer is in medium dense and is underlain by medium dense to dense reddish/greyish completely weathered formations. This layer represents the 'transition layer' from soil to highly weathered rock. This is followed by highly weathered rock made up of very dense sandy silt/silty sand layer. Weathered rock with degree of weathering varying from moderate to high underlain by more compact hard rock.

Rock stratum was encountered in all the boreholes except a few boreholes, where soft rock in the form of dense silty sand was encountered, up to the investigated depth.

### **ANALYSIS OF RESULTS**

The stratification encountered along the proposed routes mainly consists of medium dense to dense sandy silt/clayey sand at shallow depths. This layer is followed by medium dense to dense completely weathered rock of sandy silt/clayey sand layer, which is non-plastic to moderately plastic. This layer is followed by highly weathered rock consisting of very dense sandy silt/silty sand. Hard rock underlay the highly weathered rock layer.

The formation of successive layers is varying along the route. In general, the stratification follow regular pattern as described above. Standard Penetration Test (SPT) in weathered rock indicate very high 'N' value of 100 and more virtually no penetration of SPT tube in this layer. The colour and structure of the soil samples collected in split spoon closely resembles underlying mineralogical constituents of weathered rock/hard rock.

Index properties such as grain size distribution and liquid limit and plastic limit indicate that, plasticity characteristics of the soil are 'Low to Medium'. Hydrometer tests conducted on selected soil samples show that fine particles predominantly consists of silt and is non-expansive in nature.

Consolidated Undrained shear test and Direct Shear Test indicates in general, the average values of cohesive strength of soil is ranging from 0.05 to 0.2 kg/cm<sup>2</sup> and angle of internal friction is ranging from 15 to 29 degrees.

Chemical analysis of soil and water samples show that pH, Chloride and Sulphates are well within the permissible limits and no special precautions are necessary for concreting job.

Rock cores extracted from the boreholes show the presence of grey granites with pockets of amphibolites, granodiorite and mylorite rock. The rock is intruded with



pegmatite veins at some places. The granite rock shows coarse grain structure due to metamorphic activity.

In general, core recovery obtained in moderately weathered rock is ranging from Nil to 88% with Rock Quality Designation (RQD) values of Nil to 81%. In the hard rock, the percentage core recovery is ranging from 58 to 100% and RQD is varying from 70 to 100%.

It is seen from the index properties that specific gravity of rock varies from 2.55 to 2.90, water absorption ranges from 0.15 to 2 %.

Uniaxial compressive strength results indicate that strength of hard rock varies from 15 MPa to 100. MPa. Point load strength index values in the range of 0.25 to 12.0 MPa. Modulus of Elasticity (E) values of rock varies from  $0.05 \times 10^5$  MPa to  $0.8 \times 10^5$  MPa.

#### 4.8.5 RECOMMENDATIONS

The type of foundation depends on stratification, type of structure, loading, allowable settlement, etc. In the present case, the structure is Metro railway system, which is a combination of elevated, surface and underground corridor. The various structures envisaged in the system include Elevated tracks supported on piers, Elevated Stations, Underground Stations and Underground tunnels. The load coming on to the foundation system will be considerably high from the structures.

##### **Shallow Foundations**

Shallow foundations are recommended wherever hard strata (soft rock/weathered rock/hard rock) are encountered within 4.5 to 5.0 m depth below the existing ground level. Based on field and laboratory test results, an allowable bearing pressure of 45 T/sq.m is recommended. The hard stratum is underlain by a medium dense layer. Hence, adequate shoring and strutting will be necessary while carrying out foundation excavation. Necessary dewatering arrangements will also be required where water table is encountered at shallow depths.

Open foundations are also recommended for underground stations, which involve open excavation. The foundation in this case shall rest on weathered rock/hard rock. The founding level depends on the depth of excavation. Since the soil layers become dense with increase in depth, the Open foundations are feasible.



However, in open excavation, due considerations are to be given to shoring, strutting, dewatering and its possible effects on the nearby structures.

Moderately loaded structures on-ground stations can be supported on shallow foundations at depths varying from 1.5 to 3.0 m. The net allowable bearing pressure for such footings at various borehole locations has been indicated.

### Deep Foundations

Deep foundation, in the form of bored cast in-situ piles are recommended wherever the hard stratum is encountered at considerable depths. The columns supporting the elevated rail track and elevated stations are recommended to be supported on pile foundations. In particular, bored cast in-situ piles are recommended keeping in view of the site location, which are within the city and vicinity to the structures around them.

The piles are essentially end bearing piles, socketed into the hard strata. In this case, the hard strata encountered consist of soft/weathered rock and hard rock. Past experience indicate that the piles socketed in weathered rock have performed satisfactorily. In view of this, it is recommended to anchor the pile in weathered rock layer itself, wherever the thickness of weathered rock layer is considerable. The weathered rock layer encountered in the pile bore can be verified through SPT tests in the pile bore. Further, while chiselling for socketing the uniformity of strata can be ensured by measuring the number of drops Vs penetration.

Depending on the hard strata encountered at pile termination, the following depth of socketing is recommended:

Stratum at Socket Level	Depth of socketing (D=pile diameter)
Highly weathered rock/Fractured rock	4 D
Moderately weathered rock	2 D
Hard rock	1 D

The lengths of piles considering the strata at pile termination at various borehole locations have been indicated.

The safe load carrying capacity of end bearing pile depends on the characteristics of strata at pile termination, anchoring depth and structural capacity of pile section. The piles of diameter 900 mm, 1000 mm, 1200 mm and 1500 mm are considered



for evaluation. The safe load 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:

Pile Diameter (mm)	Recommended safe Axial Load for piles socketed in		
	Highly weathered rock	Moderately weathered rock	Hard rock
900	265	280	380
1000	330	345	470
1200	475	495	675
1500	740	775	1060

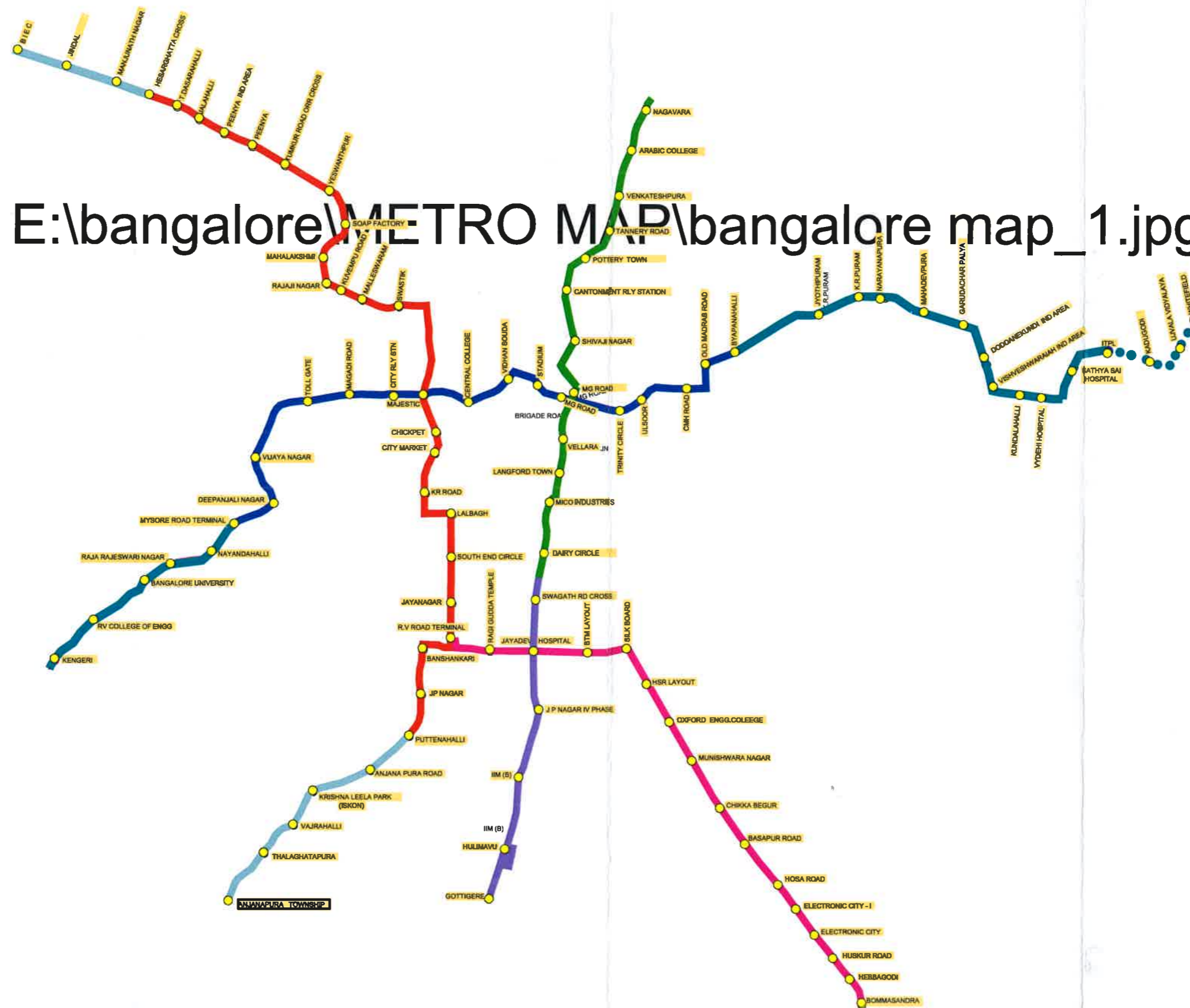
The increase in grade of concrete increases the structural capacity. However it is recommended to limit the safe loads as above, in view of the uncertainties involved in quality of in-situ concrete in the pile bore. Further, in highly weathered rock, the capacities are also governed by the properties of soft rock at termination level. Hence, it is preferable to limit the safe loads as recommended above.

The pile bore, after achieving the required depth shall be washed thoroughly to remove all the slush to ensure good bearing strata.

The uplift capacity of piles can be taken as 10% of safe vertical load and the safe horizontal load can be taken as 5% of safe vertical load.

The safe loads in piles shall be confirmed through pile load tests as per relevant Indian Standards.

**Fig 4.1 Index Plan  
Bangalore Metro Phase I & II**



E:\bangalore\METRO MAP\bangalore map\_1.jpg

**PHASE - I N-S Line**

**Phase - II (PHASE - I N-S Exten Line) Elevated**

**PHASE - I E-W Line**

**Phase - II (PHASE - I E-W Exten Line) Elevated**

**PHASE - II R.V.Road-Elec Line Elevated**

**PHASE - II N-S Line**

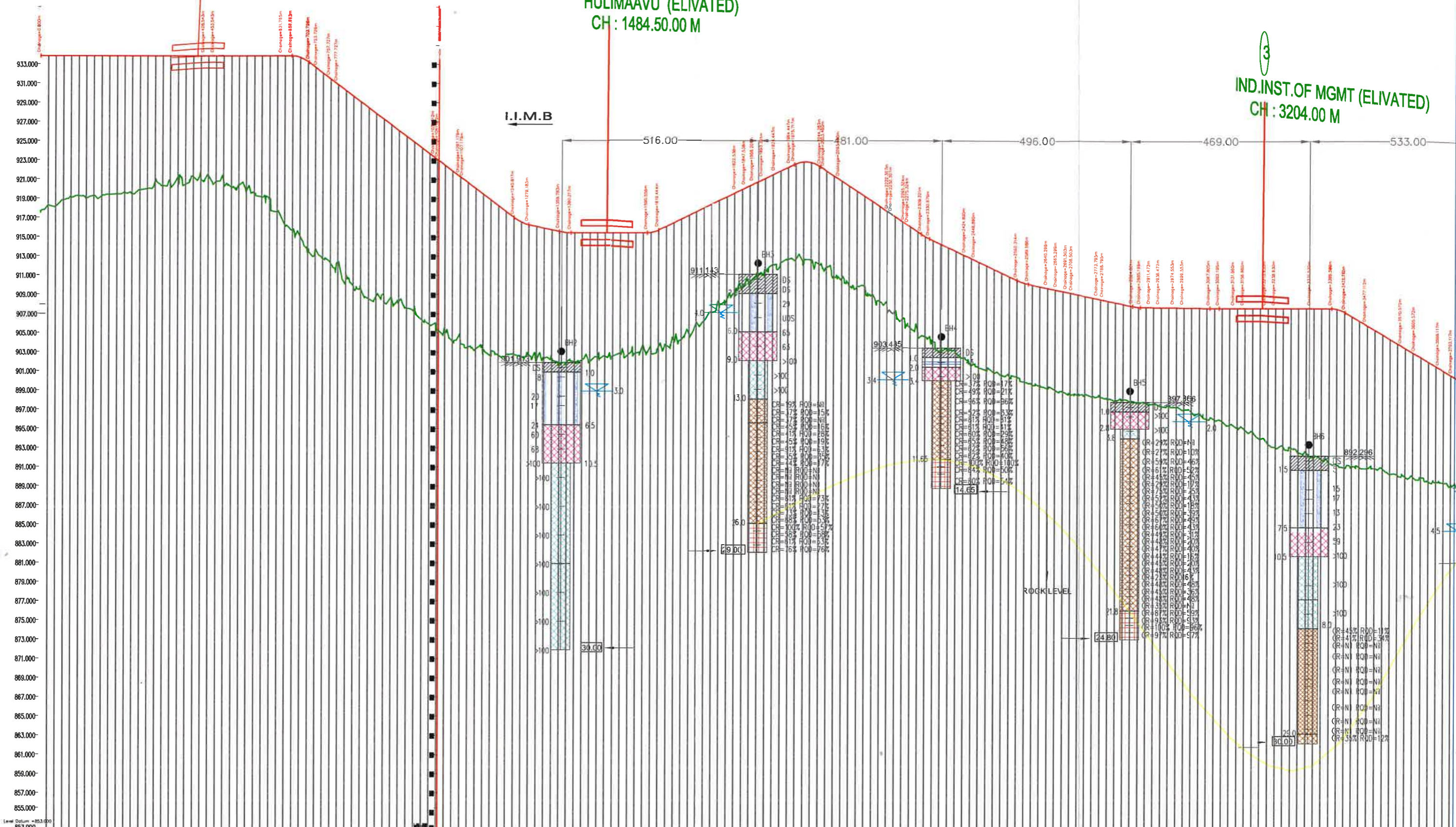
Elevated Under Ground



①  
GOTTIGERE (ELIVATED)  
CH : 411.00 M

②  
HULIMAAVU (ELIVATED)  
CH : 1484.50.00 M

③  
IND.INST.OF MGMT (ELIVATED)  
CH : 3204.00 M



VERTICAL ALIGN	HORIZONTAL ALIGN	ELEVATION DIFF.	PAV LEVELS	FOUNDATIONS	BRIDGE
0+00	0+00	933.000	933.000		
0+10	0+10	932.500	932.500		
0+20	0+20	932.000	932.000		
0+30	0+30	931.500	931.500		
0+40	0+40	931.000	931.000		
0+50	0+50	930.500	930.500		
0+60	0+60	930.000	930.000		
0+70	0+70	929.500	929.500		
0+80	0+80	929.000	929.000		
0+90	0+90	928.500	928.500		
1+00	1+00	928.000	928.000		
1+10	1+10	927.500	927.500		
1+20	1+20	927.000	927.000		
1+30	1+30	926.500	926.500		
1+40	1+40	926.000	926.000		
1+50	1+50	925.500	925.500		
1+60	1+60	925.000	925.000		
1+70	1+70	924.500	924.500		
1+80	1+80	924.000	924.000		
1+90	1+90	923.500	923.500		
2+00	2+00	923.000	923.000		
2+10	2+10	922.500	922.500		
2+20	2+20	922.000	922.000		
2+30	2+30	921.500	921.500		
2+40	2+40	921.000	921.000		
2+50	2+50	920.500	920.500		
2+60	2+60	920.000	920.000		
2+70	2+70	919.500	919.500		
2+80	2+80	919.000	919.000		
2+90	2+90	918.500	918.500		
3+00	3+00	918.000	918.000		
3+10	3+10	917.500	917.500		
3+20	3+20	917.000	917.000		
3+30	3+30	916.500	916.500		
3+40	3+40	916.000	916.000		
3+50	3+50	915.500	915.500		
3+60	3+60	915.000	915.000		
3+70	3+70	914.500	914.500		
3+80	3+80	914.000	914.000		
3+90	3+90	913.500	913.500		
4+00	4+00	913.000	913.000		
4+10	4+10	912.500	912.500		
4+20	4+20	912.000	912.000		
4+30	4+30	911.500	911.500		
4+40	4+40	911.000	911.000		
4+50	4+50	910.500	910.500		
4+60	4+60	910.000	910.000		
4+70	4+70	909.500	909.500		
4+80	4+80	909.000	909.000		
4+90	4+90	908.500	908.500		
5+00	5+00	908.000	908.000		
5+10	5+10	907.500	907.500		
5+20	5+20	907.000	907.000		
5+30	5+30	906.500	906.500		
5+40	5+40	906.000	906.000		
5+50	5+50	905.500	905.500		
5+60	5+60	905.000	905.000		
5+70	5+70	904.500	904.500		
5+80	5+80	904.000	904.000		
5+90	5+90	903.500	903.500		
6+00	6+00	903.000	903.000		
6+10	6+10	902.500	902.500		
6+20	6+20	902.000	902.000		
6+30	6+30	901.500	901.500		
6+40	6+40	901.000	901.000		
6+50	6+50	900.500	900.500		
6+60	6+60	900.000	900.000		
6+70	6+70	899.500	899.500		
6+80	6+80	899.000	899.000		
6+90	6+90	898.500	898.500		
7+00	7+00	898.000	898.000		
7+10	7+10	897.500	897.500		
7+20	7+20	897.000	897.000		
7+30	7+30	896.500	896.500		
7+40	7+40	896.000	896.000		
7+50	7+50	895.500	895.500		
7+60	7+60	895.000	895.000		
7+70	7+70	894.500	894.500		
7+80	7+80	894.000	894.000		
7+90	7+90	893.500	893.500		
8+00	8+00	893.000	893.000		
8+10	8+10	892.500	892.500		
8+20	8+20	892.000	892.000		
8+30	8+30	891.500	891.500		
8+40	8+40	891.000	891.000		
8+50	8+50	890.500	890.500		
8+60	8+60	890.000	890.000		
8+70	8+70	889.500	889.500		
8+80	8+80	889.000	889.000		
8+90	8+90	888.500	888.500		
9+00	9+00	888.000	888.000		
9+10	9+10	887.500	887.500		
9+20	9+20	887.000	887.000		
9+30	9+30	886.500	886.500		
9+40	9+40	886.000	886.000		
9+50	9+50	885.500	885.500		
9+60	9+60	885.000	885.000		
9+70	9+70	884.500	884.500		
9+80	9+80	884.000	884.000		
9+90	9+90	883.500	883.500		
10+00	10+00	883.000	883.000		







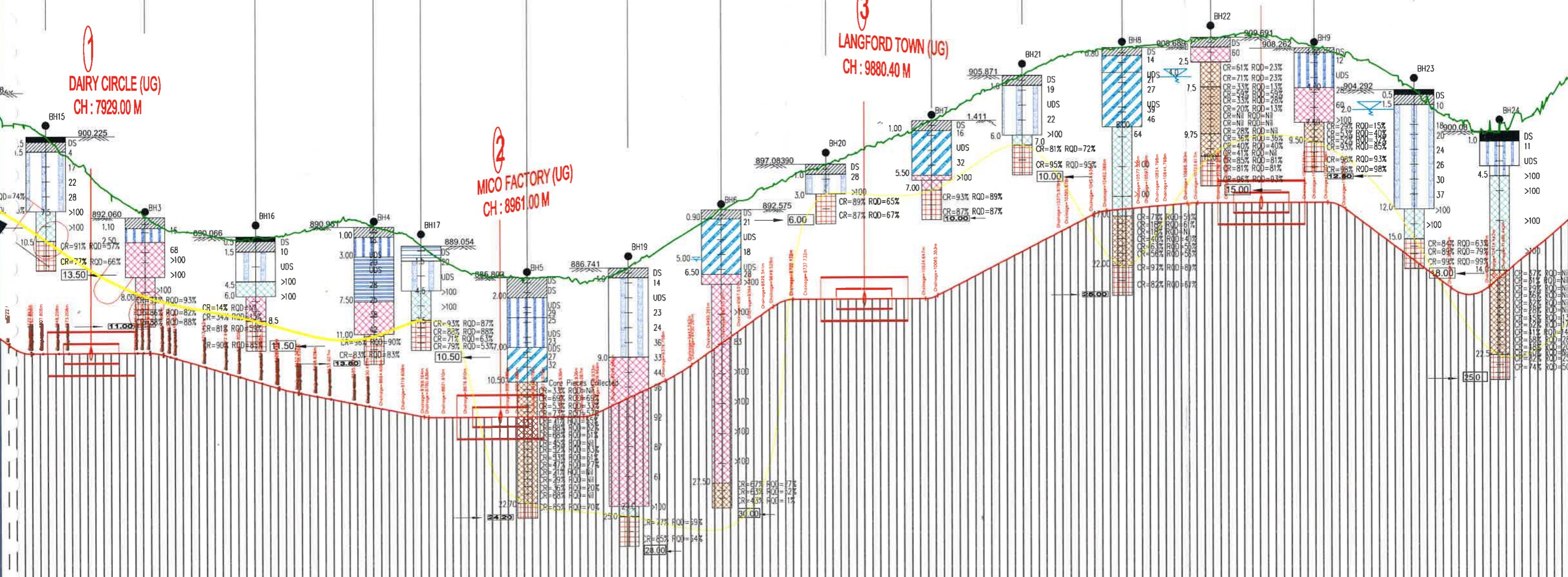
250 279 298 119 267 255 235 266 266 229 252 225 261 252 215

1 DAIRY CIRCLE (UG)  
CH : 7929.00 M

2 MICO FACTORY (UG)  
CH : 8961.00 M

3 LANGFORD TOWN (UG)  
CH : 9880.40 M

4 VELLARA ROAD (UG)  
CH : 10884.00 M



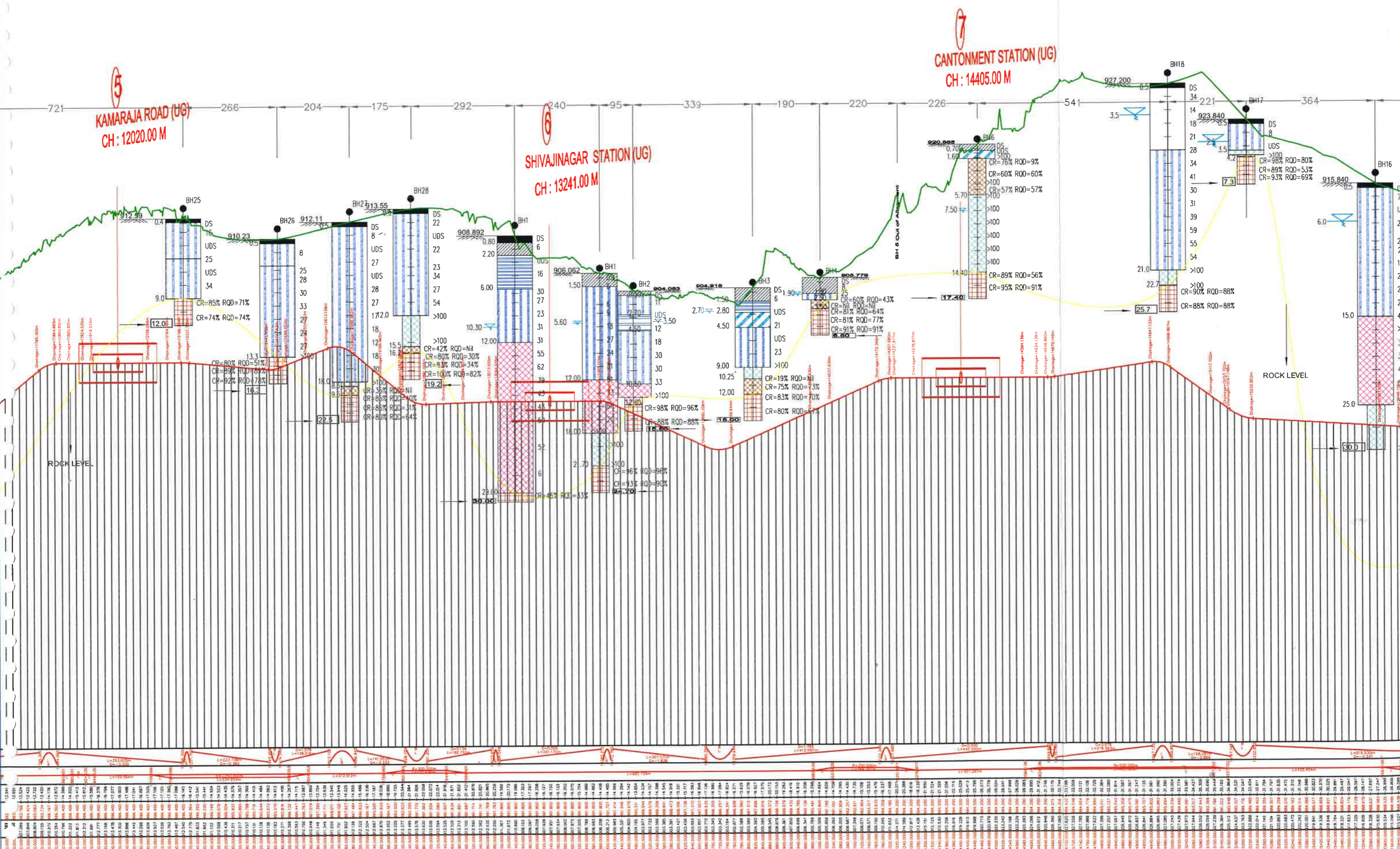
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251.00	UDS 21	82%	66%	11.00	CR=82% RQD=66%
251.50	UDS 21	82%	66%	11.00	CR=82% RQD=66%
252.00	UDS 21	82%	66%	11.00	CR=82% RQD=66%
252.50	UDS 21	82%	66%	11.00	CR=82% RQD=66%
253.00	UDS 21	82%	66%	11.00	CR=82% RQD=66%
253.50	UDS 21	82%	66%	11.00	CR=82% RQD=66%
254.00	UDS 21	82%	66%	11.00	CR=82% RQD=66%
254.50	UDS 21	82%	66%	11.00	CR=82% RQD=66%
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256.50	UDS 21	82%	66%	11.00	CR=82% RQD=66%
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5  
KAMARAJA ROAD (UG)  
CH : 12020.00 M

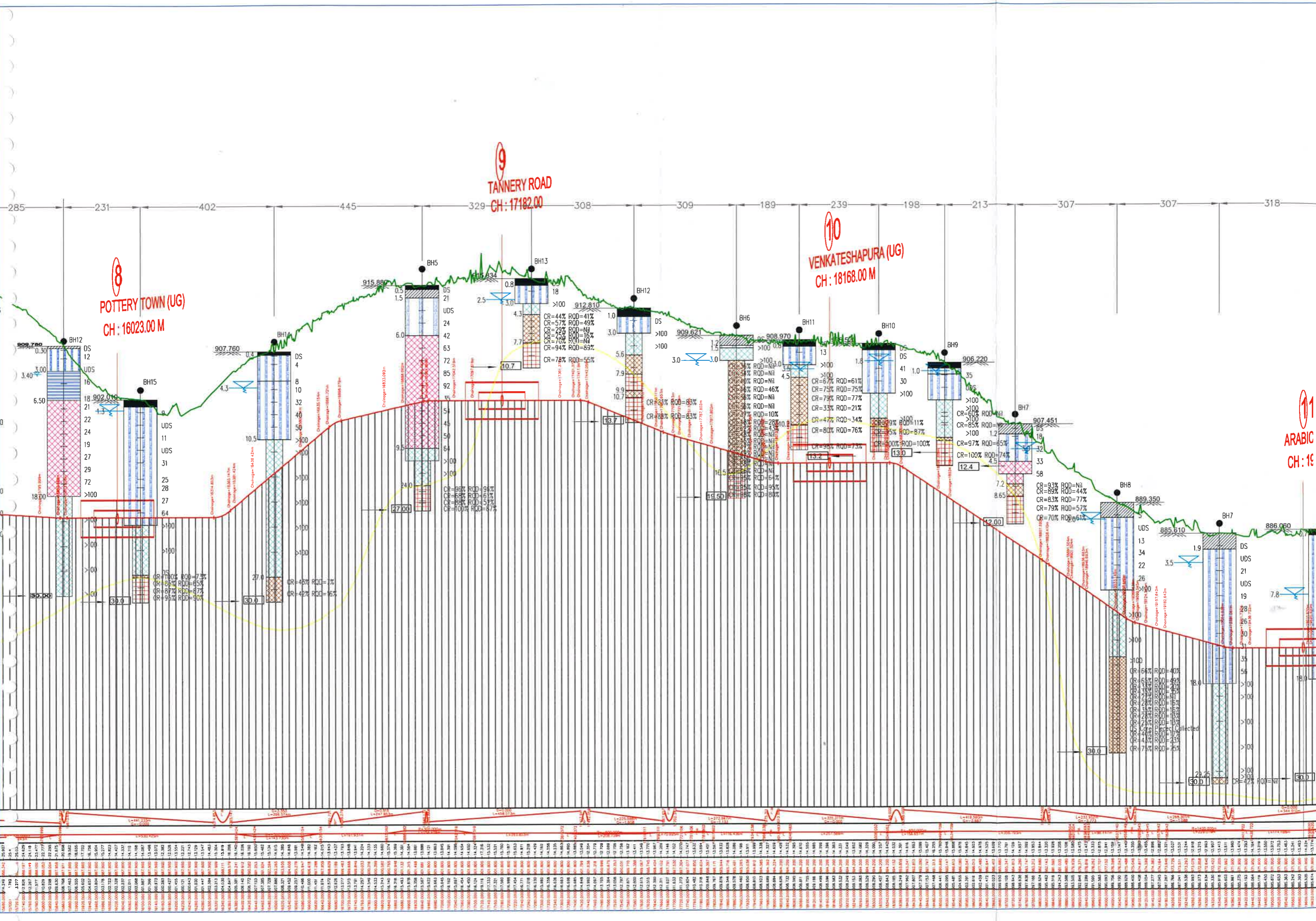
6  
SHIVAJINAGAR STATION (UG)  
CH : 13241.00 M

7  
CANTONMENT STATION (UG)  
CH : 14405.00 M



Station	CR	RQD	Notes
721	85%	71%	
266	74%	74%	
204	80%	51%	
175	89%	57%	
292	92%	75%	
240	42%	Nil	
95	60%	30%	
339	93%	34%	
190	100%	82%	
220	19%	Nil	
226	60%	43%	
541	81%	64%	
364	91%	91%	
721	85%	71%	
266	74%	74%	
204	80%	51%	
175	89%	57%	
292	92%	75%	
240	42%	Nil	
95	60%	30%	
339	93%	34%	
190	100%	82%	
220	19%	Nil	
226	60%	43%	
541	81%	64%	
364	91%	91%	





8  
POTTERY TOWN (UG)  
CH : 16023.00 M

9  
TANNERY ROAD  
CH : 17182.00

10  
VENKATESHAPURA (UG)  
CH : 18168.00 M

11  
ARABIC  
CH : 19

Station	CR	RQD	Remarks
285.00	100%	100%	CR=100% RQD=100%
286.00	100%	100%	CR=100% RQD=100%
287.00	100%	100%	CR=100% RQD=100%
288.00	100%	100%	CR=100% RQD=100%
289.00	100%	100%	CR=100% RQD=100%
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298.00	100%	100%	CR=100% RQD=100%
299.00	100%	100%	CR=100% RQD=100%
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302.00	100%	100%	CR=100% RQD=100%
303.00	100%	100%	CR=100% RQD=100%
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307.00	100%	100%	CR=100% RQD=100%
308.00	100%	100%	CR=100% RQD=100%
309.00	100%	100%	CR=100% RQD=100%
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313.00	100%	100%	CR=100% RQD=100%
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317.00	100%	100%	CR=100% RQD=100%
318.00	100%	100%	CR=100% RQD=100%



NAGAWARA

205 216 246 222 225 297 460

LEGEND

- ROAD MATERIAL
- FILLED UP SOIL
- SILTY SAND / SANDY SILT WITH CLAY BINDER
- CLAYEY SILT
- CLAYEY SAND
- COMPLETELY WEATHERED ROCK
- HIGHLY WEATHERED ROCK
- MODERATELY WEATHERED ROCK
- FRACTURED ROCK
- HARD ROCK
- BOREHOLE TERMINATION DEPTH
- BOREHOLE
- GROUND WATER TABLE DEPTH

ABBREVIATIONS

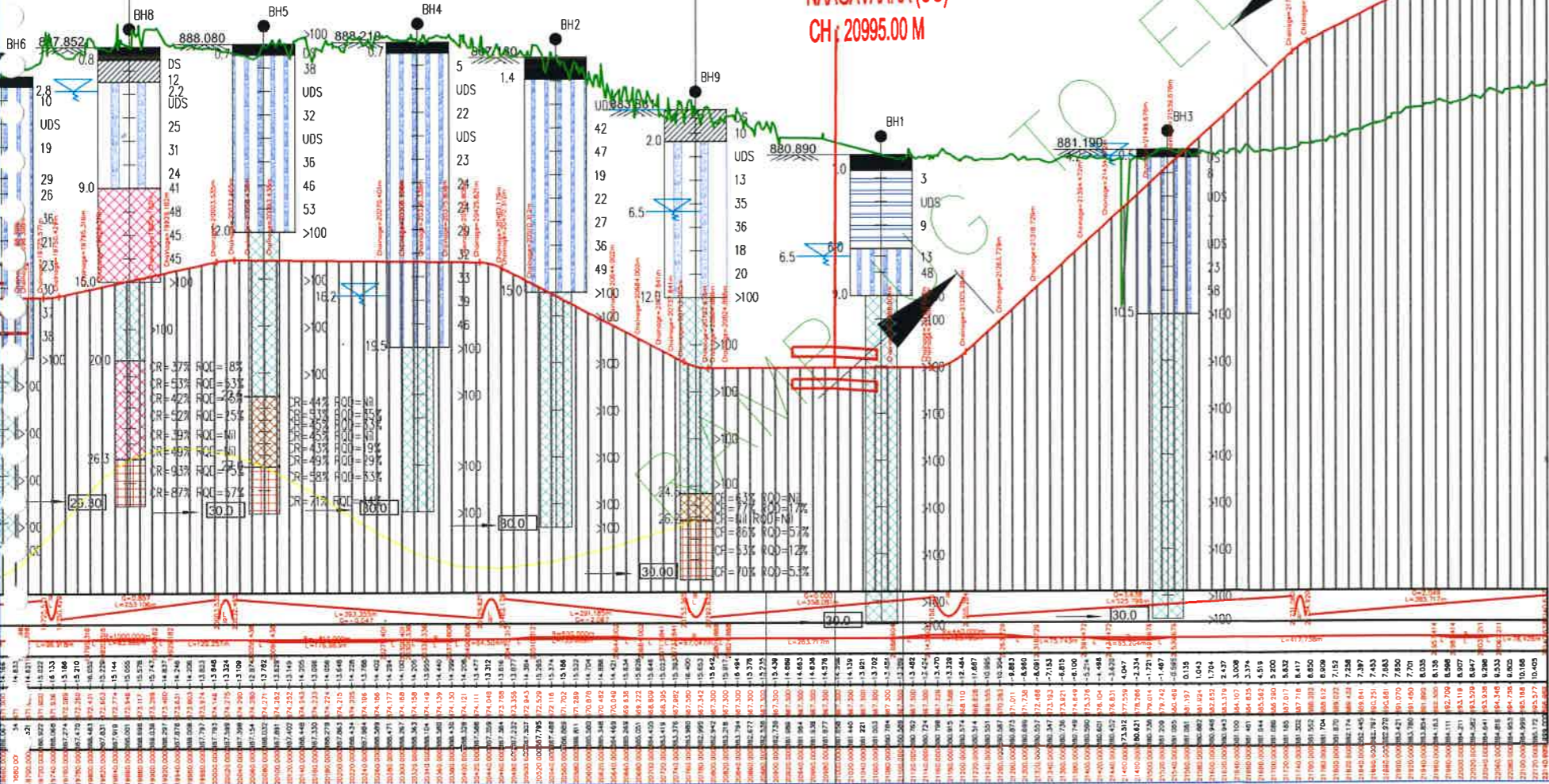
- UDS : UNDISTURBED SAMPLE
- CR : CORE RECOVERY (%)
- RQD : ROCK QUALITY DESIGNATION (%)
- EGL : EXISTING GROUND LEVEL
- DS : DISTURBED SAMPLE

SCALE  
VER: 1cm=4m  
HOR: 1cm=100m

201 LEGE (UG)  
32.00 M

12  
NAAGAVAARA (UG)  
CH: 20995.00 M

TO BE ELEVATED



**CHAPTER-5**

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**STATION PLANNING, CIVIL STRUCTURES  
& CONSTRUCTION METHODOLOGY**





## CHAPTER 5

### STATION PLANNING, CIVIL STRUCTURES & CONSTRUCTION METHODOLOGY

#### 5.1 PLANNING AND DESIGN CRITERIA FOR STATIONS

1. The stations 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.
2. The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario.
3. The platform level at elevated stations is determined by a critical clearance of 5.5 m under the concourse above the road intersection, allowing 3.5 m for the concourse height, about 1 m for concourse floor and 1.5 m for structure of tracks above the concourse. Further, the platforms are 1.09 m above the tracks. This would make the rail level in an elevated situation at least 12.5m above ground.
4. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms.
5. The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space.
6. Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.
7. Station entrances are located with particular reference to passenger catchment points and physical site constraints within the right-of-way allocated to the MRTS.



9. Office accommodation, operational areas and plant room space is required in the non-public areas at each station. The functions of such areas are given in Table 4.5.
10. The DG set, bore well pump houses and ground tank would be located generally in one area on ground.
11. The system is being designed to maximize its attraction to potential passengers and the following criteria have been observed:
  - Minimum distance of travel to and from the platform and between platforms for transfer between lines.
  - Adequate capacity for passenger movements.
  - Convenience, including good signage relating to circulation and orientation.
  - Safety and security, including a high level of protection against accidents.
12. Following requirements have been taken into account:
  - Minimum capital cost is incurred consistent with maximizing passenger attraction.
  - Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
  - Flexibility of operation including the ability to adapt to different traffic conditions changes in fare collection methods and provision for the continuity of operation during any extended maintenance or repair period, etc.
  - Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
  - Provision of display of passenger information and advertising.
13. The numbers and sizes of staircases/escalators are determined by checking the capacity against AM and PM peak flow rates for both normal and emergency conditions such as delayed train service, fire etc.
14. In order to transfer passengers efficiently from street to platforms and vice versa, station planning has been based on established principles of pedestrian flow and arranged to minimize unnecessary walking distances and cross-flows between incoming and outgoing passengers.
15. Passenger handling facilities comprise of stairs/escalators, lifts and ticket gates required to process the peak traffic from street to platform and vice-



versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit).

## 5.2 TYPICAL ELEVATED STATION

All the stations are two-level stations. The concourse length varies from 82 m to 97m for the stations located in the middle of the road and 132m to 160m for the stations located outside road. The maximum width of the station at concourse varies depending on the location of station. Passenger facilities like ticketing, information, etc as well as operational areas are provided at the concourse level. Typically, the concourse is divided into public and non-public zones. The non-public zone or the restricted zone contains station operational areas such as Station Control Room, Station Master's Office, Waiting Room, Meeting Room, UPS & Battery Room, Signaling Room, Train Crew Room & Supervisor's Office, Security Room, Station Store Room, Staff Toilets, etc. The public zone is further divided into paid and unpaid areas.

For Stations planned on the middle of the road, minimum vertical clearance of 5.5 m has been provided under the concourse. Platforms are at a level of about 13.5 m from the road. To reduce physical and visual impact of the elevated station, stations have been made narrow towards the ends.

With respect to its spatial quality, an elevated Metro structure makes a great impact on the viewer as compared to an At-grade station. The positive dimension of this impact has been accentuated to enhance the acceptability of an elevated station and the above ground section of tracks. Structures that afford maximum transparency and are light looking have been envisaged. A slim and ultra-modern concrete form is proposed, as they would look both compatible and modern high-rise environment as well as the lesser-built, low-rise developments along some parts of the corridor.

Platform roofs, that can invariably make a structure look heavy, have been proposed to be of steel frame with aluminum cladding to achieve a light look. Platforms would be protected from the elements by providing an overhang of the roof and sidewalls would be avoided, thereby enhancing the transparent character of the station building. In order to allow unhindered traffic movement below the stations, portals across the road have been proposed in the concourse part, over which the station structure would rest. The rest of the station structure is supported on a single column, which lies unobtrusively on the central verge. Typical drawing of an elevated station is given at **Fig.. 5.1**.



**Table 4.5 STATION ACCOMMODATION**

1. Station Control Room	2. Cleaner's Room
3. Station Master's Office	4. Security Room
5. Information & Enquiries	6. First Aid Room
7. Ticket Office	8. Miscellaneous Operations Room
9. Ticket Hall Supervisor & Excess Fare Collection (Passenger Office)	10. Platform Supervisor's Booth
11. Cash and Ticket Room	12. Traction Substation (alternate Stations)
13. Staff Area	14. Fire Tank and Pump Room
15. Staff Toilets	16. Commercial Outlets and Kiosks
17. Station Store Room	18. UPS and Battery Room
19. Refuse Store	20. Signaling / Communication Room

### 5.3 PASSENGER AMENITIES

Passenger amenities such as ticketing counters/automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Uniform numbers of these facilities have been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station. The same applies to provision of platform widths and staircase/escalators. Maximum capacity required at any station by the year 2041 for normal operation has been adopted for all stations. For this purpose, peak minute traffic is assumed to be 2% of the peak hour traffic. For checking the adequacy of platform area, stair widths and requirement additional of emergency evacuation stairs, a maximum accumulation of passengers in the station has been considered to be comprising waiting passengers at the platform (including two missed headways) and section load expected to be evacuated at the station in case of an emergency.

The proposed stations will have the following facilities for the information of the passenger:

- Passenger Information Display System
- Public Address System
- Clocks
- Signage.



### 5.3.1 Concourse

Concourse forms the interface between street and platforms. In elevated stations, this is contained in a length of 70 - 80 m in the middle of the station. This is where all the passenger amenities are provided. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct paid and unpaid areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms. The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow has been allowed in front of the AFCs.

### 5.3.2 Ticketing Gates

Ticketing gates' requirement has been calculated taking the gate capacity as 45 persons per minute per gate. Passenger forecast for the horizon year 2031 has been used to compute the maximum design capacity. At least two ticketing gates shall be provided at any station even if the design requirement is satisfied with only one gate. Uniform space has been provided in all stations where gates can be installed as and when required.

### 5.3.3 Ticket Counters and Ticket Issuing Machines (TIMs)

It is proposed to deploy manual ticket issuing in the beginning of the operation of the line. At a later stage, automatic TIMS would be used for which space provision has been made in the concourse. At present, ticket counters would be provided, which would be replaced with TIMS in future. Capacity of manual ticket vending counters is taken to be 10 passengers per minute and it is assumed that only 40% of the commuters would purchase tickets at the stations while performing the journey. The rest are expected to buy smart cards. Accordingly, the requirement of ticket counters has been calculated and the same provided for in the plans.

### 5.3.4 Platforms

In elevated stations, 4.5m wide side platforms have been proposed. These platform widths also have been checked for holding capacity of the platform for worst-case scenario.



### 5.3.5 Stairs, Escalators and Lifts

Provision has been made for escalators in the paid area i.e. from concourse to platforms. On each platform, one escalator has been proposed. In addition, two staircases are provided on each platform connecting to the concourse. These stairs and escalator together provide an escape capacity adequate to evacuate maximum accumulated passengers in emergency from platforms to concourse in 5.5 minutes. Lifts have been provided one each on either platform, to provide access for elderly and disabled.

Since the rise to road from the concourse is about 8m, it is proposed to provide lifts in addition to stairs for vertical movement of passengers from street to concourse.

## 5.4 TRAFFIC INTEGRATION

### 5.4.1 Concept of Traffic Integration

The objective of an integrated transport system and traffic movement is to offer maximum advantage to commuters and society from traffic and planning consideration. Various modes of transport need to be integrated in a way that each mode supplements the other. A large proportion of MRTS users will come to and depart from various stations by public, hired and private modes, for which integration facilities need to be provided at stations to ensure quick and convenient transfers.

In order to ensure that entire MRTS function as an integrated network and provides efficient service to the commuter, the following steps have been identified:

- Suitable linkages are proposed so that various corridors of MRTS are integrated within themselves, with existing rail services and with road based modes.
- Facilities needed at various stations are planned in conformity with the type of linkages planned there.

Traffic and transport integration facilities are provided for two different types of linkages:

- Feeder links to provide integration between various MRTS corridors and road based transport modes i.e. public, hired, and private vehicles.
- Walk links to provide access to the pedestrians.



### 5.4.2 Approach Adopted in Planning Traffic Integration Facilities

Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate circulation areas for various modes likely to come to important stations including feeder bus/mini-buses. Parking for private vehicles has been proposed close to the station entrances. The computer model employed for traffic demand projections provides also a breakup of station loads between passengers arriving by walk or by vehicular modes. The vehicular component has been further broken up among hired and private modes on station-to-station basis, by assessing the socio-economic profile of the catchment areas and the distance likely to be travelled by commuters before and after using the MRTS. In doing so, feeder buses being planned as part of the project as well as interchange with railways has been considered. In case at a particular station, suitable land is not available, effort has been made to provide equivalent space on the adjacent stations, assuming that park and ride commuters will shift to which ever station such a facility is available.

## 5.5 CHOICE OF SUPERSTRUCTURE

5.5.1 The choice of superstructure has to be made keeping in view the ease of constructability and the maximum standardization of the form-work for a wide span ranges. Typical cross section of Viaduct is given in **Fig 5.2**

5.5.2 Following type of superstructures have been considered:

- (i) Precast segmental box girder using external unbonded tendons.
- (ii) Precast segmental U-Channel superstructure with internal pre-stressing.

The segmental construction has been chosen mainly due to the following advantages:

- Segmental construction is an efficient and economical method for a large range of span lengths and types of structures. Structures with sharp curves and variable superelevation can be easily accommodated.
- Segmental construction permits reduction of construction time as segments may be manufactured while the substructure work proceeds, and assembled rapidly thereafter.
- 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 from piers at heights.
- Segments are easy to stack in the casting yard/sticking yard in more than one layer, thereby saving in requirement of space.
- It is easier to transport smaller segments by road trailers on city roads.



- It is easy to incorporate last minute changes in span configuration if the site situation so warrants.
- Interference to traffic during construction is significantly reduced.
- Segmental construction contributes towards aesthetically pleasing structures and good finishes.
- The overall labour requirement is less than that for conventional methods.
- Better quality control is possible in the casting yard.
- During construction, this technique shows an exceptionally high record of safety.

## 5.6 COMPARATIVE ADVANTAGES/DISADVANTAGES OF THE TWO TYPES OF SUPERSTRUCTURES EXAMINED ARE GIVEN BELOW:

### 5.6.1 Segmental Box Girder

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

The main advantages of dry-jointed externally prestressed precast segmental construction can be summarized as follows:-

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

Concept drawing of box girder span is given at **Fig 5.3**



**Note by BMRCL:**

**After due consideration of advantages, the segmental “U” girder viaduct is preferred. However the box girder option will not be closed altogether.**

### 5.6.2 Segmental ‘U’ Girder

The single U type of viaduct structure is also a precast segmental construction with internal prestressing and requires gluing and temporary prestressing of segments. The match cast joints at the interface of two segments are also provided with shear keys. The main advantages for this type of structural configuration of superstructure are:-

- Built-in sound barrier.
- Built-in cable support and system function.
- Possibility to lower the longitudinal profile by approximately 1m compared to conventional design.
- Built-in structural elements capable of maintaining the trains on the bridge in case of derailment (a standard barrier design does not allow this)
- Built-in maintenance and evacuation path on either side of the track.

Although, there may be a saving in the construction time for segmental box girder option by almost one day but the 2<sup>nd</sup> option is recommended for Bangalore Metro for phase-II as was recommended for phase-I considering the advantages as highlighted above, particularly, considering the fact that the 2<sup>nd</sup> option has inbuilt features such as top flange of ‘U’ Channel which acts as an evacuation path on either side of the tracks and also possibility to lower the longitudinal profile of the elevated viaduct.

Concept drawing of U- girder span is given at **Fig 5.4**.

## 5.7 GENERAL

5.7.1 The Phase-II N-S line is an elevated line from Gottigere to Swagath Road Cross and the remaining length from Dairy Circle to Nagavara is a underground line.

The break-up of length (in meters) of the Phase-II N-S corridor is given below:-

Elevated: from Ch. 0 to Ch.6950	= 06.98 km
Underground from Ch.7440 to Ch.21300	= 13.79 km
Ramps from Ch.6950 to 7440	= 00.48 km
<b>Total length</b>	<b>= 21.255 km</b>



## 5.8 CONSTRUCTION METHODOLOGY

### 5.8.1 Elevated Sections of the Corridor

The Ph-II N-S line on south end is elevated corridor and the total length of elevated corridor is 06.95 kms. Thus the elevated sections can be constructed through 2 different contracts. The remaining portion is underground section of 13.86 km, which can be constructed through two contracts.

### 5.8.2 Pre-Cast Construction

For the elevated sections it is recommended to have pre-cast segmental construction for super structure of the viaduct. For stations also the superstructure is generally of pre-cast members. The pre-cast construction will have the following advantages:-

- Reduction in construction period due to concurrent working for substructure and superstructure.
- For segmental, pre-cast element (of generally 3.0m length), transportation from construction depot to site is easy and economical.
- Minimum inconvenience is caused to the public utilising the road as the superstructure launching is carried out through launching girder requiring narrow width of the road.
- As the pre-cast elements are cast on production line in a construction depot, very good quality can be ensured.
- The method is environment friendly as no concreting work is carried at site for the superstructure.

#### **Note of BMRCL:**

***When it is twin "U" girders, we can think of pre-stressing the girder in stocking yard and erect at site by two road cranes which will be faster. This will be suitable as there are broad roads with not much sharp bends enabling transport of long girders on trailers to launching site.***

### 5.8.3 Casting of Segments

For viaducts segmental pre-cast construction requires a casting yard. The construction depot will have facilities for casting beds, curing and stacking areas, batching plant with storage facilities for aggregates and cement, site testing laboratories, reinforcement steel yard, fabrication yard, etc. An area of about 2.5 Hect. to 3 Hect is required for each construction depot (one per contract).

For casting of segments both long line and short line method can be adopted. However the long line method is more suitable for spans curved in plan while short line method is good for straight spans. A high degree of accuracy is required for setting out the curves on long line method for which pre calculation



of offsets is necessary. Match casting of segments is required in either method. The cast segments are cured on the bed as well as in stacking yard. Ends of the segments are to be made rough through sand blasting so that gluing of segments can be effective.

The cast segment will be transported on trailers and launched in position through launching girders.

**Note of BMRCL:**

***If it is not a segmental construction, the full girder will be cast in casting yard and not segments making up the full girder.***

#### 5.8.4 Launching Scheme

Launching girder is specially designed for launching of segments. Initially, the launching girder is erected on pier head at one end of the work. The segments are lifted in sequence and dry matched while hanging from the launching girder. After dry matching, the segments are glued with epoxy and pre-stressed from one end. The girder is lowered on the temporary / permanent bearings after pre-stressing. The launching girder then moves over the launched span to next span and the sequences continue.

**Note of BMRCL:**

***If it is a full length girder, it will be erected by road cranes.***

#### 5.8.5 Sub-structure

Sub-structure for the elevated section will consist of open foundations in rock area and pile foundations where soil is encountered or rock is more than 5 to 6 m below the ground level. It is proposed to provide 4 piles of 1200 mm diameter. A pile cap of thickness of about 2 m will be cast over the piles. It is proposed to keep the pile cap / open foundation top about 500 mm below the road level so as to provide necessary drainage from the viaduct and leave space for crossing of utilities if necessary.

Circular pier of about 1600 mm diameter is proposed to cast in single lift including pier cap to give good finish without any joint in the concrete. For protection of the pier from collision from moving vehicles on the road, a concrete guard is also provided around the pier up to a height of 1 m.

#### 5.8.6 Underground Section of the corridor

The northern portion of Ph-II N-S line is underground section of about 13.79 km, which is proposed for construction through two contracts on design & build basis. The full section in between stations is proposed to be constructed as twin bored tunnels with TBM/EPBMs. The tunnel cross section for machine bored tunnel is given at Fig 5.5. The twelve underground stations are proposed to be constructed with cut & cover method.





## 5.9 CONSTRUCTION OF THE STATIONS

- 5.9.1 It is proposed to construct the elevated stations with elevated concourse over the road at most of the locations to minimise land acquisition. To keep the rail level low, it is proposed not to take viaduct through the stations. Thus a separate structural configuration is required (although this may necessitate the break in the launching operations at each station locations)
- 5.9.2 Sub-structure for the station portion will be similar to that of viaduct and will be constructed in the same manner. However, there will be 3 rows of piers in the station area which will be located on the median and on foot paths on either side.
- 5.9.3 Super-structure will consist of 3 precast U Girders for supporting the track structure and I Girders / Double T Girders for supporting the platform and concourse areas. A pre-cast or cast-in-situ prestressed cross girder will be required over the middle piers for supporting the platform structure. L-shaped pre-cast cross girders are planned for supporting the concourse girders and escalators at mezzanine level. All the members will be pre-cast in the construction depot and launched at site through cranes.
- 5.9.4 On the Ph-II N-S line, there are 06 elevated stations it is proposed to have 2 Contracts for the 06 Ph-II elevated stations.
- 5.9.5 The twelve underground stations will be part of the design & built underground contract package.

## 5.10 GRADE OF CONCRETE

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

i)	Piles, Pile cap and open foundation	-	M -30
ii)	Piers	-	M -40
iii)	All precast element for viaduct and station	-	M -45
iv)	Cantilever piers and portals	-	M -45
		-	M -60
v)	Other miscellaneous structure	-	M -30
vi)	Pre cast Tunnel linings	-	M -45

For all the main structures, permeability test on concrete sample is recommended to ensure impermeable concrete.

## 5.11 REINFORCEMENT AND PRESTRESSED STEEL

It is proposed to use HYSD 415 or TMT steel as reinforcement bars.

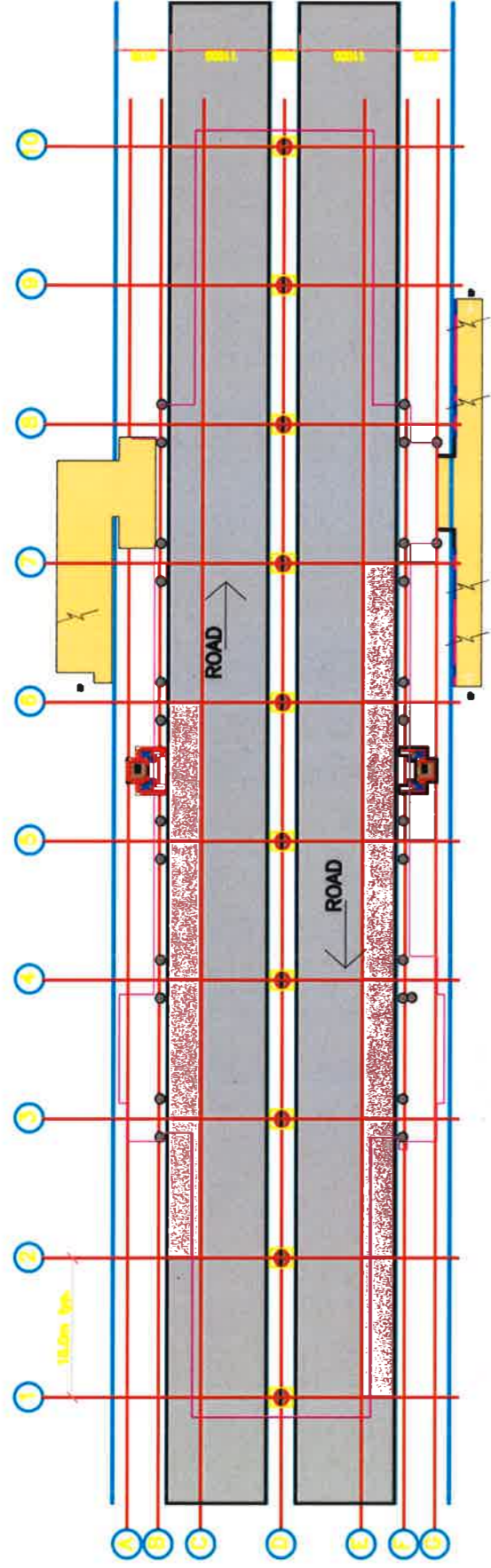
For pre-stressing work, low relaxation high tensile steel strands with the configuration 12 T 13 and or 19 K 15 is recommended (confirming to IS:14268).



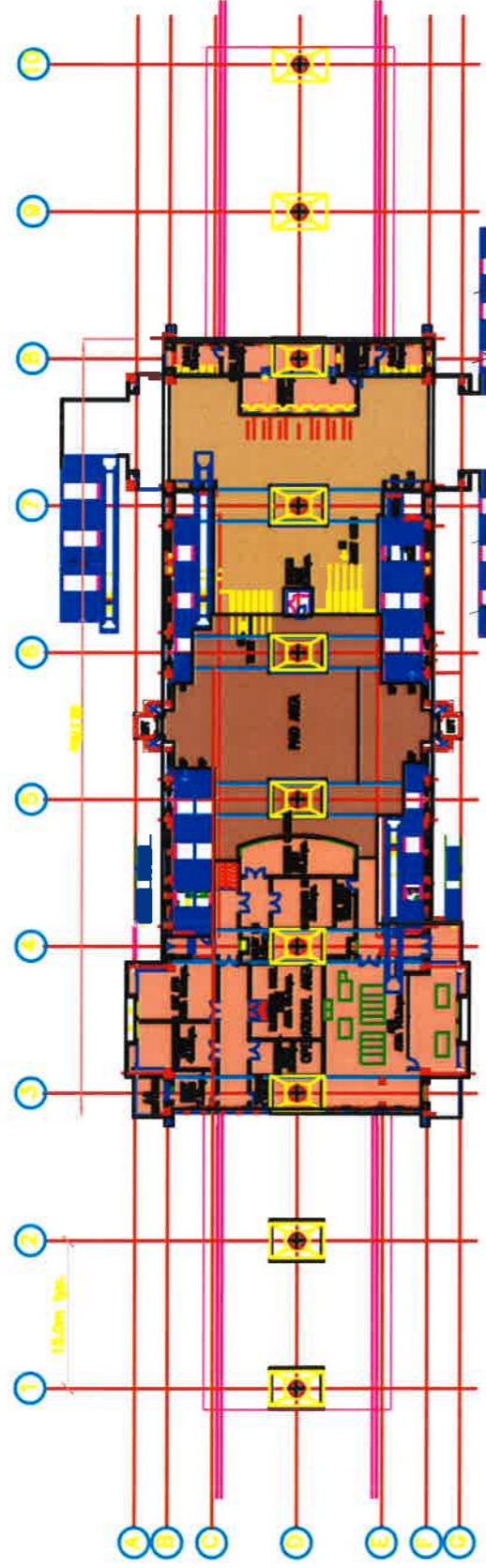
## 5.12 ROAD WIDTH REQUIRED DURING CONSTRUCTION

As most of the construction is to be carried out on the middle of the road, central two lanes including median will be required for construction activities. During piling and open foundation work, a width of about 8m will be required for construction and the same will be barricaded. It is proposed that two lanes are provided for traffic on either side during construction by widening of roads, if necessary. In certain cases, one way traffic may be resorted to.

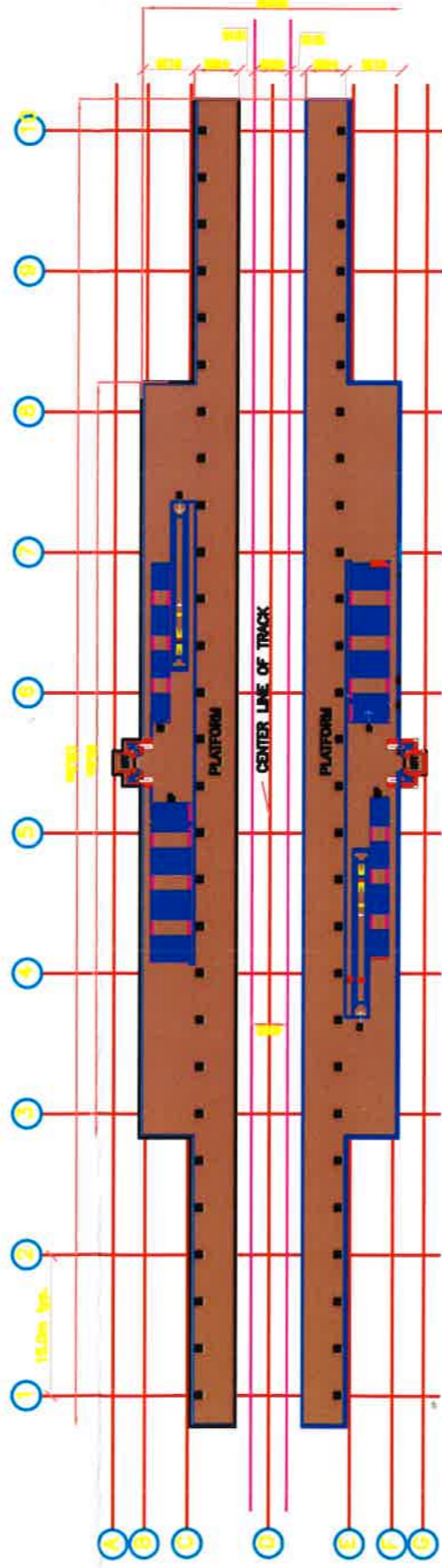
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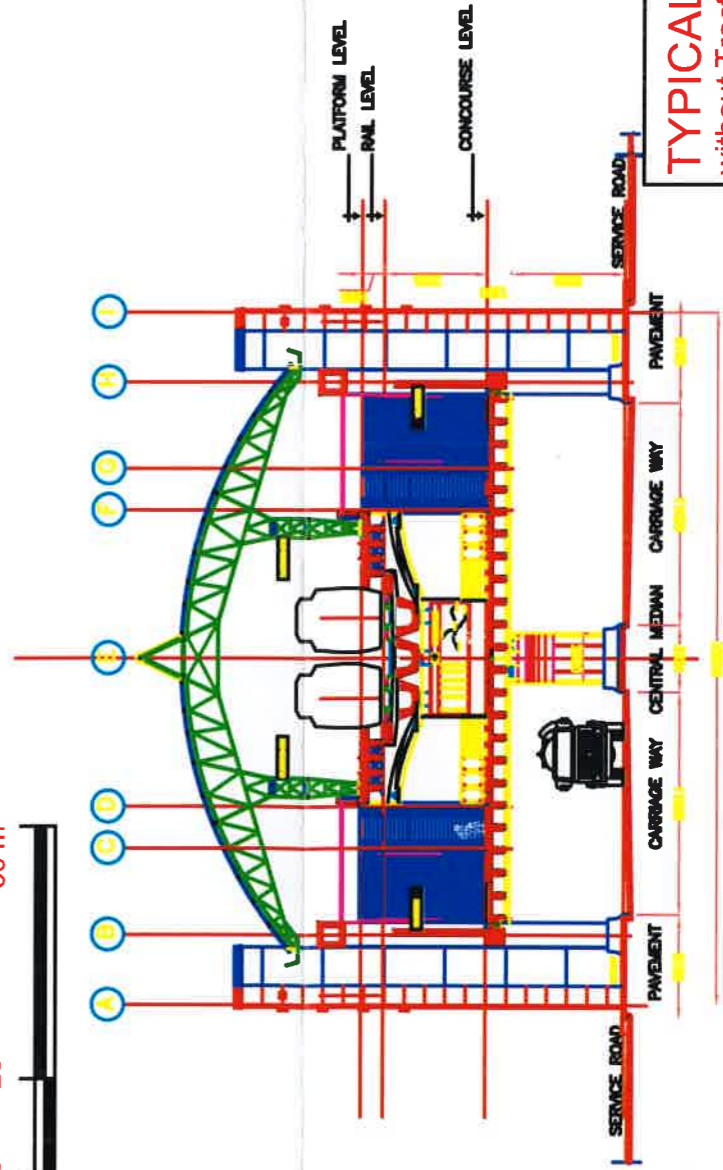
ROAD LEVEL PLAN



CONCOURSE LEVEL PLAN



PLATFORM LEVEL PLAN

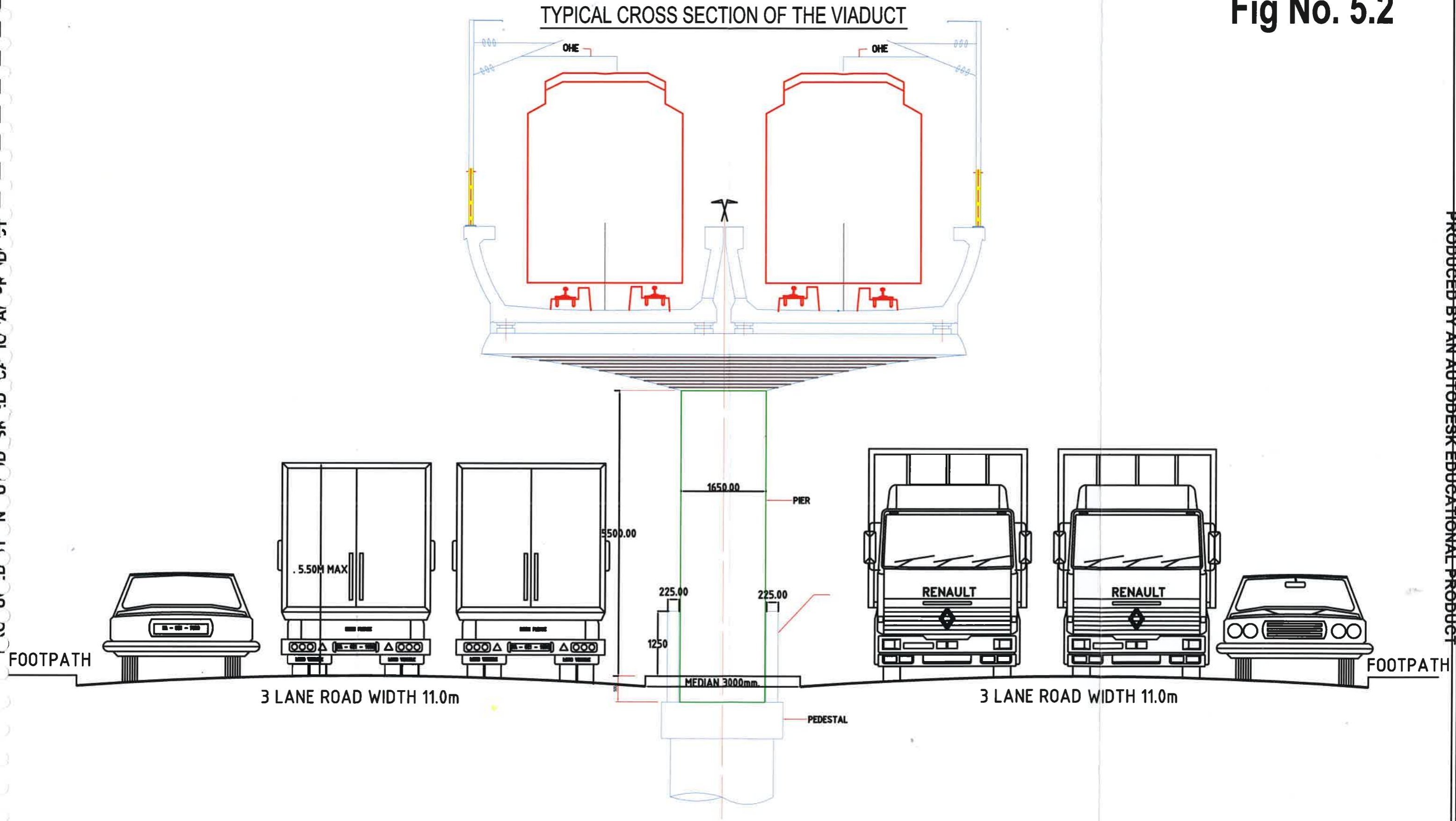


**TYPICAL ELEVATED STATION**  
without Traction Sub Station  
BANGALORE METRO, Phase II

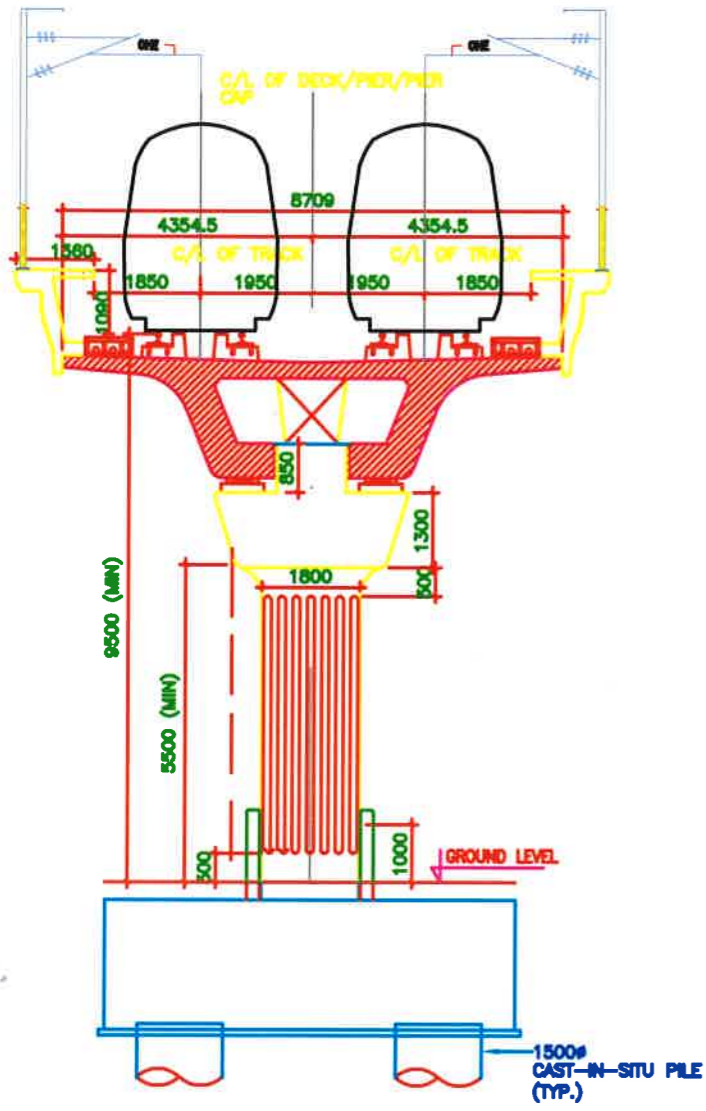
Figure 5.1



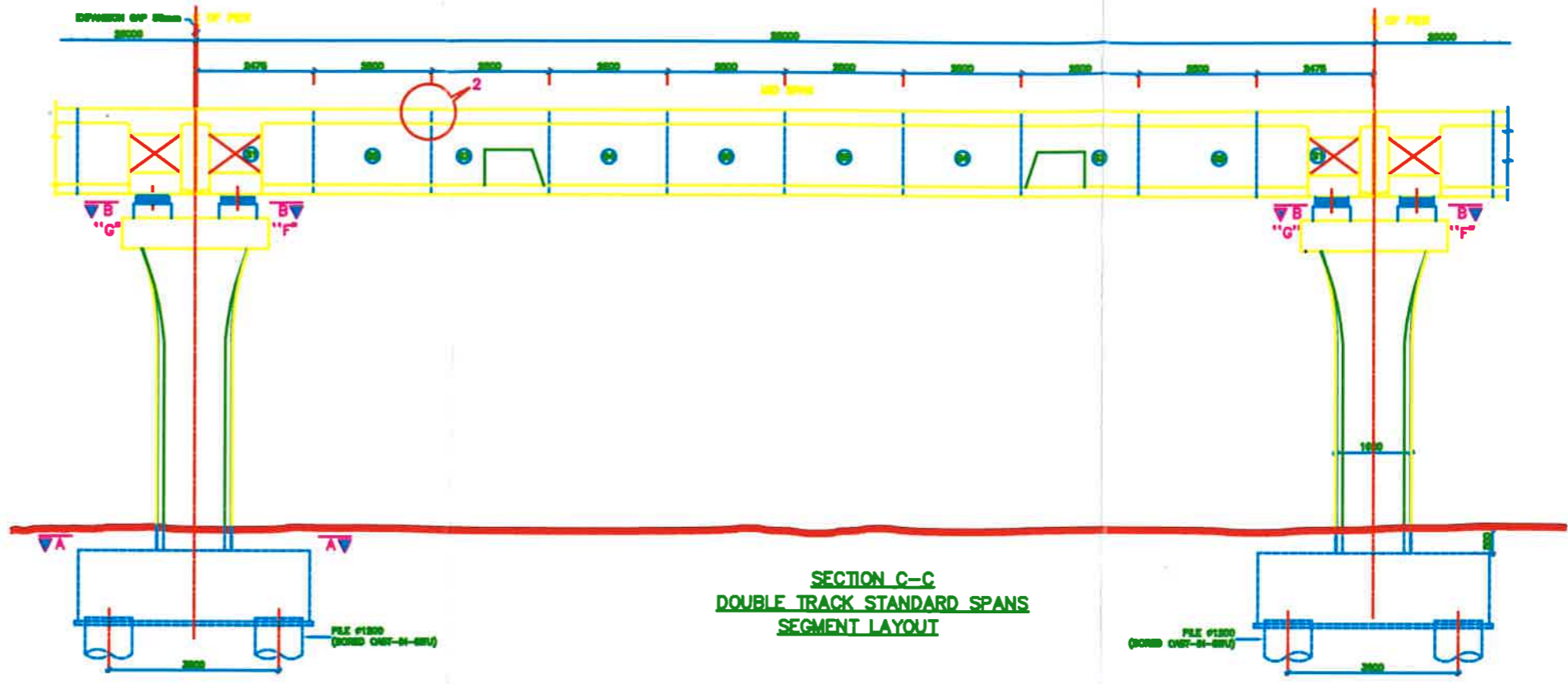
Fig No. 5.2



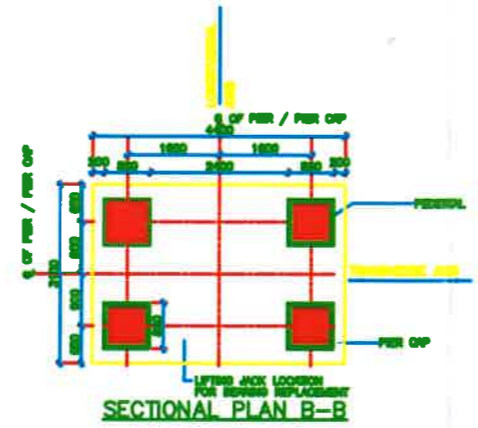
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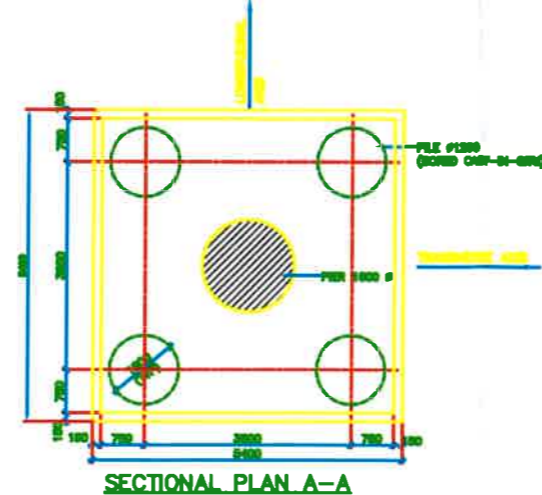
TYPICAL CROSS SECTION  
(SCALE 1:100)



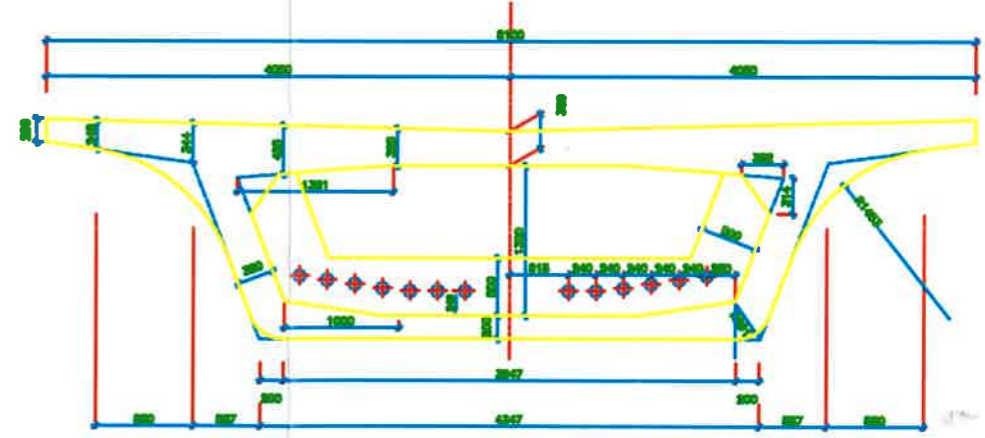
SECTION C-C  
DOUBLE TRACK STANDARD SPANS  
SEGMENT LAYOUT



SECTIONAL PLAN B-B



SECTIONAL PLAN A-A



DETAILS OF CROSS-SECTION AT MID SPAN  
DETAIL -1

NOTE  
ALL DIMENSIONS ARE IN MILLIMETRES

ALL DIMENSIONS ARE TENTATIVE AND LIKELY TO CHANGE DURING DETAIL DESIGN	(Name and Designation) Certified that this document has been designed and checked in accordance with DMRC Quality Assurance Plan	
	Authorized Signatory for DMRC	
DRAWN BY	<b>Bangalore Metro Phase-2</b>	
CHECKED BY	GENERAL ARRANGEMENT OF STANDARD SPAN	
VERIFIED BY	BOX GIRDER WITH EXTERNAL PRESTRESSING	
DATE	DRG. NO.	STATUS

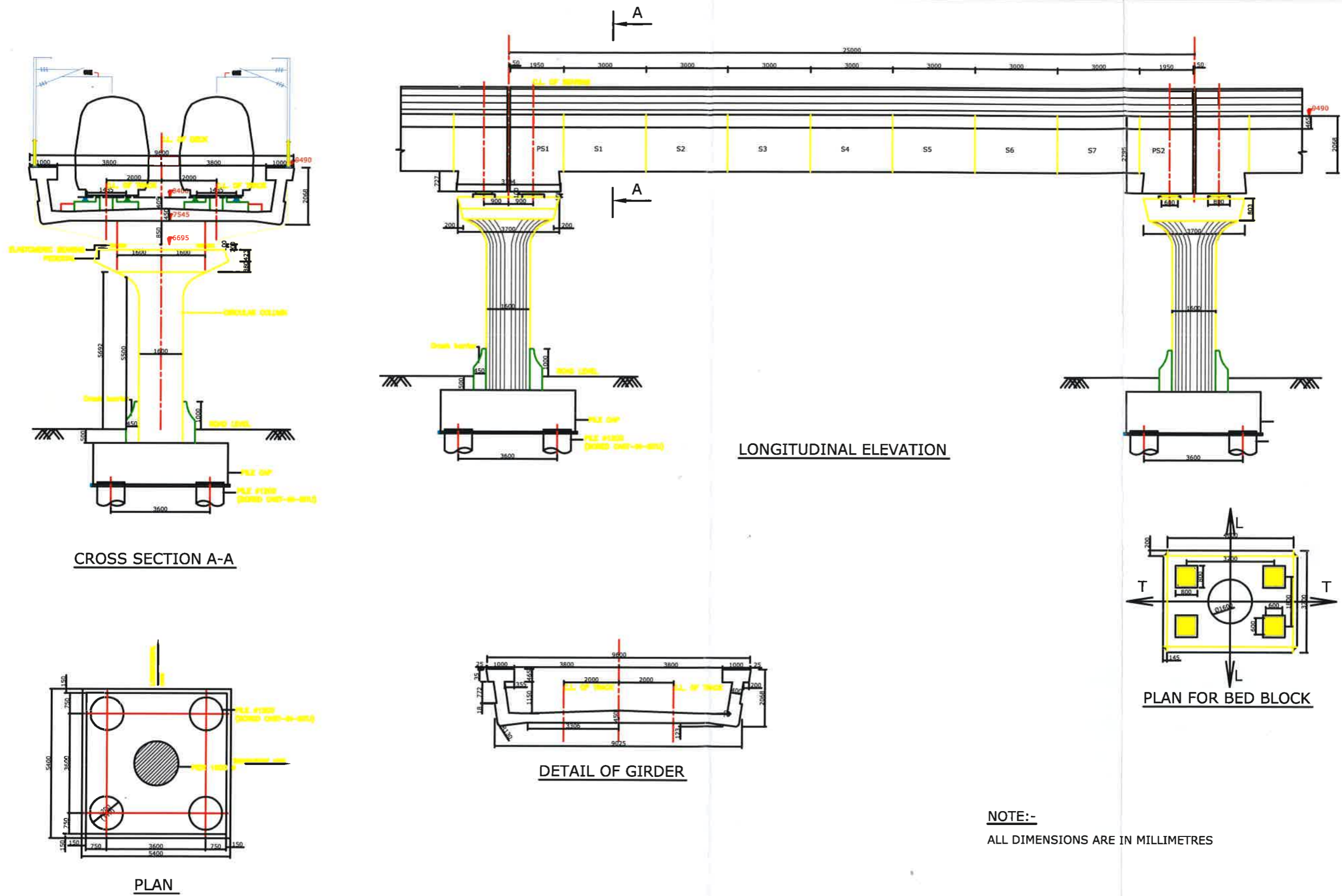
REV.	PARTICULARS	DRN.	CHKD.	VER.	DATE

REFERENCE DRAWINGS	
DRG. NO.	DESCRIPTION



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LONGITUDINAL ELEVATION

CROSS SECTION A-A

DETAIL OF GIRDER

PLAN FOR BED BLOCK

PLAN

NOTE:-  
ALL DIMENSIONS ARE IN MILLIMETRES

**HIGHSPEED RAIL LINK to BANGALORE INTERNATIONAL AIRPORT**  
GENERAL ARRANGEMENT OF VIADUCT U-GIRDER WITH INTERNAL PRESTRESSING

FIGURE-5.4

### Kinematic Envelope on Tangent Track

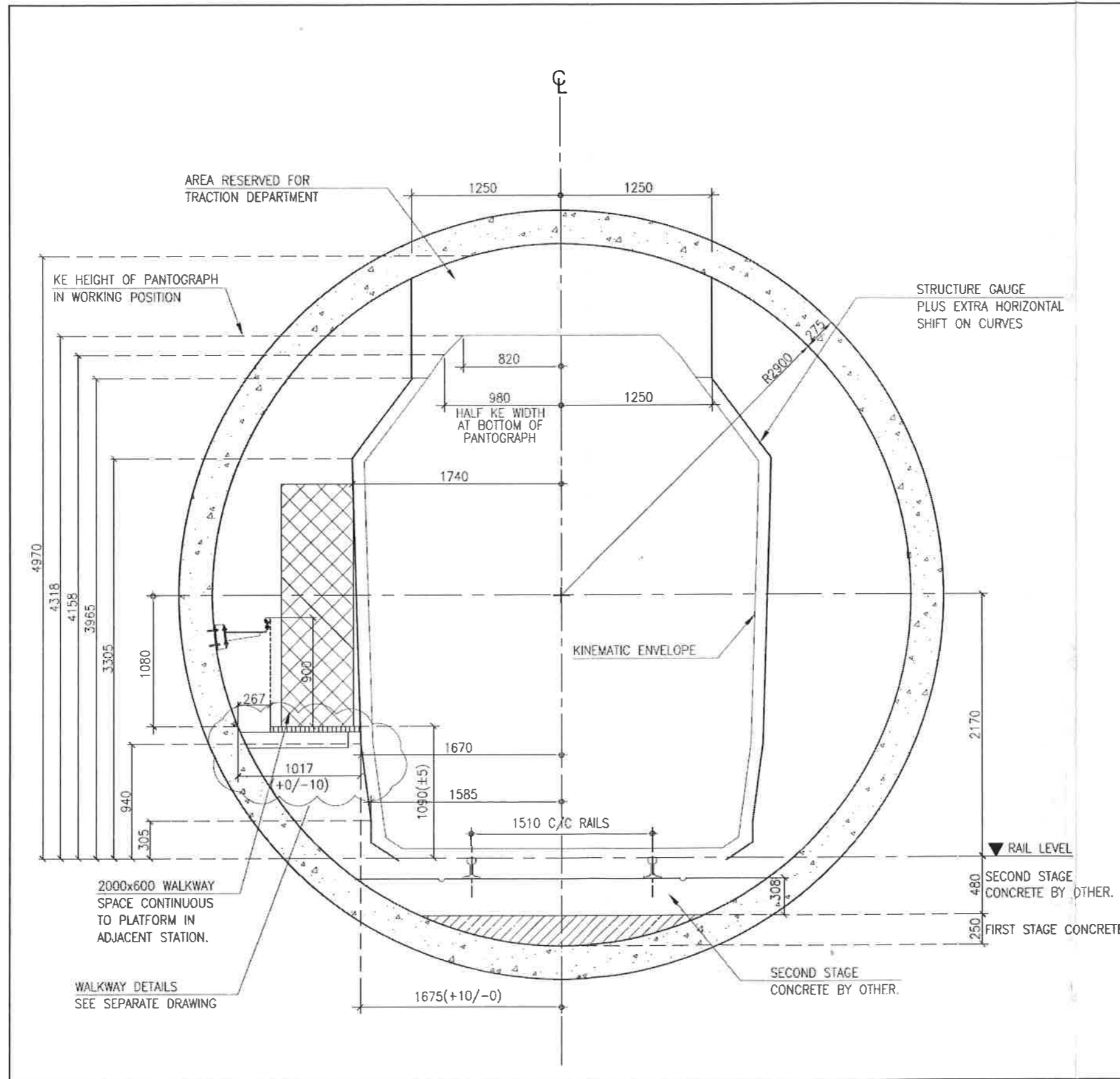


Fig. 5.5 Kinematic Envelope on Tangent Track

**CHAPTER-6**

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**TRAIN OPERATION PLAN**





## CHAPTER 6

### TRAIN OPERATION PLAN

#### 6.1 Operation Philosophy

The underlying operation philosophy is to make the Bangalore Metro 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.
- A short train consists of 3 coaches with high frequency service which can be increased to 6 Coaches to meet future requirements.
- Multi-tasking of train operation and maintenance staff.

#### 6.2 Stations

List of stations for the Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) of Bangalore Metro Phase -II are given below:

Gottigere – IIMB- Nagavara Corridor of Bangalore Metro Phase -II				
S.No	Name of Stations	Change (in m)	Inter – Station Distance (in m)	Type of Station (Elevated/U/G)
	Dead End	0.00	-	
1	Gottigere	411.00	411.00	Elevated
2	Hulimavu	1484.50	1073.50	Elevated
3	IIMB	3204.00	1719.50	Elevated
4	J P Nagar-IV Phase	4575.00	1371.00	Elevated
5	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	5414.00	839.00	Elevated
6	Swagath Road Cross	6777.00	1363.00	Elevated
7	Dairy Circle	7929.00	1152.00	Underground



<b>Gottigere – IIMB- Nagavara Corridor of Bangalore Metro Phase -II</b>				
<b>S.No</b>	<b>Name of Stations</b>	<b>Change (in m)</b>	<b>Inter – Station Distance (in m)</b>	<b>Type of Station (Elevated/U/G)</b>
8	MICO Industries	8961.00	1032.00	Underground
9	Langford Town	9880.40	919.40	Underground
10	Vellara	10884.00	1003.60	Underground
11	M. G. Road Integration with East–West Line	12020.00	1136.00	Underground
12	Shivaji Nagar	13241.00	1221.00	Underground
13	Cantonment Railway Station	14405.00	1164.00	Underground
14	Pottery Town	16023.00	1618.00	Underground
15	Tannery Road	17182.00	1159.00	Underground
16	Venkateshpura	18168.00	986.00	Underground
17	Arabic College	19592.00	1424.00	Underground
18	Nagavara	20995.00	1403.00	Underground
	Dead End	21255.00	260.00	

### 6.3 Train Operation Plan

#### 6.3.1 Salient Features

- Running of services for 19 hours of a day (5 AM to Midnight) with a station dwell time of 30 seconds.
- Make up time of 5-10% with 8-12% coasting.
- Scheduled speed for this corridor has been assumed as 34 Kmph.

#### 6.3.2 Traffic Demand

Peak hour peak direction traffic demands (PHPDT) for the Bangalore Metro Corridor for the year 2016, 2021, 2031 and 2041 for the purpose of planning are indicated in Attachment I/A, B, C & D.



### 6.3.3 Train formation

To meet the above projected traffic demand, the possibility of running trains with composition of 3 Car and 6 Car trains with different headways has been examined.

The basic details of train configuration selected for the Bangalore Metro Corridor is as under:

#### Composition

DMC : Driving Motor Car

TC : Trailer Car

MC : Motor Car

3 Car Train Composition : DMC + TC + DMC

6 Car Train Composition : DMC + TC + MC + MC + TC + DMC

#### Capacity @ 6 persons per sqm of standee area( being considered for calculating optimum headway for train operation):

DMC : 248 Passengers (Sitting-43, Crush Standing-205)

TC/MC : 270 Passengers (Sitting-50, Crush Standing-220)

3 Car Train : 766 Passengers (Sitting-136, Crush Standing-630)

6 Car Train : 1576 Passengers (Sitting-286, Crush Standing-1290)

#### Capacity @ 8 persons per sqm of standee area:

DMC : 322 Passengers (Sitting-43, Crush Standing-273)

TC/MC : 356 Passengers (Sitting-50, Crush Standing-293)

3 Car Train : 975 Passengers (Sitting-136, Crush Standing-839)

6 Car Train : 2004 Passengers (Sitting-286, Crush Standing-1718)

### 6.3.4 Train Operation Plan

For Rolling Stock, following two options are proposed:

(a) Option – 1 (Recommended)

In this option, 25 KV AC traction has been proposed resulting in increase in the weight of the car and thus the axle load (axle load increased to 16T as against 15T axle load of existing Bangalore Metro Stock). All other parameters including passenger capacity remain the same as in existing Bangalore Metro Stock.



(b) Option -2

Existing Bangalore Metro Rolling Stock with 750V DC traction has been proposed. The Rolling Stock parameters have been updated based on BMRCL's advice received as a part of their comments on Phase-II DPR.

The Train Operation Plan is common for both the above two options as the passenger capacity and performance parameters are the same.

In view of above, based on the projected PHPDT demand, train operation has been planned for Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) for the year 2016, 2021, 2031 and 2041 as detailed below:

**Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II):**

▪ **Year 2016 (Refer Attachment I/A)**

- 4 min Headway with 3-car train.
- Available Peak Hour Peak Direction Capacity of 11490 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 14625 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 11935 is in the Section between Swagath Road Cross and Dairy Circle and the PHPDT demand in the section between MICO Industries and Langford Town is 11852, demand in the remaining sections is in the range of 11726 to 3641 only. The planned capacity of 11490 (14625 under dense loading) is less than the PHPDT demand in four (zero, with dense loading capacity) sections out of seventeen sections.
- With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2016 is tabulated and represented on a chart enclosed as Attachment I/A.



▪ **Year 2021 (Refer Attachment I/B)**

- 3 min Headway with 3-car train.
- Available Peak Hour Peak Direction Capacity of 15320 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 19500 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 16381 is in the Section between Swagath Road Cross and Dairy Circle and the PHPDT demand in the section between MICO Industries and Langford Town is 16252, demand in the remaining sections is in the range of 16053 to 4606 only. The planned capacity of 15320 (19500 under dense loading) is less than the PHPDT demand in six (zero, with dense loading capacity) sections out of seventeen sections.
- With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2021 is tabulated and represented on a chart enclosed as Attachment I/B.

▪ **Year 2031 (Refer Attachment I/C)**

- 3 min Headway with alternate 3-car and 6-car train.
- Available Peak Hour Peak Direction Capacity of 23420 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 29790 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 22806 is in the Section between Swagath Road Cross and Dairy Circle and the PHPDT demand in the section between MICO Industries and Langford Town is 22428, demand in the remaining sections is in the range of 22153 to 6356 only. The planned capacity of 23420 (29790 under dense loading) is more than the PHPDT demand of seventeen sections.
- Traffic demand and train capacity for this corridor in the year 2031 is tabulated and represented on a chart enclosed as Attachment I/C.



▪ **Year 2041 (Refer Attachment I/D)**

- 3 min Headway with alternate 3-car and 6-car train.
- Available Peak Hour Peak Direction Capacity of 23420 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 29790 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 25315 is in the Section between Swagath Road Cross and Dairy Circle and the PHPDT demand in the section between MICO Industries and Langford Town is 24895, demand in the remaining sections is in the range of 24590 to 7055 only. The planned capacity of 23420 (29790 under dense loading) is less than the PHPDT demand in six (zero, with dense loading capacity) sections out of seventeen sections.
- With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2041 is tabulated and represented on a chart enclosed as Attachment I/D.

In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by either varying the rake composition or adjusting the Headway.

All infrastructure and maintenance facilities should be planned for 6-car trains.

The PHPDT capacity provided on the three sections in different years of operation is tabulated below:

Capacity Provided for - Gottigere – IIMB- Nagavara Corridor

LINE	YEAR			
	2016	2021	2031	2041
Gottigere – IIMB- Nagavara				
Cars/trains	3	3	Alternate 3car /6-car train	Alternate 3car /6-car train
Head way (Minutes)	4	3	3	3
Max. PHPDT Demand	11935	16381	22806	25315
PHPDT Capacity Available @ 6 persons per sqm of standee area	11490 (14625*)	15320 (19500*)	23420 (29790*)	23420 (29790*)

\* @ 8 persons per square meter of standee area





## 6.4 Train frequency

### Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II)

The train operation of Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) provides for the following train frequency:

Name of Corridor	2016		2021		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	Peak Hour h/w	Lean Hour h/w
Gottigere – IIMB- Nagavara Corridor	4 min	6 to 15 min	3 min	5 to 15 min	3 min	5 to 15 min	3min	5 to 15 min

\*No services are proposed between 00.00 hrs to 5.00 hrs, which are reserved for maintenance of infrastructure and rolling stock.

### 6.4.1 Hourly Train Operation plan

The hourly distribution of daily transport capacity is presented in **Table 1.1, 1.2, 1.3 & 1.4** for years 2016, 2021, 2031 & 2041 for Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) are enclosed as Attachment II. Number of train trips per direction per day for Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) is worked out as 178 in the year 2016, 216 in the year 2021, 216 in the year 2031 & 216 for in the year 2041 respectively. The directional splits for Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II) are presented in **Table 2** enclosed as Attachment III.

### 6.4.2 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for Bangalore Metro Corridor is given in **Table 3** is enclosed as Attachment IV.

## 6.5 Year wise rake Requirement

Based on Train formation and headway as decided above to meet Peak Hour Peak Direction Traffic Demand, Rake requirement has been calculated and enclosed as Attachment V & has been tabulated below:



Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches
Gottigere – IIMB-Nagavara Corridor (North-South Corridor-II)	2016	4	23 rakes of 3-car each	3 car	69
	2021	3	31 rakes of 3-car each	3 car	93
	2031	3	17 rakes of 3-cars and 15 rakes of 6-cars	Alternate 3 car/6 car	141
	2041	3	17 rakes of 3-cars and 15 rakes of 6-cars	Alternate 3 car/6 car	141

Requirements of coaches is calculated based on following assumptions-

**Assumptions -**

- (i) Train Composition planned as under
  - 3 Car Train Composition : DMC-TC-DMC  
Train Carrying Capacity of 3 Car Train : 766 passengers (@ 6 per sqm of standee area)  
: 975 passengers (@ 8 per sqm of standee area)
  - 6-Car Train Composition : DMC+TC+MC+MC+TC+DMC  
Train Carrying Capacity of 6 Car Train : 1576 passengers (@ 6 per sqm of standee area)  
: 2004 passengers (@ 8 per sqm of standee area)
- (ii) Coach requirement has been calculated based on headway during peak hours.
- (iii) Traffic reserve is taken as one train per section to cater to failure of train on line and to make up for operational time lost.
- (iv) Repair and maintenance reserve has been estimated as 8 % of total requirement (Bare +Traffic Reserve).
- (v) The calculated number of rakes in fraction is rounded off to next higher number.
- (vi) Schedule speed is taken as 34 kmph for all the sections.
- (vii) Total Turn round time is taken as 6 min at terminal stations.



## Gottigere – IIMB- Nagavara Corridor of BANGALORE METRO – Phase II

SUMMARY SHEET AS ON: 06.05.11

OPTION 1 (Voltage: 25 KV ac)

1. **Corridor:** Gottigere – IIMB- Nagavara Corridor (North-South Corridor-II):— Standalone Line.
2. **Route Length (Centre to Centre):** 20.584 km
3. **Average Interstation Distance:** 1.211 km
4. **Number of Stations:** 18 Stations
5. **Gauge:** 1435 mm
6. **Traction Power Supply**
  - i) Voltage: 25 KV ac
  - ii) Current Collection: Overhead Current Collection System
7. **Rolling Stock:**
  - i) Coach Size:

<b>Particular</b>	<b>Length*</b>	<b>Width</b>	<b>Height</b>
<b>Driving Motor Car (DMC)</b>	21.05 m	2.88 m	3.88 m
<b>Trailer Car (TC)/Motor Car (MC)</b>	20.8 m	2.88 m	3.88 m

- ii) Passenger Carrying Capacity (Crush @ 6 passenger/sqm of standee area)

	<b>SEATED</b>	<b>STANDING</b>	<b>TOTAL</b>
<b>DMC</b>	43	205	248
<b>TC/MC</b>	50	220	270
<b>3-CAR</b>	136	630	766
<b>6-CAR</b>	286	1290	1576

**Seating: Longitudinal**

- ii) Passenger Carrying Capacity (Crush @ 8 passenger/sqm of standee area)

	<b>SEATED</b>	<b>STANDING</b>	<b>TOTAL</b>
<b>DMC</b>	43	273	316
<b>TC/MC</b>	50	293	343
<b>3-CAR</b>	136	893	975
<b>6-CAR</b>	286	1718	2004

**Seating: Longitudinal**

- iii) Weight: (Crush @ 8 passenger/sqm of standee area)

	<b>TARE</b>	<b>PASSENGER</b>	<b>GROSS</b>
<b>DMC</b>	40	20.54	60.54
<b>TC</b>	39	22.295	61.295
<b>MC</b>	39	22.295	61.295
<b>3-CAR</b>	119	63.375	182.375
<b>6-CAR</b>	236	130.26	366.26



- iv) Axle Load: To be designed for 16T
- v) Max Acceleration :  $0.95 \text{ m/s}^2 \pm 5\%$
- vi) Max Deceleration :  $1.1 \text{ m/s}^2$  (Normal Brake)  
 $>1.3 \text{ m/s}^2$  (Emergency Brake)
- vii) Schedule Speed : 34 Kmph
- viii) Composition : 3-car = DMC + TC + DMC  
: 6-car = DMC+TC+MC+MC+TC+DMC
- ix) Cost per car: Rs. 8.4 Crores exclusive of taxes and duties at Jan 2011 Price Level.
- x) Capacity Provided & Rake Requirement:

YEAR	2016	2021	2031	2041
HEADWAY	4	3	3	3
CARS/TRAIN	3	3	Alternate 3 car/6 car	Alternate 3 car/6 car
Max.PHPDT Demand	11935	16381	22806	25315
PHPTD Capacity @6persons per sqm	11490 (14625*)	15320 (19500*)	23420 (29790*)	23420 (29790*)
Rakes Reqd	23 rakes of 3-car each	31 rakes of 3-car each	17 rakes of 3-cars and 15 rakes of 6-cars	17 rakes of 3-cars and 15 rakes of 6-cars
Cars Reqd	69	93	141	141

\* @8 persons per square meter of standee area



**PHPDT Demand and Capacity Chart**

Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II

Year: 2016  
 No. of Cars per Train: 3  
 Passenger Capacity @ 6 persons/sqm of a 3-Car Train: 766  
 Passenger Capacity @ 8 persons/sqm of a 3-Car Train: 975  
 Headway (min) 4

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	Gottigere	Hulimavu	3960	11490	14625
2	Hulimavu	IIMB	5658	11490	14625
3	IIMB	J P Nagar-IV Phase	6474	11490	14625
4	J P Nagar-IV Phase	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	7230	11490	14625
5	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	Swagath Road Cross	11545	11490	14625
6	Swagath Road Cross	Dairy Circle	11935	11490	14625
7	Dairy Circle	MICO Industries	11726	11490	14625
8	MICO Industries	Langford Town	11852	11490	14625
9	Langford Town	Vellara	10950	11490	14625
10	Vellara	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	10754	11490	14625
11	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	Shivaji Nagar	8929	11490	14625
12	Shivaji Nagar	Cantonment Railway Station	8128	11490	14625
13	Cantonment Railway Station	Pottery Town	7843	11490	14625
14	Pottery Town	Tannery Road	7410	11490	14625
15	Tannery Road	Venkateshpura	7064	11490	14625
16	Venkateshpura	Arabic College	5599	11490	14625
17	Arabic College	Nagavara	3641	11490	14625

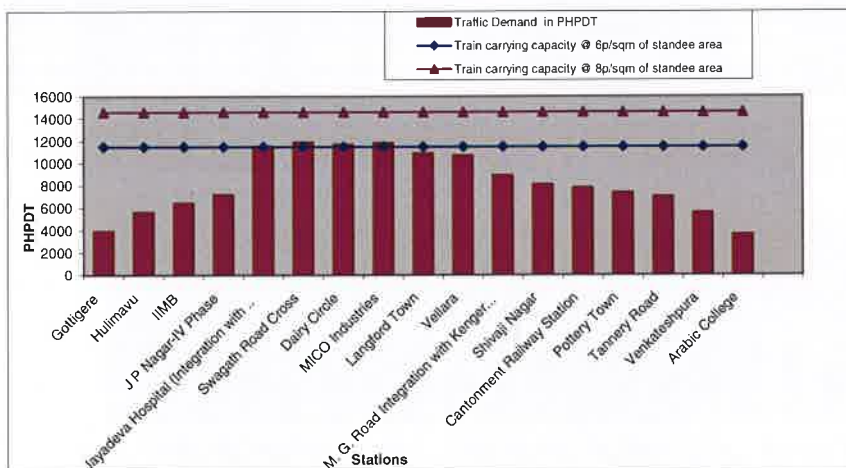


Fig 1.1



**PHPDT Demand and Capacity Chart**

Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II

Year: 2021  
 No. of Cars per Train: 3  
 Passenger Capacity @ 6 persons/sqm of a 3-Car Train: 766  
 Passenger Capacity @ 8 persons/sqm of a 3-Car Train: 975  
 Headway (min) 3

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	Gottigere	Hulimavu	6732	15320	19500
2	Hulimavu	IIMB	9618	15320	19500
3	IIMB	J P Nagar-IV Phase	11005	15320	19500
4	J P Nagar-IV Phase	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	12291	15320	19500
5	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	Swagath Road Cross	15769	15320	19500
6	Swagath Road Cross	Dairy Circle	<b>16381</b>	15320	19500
7	Dairy Circle	MICO Industries	16053	15320	19500
8	MICO Industries	Langford Town	16252	15320	19500
9	Langford Town	Vellara	15704	15320	19500
10	Vellara	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	15492	15320	19500
11	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	Shivaji Nagar	12750	15320	19500
12	Shivaji Nagar	Cantonment Railway Station	11516	15320	19500
13	Cantonment Railway Station	Pottery Town	11078	15320	19500
14	Pottery Town	Tannery Road	10412	15320	19500
15	Tannery Road	Venkateshpura	9878	15320	19500
16	Venkateshpura	Arabic College	7622	15320	19500
17	Arabic College	Nagavara	4606	15320	19500

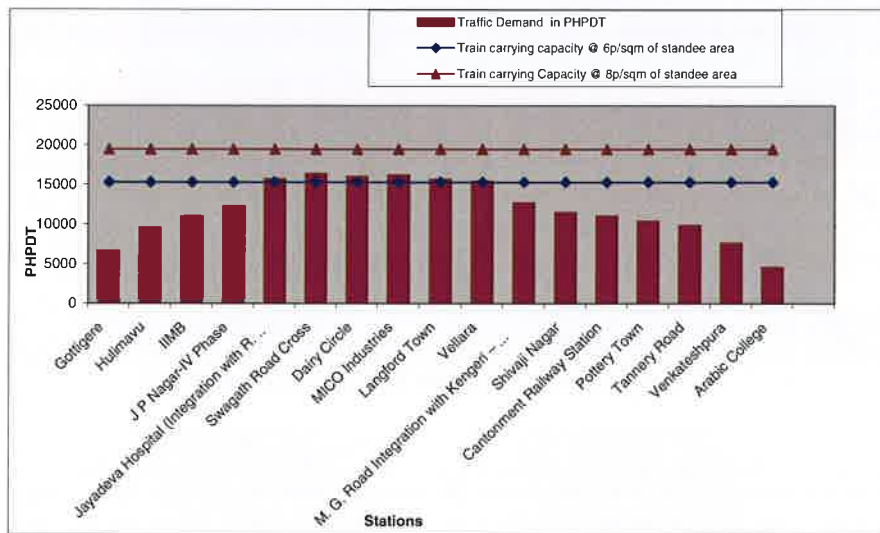


Fig 1.2





**PHPDT Demand and Capacity Chart**

Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II

Year: 2031

No. of Cars per Train: Alternate 3/6 cars

Passenger Capacity @ 6 persons/sqm of a 3-Car Train: 766

Passenger Capacity @ 8 persons/sqm of a 3-Car Train: 975

Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1576

Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2004

Headway (min) 3

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	Gottigere	Hulimavu	9291	23420	29790
2	Hulimavu	IIMB	13273	23420	29790
3	IIMB	J P Nagar-IV Phase	15187	23420	29790
4	J P Nagar-IV Phase	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	16961	23420	29790
5	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	Swagath Road Cross	21961	23420	29790
6	Swagath Road Cross	Dairy Circle	<b>22806</b>	23420	29790
7	Dairy Circle	MICO Industries	22153	23420	29790
8	MICO Industries	Langford Town	22428	23420	29790
9	Langford Town	Vellara	21672	23420	29790
10	Vellara	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	21380	23420	29790
11	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	Shivaji Nagar	17595	23420	29790
12	Shivaji Nagar	Cantonment Railway Station	15892	23420	29790
13	Cantonment Railway Station	Pottery Town	15288	23420	29790
14	Pottery Town	Tannery Road	14368	23420	29790
15	Tannery Road	Venkateshpura	13631	23420	29790
16	Venkateshpura	Arabic College	10518	23420	29790
17	Arabic College	Nagavara	6356	23420	29790

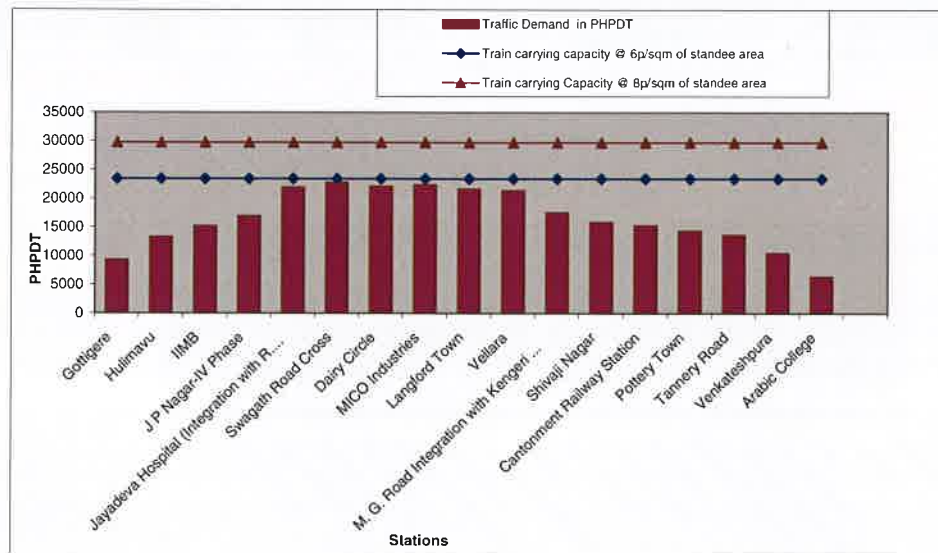


Fig 1.3



**PHPDT Demand and Capacity Chart**

Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II

Year: 2041

No. of Cars per Train: Alternate 3/6 cars

Passenger Capacity @ 6 persons/sqm of a 3-Car Train: 766

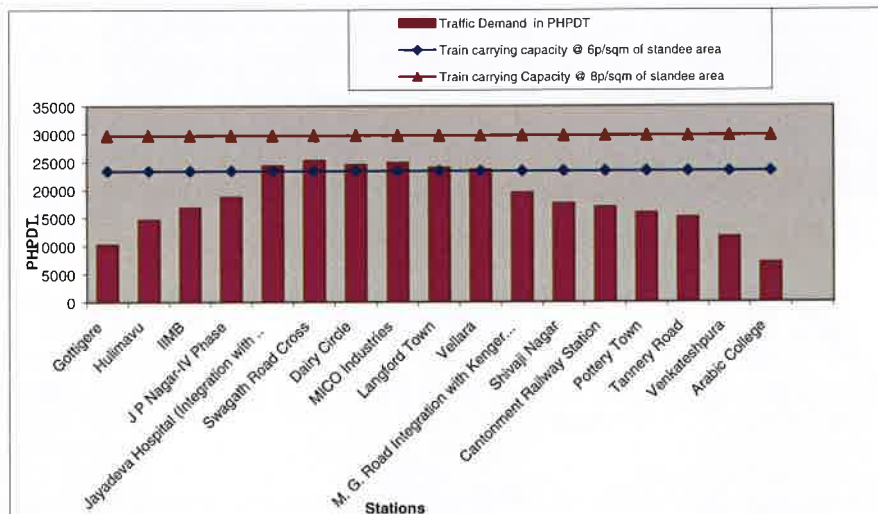
Passenger Capacity @ 8 persons/sqm of a 3-Car Train: 975

Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1576

Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2004

Headway (min) 3

S.N	FROM	TO	Traffic Demand in PHPDT	Train carrying capacity @ 6p/sqm of standee area	Train carrying capacity @ 8p/sqm of standee area
1	Gottigere	Hulimavu	10313	23420	29790
2	Hulimavu	IIMB	14733	23420	29790
3	IIMB	J P Nagar-IV Phase	16857	23420	29790
4	J P Nagar-IV Phase	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	18827	23420	29790
5	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	Swagath Road Cross	24377	23420	29790
6	Swagath Road Cross	Dairy Circle	<b>25315</b>	23420	29790
7	Dairy Circle	MICO Industries	24590	23420	29790
8	MICO Industries	Langford Town	24895	23420	29790
9	Langford Town	Vellara	24056	23420	29790
10	Vellara	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	23731	23420	29790
11	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	Shivaji Nagar	19530	23420	29790
12	Shivaji Nagar	Cantonment Railway Station	17641	23420	29790
13	Cantonment Railway Station	Pottery Town	16970	23420	29790
14	Pottery Town	Tannery Road	15949	23420	29790
15	Tannery Road	Venkateshpura	15130	23420	29790
16	Venkateshpura	Arabic College	11675	23420	29790
17	Arabic College	Nagavara	7055	23420	29790





**TABLE 1.1**  
**Hourly Train Operation Plan for Bangalore Metro : Gottigere - IIMB- Nagavara**  
**corridor ( North- South Corridor-II): Ph II**

**Year: 2016**

**Configuration: 3 Car**

**Headway(min): 4**

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	12	5	5
6 to 7	10	6	6
7 to 8	6	10	10
8 to 9	4	15	15
9 to 10	4	15	15
10 to 11	4	15	15
11 to 12	6	10	10
12 to 13	10	6	6
13 to 14	12	5	5
14 to 15	12	5	5
15 to 16	10	6	6
16 to 17	6	10	10
17 to 18	4	15	15
18 to 19	4	15	15
19 to 20	4	15	15
20 to 21	6	10	10
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
<b>Total No. of train trips per direction per day</b>		<b>178</b>	<b>178</b>



**TABLE 1.2**  
**Hourly Train Operation Plan for Bangalore Metro : Gottigere - IIMB- Nagavara**  
**corridor ( North- South Corridor-II): Ph II**

**Year: 2021**

**Configuration: 3 Car**

**Headway(min): 3**

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	12	5	5
6 to 7	10	6	6
7 to 8	5	12	12
8 to 9	3	20	20
9 to 10	3	20	20
10 to 11	3	20	20
11 to 12	5	12	12
12 to 13	10	6	6
13 to 14	12	5	5
14 to 15	12	5	5
15 to 16	10	6	6
16 to 17	5	12	12
17 to 18	3	20	20
18 to 19	3	20	20
19 to 20	3	20	20
20 to 21	5	12	12
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
<b>Total No. of train trips per direction per day</b>		<b>216</b>	<b>216</b>



**TABLE 1.3**  
**Hourly Train Operation Plan for Bangalore Metro : Gottigere - IIMB- Nagavara**  
**corridor ( North- South Corridor-II): Ph II**  
**Year: 2031**

**Configuration: Alternate 3/6 cars**

**Headway(min): 3**

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	12	5	5
6 to 7	10	6	6
7 to 8	5	12	12
8 to 9	3	20	20
9 to 10	3	20	20
10 to 11	3	20	20
11 to 12	5	12	12
12 to 13	10	6	6
13 to 14	12	5	5
14 to 15	12	5	5
15 to 16	10	6	6
16 to 17	5	12	12
17 to 18	3	20	20
18 to 19	3	20	20
19 to 20	3	20	20
20 to 21	5	12	12
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
<b>Total No. of train trips per direction per day</b>		<b>216</b>	<b>216</b>

Note:

1. In the above case, the operation will be by using combination of 3-car rakes and 6-car rakes.
2. As the number of rakes in operation of 3-car and 6-car configuration are in the ratio of 1:1, the train trips of 3-car and 6-car trains will also be in the same ratio.
3. Hence, out of 216 trips, about 108 trips will be of 3-car trains and 108 trips will be of 6-car trains.



**TABLE 2**  
**Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II**  
**PHPDT for the Year 2016**

S.No	From Station	To Station	Maximum PHPDT	Directional Split to Nagavara	Directional Split to Gottigere
1	Gottigere	Hulimavu	3960	50%	50%
2	Hulimavu	IIMB	5658	50%	50%
3	IIMB	J P Nagar-IV Phase	6474	50%	50%
4	J P Nagar-IV Phase	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	7230	50%	50%
5	Jayadeva Hospital (Integration with R. V. Road – Bommasandra Line )	Swagath Road Cross	11545	50%	50%
6	Swagath Road Cross	Dairy Circle	11935	50%	50%
7	Dairy Circle	MICO Industries	11726	50%	50%
8	MICO Industries	Langford Town	11852	50%	50%
9	Langford Town	Vellara	10950	50%	50%
10	Vellara	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	10754	50%	50%
11	M. G. Road Integration with Kengeri – Whitefield (East –West) Line	Shivaji Nagar	8929	50%	50%
12	Shivaji Nagar	Cantonment Railway Station	8128	50%	50%
13	Cantonment Railway Station	Pottery Town	7843	50%	50%
14	Pottery Town	Tannery Road	7410	50%	50%
15	Tannery Road	Venkateshpura	7064	50%	50%
16	Venkateshpura	Arabic College	5599	50%	50%
17	Arabic College	Nagavara	3641	50%	50%



**TABLE 3**  
**Vehicle Kilometer**  
**Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II**

Year	2016		2021		2031		2041	
	Section Length	20.58	20.58	20.58	20.58	20.58	20.58	20.58
No of cars per Train	3	3	3	3	6	3	6	
No of working Days in a year	340	340	340	340	340	340	340	
Number of Trains per day each Way	178	216	108	108	108	108	108	
Daily Train -KM	7328	8892	4446	4446	4446	4446	4446	
Annual Train - KM (10 <sup>5</sup> )	24.91	30.23	15.12	15.12	15.12	15.12	15.12	
Annual Vehicle - KM (10 <sup>5</sup> )	74.74	90.70	45.35	45.35	90.70	45.35	90.70	





Attachment V

**Rake Requirement**

**Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North-South Corridor-II): Ph II, Year : 2016**  
**Passenger Capacity @ 6 Persons/sqm In 3 Car Train: 766**      **Schedule Speed in Kmph= 34**

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North-South Corridor-II); Ph II	20.58	34.0	11935	11490	4	20	1	2	23	3	69
Total Turn Round Time(min) 6											

**Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North-South Corridor-II): Ph II, Year : 2021**  
**Passenger Capacity @ 6 Persons/sqm In 3 Car Train: 766**      **Schedule Speed in Kmph= 34**

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North-South Corridor-II); Ph II	20.58	34.0	16381	15320	3	27	1	3	31	3	93
Total Turn Round Time(min) 6											



**Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II, Year : 2031**  
**Passenger Capacity @ 6 Persons/sqm in 3 Car Train: 766**  
**Schedule Speed in Kmph= 34**

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II	20.584	34	22806	23420	6	14	1	2	17	3	51
					6	14	0	1	15	6	90
					3 min effective headway using alternate 3 car/ 6 car trains	28	1	3	32		141
Total Turn Round Time(min) 6											

**Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II, Year : 2041**  
**Passenger Capacity @ 6 Persons/sqm in 3 Car Train: 766**  
**Schedule Speed in Kmph= 34**

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : Gottigere - IIMB- Nagavara corridor ( North- South Corridor-II): Ph II	20.58	34.0	25315	7660	6	14	1	2	17	3	51
				15760	6	14	0	1	15	6	90
				23420	3 min effective headway using alternate 3 car/ 6 car trains	28	1	3	32		141
Total Turn Round Time(min) 6											
			Total								

**Important Note:**

- 1) The Rolling Stock should be designed such that it should be possible to couple two independent 3-car trainsets and operate them as a 6-car Trainset.
- 2) For the year 2021, based on operational experience and traffic demand, train operation can also be planned using combination of 3 -car & 6-car train at 3.5 min headway instead of 3 car trainset at 2.5 min headway using the available number of rakes/cars.
- 3) For the year 2031, based on operational experience and traffic demand, the number of 6 -car trainset in operation can be increased/decreased as required.

**CHAPTER-7**

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**ROLLING STOCK**



## CHAPTER - 7

### ROLLING STOCK

#### 7.1 Introduction

The required transport demand forecast is the governing factor for the choice of the Rolling Stock. The forecasted Peak Hour Peak Direction Traffic for Phase II calls for a Mass Rapid Transit System as proposed for Phase I.

#### 7.2 Optimization of Coach Size

The following optimum size of the coach, as opted for Bangalore Metro Phase I, has been chosen for this corridor as mentioned in Table 7.1.

Table 7.1 Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC)	21.05 m	2.88 m	3.88 m
Trailer car (TC)/Motor Car (MC)	20.8 m	2.88 m	3.88 m

#### 7.3 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 3 persons per square meter of standing floor area in normal state and 6 persons in crush state of peak hour.

Therefore, for the Rail Vehicles with 2.88 m maximum width and longitudinal seat arrangement, conceptually the crush capacity of 43 seated, 205 standing thus a total of 248 passengers for a Driving Motor Car, and 50 seated, 220 standing thus a total of 270 for a trailer/motor car is envisaged.

Following train composition is recommended:

3-car Train: DMC + TC + DMC

6-car Train: DMC + TC + MC + MC + MTC + DMC

Table 7.2 and 7.3 shows the carrying capacity of Mass Rail Vehicles with standing passenger @ 6 passengers per sqm of standee area and @ 8 passengers per sqm of standee area respectively.



Table 7.2

Carrying Capacity of Mass Rail Vehicles (Crush@6 Person/sqm of standee area)

	Driving Motor car		Trailer car / Motor car		3 Car Train		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush	Normal	Crush
<b>Seated</b>	43	43	50	50	136	136	286	286
<b>Standing</b>	102	205	110	220	314	630	644	1290
<b>Total</b>	145	248	160	270	450	766	930	1576

NORMAL-3 Person/sqm of standee area

CRUSH -6 Person/sqm of standee area

Table 7.3

Carrying Capacity of Mass Rail Vehicles (Crush@8 Person/sqm of standee area)

	Driving Motor car		Trailer car / Motor car		3 Car Train		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush	Normal	Crush
<b>Seated</b>	43	43	50	50	136	136	286	286
<b>Standing</b>	102	273	110	293	314	839	644	1718
<b>Total</b>	145	316	153	343	450	975	930	2004

NORMAL-3 Person/sqm of standee area

CRUSH -8 Person/sqm of standee area

**Note of BMRCL:**

**The passenger carrying capacity is considered at 8 persons /sqm for running the train schedules at peak hours. The crush capacity is 43 sitting + 273 standing for DMC and 50 seated + 293 standing for TC/MC car.**

**7.4 WEIGHT**

The weights of motorcar and trailer cars have been estimated as in Table 7.3, referring to the experiences in Delhi Metro, the average passenger weight has been taken as 65 kg.

Table 7.3 Weight of Mass Rail Vehicles (TONNES)

	DMC	TC	MC	3 Car train	6 Car train
<b>TARE (maximum)</b>	40	39	39	119	236
<b>Passenger</b>					
(Normal)	9.425	10.40	10.40	29.25	60.45
(Crush @6p/sqm)	16.12	17.55	17.55	49.79	102.44
(Crush @8p/sqm)	20.54	22.295	22.295	63.375	130.26
<b>Gross</b>					



(Normal)	49.425	49.4	49.4	148.25	296.45
(Crush @6p/sqm)	56.12	56.55	56.55	168.79	338.44
(Crush @8p/sqm)	60.54	61.295	61.295	182.375	366.26
Axle Load @6 person/sqm	14.03	14.138	14.138		
Axle Load @8 person/sqm	15.135	15.324	15.324		

The axle load @ 6persons/sqm of standing area works out in the range of 14.03T to 14.138T. Heavy rush of passenger, having 8 standees per sq. meter can be experienced occasionally. It will be advisable to design the coach with sufficient strength so that even with this overload, the design will not result in over stresses in the coach. Coach and bogie should, therefore, be designed for **16T axle load**.

**Note of BMRCL:**

**Axle load should be 17T with OHE Traction.**

### 7.5 Performance Parameters

The recommended performance parameters are:

Maximum Design Speed: 90 kmph

Maximum Operating Speed: 80 kmph

Max. Acceleration:  $0.95 \text{ m/s}^2 \pm 5\%$

Max. Deceleration  $1.1 \text{ m/s}^2$  (Normal brake)

More than  $1.3 \text{ m/s}^2$  (Emergency brake)

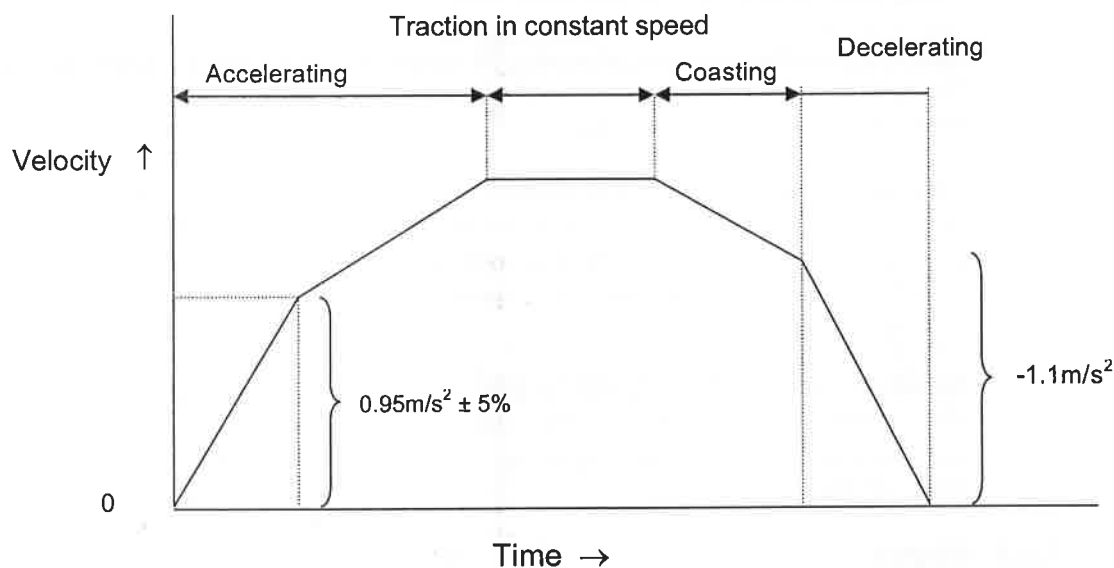


Fig 7.1



## 7.6 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.

## 7.7 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-

#### 7.7.1 Car body

In the past carbon high tensile steel was invariably used for car bodies. In-fact almost all the coaches built by Indian Railways are of this type. These steel bodied coaches need frequent painting and corrosion repairs, which may have to be carried out up to 4-5 times during the service life of these coaches. It is now a standard practice to adopt stainless steel or aluminum for car body.

The car bodies with aluminum require long and complex extruded sections which are still not manufactured in India. Therefore aluminum car body has not been considered for use. Stainless steel sections are available in India and therefore stainless steel car bodies have been specified. No corrosion repair is necessary on stainless steel cars during their service life.

Stainless steel car body leads to energy saving due to its lightweight. It also results in cost saving due to easy maintenance and reduction of repair cost from excellent anti corrosive properties as well as on improvement of riding comfort and safety in case of a crash or fire.

#### 7.7.2 Bogies

Bolster less lightweight fabricated bogies with rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 4,20,000km. Use of air spring at secondary stage is considered with





a view to keep the floor levels of the cars constant irrespective of passenger loading unlike those with coil spring. Perturbation from the track are also dampened inside the car body on account of the secondary air spring along with suitable Vertical Hydraulic Damper. The primary suspension system improve 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.

### 7.7.3 Braking System

The brake system shall consist of –

- (i) An electro-pneumatic (EP) service friction brake
- (ii) A fail safe, pneumatic friction emergency brake
- (iii) A spring applied air-release parking brake
- (iv) An electric regenerative service brake
- (v) Provision of smooth and continuous blending of EP and regenerative braking

The regenerative braking will be the main brake power of the train and will regain the maximum possible energy and pump it back to the system and thus fully utilize the advantage of 3 phase technology. The regenerative braking should have air supplement control to bear the load of trailer car. In addition, speed sensors mounted on each axle, control the braking force of the axles with anti skid valves, prompting re-adhesion in case of a skid. The brake actuator shall operate either a tread brake or a wheel disc brake, preferably a wheel disc brake.

### 7.7.4 Propulsion System Technology

In the field of Electric Rolling Stock, DC series traction motors have been widely used due to its ideal characteristics and good controllability for traction applications. But these required intensive maintenance because of commutators and electro-mechanical contactors, resistors etc

The brush less 3 phase induction motors has now replaced the D.C. Series motors in traction applications. The induction motor, for the same power output, is smaller and lighter in weight and ideally suited for rail based Mass Rapid Transit applications. The motor tractive effort and speed is regulated by 'Variable Voltage and Variable frequency' control and can be programmed to suit the track profile and operating requirements. Another advantage of 3 phase a.c. drive and

VVVF control is that regenerative braking can be introduced by lowering the frequency and the voltage to reverse the power flow and to allow braking to very low speed.

For this corridor, three phase a.c. traction drive that are self-ventilated, highly reliable, robust construction and back up by slip/slid control have been recommended for adoption.

The AC catenary voltage is stepped down through a transformer and converted to DC voltage through converter and supply voltage to DC link, which feeds Inverter operated with Pulse Width Modulation (PWM) control technology and using Insulated Gate Bipolar Transistors (IGBT). Thus 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 contains an Insulated Gate Bipolar Transistor (IGBT) and gate drive circuit and



protection. The advanced IGBT incorporates its own over current protection, short circuit protection, over temperature protection and low power supply detection. The IGBT has internal protection from over current, short circuit, over temperature and low control voltage.

The inverter unit uses optical fiber cable to connect the control unit to the gate interface. This optical fiber cable transmits the gate signals to drive the advanced IGBT via the gate interface. This optical fiber cable provides electrical isolation between the advanced IGBT and the control unit and is impervious to electrical interference. These are recommended for adoption in Trains of MRTS.

### 7.7.5 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.

Interior View



### 7.7.6 Passenger Doors

For swift evacuation of the passenger in short dwell period, four doors of adequate width, on each side of the coach have been considered. These doors shall be of such dimensions and location that all the passenger inside the train are 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 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 DMRC.



Passenger Doors



### 7.7.7 Air-conditioning

With heavy passenger loading of 6 persons/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 25°C with 65% RH all the times under varying ambient conditions up to full load. For emergency situations such as power failure or both AC 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.

### 7.7.8 Cab Layout and Emergency Detrainment Door.

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 has been provided at the left side of the cabin.

Driving cab



To permit emergency detrainment, saloon side doors shall be used to disembark the passengers.



### 7.7.9 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. The rolling stock is provided with Talk Back Units inside the cars, which permit conversation between passengers and the drivers.in case of any emergency.

### 7.7.10 Noise and Vibration

The trains will pass through heavily populated urban area .The noise and vibration for a metro railway becomes an important criteria 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.
- 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.

### 7.7.11 Passenger Safety Features

#### (i) ATP/ATO

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 data like speed etc for safest control.

#### (ii) Fire

The rolling stock is provided with fire retarding materials having low fire load, low heat release rate, low smoke and toxicity inside the cars. The electric cables used are also normally low smoking zero halogen type which ensures passenger safety in case of fire.



**(iii) Emergency door**

The rolling stock is provided with emergency evacuation facilities at several vehicles to ensure well-directed evacuation of passengers in case of any emergency including fire in the train.

**(iv) Crash worthiness features**

The rolling stock is provided with inter car couplers having crashworthiness feature which reduces the severity of injury to the passengers in case of accidents.

**(v) Gangways**

Broad gangways are provided in between the cars to ensure free passenger movement between cars in case of any emergency.



Gangways

The salient features of the proposed Rolling Stock are enclosed as Attachment-I



**Salient Features of Rolling Stock for Mass Rapid Transit System**

S.No.	Parameter	Details
1	Gauge (Nominal)	1435mm
2	Traction system	
2.1	Voltage	25 KV ac
2.2	Method of current collection	Overhead Current Collection System
3	Train composition	
3.1	3 car train	DMC+TC+DMC
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.
5.4	Locked down Panto height	4048 mm
6	Designed - Passenger Loading	
6.1	Design of Propulsion equipment	8 Passenger/ m <sup>2</sup>
6.2	Design of Mechanical systems	10 Passenger/ m <sup>2</sup>
7	Carrying capacity	
7.1	Carrying capacity-@ 8 standees/sqm	
7.1.1	Coach carrying capacity	
	DMC	316 (seating - 43 ; standing - 273)
	TC	343 (seating - 50 ; standing - 293)
	MC	343 (seating - 50 ; standing - 293)
7.1.2	Train Carrying capacity	
	3 car train	975 (seating - 136 ; standing - 839)
	6 car train	2004 (seating - 286 ; standing - 1718)
7.2	Carrying capacity- @ 6 standees/sqm (considered for calculating optimum headway)	
7.2.1	Coach carrying capacity	
	DMC	248 (seating - 43 ; standing - 205)
	TC	270 (seating - 50 ; standing - 220)
	MC	270 (seating - 50 ; standing - 220)



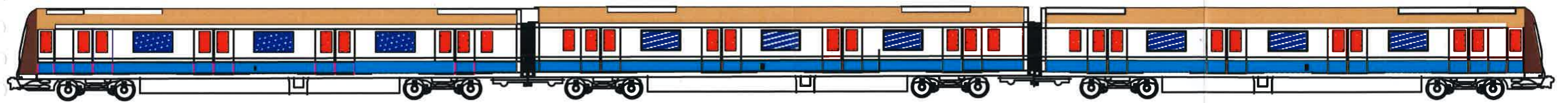


7.2.2	Train Carrying capacity	
	3 car train	766 (seating - 136 ; standing - 630)
	6 car train	1576 (seating - 286 ; standing - 1290)
<b>8</b>	<b>Weight (Tonnes)</b>	
8.1	Tare weight (maximum)	
	DMC	40
	TC	39
	MC	39
8.2	Passenger Weight in tons(@ 8 person per sqm)	@ 0.065 T per passenger
	DMC	20.54
	TC	22.295
	MC	22.295
8.3	Gross weight in tons	
	DMC	60.54
	TC	61.295
	MC	61.295
<b>9</b>	<b>Axle load(T)(@ 8 persons per sqm of standee area)</b>	<b>Not more than 16T System should be designed for 16T axle load</b>
<b>10</b>	<b>Speed</b>	
10.1	Maximum Design Speed	90 Kmph
10.2	Maximum Operating Speed	80 Kmph
<b>11</b>	<b>Wheel Profile</b>	UIC 510-2, Appendix B
<b>12</b>	<b>Traction Motors Ventilation</b>	Self
<b>13</b>	<b>Acceleration on level tangent track</b>	0.95 m/sec <sup>2</sup> ± 5%
<b>14</b>	<b>Deacceleration on level tangent track</b>	1.1 m/sec <sup>2</sup> (>1.3 m/sec <sup>2</sup> during emergency)
<b>15</b>	<b>Type of Bogie</b>	Fabricated
<b>16</b>	<b>Secondary Suspension springs</b>	Air
<b>17</b>	<b>Brakes</b>	<ul style="list-style-type: none"> <li>- An electro-pneumatic (EP) service friction brake</li> <li>- An electric regenerative service brake</li> <li>- Provision of smooth and continuous blending of EP and regenerative braking</li> <li>- A fail safe, pneumatic friction emergency brake</li> <li>- A spring applied air-release parking brake</li> <li>- The brake actuator shall operate a Wheel Disc Brake</li> <li>- Brake Control Electronics (BCE) and Brake Control Unit (BCU) for each individual bogie</li> </ul>





<b>18</b>	<b>Coupler</b>	
	For 6 car Train between two MC car	Automatic coupler with mechanical, electrical & pneumatic coupling
	Front cab end of DMC car	Automatic coupler with mechanical & pneumatic coupling but without electrical coupling head
	Between cars of same Unit	Semi-permanent couplers
<b>19</b>	<b>Detrainment Door</b>	Side doors
<b>20</b>	<b>Type of Doors</b>	External sliding
<b>21</b>	<b>Passenger Seats</b>	Stainless Steel
<b>22</b>	<b>Cooling</b>	
22.1	VVVF & APS	Self/Forced
22.2	TM	Self ventilated
<b>23</b>	<b>Control System</b>	Train line control by 110V dc signals for vital safety equipments/items and Train Management System for other control equipment monitoring
<b>24</b>	<b>Traction Motors</b>	3 phase VVVF controlled
<b>25</b>	<b>Temperature Rise Limits</b>	
25.1	Traction Motor	Temperature Index <b>minus</b> 70 deg C
25.2	VVVF & APS	10 deg C temperature margin for Junction temperature
<b>26</b>	<b>HVAC</b>	- Cooling, Heating & Humidifier (As required) - Automatic controlling of interior temperature throughout the passenger area at 25°C with 65% RH all the times under varying ambient conditions up to full load.
<b>27</b>	<b>PA/PIS including PSSS (CCTV)</b>	Required
<b>28</b>	<b>Passenger Surveillance</b>	Required
<b>29</b>	<b>Battery</b>	Nickel Cadmium
<b>30</b>	<b>Headlight type</b>	LED
<b>31</b>	<b>Coasting</b>	Minimum 8% coasting to achieve specified commercial speed.



**DMC**

**TC**

**DMC**

**3 Car Composition ; 4 min Headway ; Peak Capacity 15000 ; Train Capacity 1000 ( 136 seating , 864 Standees )**



**6 Car Composition ; 3 min Headway ; Peak Capacity 41360 ; Train Capacity 2068 ( 286 seating , 1782 Standees )**

**Fig 7.1**

**CHAPTER-8**

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**POWER SUPPLY SYSTEM AND  
TUNNEL VENTILLATION SYSTEM**



## CHAPTER 8

# POWER SUPPLY ARRANGEMENTS AND TUNNEL VENTILATION

### 8.1 Power Requirements

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, fire fighting etc) and workshops, depots & other maintenance infrastructure within premises of metro system. The power requirements of a metro system are determined by peak-hour demands of power for traction and auxiliary applications. Broad estimation of auxiliary and traction power demand is made based on the following requirements:-

- (i) Specific energy consumption of rolling stock – 75KWh/1000 GTKM
- (ii) Regeneration by rolling stock – 30%
- (iii) Elevated station load – initially 200KW, which will increase to 500 KW in the year 2041
- (iv) Underground Station load – initially 2000 kW, which will increase to 2500 kW in the year 2041
- (v) Depot auxiliary load - initially 2500KW, which will increase to 3500 KW in the year 2041

Keeping in view of the train operation plan and demand of auxiliary and traction power, power requirements projected for the year 2016, 2021 , 2031 and 2041 are summarized in table 8.1 below:-

**Table 8.1 Power Demand Estimation (MVA)**

Corridor		Year			
		2016	2021	2031	2041
Corridor – 2 Gottigere – IIMB -Nagavara [21.25 kms & 18 Stns. (12 U/G)].	Traction	9.0	11.2	19.1	20.2
	Auxiliary	34.2	34.2	39.3	45.1
	Total	43.2	45.4	58.4	65.3

Detailed calculations of power demand estimation are attached at **Annexure –8.1**

### 8.2 Need for High Reliability of Power Supply

The proposed Section of the Bengaluru metro phase-II system is being designed to cater to about 24000 passengers per direction during peak hours



when trains are expected to run at 3 minutes intervals in 2041. Incidences of any power interruption, apart from affecting train running, will cause congestion at stations. Interruption of power at night is likely to cause alarm and increased risk to traveling public. Lack of illumination at stations, non-visibility of appropriate signages, disruption of operation of lifts and escalators is likely to cause confusion, anxiety and ire in commuters, whose tolerance level are low on account of stress. Effect on signal and communication may affect train operation and passenger safety as well. Therefore, reliable and continuous power supply is mandatory for efficient metro operations.

To ensure reliability of power supply, it is essential that both the sources of 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 220kV or 66kV from stable grid sub-stations and further transmission & distribution is done by the Metro Authority itself.

### 8.3 Sources of Power Supply

The high voltage power supply network of Bengaluru has 220kV and 66kV network to cater to various types of demand in vicinity of the proposed corridor. 220 KV sub-stations are generally located at outskirts of the city. 66 kV sub stations are located to the alignment of Corridors. Keeping in view the reliability requirements, two input sources of 66 kV Voltage level are normally considered for each corridor. Therefore, to achieve the desired reliability, two Receiving Sub Stations (66 / 33 / 25 kV) are proposed to be set up for Corridor – 2. Based on the discussions with Director/KPTCL, it is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations at 66kV voltage through cable feeders.

**Table 8.2 Sources of Power Supply**

Corridor	Grid sub-station (with Input voltage)	Location of RSS of Metro Authority	Approx. length of cables
Gottigere – IIMB – Nagavara.	Nimhans GSS (220 / 66 KV) or Two number 66 KV bays from Audugodi Sub-station	Hulimavu Depot or depending upon simulation study and availability of land (66 / 33/25 KV)	7 km, 66 KV * (Double Circuit Cables).
	East Division GIS GSS (220/66 KV)	Pottery Town (66 / 33/25 KV)	3 km, 66 KV (Double Circuit Cables).

Summary of expected power demand at various sources is given in Table – 8.3. Director/KPTCL have confirmed availability of requisite power at their



above sub-stations vide Memo No./KPTCL/CEE/P&C/KCO-88/25958, dated:- 28.10.2010 and further discussion held with Director Transco / Bengaluru on 18.05.2011. (Annexure – 8.2). As per KPTCL Memo dated: - 28.10.2010 KPTCL has indicated that Metro authorities to acquire additional land at Nimhans for locating the 66 KV terminal bays at BMRCL's cost. This cost will be additional to the estimate.

As no other power source is available on the line two feeders are to be laid from Nimhans to the RSS, which will have additional cost implication. If land is available only at Kothanur depot than 66 KV two feeders of 7 KM are to be laid costing 18 Crores extra. The final decision of location of RSS can be taken based on simulation report and availability of land.

**Note of BMRCL:**

***KPTCL has reviewed the power requirement and it is indicated by KPTCL that any power requirement above 20MVA would be catered only at 220KV station as per KERC grid code. Accordingly KPTCL has proposed two 220 circuits from 400/220 KV Mailasandra station situated about 4-5 KM distance and to avail from Manyata 220KV station or by putting up a new station on Peenya- Hebbal- Hoody 220 KV line close to the corridor. The additional land in both the cases has to be acquired by BMRCL.***

**Table 8.3 Power Demand Projection for various sources.**

Corridor	Input Source / Receiving Sub Station (RSS)	Peak Demand – Normal (MVA)				Peak Demand – Emergency (MVA)			
		2016	2021	2031	2041	2016	2021	2031	2041
Gottigere – IIMB – Nagavara	As per Simulation study and availability of land.								
	Traction	5.0	6.2	10.1	10.6	9	11.2	19.1	20.2
	Auxiliary	17.6	17.6	20.3	23.1	34.2	34.2	39.3	45.1
	Total	22.6	23.8	30.4	33.7	43.2	45.4	58.4	65.3
	Near Pottery Town								
	Traction	4.0	5.0	9.0	9.6	9	11.2	19.1	20.2
	Auxiliary	16.6	16.6	19.0	22.0	34.2	34.2	39.3	45.1
	Total	20.6	21.6	28.0	31.6	43.2	45.4	58.4	65.3
	<b>TOTAL (A + B)</b>								





The 66 kV power supply will be stepped down to 25kV single phase for traction purpose at the RSS of Bengaluru Metro and the 25kV traction supply will be fed to the OHE at viaduct through cable feeders. For feeding the auxiliary loads, the 66 kV power supply received will be stepped down to 33 kV will be distributed along the alignment through 33kV Ring main cable network. These cables will be laid in dedicated ducts along the viaduct tunnel walls. In addition one 33 KV link for emergency can also be provided at the interchange station at M.G. Road, If one RSS trips on fault or input supply failure, train services can be maintained from the other RSS. However, in case of total grid failure, all trains may come to a halt but station lighting & other essential services can be catered to by stand-by DG sets. Therefore, while the proposed scheme is expected to ensure adequate reliability, it would cater to emergency situations as well.



**Typical High Voltage Receiving Sub-station**

The 66kV cables will be laid through public pathways from Karnataka Power Transmission Corporation Limited Grid Sub-stations to RSS of Metro Authority. For corridor – 2, each of RSS shall be provided with 2nos. (one as standby) 66/25 kV, 21 MVA single-phase traction Transformers for feeding Traction and 66/33 KV, 50 MVA three phase Transformers for feeding auxiliary loads. The capacity of transformers will be reviewed considering the load requirement/distribution of both the corridors at the time of detailed design and once simulation results.

Conventional Outdoor type 66 kV Switchgear is proposed for RSS's to be located in approx. 100 X 80 m (8000 sq. mtr.) land plot. In case of difficulty in land acquisition, Gas Insulated Sub – stations (GIS) sub stations may be planned. Requirement of land for GIS will be approx. 60 X 60 m (3600 sq. m)



but the cost of sub station works will increase by nearly Rs. 10 Crore per RSS.

#### 8.4 Selection of Traction System

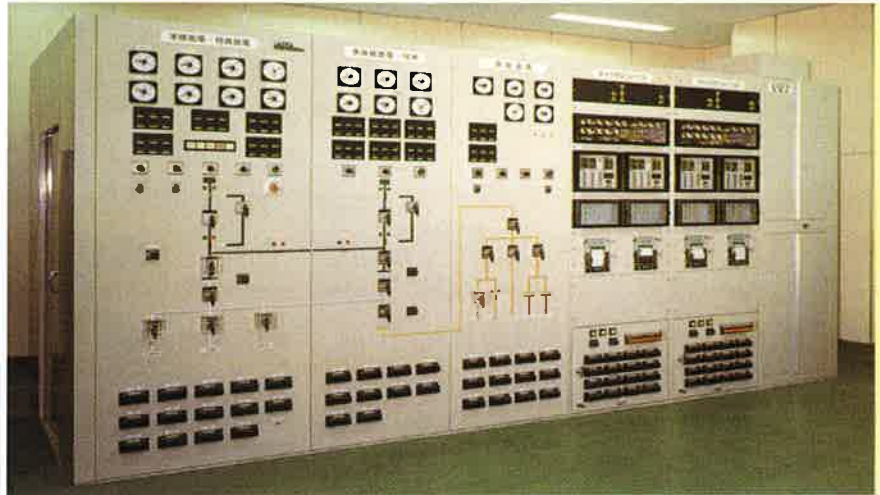
Nagavara to Gottigere is a stand alone line not having train interchange with any of the lines of phase-I of BMRCL. Further in phase-I the tunnel diameter of 5200 mm and the aesthetics were the two main consideration for recommending 750 V d. c. It is learnt that due to problems faced by BMRCL in accommodating the utilities in the tunnel and as the civil contractors have brought in tunnel boring machine of 5600 mm diameter. BMRCL has decided to provide tunnel diameter of 5600 mm even in phase-I. Further most of the section of the line is underground and aesthetic is not the guiding consideration. This is possible if, like DMRC static and dynamic electrical clearances are as per IEC-60913 and minimum contact wire height is as per safety clearance in accordance with EN-50122-1.

On techno-economic consideration, it is recommended to adopt 25 KV single phase A.C. Traction with 5600 mm finished tunnel diameter. It in addition has the following merits.

- Lower initial cost.
- Lower operating and maintenance cost as in case of 25 KV ac traction the regeneration is up-to 30% and the line losses are around 0.5% in comparison to D.C. losses up-to 6 – 7%.
- A.C. system poses lesser Fire hazards as current levels are much lower than D.C.
- Stray current problems and hence the corrosion is controlled.

#### 8.5 Auxiliary Supply Arrangements for Stations & Depot

Auxiliary sub-stations (ASS) are envisaged to be provided at each station (3 ASS's for Underground stations and 1 ASS for elevated station) for stepping down 33 kV supply to 415 V for auxiliary applications. A separate ASS is required at depot. The ASS will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 200kW for elevated / at-grade stations which is likely to increase up to 500 KW in the year 2041 and 2000 kW for Underground Station which is likely to increase up to 2500 KW in the year 2041. In order to meet the requirement of auxiliary power two dry type cast resin transformers (33/0.415kV) of 630kVA capacity are proposed to be installed at the elevated stations (one transformer as standby) and one transformer of 1.6 MVA at each underground ASS. For Property Development within the footprints of the station, a provision to add third transformer at a later date may be kept at elevated station.



**Typical Indoor Auxiliary Sub-station**

### **8.6 Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC)**

25kV ac traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Booster Transformer and Return Conductor (BT/RC) System is proposed for EMI mitigation. Concrete structures of elevated viaducts are not good electrical earths and therefore, Earthing and Bonding of the traction system shall be in accordance with the latest standards EN50122-1, IEEE80 and other relevant standards. Two earth conductors –Overhead Protection Cable (OPC) and Buried Earth Conductor (BEC) are proposed to be laid along with elevated viaduct and all the metallic structures, structural reinforcement, running rails etc will be connected to these conductors to form an equiv-potential surface & a least resistance path to the fault currents. The overhead protection cable will also provide protection against lightning to the 25kV OHE and the elevated viaduct. Similar arrangements have been adopted on Delhi Metro as well.

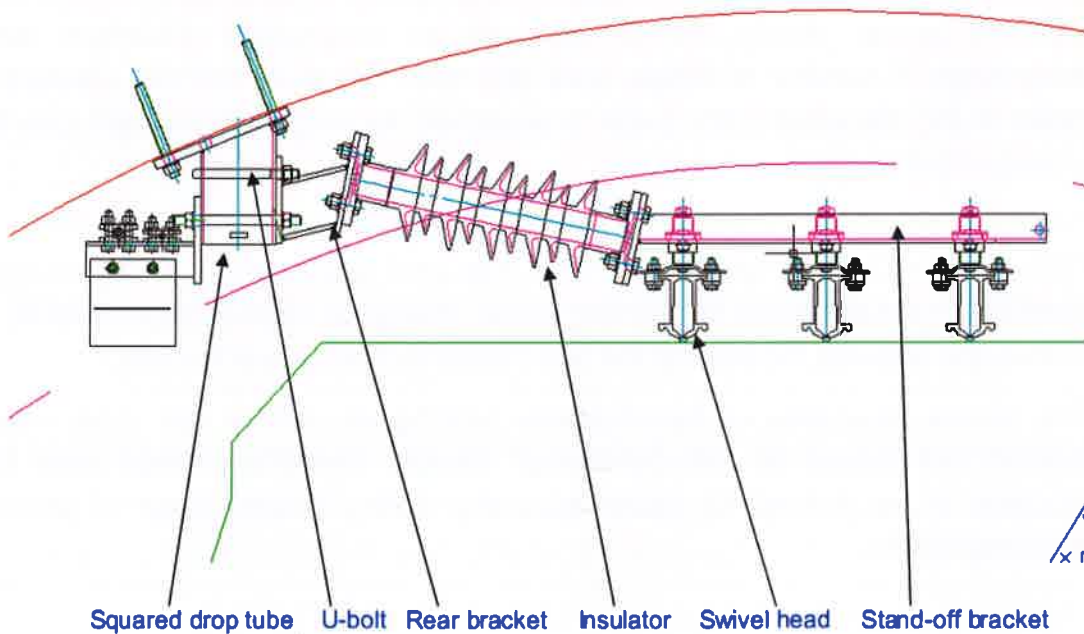
Detailed specification of equipment e.g. power cables, transformer, switchgear, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signaling & telecomm, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMI/EMC plan will be required to be developed during project implementation stage.



### 8.7 25 kV RIGID OHE SYSTEM.

The proposed 25kV Rigid OHE system in underground section is similar to the one installed in underground Metro Corridor of Delhi Metro. 25kV Rigid OHE system comprises a hollow Aluminum Conductor Rail of adequate cross section with 107 sq.mm copper contact wire held with elastic pinch. The Al conductor rail is supported by an insulator & cantilever arrangement attached to drop-down supports fixed to tunnel roof. The supports are located at every 10metre and there is no tension in the conductors and hence, no tensioning equipment in tunnel. The design of 25kv rigid OHE system shall be in accordance to electrical clearances & contact wire height as per IEC 60913, which is summarized below:

- a) Contact wire height .....4570mm
- b) Structure to Live parts clearances.....270/170/150mm  
(Static/Dynamic/Absolute min dynamic)
- c) Vehicle to Live parts clearances.....290/190/150mm  
(Static/Dynamic/Absolute min dynamic)



**Definitive Design  
25 V ROCS Support**

### 8.8 25kV Flexible Overhead Equipment (OHE) system

25kV ac flexible OHE system shall comprise 107 sqmm HD-copper contact wire and 65 sq.mm Cd-copper catenary wire. Return conductor (RC) shall be All Aluminum Conductor (AAC) of 233 sq.mm cross section. From safety considerations, Hydraulic type Anti-Tensioning Device (ATDs) are proposed



on mainlines which does not require use of balance weight for tensioning of OHE conductors. Proven catenary fittings are proposed similar to DMRC system.

### 8.9 Rating of Major Equipment

25kV ac Overhead Equipment (OHE) shall comprise 107mm<sup>2</sup> HD-copper contact wire and 65 mm<sup>2</sup> Cd-copper catenary wire. Return conductor (RC) shall be All of OHE conductors.

Based on emergency demand expected at each RSS as shown in Table 7.3, 2 nos. 66/25kV traction transformers of 21 MVA capacity and 2 nos. 50 MVA capacity Auxiliary transformers shall be provided at each RSS in Corridor –II, being standard design (one to be in service and second one to serve as standby). The 66kV incoming cable shall be 3-phase single core XLPE insulated with 630 mm<sup>2</sup> Aluminum conductor to meet the normal & emergency loading requirements and fault level of the 66 kV supply.

33kV and 25kV switchgear shall be rated for 1250 A being standard design. 33kV cable ring network shall be adequately rated to transfer requisite auxiliary power during normal as well as emergency situations and accordingly 3 number of Single core 300 mm<sup>2</sup> FRLSOH Copper conductor cable XLPE insulated 33kV cable is proposed for ring main network due to underground section.

Adequate no. of cables are required for transfer of traction power from Metro's RSS to 25kV OHE. Single-phase XLPE insulated cables with 240mm<sup>2</sup> copper conductors are proposed for traction power. Based on current requirements, 2 cables are required for each of the two circuits to feed power to OHE.

The above capacities of transformers, switchgear, cables etc. have been worked out based on the conceptual design. Therefore, these may be required to be revised for better accuracy during design stage of project implementation.

### 8.10 Standby Diesel Generator (DG) Sets

In the unlikely event of simultaneous tripping of all the input power sources or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide a standby DG set of 200 KVA capacity at the elevated stations and 2 X 1000/750 KVA at Underground stations to cater to the following essential services:

- (i) Essential lighting
- (ii) Signaling & telecommunications
- (iii) Fire fighting system





- (iv) Lift operation
- (v) Fare collection system
- (vi) Tunnel Ventilation (for Underground Stations)

Silent type DG sets with low noise levels are proposed, which do not require a separate room for installation.

### **8.11 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 33kV ac switchgear, transformers, 25kV ac switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system.

### **8.12 Energy Saving Measures**

Energy charges of any metro system constitute a substantial portion of its operation & maintenance (O & M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement during initial years of operation. Subsequently, traction power consumption increases with increase in train frequency/composition in order to cater more traffic. The proposed system of Bengaluru Metro includes the following energy saving features:

- (i) Modern rolling stock with 3-phase VVVF drive and lightweight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor.
- (ii) Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 25kV ac OHE to be consumed by nearby trains.
- (iii) Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66%



- & 100%) and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc).
- (iv) Machine-room less type lifts with gearless drive has been proposed with 3-phase VVVF drive. These lifts are highly energy efficient.
  - (v) The proposed heavy-duty public services escalators will be provided with 3-phase VVVF drive, which is energy efficient & improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by passengers.
  - (vi) The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc) have been incorporated in the system design.
  - (vii) Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.

### 8.13 Electric Power Tariff

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 25 – 35% of total annual working cost. Therefore, it is the key element for the financial viability of the project. The annual energy consumption is assessed to be about 127 million units in initial years (2016), which will increase to 180 Million Units by year 2041 for Phase-II Corridor –2. In addition to ensuring optimum energy consumption, it is also necessary that the electric power tariff be kept at a minimum in order to contain the O& M costs. Therefore, the power tariff for this Corridor should be at effective rate of purchase price (at 66 kV voltage level) plus nominal administrative charges i.e. on a no profit no loss basis. This is expected to be in the range of Rs. 3.00-3.30 per unit. It is proposed that Government of Karnataka take necessary steps to fix power tariff for Bengaluru Metro at “No Profit No Loss” basis. Financial analysis has been carried out based on this tariff for the purpose of finalizing the DPR. Similar approach is being pursued for Delhi Metro.

### 8.14 Ventilation

#### 8.14.1 Introduction:

This chapter covers the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed Bengaluru Metro alignment. It includes the following:

- Station Air-conditioning System
- Ventilation System for station plant rooms (ancillary spaces)





- Station Smoke Management System
- Tunnel Ventilation System

#### **8.14.2 Alignment:**

The proposed alignment has one corridor of underground section, North-South Corridor -II is having underground section of about 13 km and includes 12 underground stations.

The MRTS alignment passes through the heart of the city. The underground section of North-South corridor starts from Dairy Circle and passes Shivaji Nagar, Arabic College and Nagavara Metro Stations. The inter-station distances vary from 919 meters to 1618 mtr.

#### **8.14.3 Need for Ventilation and Air Conditioning**

The underground stations of the Metro Corridor are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from outside and do not have natural ventilation. It is therefore, essential to provide forced ventilation in the stations and inside the tunnel for the purpose of:

- Supplying fresh air for the physiological needs of passengers and the authority's staff;
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the sub-way;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Escalators, Fare Gates etc. working in the stations;
- Removing heat from air conditioning plant and sub-station and other equipment, if provided inside the underground station.

This large quantity of heat generated in M.R.T. underground stations cannot be extracted by simple ventilation. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the maximum possible extent. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered appropriate. In winter months it may not be necessary to cool the ventilating



air as the heat generated within the station premises would be sufficient to maintain the comfort requirement.

#### **8.14.3 External Environment Conditions and Weather data**

The analysis of Bengaluru weather suggests that the summer season for Bengaluru is generally between March to May. The maximum dry bulb temperature is seen to have reached up to 37 deg C during end of April. The winter months can be assumed from November to January when the maximum temperatures are around 26 deg C. The rest of the months generally have temperate conditions.

The high air pollution of Bengaluru throughout the year adds a new dimension and there is critical need for maintaining desired Air-Quality (Environmental control) in public places like MRT stations. High content of suspended particles, Carbon Mono oxide, Sulphur dioxide etc. discharged in the air from moving traffic, industries, etc requires consideration of appropriate measures for air-pollution control in Metro stations, while designing the VAC system.

The design weather data from the ASHRAE handbooks have been used to arrive at the design criteria. For VAC system, it is suggested that 1% criteria would be acceptable on techno economic reasons.

#### **8.14.4 Sub Soil Temperature**

The temperature conditions of sub-soil play a vital role in the system design of the underground stations. It is proposed that water table surrounding the underground alignment shall be reviewed and is vital for facilitating adequate heat exchange between the tunnel structures and soil. The sub soil temperature of Bengaluru is to be obtained/ measured.

#### **8.14.5 Internal Design conditions in Underground Stations**

With hot and humid ambient conditions of Bengaluru during the summer and monsoon months, it is essential to maintain appropriate conditions in the underground stations in order to provide a 'comfort-like' and pollution-free environment. The plant capacity and design of VAC system needs to be optimized for the "Designed inside Conditions".

The Indian Standards & Codes, which pertain to office-buildings, commercial centers and other public utility buildings. The standards used for buildings are not directly applicable for the underground spaces, as the heat load gets added periodically with the arrival of the train.

The patrons will stay for much shorter durations in these underground stations, the comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat gets dissipated is given out by the process



of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin, which gets promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The 'Effective Temperature' criterion was used in selecting the comfort condition in earlier metros, in this criteria comfort is defined as the function of temperature and the air velocity experienced by a person. More recently a new index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient condition of the metabolic rate and is evaluated based on the changes to the surrounding ambient of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a subway system where the train headway is expected to be six minutes or less, then RWI is the preferred criterion.

#### 8.14.6 Design parameters for VAC system

Based on the above, the following VAC system design parameters are assumed in the present report.

(1) Outside ambient conditions:

This is based upon ASHRAE recommended design conditions for 1% criteria, as under

**1% Criteria**

Summer : 33.5 DB, 19.8 WB

Monsoon: 23.1 DB, 28.2 WB

For Bengaluru Metro Underground Corridor it is suggested to use 1% criteria, which is defined as the conditions, when the DB or WB temperatures are likely to exceed for only 1% of the total time.

(2) Inside design conditions:

Platform/Concourse areas - 27 deg. C at 55 % RH

(3) Tunnel design conditions

Normal conditions -- Max. DB 40 deg. C

Congested conditions -- Max. DB 45 deg. C

(4) Minimum fresh air - 10 % or 18 cmh / person

(In station public areas).



### 8.14.7 Design Concepts for VAC system

There are various VAC design concepts technically feasible in a subway system that can provide and maintain acceptable subway environment conditions under different requirement and constraints. These are: Open type; Closed type; platform screen doors etc. The experience available from the design of VAC system for Delhi Metro provides key guidelines for Bengaluru Metro.

The station premises (public areas) are equipped with separate air-conditioning system during the summer and monsoon months to provide acceptable environment for patrons.

There shall be provision of Trackway Exhaust System (TES) by which platform air can be re-circulated. The train cars reject substantial heat inside subway. The TES is installed in the train ways of each station to directly capture heat rejected by the vehicle propulsion, braking, auxiliary and air conditioning systems as the train dwells in the station. When the trains dwell at the stations TES would capture a large portion of heat released by the train air conditioners mounted on the roof tops and under gear heat because of braking, before it is mixed with the platform environment. The TES includes both an under platform exhaust (UPE) duct and an Over-trackway exhaust (OTE) duct. The TES uses ducts formed in the under platform void and over the trackway. Exhaust intakes are to be located to coincide with the train-borne heat sources.



**Trackway Exhaust Fan**

### 8.14.8 Station Air Conditioning

The platform and concourse areas will be air-conditioned using supply 'Air Handling Units' located in Environmental Control System (ECS) plant rooms throughout the station. Each platform will be served by at least two separate air handling units (AHU's) with the distribution systems combined along each



platform to ensure coverage of all areas in the event of single equipment failure. Based on the initial estimation about 4 units of 27.5 m<sup>3</sup>/s each would be needed for the full system capacity.

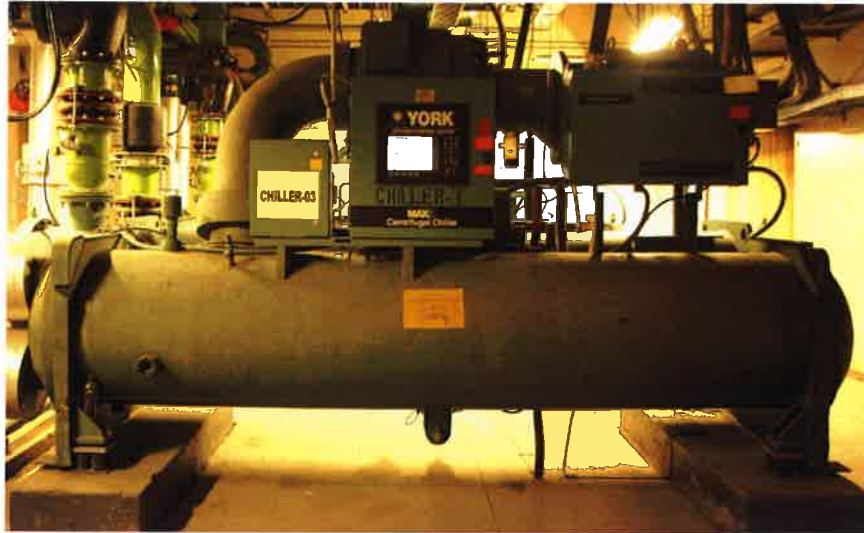


**Air Handling Unit**

These air conditioning systems mix return air with a desired quantity of outside air. The outside air requirement is based on occupancy, with a minimum of 5 liters per second per person or 10% of circulated air volume, whichever is the greater. The provision of free cooling by a simple two-position economizer control system will be included, with the use of enthalpy sensors to determine the benefits of using return air or outside air. This will signal the control system to operate dampers between minimum and full fresh air, so as to minimize the enthalpy reduction needed to be achieved by the cooling coil. This mixture of outside and return air is then filtered by means of suitable filters and then cooled by a cooling coil before being distributed as supply air via high level insulated ductwork to diffusers, discharging the air into the serviced space in a controlled way to minimize draughts. Return air to the platform areas is extracted via the Track way Exhaust System and either returned to the AHUs or exhausted as required.

Water-cooled chiller units with screw compressors are recommended to be provided at each station, which are energy efficient. These units can be installed in a chiller plant room at surface level. Based on the initial concept design, the estimated capacity for a typical station would be around 900 TR, hence three units of 300TR (including one stand-by) may be required for full system capacity (i.e. design PHPDT traffic requirement). During the detail design stage this estimated capacity might get marginally changed for individual station depending on the heat loads calculated through SES analysis.





**Chiller**

#### **8.14.9 Ventilation and Air Conditioning of Ancillary Spaces**

Ancillary spaces such as Staff Room, Equipment Room, will be mechanically ventilated or air conditioned in accordance with the desired air change rates and temperatures/humidity.

All ancillary areas that require 24-hour air conditioning will be provided with Fan Coil Units (FCUs) main Chilled Water plant for running during the revenue hours and with Air Cooled Chillers or standby AC units or VRV system for running during the non-revenue hours. Return air will be circulated through washable air filters.



**Air Cooled Chiller**



Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filter, common to a group of ancillary areas.

#### **8.14.10 Station Smoke Management System**

The Track way Exhaust and Concourse Smoke Extract Fans will be provided for smoke extract purposes from the public areas and will operate in various modes depending on the location of the fire. The control of this system in fire mode will be fail-safe. These exhaust fans will be provided with “essential” power supplies, with automatic changeover on loss of supply.

Down stand beams will be provided underneath the ceiling around floor openings for stairs and escalators, so that a smoke reservoir is formed on the ceiling. The smoke will be contained in this reservoir at ceiling level and exhausted to atmosphere. By controlling smoke in this manner, it is possible to maintain a relatively smoke clear layer above human head height and to protect the escape route, giving sufficient time for evacuation. The stations will be designed to accommodate the full smoke exhaust volumes and thus prevent the reservoir from completely filling with smoke. To provide an additional barrier against smoke migration, the overall smoke management system would be designed to provide a draught of fresh air through entrances and escape routes, to assist in protecting those routes from smoke.

#### **8.14.11 Space Requirement for VAC System**

The station air conditioning equipment plant rooms are normally located at each end of the concourse for the two level stations. The approximate area for air handling equipment room would be 800 sq. m at each end of the station. There shall be supply shafts and exhaust shafts of about 10m<sup>2</sup> each at each end of the stations.

#### **8.14.12 Design Concepts for TVS system**

There are various TVS design concepts technically feasible in a subway system that can provide and maintain acceptable subway environment conditions under different requirement and constraints. These are: Open type; Closed type; Use of jet fans; use of mid-shafts; etc. The experience available from the design of TVS system for Delhi Metro also provides key guidelines.

From the experience of DMRC, it can be concluded that with open shaft system the piston effects can be sufficient to maintain acceptable conditions inside the tunnel, as long as the ambient DB temperature remains below 33<sup>0</sup> C. When the outside temperature is higher than 33<sup>0</sup> C the tunnel shafts should be closed to prevent any further exchange of air with atmosphere.

Under the normal train running the train heat generated inside the tunnel sections would be removed by the train piston action. It is envisaged that for





the design outside conditions, it may not be necessary to provide forced ventilation using Tunnel Ventilations Fans for normal operating conditions. Two tunnel ventilation shafts would be provided at the end of the stations. These end-shafts at the stations also serve as Blast Relief Shafts i.e. the piston pressure is relieved to the atmosphere before the train reaches the station. All these shafts are connected to the tunnels through dampers. The dampers are kept open when the exchange of air with the atmosphere is permitted (Open Mode). For the Closed Mode system the shaft dampers can be in closed mode and the displaced air is dumped in the adjacent tunnel.

Generally each tunnel ventilation shaft is connected to a fan room in which there are two reversible tunnel ventilation fans (TVF) are installed with isolation dampers. These dampers are closed when the fan is not in operation. There is a bypass duct around the fan room, which acts as a pressure relief shaft when open during normal conditions, and enables the flow of air to bypass the TV fans, allowing air exchange between tunnel with flows generated by train movements. Dampers are also used to close the connections to tunnels and nozzles under different operating conditions. The details for the shaft sizes, airflow exchange with the atmosphere, fan capacities can be estimated in a more accurate manner with the help of Computer Simulations during the detailed design stage.



**Tunnel Ventilation Dampers**

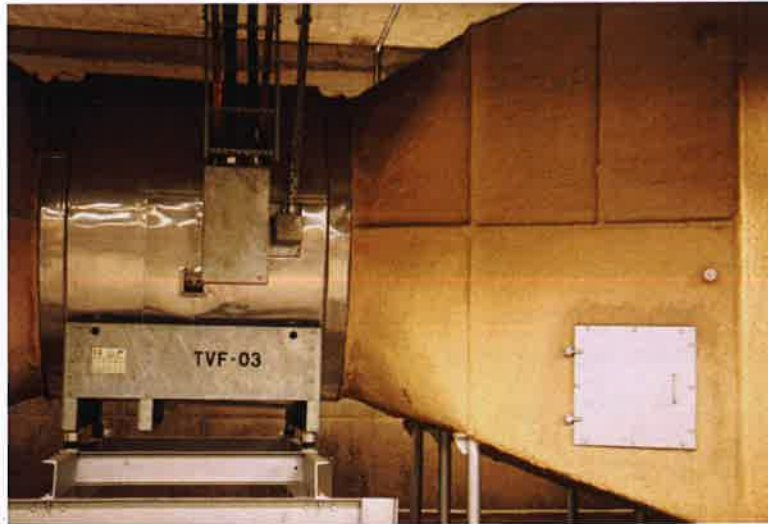
### **8.15 Tunnel Ventilation Systems (TVS)**

The TVS is provided in a Subway system essentially to carry out the following functions:

- (a) Provide a tenable environment along the path of egress from a fire incident in enclosed stations and enclosed train ways.



- (b) Produce airflow rates sufficient to prevent back layering of smoke in the path of egress within enclosed trainways.
- (c) Be capable of reaching full operational mode within 180 seconds.
- (d) Accommodate the maximum number of trains that could be between ventilation shafts during an emergency.



**Tunnel Ventilation Fan**

Tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be two fans in a fan room at each end of the station. The fan capacity depends on the inter-station distances and may vary from 60 m<sup>3</sup>/s to 100 m<sup>3</sup>/s depending upon the length and cross section of the tunnel. The exact capacity will be obtained through the simulation during detailed design stage. If necessary, nozzle type structures made up of concrete or steel may also be constructed to achieve desired airflow and air velocity in the tunnel sections. Alternatively booster fans (jet fans) may be installed to direct the flow in the desired direction. These fans may also be used for emergency ventilation at crossover locations.

The Trackway Exhaust System (part of Tunnel Ventilation System) will have two fans of each 25 m<sup>3</sup>/sec. for each platform. The connections to tunnels and shafts will be through damper units that may be either electrically or pneumatic actuated.

There are various operating modes (scenarios) for the Tunnel Ventilation system. These are described as under:



### 8.15.1 Normal Conditions

Normal condition is when the trains are operating to timetable throughout the system, at prescribed headways and dwell times, within given tolerances. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system and, in some cases, the track way exhaust system.

During summer and the monsoon seasons, the system will be functioning essentially with the station air conditioning operating. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements. The platform air captured by the track way exhaust system shall be cooled and recirculated in the station. For less severe (i.e. cool) environmental conditions (or in the event of an AC system failure), station air conditioning will not be used and ventilation shafts will be open to atmosphere (open system) with the track way exhaust system operating. For cold conditions, the closed system or open system mode may be used, but without any station air conditioning. System heating is achieved by the train heat released into the premises.

### 8.15.2 Congested Conditions

Congested conditions occur when delays cause disruption to the movement of trains. It is possible that the delays may result in the idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures may result reduced performance of coach air conditioners that may lead to passenger discomfort.

During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The open system congested ventilation shall be via a 'push-pull' effect where tunnel vent fans behind the train are operated in supply and tunnel vent fans ahead of the trains are operated in exhaust mode. Nozzles or booster (jet) fans will be used to direct air into the desired tunnel, if required.

### 8.15.3 Emergency Conditions

Emergency conditions are when smoke is generated in the tunnel or station track way. In emergency conditions, the tunnel ventilation system would be set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for the fire fighting purposes. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction depending upon the location of Fire on the train.



#### 8.15.4 Pressure Transients

a) Portal Entry and Exit Pressure Transients – As a train enters a portal, passengers will experience a rise in pressure from when the nose enters until the tail enters. After the tail enters the pressure drops. Similarly, as the nose exits a portal, pressure changes are experienced in the train. There is one location of the portal between Swagath Road Cross to Dairy Circle station.

b) Wayside Pressure Transients – As trains travel through the system they will pass structures, equipment and patrons on platforms. Equipment would include cross passage doors, lights, dampers, walkways etc. Pressures are positive for the approaching train and negative for retreating trains. Most rapid changes occur with the passage of the train nose and tail. The repetitive nature of these pressures may need to be considered when considering fatigue in the design of equipment.

The detailed analysis to assess the effect of pressure transients will be done during the design stage. For the portal entry/exits the effect of higher train speed may pose discomfort to the passengers. Although, based on the recent studies, it is assumed that a design train speed of 80 kmph would not be of major concern. The estimation of Way-side transients during design stage would be necessary to select design mechanical strength of the trackside fixtures, e.g. false ceilings, light fittings etc at the platform levels.

#### 8.15.5 Space Requirement for Tunnel Ventilation System

The tunnel ventilation equipment plant rooms are normally located at each end of the concourse for the two level stations. The approximate area for tunnel ventilation fan room would be 600 sq. m. respectively at each end of the station. The tunnel vent shafts of approximately 20 sq. m. area will be constructed at each end of the stations. There shall be supply shaft and exhaust shafts of similar dimensions at the stations.

The inter – station separation between Cantonment Railway Station underground station and Pottery Town underground station is beyond 1.5 km as per the final alignment plan hence mid section ventilation shafts is required for which additional fund provisions to the tune of Rs. 5.0 Crores for Electrical and Mechanical works (Ventilation, E&M, BMS, ASS, etc) and Rs.20.0 crores for civil works and land will be needed for mid-shafts.

#### 8.15.6 Control and monitoring Facilities

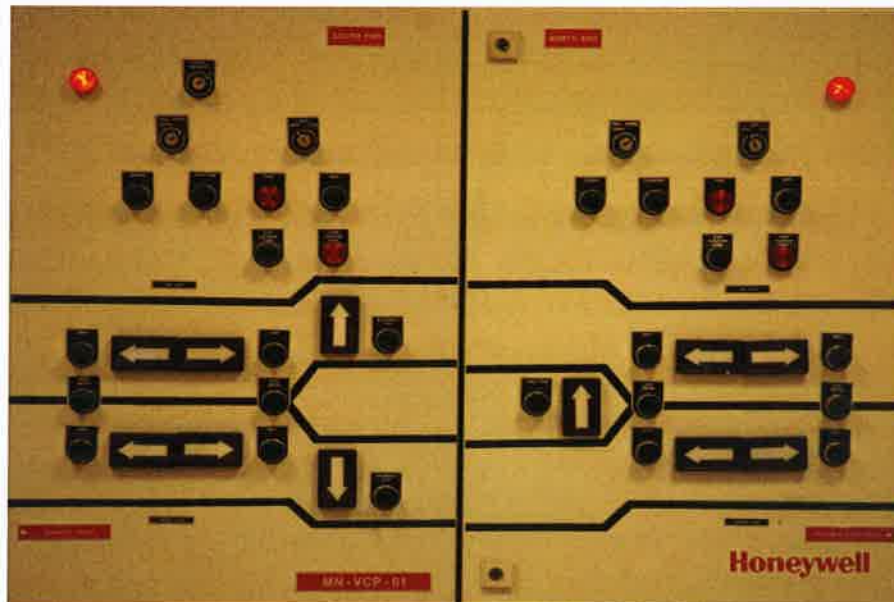
For the underground stations the control and monitoring of station services and systems such as station air-conditioning, ventilation to plant rooms, lighting, pumping systems, lifts & Escalators, etc shall be performed at Station Control Room (SCR). However, the operation and control of Tunnel





Ventilation as well as Smoke Management system will normally be done through OCC. All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at stations shall be transmitted to the OCC via communication network (such as FOTS).

There shall be an Auxiliary Power Controller at OCC who will be monitoring these services and systems. The command signals will be initiated at OCC and relayed up to the relevant equipment for operation. The feedback signal is received through SCADA whether the command is implemented or not. The control from OCC is generally performed using 'Mode Tables' for each system. This table defines the sequence of the desired equipment that needs to be operated based on the event. The abnormal conditions such as train congestion, emergency, fire in subway would be detected by various components and the emergency response thereto will be activated based on the mode tables. In the event that remote control is not possible due to any reason, the local control via SCR would be performed. In case the control at work station in SCR is also not available, the manual overriding provisions shall be provided through Ventilation Control Panel (VCP) place in the SCR.



**Ventilation Control Panel**

The OCC will also be used for logging the alarm status, fault occurrences, and other maintenance related data for the above systems.

### 8.15.7 Codes and Standards

The concept VAC design is guided by the following codes and standards:

- (a) SEDH – Subway Environment Design Handbook
- (b) ASHRAE – Handbook, current series.



- (c) CIBSE – relevant document.
- (d) NFPA – 130.
- (e) ECBC- Energy Conservation Building Code.



**Bangalore Metro Phase-II N-S Line  
Gottigere to Nagavara**

Annexure-8.1 (A)

POWER REQUIREMENTS	Year 2021				Year 2031				Year 2041			
	Year 2016	Year 2021	Year 2031	Year 2041	Year 2016	Year 2021	Year 2031	Year 2041	Year 2016	Year 2021	Year 2031	Year 2041
Traction power requirements	3 (2DTC+1TC)	3 (2DTC+1TC)	3 (2DTC+1TC)	3 (2DTC+1TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2 MC+2TC)	3 (2DTC+1TC)	3 (2DTC+1TC)	3 (2DTC+1TC)	3 (2DTC+1TC)
No of cars												
Tare weight of train	119 T	119 T	119 T	119 T	236.0 T	236.0 T	236.0 T	236.0 T	119.0 T	119.0 T	119.0 T	119.0 T
Passenger weight	63 T	63 T	63 T	63 T	130.2 T	130.2 T	130.2 T	130.2 T	63.0 T	63.0 T	63.0 T	63.0 T
Total Train weight	182 T	182 T	182 T	182 T	366.2 T	366.2 T	366.2 T	366.2 T	182.0 T	182.0 T	182.0 T	182.0 T
Section length	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM
Headway	4 mts	3 mts	6 mts	6 mts	6 mts	6 mts	6 mts	6 mts	6 mts	6 mts	6 mts	6 mts
Specific Energy consumption	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM	75 KWhr/1000 GTKM
No. of trains/hr in both directions	30	40	20	20	20	20	20	20	20	20	20	20
Peak traction power requirement	8.7 MW	11.6 MW	5.8 MW	5.8 MW	11.7 MW	11.7 MW	11.7 MW	11.7 MW	5.8 MW	5.8 MW	5.8 MW	11.7 MW
Less Regeneration @30%	2.6 MW	3.5 MW	1.7 MW	1.7 MW	3.5 MW	3.5 MW	3.5 MW	3.5 MW	1.7 MW	1.7 MW	1.7 MW	3.5 MW
Depot Power requirement	2.0 MW	2.0 MW	2.5 MW	2.5 MW	2.5 MW	2.5 MW	2.5 MW	2.5 MW	3.0 MW	3.0 MW	3.0 MW	3.0 MW
Net traction power requirement	8.1 MW	10.1 MW	6.6 MW	6.6 MW	10.7 MW	10.7 MW	10.7 MW	10.7 MW	7.1 MW	7.1 MW	7.1 MW	11.2 MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	9.0 MVA	11.2 MVA	7.3 MVA	7.3 MVA	11.5 MVA	11.5 MVA	11.5 MVA	11.5 MVA	7.8 MVA	7.8 MVA	7.8 MVA	12.3 MVA
Station aux power requirement												
Elevated/at-grade station	0.20 MW	0.20 MW	0.30 MW	0.30 MW	0.30 MW	0.30 MW	0.30 MW	0.30 MW	0.50 MW	0.50 MW	0.50 MW	0.50 MW
Underground stations power	2.00 MW	2.00 MW	2.25 MW	2.25 MW	2.25 MW	2.25 MW	2.25 MW	2.25 MW	2.50 MW	2.50 MW	2.50 MW	2.50 MW
no. of elevated/at-grade stations	6	6	6	6	6	6	6	6	6	6	6	6
no. of underground stations	12	12	12	12	12	12	12	12	12	12	12	12
Total Station Aux Power requirement	2.52 MW	2.52 MW	2.88 MW	2.88 MW	2.88 MW	2.88 MW	2.88 MW	2.88 MW	3.30 MW	3.30 MW	3.30 MW	3.30 MW
Depot Aux power requirement	2.5 MW	2.5 MW	3.0 MW	3.0 MW	3.0 MW	3.0 MW	3.0 MW	3.0 MW	3.5 MW	3.5 MW	3.5 MW	3.5 MW
Total Aux Power requirement	27.7 MW	27.7 MW	31.8 MW	31.8 MW	31.8 MW	31.8 MW	31.8 MW	31.8 MW	36.5 MW	36.5 MW	36.5 MW	36.5 MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	34.2 MVA	34.2 MVA	39.3 MVA	39.3 MVA	39.3 MVA	39.3 MVA	39.3 MVA	39.3 MVA	45.1 MVA	45.1 MVA	45.1 MVA	45.1 MVA
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	43.2 MVA	45.4 MVA	46.5 MVA	46.5 MVA	51.1 MVA	51.1 MVA	51.1 MVA	51.1 MVA	52.9 MVA	52.9 MVA	52.9 MVA	57.4 MVA
Total for 2041												

Note:-  
The requirement of PD load is not considering in estimation of power calculation.





Annexure 8.1 (B)

**Bangalore METRO Phase-II**

**Approximate Energy Consumption**

Year	Gottigere -IIMB - Nagavara Corridor					Total for 2031	Total for 2041	Total for 2041
	Year 2016	Year 2021	Year 2031	Year 2041	Year 2041			
LENGTH (KM)	21.25 KM	21.25 KM	21.25 KM	21.25 KM	21.25 KM		21.25 KM	
No. of trains per direction in a day	178	216	108	108	108		108	
WEIGHT OF TRAIN & PASSENGER	182.0 T	182.0 T	182.0 T	182.0 T	182.0 T		182.0	
SFC (NET ) with 3.0% regen	KWH/1000 53 GTKM	KWH/1000 53 GTKM	KWH/1000 53 GTKM	KWH/1000 53 GTKM	KWH/1000 53 GTKM		KWH/1000 53 GTKM	
Yearly Traction Energy consumption with 365 days working with 3.0% regen	26.38 million units	32.02 million units	16.01 million units	16.01 million units	16.01 million units		32.21 million units	48.22 million units
<b>Station aux power requirement</b>								
Elevated/at-grade station	0.20 MW	0.20 MW	0.30 MW	0.30 MW	0.30 MW		0.50 MW	0.50 MW
U/G station	2.00 MW	2.00 MW	2.25 MW	2.25 MW	2.25 MW		2.50 MW	2.50 MW
no. of elevated/at-grade stations	6	6	6	6	6		6	6
no. of U/G stations	12	12	12	12	12		12	12
Total Station Aux Power requirement	25.2 MW	25.2 MW	28.8 MW	28.8 MW	28.8 MW		33.0 MW	33.0 MW
Depot Aux power requirement	2.5 MW	2.5 MW	3.0 MW	3.0 MW	3.0 MW		3.5 MW	3.5 MW
Total Aux Power requirement	27.7 MW	27.7 MW	31.8 MW	31.8 MW	31.8 MW		36.5 MW	36.5 MW
Total Aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	34.2 MVA	34.2 MVA	39.3 MVA	39.3 MVA	39.3 MVA		45.1 MVA	45.1 MVA
Diversity factor of aux loads	0.4	0.4	0.4	0.4	0.4		0.4	0.4
Yearly Aux Energy consumption 20 hrs/day and 365 days working (million units)	99.92 million units	99.92 million units	114.70 million units	114.70 million units	114.70 million units		131.66 million units	131.66 million units
<b>Net Annual Energy Consumption (Traction &amp; Aux)</b>	<b>126.3 million units</b>	<b>131.9 million units</b>	<b>130.7 million units</b>	<b>146.9 million units</b>	<b>162.9 million units</b>		<b>163.9 million units</b>	<b>179.9 million units</b>



KARNATAKA POWER TRANSMISSION CORPORATION LTD

No: KPTCL/CEE/P&C/KCO-88/25958  
Encl: Copy of the minutes

O/o the Chief Engineer Elcty  
Planning and co-ordination  
KPTCL, Kaveri Bhavan,  
Bangalore-09  
Date:- 30.10.2010

2 NOV 2010

To  
Shri. Sharad Sharma,  
Executive Director (Elect),  
Delhi Metro Rail Corporation limited,  
Metro Bhavan, 13, Fire Brigade lane,  
Barakhamba Road, Connought Place,  
New Delhi - 110001.

Sir,

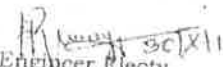
Sub: -Power supply for Phase-2 of Bangalore Metro Rail Project.  
Ref: - Meeting of KPTCL, DMRCL and BMRCL on 20.10.2010 at  
conference hall-2, KPTCL, Kaveri Bhavan.

\*\*\*\*\*

The copy of the proceedings of the meeting referred above is enclosed for further needful.

It is herewith requested to confirm the actions to be initiated by DMRCL as discussed in the above meeting.

Yours faithfully

  
Chief Engineer Elcty  
Planning and co-ordination

- Copies to:
- The Chief Engineer Elcty, Transmission Zone, Bangalore, KPTCL.
  - The Superintending Engineers(EI), BMAZ, North/South, KPTCL.
  - The Executive Assistant to D(T), KPTCL.
  - All the concerned officers.

OFFICE OF ED ELECTRICAL	
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D. CEE/EGS	CEE/UG
D. CEE/Order	CEE/TR
D. CEE/AT	CEE/UD
PA	GM/Maint.

  
9/11/10

**CHAPTER-9**

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**SIGNALLING SYSTEM**



## **CHAPTER 9**

### **SIGNALLING SYSTEM**

#### **9.0 SIGNALLING**

##### **9.1 Introduction**

The signaling system shall provide the means for an efficient train control, ensuring safety in train movements. It assists in optimization of metro infrastructure investment and running of efficient train services on the network.

##### **9.2 Signalling and Train Control**

###### **9.2.1 Overview**

Metro carries large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability. At the same time heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. These requirements of the metro are planned to be achieved by adopting 'Distance to go' ATP (Automatic Train Protection) and ATS (Automatic Train Supervision) sub-systems. This will:

- Provide high level of safety with trains running at close headway ensuring continuous safe train separation.
- Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.
- Provides safety and enforces speed limit on section having permanent and temporary speed restrictions.
- Improve capacity with safer and smoother operations. Driver will have continuous display of Target Speed / Distance to Go status in his cab enabling him to optimize the speed potential of the track section. It provides signal / speed status in the cab even in bad weather.
- Increased productivity of rolling stock by increasing line capacity and train speeds, and enabling train to arrive at its destination sooner. Hence more trips will be possible with the same number of rolling stock.



- Improve maintenance of Signalling and telecommunication equipments by monitoring system status of trackside and train born equipments and enabling preventive maintenance.

Signalling & Train Control system on the line shall be designed to meet the required headway during peak hours.

**Note of BMRCL:** The word “Distance to go” may be read as “Dynamic distance to go”.

### 9.2.2 System Description and Specifications

The Signalling and Train Control system shall be as below. Sub-system/ components will conform to international standards like CENELEC, IEC, BS, IS, ITU-T etc:

#### a. Continuous Automatic Train Control

Continuous Automatic Train Control will consist of - ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems:

##### (i) Automatic Train Protection (ATP)

Automatic Train Protection is the primary function of the train control systems. This sub-system will be inherently capable of achieving the following objectives in a fail-safe manner. Line side signals will be provided at diverging routes (i.e. at points & crossings), which shall serve as backup signalling in case of failure of ATP system. However, in such cases, train speed will be automatically restricted to 25 kmph.

- Cab Signalling
- Track Related Speed Profile generation based on line data and train data continuously along the track
- Continuous monitoring of braking curve with respect to a defined target point
- Monitoring of maximum permitted speed on the line and speed restrictions in force
- Detection of over-speed with audio-visual warning and application of brakes, if necessary
- Maintaining safety distance between trains
- Monitoring of stopping point
- Monitoring of Direction of Travel and Rollback

The cab borne equipment will be of modular sub-assemblies for each function for easy maintenance and replacement. The ATP assemblies



will be fitted in the vehicle integrated with other equipment of the rolling stock.

**Note of BMRCL:**

***As an alternative to the signaling system provided in Phase-I, the signalling/train control system for Gottigere-Nagawara Line will be of communication based train control (CBTC) as it has following advantages.***

- \* Higher commercial speeds***
- \* Lesser wayside equipment***
- \* Shorter head way***
- \*Most resilient to operation disturbances***

***Necessary fall back arrangements would be provided.***

**(ii) Automatic Train Operation (ATO)**

This system will operate the trains automatically from station to station while remaining within the safety envelope of ATP & open the train doors. Driver will close the train doors and press a button when ready to depart. In conjunction with ATP/ ATS, ATO can control dwell time at stations and train running in accordance with headway/ timetable.

**(iii) Automatic Train Supervision (ATS)**

A train supervision system will be installed to facilitate the monitoring of train operation and also remote control of the station. The train supervision will log each train movement and display it on the workstations with each Traffic Controller at the OCC and on one workstation placed in the Station Control room (SCR) with each Station Controller.

The centralized system will be installed in the Operation Control Centre. The OCC will have a projection display panel showing a panoramic view showing the status of tracks, points, signals and the vehicles operating in the relevant section/ whole system. ATS will provide following main functionalities:

- Automatic Route setting
- Automatic Train Regulation
- Continuous Tracking of train position
- Display Panel & Workstation interface



- Adjustment of station dwell time
- Link to Passenger Information Display System for online information
- Computation of train schedules & Timetable

**b. Interlocking System:**

**(i) Computer Based Interlocking (CBI)**

At all stations with points and crossings, Computer Based Interlocking (CBI) will be provided for operation of points and crossings and setting of routes.

The setting of the route and clearing of the signals will be done by workstation, which can be either locally (at station) operated or operated remotely from the OCC.

This sub-system is used for controlling vehicle movements into or out of stations automatically from a workstation. All stations having points and crossings will be provided with workstations for local control. Track occupancy, point position, etc. will be clearly indicated on the workstation. It will be possible to operate the workstation locally, if the central control hands over the operation to the local station. The interlocking system design will be on the basis of fail-safe principle.

The equipment will withstand tough environmental conditions encountered in a Mass Transit System. Control functions in external circuits will be proved both in the positive and negative wires. Suitable IS, IRS, BS standards or equivalent international standards will be followed in case wiring, installation, earthing, cabling, power supply and for material used in track circuits, relays, point operating machines, power supply etc.

**(ii) Track Circuits**

Audio Frequency Track Circuit will be used for vehicle detection and for transmission of data from track to train.

**Note of BMRCL:**

***AFTC/Axle counter system as required for fall back arrangement will be used.***

**(iii) Point Machines**

Non-Trailable Electrical Point Machine capable of operating with either 110V DC or 3-phase 380V AC will be used on main line. The depot point machine will preferably be trailable type.





### c. Train Depot: Signalling

All depot lines except the one which is used for shunting and in the workshop shall be interlocked. A workstation shall be provided in the Depot Control Centre for electrical operation of the points, signals and routes of the depot yard. Audio Frequency Track Circuits will be used in the depot as well.

**Note of BMRCL:**

***AFTC/ any other track occupation detection method shall be used for train detection.***

#### 9.2.3 Standards

The following standards 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 centralised in the equipment room at the station. The depot shall be interlocked except for lines mainly used for shunting, workshop/inspection shed areas.
▪ Operation of Points	With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.
▪ Track Circuit	Audio frequency Track circuits on running section, test track and in depot.
▪ Signals at Stations with point & crossings	Line Side signals to protect the points (switches). LED type signals for reliability and reduced maintenance cost.
▪ UPS (uninterrupted power at stations as well as for OCC)	For Signalling and Telecommunications
▪ Train protection system	Automatic Train Protection system.
▪ Train System Describer	Automatic Train Supervision system. Movement of all trains to be logged on to a central computer and displayed on workstations in the Operational Control Centre and at the SCR. Remote control of stations from the OCC.
▪ Redundancy for TP/ Train Describer.	Redundant Train borne equipment and ATS equipment at OCC.



▪ Cables	Outdoor cables will be steel armoured as far as possible.
▪ Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for signal application.
▪ Immunity to External Interface.	All data transmission on telecom cables/OFC/Radio. All Signalling and telecom cables will be separated from power cables. CENELEC standards to be implemented for EMC.
▪ Train Working under emergency	Running on site with line side signal with speed automatically restricted between 15-25 kmph.
▪ Environmental Conditions	Air-conditioners for all equipment rooms.
▪ 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.

**Note of BMRCL:**

***Axle counters will be provided for CBTC system to aid for fallback signaling.***

### 9.3 Space Requirement for Signalling Installations

Adequate space for proper installations of all Signalling equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for Signalling equipment shall be generally 60 sq.m for UPS Room (common for signalling and telecom) and for Signalling Equipment Room 50 sq.m at interlocked station with points & 20 sq.m at other stations. These areas shall also cater to local storage and space for maintenance personnel to work. At the OCC and the Depot, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

### 9.4 Maintenance Philosophy for Signalling Systems



The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipments shall be followed. Card / module / sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully

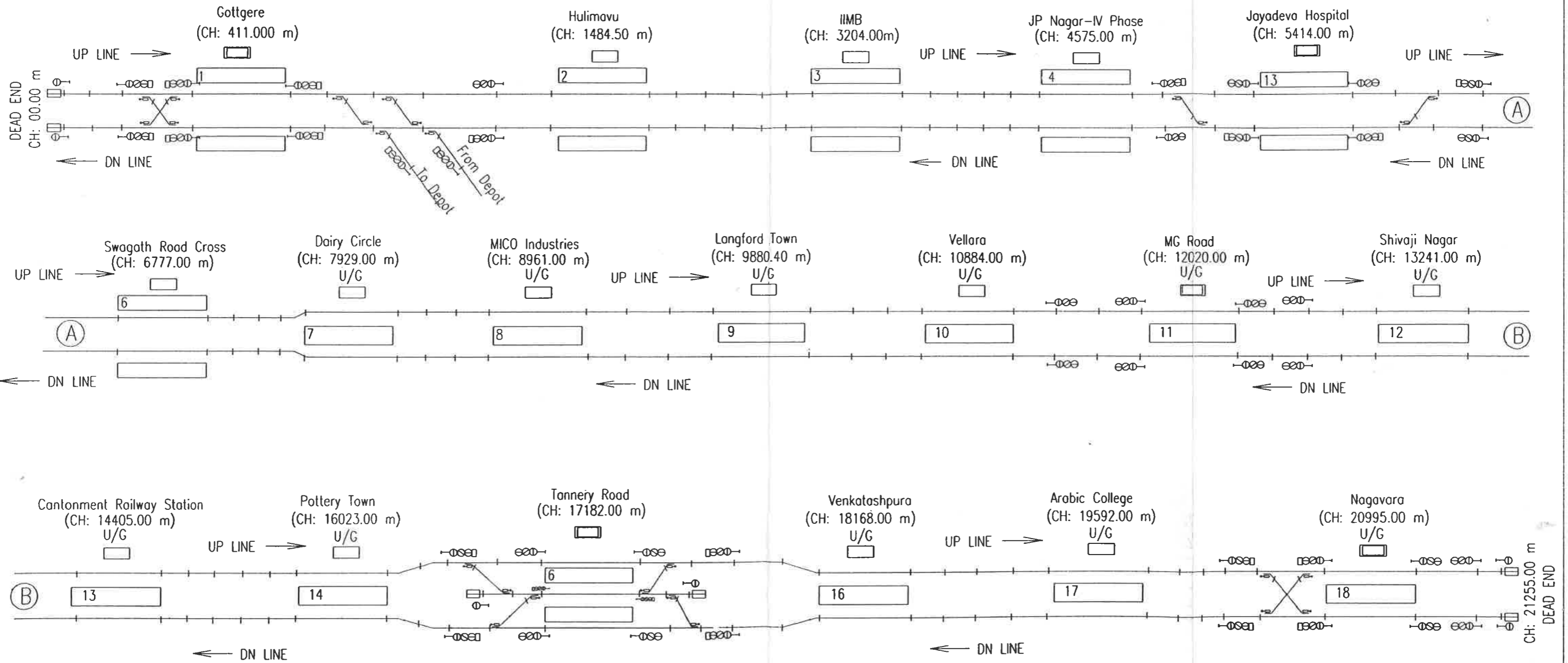



equipped transport vehicle for effectively carrying out the maintenance from station to station.

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 equipments to rectify the faults and undertake minor repairs. Cards / modules / equipments requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

North South Corridor - II of Bangalore Metro Phase -II

 INTERLOCKED STATION  
 SECONDARY STATION



 DELHI METRO RAIL CORPORATION LTD.  
 Metro Bhawan, Barakhamba Road, New Delhi 110001.  
 CONCEPTUAL SIGNALLING SCHEME PLAN (Sig 201/16)  
 From Gottgere to Nagavara (North South Corridor)  
 Based on P-Way Plan No DMRC/NS/Corr/Ph-II(Bangalore) dt 23.5.11  
 Drawn By Satish Kumar JE/Sig | Date 23rd May 2011

**CHAPTER-10**

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**TELECOMMUNICATION &  
AUTOMTIC FARE COLLECTION SYSTEM**



## CHAPTER 10

# TELECOMMUNICATIONS AND AUTOMATIC FARE COLLECTION SYSTEM

### 10.1 INTRODUCTION

The Telecommunication system acts as the communication backbone for Signalling systems and other systems such as SCADA, AFC etc and provides telecommunication services to meet operational and administrative requirements of metro network.

### 10.2 OVERVIEW

The telecommunication facilities proposed are helpful in meeting the requirements for: -

1. Supplementing the Signalling system for efficient train operation.
2. Exchange of managerial information
3. Crisis management during emergencies
4. Passenger information system

The proposed Telecom system will cater to the following requirements:

- Train Traffic Control
- Assistance to Train Traffic Control
- Maintenance Control
- Emergency Control
- Station to station dedicated communication
- Telephone Exchange
- Passenger Announcement System and Passenger Information and Display System within the station and from Central Control to each station.
- Centralized Clock System
- Train Destination Indicator
- Instant on line Radio Communication between Central Control and Moving Cars and maintenance personnel.
- Data Channels for Signalling, SCADA, Automatic Fare Collection etc.



**Note of BMRCL:**

***Closed circuit television system at stations and centralized surveillance centre shall be set up. It will be possible to view images from train at the centralized surveillance room through Broad Band Radio system (BBRS).***

**10.3 TELECOMMUNICATION SYSTEM AND TRANSMISSION MEDIA**

**i) Optical Fibre Cable - Main Telecommunication Bearer**

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a 48 Fibre optical fiber cable is proposed to be laid in ring configuration with path diversity.

Minimum SDH STM-16 based system shall be adopted with SDH nodes at every station and OCC. Access 2MB multiplexing system will be adopted for the lower level at each node, equipped for channel cards depending on the requirement of channels in the network specially for the SCADA system. Further small routers and switches shall be provided for LAN network at stations. Alternatively a totally IP Based High Capacity, high reliable and fault tolerant MPLS Ethernet Network can be provided in lieu of SDH/MUX.

**Note of BMRCL:**

***There shall be 96 fibre optical fibre cables. This may be 2 x 48 fibres. In addition to SDH, STM-16 gigabit Ethernet system will be provided at every station and OCC.***

**ii) Telephone Exchange**

For an optimized cost effective solution Small exchanges of 30 port each shall be planned at Stations and a 60 Port Exchange at the Terminal Stations shall be provided. The Exchanges will serve the subscribers at all the stations and OCC. The exchanges will be interconnected at multiple 2 MB level through optical fibre cable. The Exchanges shall be software partitioned for EPABX and Direct Line Communication from which the phones shall be extended to the stations. Alternatively, only for non- operational (other than Direct Line Communication) a separate IP Based phone system can be implemented.





**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 TETRA International standard. This system now is widely adopted for mobile radio communication in metro / rapid transit services abroad. All the stations 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 and will have to be kept same as that of the other lines for Radio portability. The system shall provide Instant mobile radio communication between the motorman of the moving cars and the Central Control. The motorman can also contact any station in the Corridor 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. As per initial study for North-South Corridor-II, 2 Base Station with a 40 m antenna height be required for the Elevated portion (IIMB and Swagath Road Cross)

For Underground Section, 3 Base Station shall be required at MICO Industries, Shivaji Nagar and Venkateshpura, feeding through Bi-directional Amplifiers and Leaky Coaxial Cables, the adjacent stations/tunnels.

In addition to the TETRA Radio Coverage for the internal use of the Metro, the city is also likely to have Mobile Coverage from Private Operators.

In the elevated sections it is expected that coverage shall be available from the adjoining sites of the Mobile Operators. However, in the underground stations / tunnels, coverage needs to be specially extended by the Mobile Operators. To enable the Mobile Operators to do so, the Metro Authority will have to have an agreement with a group of Mobile Operators according to which Metro shall provide an Air-conditioned room (approx. 20 sq. m) at each underground station to the Mobile Operator Group. The Mobile Operators



shall install all their repeater equipment in this room and then extend the coverage inside the tunnel by laying their own LCX cable in each tunnel and through antennas strategically placed in the concourse area. Further, for City Emergency Services like Police, the mobile operators shall also design their LCX network to support the police wireless coverage in the tunnels /station area. The detailed Agreement covering both the Mobile / Emergency Service Radio Coverage shall have to be finalised by the Metro Authority with the respective parties, at the time of implementation.

**iv) Passenger Announcement System**

The system shall be capable of announcements from the local station as well as from OCC. Announcements from station level will have over-riding priority in all announcements. The System shall be linked to Signalling System for Automatic Train Actuated announcement.

**v) 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 of the OCC shall preferably be same for all corridors. The Master Clock signal shall also be required for synchronization of SDH and Exchanges. The System will ensure identical display of time at all locations. Clocks are to be provided at platforms, concourse, Station Master's Room and other service establishments etc.

**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 boards shall be provided at all platforms and concourses of all stations. The System shall be integrated with the PA System and available from the same MMI.

At Interchange station with other Lines, colocated PIDS Boards will be required for passenger information of Interchanging Lines.

**vii) Network Monitoring and Management**

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 and Telephone Exchange. The NMS preferably shall be common for all lines of the Metro. In case it is a stand alone line, then separate NMS can be planned

**viii) Closed Circuit Television (CCTV) System**

The CCTV system shall provide video surveillance and recording function for the operations to monitor each station. The monitoring shall be possible both locally at each station and remotely from the OCC.

The CCTV system backbone shall be based on IP technology and shall consist of a mix of Fixed Cameras and Pan/Tilt/Zoom (PTZ) Cameras. Cameras shall be located at areas where monitoring for security, safety and crowd control purpose is necessary. Additionally a Broad Band Radio shall be provided at Station Platform for Transmission of Platform Image to the On-Board CCTV Monitor, to watch the entraining/detraining of passenger, while closing of train doors.

**Note by BMRCL:**

***BBRS sub system shall be included to facilitate video picture transmission from the train to OCC.***

**ix) Standards**

The standards proposed to be adopted for telecommunication systems are shown in Table 10.1 below:

**TABLE 10.1**

System	Standards
• Transmission System	<b>SDH based</b> for the entire telecom network.
• Transmission Media	<b>Optical Fibre system</b> as the main bearer for bulk of the telecommunication network,
• Telephone Exchange	EPABX of minimum 30 ports is to be provided at stations and an Exchange of 60 Ports to be provided at Terminal Station.
• Train Radio System	<b>Digital Train radio (TETRA) communication between motorman of moving cars, stations, maintenance personnel and central control.</b>



System	Standards
• Train Destination Indicator System	LED/LCD based boards with adequate visibility to be provided at convenient location at all stations to provide bilingual visual indication of the status of the running trains, and also special messages in emergencies.
• Centralized clock system	Accurate display of time through a synchronisation system of slave clocks driven from a master clock at the OCC and sub – master clock in station. This shall also be used for synchronisation other systems.
• Passenger Announcement System	Passenger Announcement System covering all platform and concourse areas with local as well as Central Announcement.
• Redundancy (Major System)	Redundancy on Radio base station equipment. Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
• Environmental Conditions	All equipment rooms to be air-conditioned.

**Note of BMRCL:**

- **The Transmission system will be SDH and GE based for entire telecom network.**
- **Broad Band Radio System to work in frequency band as allotted to Bangalore Metro shall also be provided.**

**x) 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 case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for S & T equipment shall be generally 30 sq.m each for Telecom Room and 50 sq.m. for UPS Room (common for signal and telecom). These areas shall also cater to local storage and space for maintenance personnel to work. At the OCC, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

**xi) Maintenance Philosophy for Telecom systems**

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipments shall be followed. Card / module / sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they



shall be trained in 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 equipments to rectify the faults and undertake minor repairs. Cards / modules / equipments requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop

## **10.4 AUTOMATIC FARE COLLECTION**

### **10.4.1 INTRODUCTION**

Mass Rapid Transit 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.

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.

Relative advantages of automatic fare collection system over manual system are as follows:

**(A) Manual fare collection systems have the following inherent disadvantages:**

1. Large number of staff is required for issue and checking of tickets.
2. Change of fare structure is time consuming as has to be done at each station
3. Manipulation possible by jamming of mechanical parts.
4. Staff and passenger interaction leading to more changes of confrontation
5. 100% ticket checking at entry/exit impossible.



**(B) Automatic fare collection systems have the following advantages:**

1. Less number of staff required.
2. Less possibility of leakage of revenue.
3. Recycling of ticket fraudulently by staff avoided.
4. Efficient and easy to operate, faster evacuation both in normal and emergency.
5. System is amenable for quick fare changes.
6. Management information reports generation easy.
7. System has multi-operator capabilities. Same Smart Card can be used for other applications also.
8. AFC systems are the worldwide accepted systems for Metro environment.

The proposed ticketing system technology shall be same as that to be provided on the other Lines i.e. Contact less Smart Token/Card type. The equipments 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 Masters room. For Interoperability of Ticket with other lines, the Central Computer of N-S Corridor II shall be interfaced with Central Computer of already operational Line. If required the existing Central Computer can also be expanded to support the new line.

**C) Choice of Control Gates**

Retractable flap type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern metros internationally. Tripod turnstile type or flap type gates offer fewer throughputs and require more maintenance.

**D) Passenger Operated Machine**

Passenger Operated Machines (Automatic Ticket Vending Machines) at least 2 at each station shall be provided at stations.

**E) AFC equipment Requirement**

AFC equipment Requirement is given in Table attached.

**10.4.2 Standards**

The standard proposed for AFC systems are given in Table 10.2:

**TABLE 10.2**



Standards	Description
<ul style="list-style-type: none"><li>Fare media</li></ul>	<ul style="list-style-type: none"><li>a) <b>Contactless smart token</b> – For single journey. They shall have stored value amount for a particular journey. Tokens are captured at the exit gate.</li><li>b) <b>Contactless smart card</b> – For multiple journeys.</li></ul>
<ul style="list-style-type: none"><li>Gates</li></ul>	Computer controlled automatic gates at entry and exit. There will be following <b>types of gates</b> : <ul style="list-style-type: none"><li>• <b>Entry</b></li><li>• <b>Exit</b></li><li>• <b>Reversible – can be set to entry or exit</b></li><li>• <b>Wide reversible</b> -gate for disabled people.</li></ul>
<ul style="list-style-type: none"><li>Station computer, Central computer and AFC Net work</li></ul>	All the <b>fare collection equipments</b> shall be connected in a <b>local area network</b> 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 centre through the optic fibre communication channels. The centralised control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.
<ul style="list-style-type: none"><li>Ticket office machine (TOM/EFO)</li></ul>	Manned <b>Ticket office machine</b> shall be installed in the stations for selling cards/ tokens to the passengers.
<ul style="list-style-type: none"><li>Ticket reader and portable ticket decoder.</li></ul>	<b>Ticket reader</b> shall be installed near EFO for passengers to check information stored in the token / cards.
<ul style="list-style-type: none"><li>UPS (uninterrupted power at stations as well as for OCC).</li></ul>	Common UPS of S&T system will be utilised.
<ul style="list-style-type: none"><li>Maintenance philosophy</li></ul>	Being fully Contactless systems, manpower requirement for maintenance is much less compared to system with magnetic tickets. However, adequate facilities to be provided similar to that of S&T systems.

### 10.5 Integration of AFC with Suburban/Bus System

Common Smart Card based ticketing for both Suburban and Bus systems is not proposed at this stage as this will required installation of AFC system at all suburban stations and in buses also. A Clearing House system will also be required for separation of revenue among various operators. However, the proposed system shall have multi operator capability and in future it will be possible to integrate various transport providers and other agencies by setting up a Clearing House and facilities at locations of other Operators.







**Entry/Exit Gates**



**Ticket Office Machine**



Ref : DMRC/20/11-296/2008 dated 21.04.2011												
AFC Equipments Estimate for Bangalore Metro N-S Corridor-II (projection for 2016 OPT II)												
S.No.	Station	Hourly Boarding	Hourly Alighting	Peak Min Boarding	Peak Min alighting	Gate		Disabled Gate	TOM	EFO	TR	TVM
						Entry	Exit					
1	Goltigere	3960	1862	79	37	3	2	1	4	2	4	2
2	Hulimava	1697	2792	34	56	2	2	1	2	2	4	2
3	IIMB	1026	613	21	12	2	2	1	2	2	4	2
4	J P Nagar -IV Phase	981	508	20	10	2	2	1	2	2	4	2
5	Jayadeva Hospital	6348	9167	127	183	4	6	1	6	2	4	2
6	Swagath Road Cross	776	604	16	12	2	2	1	2	2	4	2
7	Dairy Circle	293	406	6	8	2	2	1	2	2	4	2
8	MICO Industries	210	233	4	5	2	2	1	2	2	4	2
9	Langford Town	1038	494	21	10	2	2	1	2	2	4	2
10	Vellara	340	311	7	6	2	2	1	2	2	4	2
11	Kamraj Road	2094	2229	42	45	2	2	1	2	2	4	2
12	Shivaji Nagar	869	1014	17	20	2	2	1	2	2	4	2
13	Cantonment Railway Station	308	274	6	5	2	2	1	2	2	4	2
14	Pottery Town	467	629	9	13	2	2	1	2	2	4	2
15	Tannery Road	370	446	7	9	2	2	1	2	2	4	2
16	Verkaleshpura	1479	1037	30	21	2	2	1	2	2	4	2
17	Arabic College	1968	1710	39	34	2	2	1	2	2	4	2
18	Nagavara	3641	2278	73	46	2	2	1	4	2	4	2
	<b>Total</b>					<b>39</b>	<b>40</b>	<b>18</b>	<b>44</b>	<b>36</b>	<b>72</b>	<b>36</b>
<b>Assumptions:</b>												
	1. Each station has only 2 access											
	2. Minimum AFC equipments at a station with "2 access- 1 for entry, 1 for exit": 2 entry gates, 2 exit gates, 2 EFO, 2 TOM, 4 TR, 2 TVM											
	3. One Disabled gate at each station.											
	4. Throughput of gate 30 passengers per minute, TOM 10 transactions per minutes.											
	5. 50 % passenger are assumed on Smart Card and 50% on single journey token.											

**CHAPTER-11**

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**TRAIN MAINTENANCE DEPOT**



## CHAPTER-11

### MAINTENANCE DEPOTS

11.1	<u>Corridor</u>	<u>Gauge (mm)</u>	<u>Route Length (kms)</u>
	Option 1: Gottigere - IIMB – Nagavara	1435	20.58
	Option 2: Gottigere - IIMB – Nagavara	1435	21.78

**Option1:** That space of about 15.16 Hect. measuring about 500 mts X 300 mts. is available at southern end at Hulimavu village where a depot-cum workshop for inspection, minor maintenance / repairs and overhauling is proposed to be established

OR

**Option 2:** That space of about 15.16 Hect. measuring about 650 mts X 250 mts. is available at southern end at Kothanur village where a depot-cum workshop for inspection, minor maintenance / repairs and overhauling is proposed to be established.

In the Draft DPR submitted, the proposed depot was in the Hulimavu area. BMRCL vide letter dt.02-09-11 & 20-09-11 had insisted to change the depot area stating that the Hulimavu area is on tank bed. However, no suitable Govt land could be identified for locating this depot and a private land could only be located for this purpose which will be costlier by more than Rs.550 Crores as compared to Option 1. It is seen that the Govt Order regarding Hulimavu tank bed i.e. No.PWD 82 IMB 85 dt 11-02-1988 recommended for "Foreshore Planting, water sheet to be retained" by forest department. However, in spite of this order, nothing has happened since 1988. As of now there are sizable unauthorized encroachments in this tank bed area and is dirty and has become a breeding space for mosquitoes and hence health hazard. If this area is developed as a depot, the whole area will get a face lift with proper landscaping and open area in this locality. In addition the extra cost of more than Rs.550 Crores for acquisition of Pvt lands will be saved. Therefore it is recommended that the depot of Hulimavu area is confirmed after getting proper Governments clearance.



**Note By BMRCL:**

*The proposal to have depot at Hulimavu tank bed is noted and it found not possible to get Government clearance for this proposal. Hence it decided to go for the second option and private land measuring 15.16ha and 0.8 ha of Govt. land is located behind Meenakshi temple on Bannerghatta road.*

- For establishment of train maintenance facilities for the trains of the above corridor of following assumption are made:
- SBL are proposed to be of the length of 160 mts. for accommodating two 3-Car rakes on each line.
- The length of IBLs in depot are proposed for single 6-Car train length.

However any augmentation brought about over & above the provisions of current TOP during ensuring period of 2016 – 2041 shall invite additional infrastructure with more land requirement.

**11.2** In broad terms this chapter covers conceptual design of a Workshop-cum depot at Hulimavu/Kothanur village on following aspects and will work as a guide for detailed design later:

- Layout of Stabling-shed, Inspection-shed, heavy repair, minor repairs, maintenance workshop and cleaning of Rolling Stock.
- Operational and functional safety requirements.
- Ancillary buildings for other maintenance facilities.
- Electrical & Mechanical Services, power supply and distribution system.
- Water Supplies, Drainage & Sewerage.

**11.3 MAINTENANCE NEEDS TO ROLLING STOCK**

- Monitoring of the performance of equipment by condition monitoring of key parameters. The concept is to evolve the need based maintenance regime, which can be suitably configured in the form of schedules like daily check, “A” checks, “B” type checks, “IOH” and “POH”.
- Labor intensive procedures are kept to the minimum. Automation with state of the art machinery to ensure quality with reliability.
- Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.



- Energy conservation is given due attention.

## 11.4 ROLLING STOCK MAINTENANCE NEEDS

### 11.4.1 Maintenance Schedule

The following maintenance schedule has been envisaged for conceptual design of depots assuming 500 kms for both lines running per train per day, taking in consideration the passenger load of 2016, 2021, 2031 and 2041 respectively.

Type of Schedule	Interval	Work Content	Locations
Daily	Daily	Check on the train condition and function at every daily service completion. Interval cleaning/mopping of floor and walls with vacuum cleaner.	Stabling lines
"A" Service Check	5,000 Km (10 days)	Detailed inspection and testing of sub - systems, under frame, replacement / topping up of oils & lubricants.	Inspection bays
"B" Service Check	15,000 Km (30 days)	Detailed Inspection of 'A' type tasks plus items at multiples of 15,000 Km ('B' type tasks)	Inspection bays
Intermediate Overhaul (IOH)	420,000 Km, (3 Years)	Check and testing of all sub-assemblies (Electrical + Mechanical). Overhaul of pneumatic valves, Compressor. Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
Periodical Overhaul (POH)	840,000 Km, (6 Years)	Dismantling of all sub-assemblies, bogies suspension system, traction motor, gear, control equipment, air-conditioning units etc. Overhauling to bring them to original condition. Checking repair and replacement as necessary. Inspection and trial.	Workshop
Heavy Repairs	-	Changing of heavy item such as bogies, traction motor, axles, gear cases & axle boxes etc.	Workshop

### 11.4.2 Washing Needs of Rolling Stock

Cleanliness of the trains is essential. Following schedules are recommended for environment of Bangalore:

S.N.	Kind Inspection	Maint. Cycle	Time	Maintenance Place
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1.	Outside cleaning (wet washing on automatic washing plant)	3 Days	10 Mins.	Single Pass through Automatic washing plant of Depot
2.	Outside heavy Cleaning (wet washing on automatic washing plant and Front Face, Vestibule/Buffer area. Floor, walls inside/outside of cars and roof. Manually)	30 days	2 Hrs.	(Automatic washing plant & cleaning & washing shed)

11.5 (i) Year-wise planning of maintenance facility setup at depot-cum- workshop at Hulimavu / Kothanur is tabulated below as per TOP:

Year	Head way in minutes	No. of trains	No. of Coaches
2016	4	23 (3-Car)	69
2021	3	31 (3-Car)	93
2031	6	17 (3-Car)	51
	6	15 (6-Car)	90
2041	Same as in the Year 2031		

(ii) Average earning/day/rake (19 hrs working)

Year	3-Cars trains Earning/day/train (Kms)	6-Cars trains Earning/day/train (Kms)	Remarks
2016	532	-	i) 'A' inspection frequency after every 10 days ii) 'B' inspection frequency after every 30 days
2021	533	-	
2031	504	535	
2041	504	535	

(ii) Distribution of Stabling / Inspection lines in Depot and Stabling terminal at stations at Gottigere & Nagavara:

Year	Depot cum workshop at Hulimavu / Kothanur		Terminal Stations	
	SBLs	IBLs	Gottigere	Nagavara
2016	9 Lines X 6-Car	4 Lines X 6-Car	1 Line X 6-Car	1 Line X 6-Car
2021	13 Lines X 6-Car	-do-	-do-	-do-
2031	18 Lines X 6-Car	-do-	2 Lines X 6-Car	2 Lines X 6-Car
2041	-do-	-do-	-do-	-do-





**11.6.1 Requirement of inspection lines at Nagavara:**

Schedule	Maintenance Requirement (No. of Cars)	Lines Needed
<b>i) Year 2016 - Maximum no. of rake holding is (23 X 3-Cars) 69 Cars</b>		
'A' Checks (5000 km) 10 days	23 X 3-Cars = 69 Cars	2 Lines x 6-Car with Sunken Floor
'B' Checks (15000 km) 30 days	23 X 3-Cars = 69 Cars	1 Line x 6-Car with Sunken Floor
Unscheduled line	For minor repairs, testing and after IOH/POH	1 Line x 6-Car with Sunken Floor
Total requirement for expansion		1 bay of 4 lines each
<b>ii) Year 2021 - Maximum no. of rake holding is (31 X 3-Cars) 93 Cars</b>		
'A' Checks (5000 km) 10 days	31 X 3-Cars = 93 Cars	2 Line x 6-Car with Sunken Floor
'B' Checks (15000 km) 30 days	31 X 3-Cars = 93 Cars	1 Line x 6-Car with Sunken Floor
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line x 6-Car with Sunken Floor
Requirement: Same as above		1 bay of 4 lines each
<b>iii) Year 2031 (Maximum no. of rake holding is (17 X 3-Car) + (15 X 6-Car) = 141 Cars</b>		
'A' Checks (5000 km) 10 days	(17 X 3-Car) +(15 X 6-Car) = 141 Cars	1 Lines X 2 X(3-Car) (with sunken floor)
'B' Checks (15000 km) 30 days	(17 X 3-Car) +(15 X 6-Car) = 141 Cars	1 Line x 6-Car with sunken floor
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6-Car with sunken floor
Requirement: Same as above		1 bay of 4 lines each
<b>iv) Year 2041 (Maximum no. of rake holding is (17 X 3-Car) + (15 X 6-Car) = 141 Cars</b>		
'A' Checks (5000 km) 10 days	(17 X 3-Car) +(15 X 6-Car) = 141 Cars	2 Lines X 6-Car with sunken floor
'B' Checks (15000 km) 30 days	(17 X 3-Car) +(15 X 6-Car) = 141 Cars	1 Line X 6-Car with sunken floor
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6-Car with sunken floor
Requirement: Same as above		1 bay of 4 lines each



**11.6.2** Facilities shall be provided to carry out the inspection of the following sub-systems/equipments:

- Electronics; PA/PIS
- Mechanical components, couplers etc
- Batteries
- Air conditioner
- Brake modules
- Bogie
- Traction Motor
- Vehicle doors, windows and internal fittings
- Power system including converter, circuit breaker etc.

These activities shall be grouped into “A” checks. The minor scheduled inspections (“A” checks) shall be carried out during the day off peak and night. Since “B” checks take longer time, these cannot be completed in the off peak times. One inspection line will be nominated for “A” checks. For “B” checks, separate line will be nominated where the rakes may be kept for long time. One dedicated line in Depots will be used for the adjustment and testing after integration of IOH/POH equipment on Coaches.

## 11.7 DESIGN OF DEPOT FACILITIES

**11.7.1 (a) Stabling Lines at Depot at Hulimavu / Kothanur and terminal station at Nagavara:**

S.No.	3-Car
1	Length of 3-Car rake = 67 mts.
2	Minimum length of SBL=134 m (2 Rakes of 3-Cars) + 10 m (Signal loop) +5 m (Gap between two rakes) + 10 m (Friction buffers) = 159 mts. (Say 160 mts.)

**(b)** Stabling lines are designed for 160 m length to cater for safe gap from the friction buffer stops and the signaling interlocking needs. Looking to the car width of 2880 on SG, 5.0m “Track Centre” is proposed for all the stabling lines. Thus, space between stabling shall be sufficient to include 800mm wide paved pathway to be constructed between tracks to provide access for



internal train cleaning and undercarriage inspection with provision of following facilities:

- (i) Each stabling line to have water connection facility so that local cleaning, if required, is facilitated.
- (ii) Platforms at suitable points at each end of stabling lines to enable train operators to board or de-board conveniently.

### 11.7.2 Inspection Sheds at Hulimavu / Kothanur Depot:

All IBLs are computed for the length of two trains of 3-Cars i.e 160 mts. There shall be one inspection bay of 160 X 28 m size with four inspection lines having sunken floor and overhead roof inspection platforms at Hulimavu / Kothanur. The floor will be sunken by 1100 mm. The track spacing between the adjacent IBLs shall be 6.25 m/s. Roof Inspection platforms and walk-ways for roof inspection supported on the columns shall be provided. There would be lighting below the rail level to facilitate the under frame inspection. Ramps of 1:8 slopes, 3 meter wide have been provided with sunken floor system for movement of material for the cars. Further, 5m cross pathways are left at each end for movement of material by fork lifter/Leister/Hand trolley. 415V 3 phase 50 Hz, 230V 1 phase 50 Hz AC supply and Pneumatic supply shall also be made available on each inspection shed columns. Air-circulators shall be provided on each column. Each inspection line shall be provided with EOT crane of 1.5 T to facilitate lifting of equipment. Roof and walls shall be of such design that optimum natural air ventilation occurs all the time and sufficient natural light is also available.

- There shall be arrangement for cleaning of HVAC filters with high pressure water jet adjacent to Inspection bays.

### 11.8 Requirement of workshop lines at Hulimavu / Kothanur Depot:

Year	IOH	POH	Heavy lifting un schedule	Wheel & Bogie storage	Total	Remarks
2016	1	-	2	1	4*	In case of space constraints for carrying out other activities possibility of shifting Bogie overhauling to other Depots of the other corridors may have to be planned.
2021	1	-	2	1	4*	
2031	1	1	2	2	6	
2041	1	1	2	3	6	
Remarks	<ul style="list-style-type: none"><li>• All the Workshop lines shall be interconnected through turn –tables.</li><li>• Each bay shall be spanned with two 15T / 3T overhead Cranes.</li></ul>					



	<ul style="list-style-type: none"><li>• One embedded line shall be provided with Pit-jacks for lifting of 3-Car unit simultaneously.</li><li>• The unscheduled line shall be provided with Pits of complete Coach length for facilitating under-carriage inspection.</li><li>• Workshop will have an array of service rooms which cater for servicing &amp; overhauling of Equipments.</li><li>• Assembling / disassembling overhauling testing facilities shall be facilitated and suitably placed.</li> <li>• There shall be washing &amp; cleaning equipment available on shop floor. Air circulators, Power supply points, compressed air lines shall be provided on every column.</li><li>• Repair &amp; stacking of heavy equipments such as HVAC, Convertors and Motors shall be so located that it does not effect movement inside the workshop.</li><li>• Interconnectivity with mechanical repair section shall be so available that Wheels / Bogies / brake equipments are carried in and out of the repair section without causing inconvenience to any other activity.</li><li>• The unscheduled heavy lifting bay lines shall be extended upto half of the workshop bay length beyond which space shall be kept overhauling, repairs, cleaning disassembling / assembling of Bogies.</li></ul> <p>*Provision of expansion of workshop by one bay on 2-lines is to be kept from the year 2031.</p>
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### 11.9 Operational Features at Hulimavu / Kothanur Depot:

The rake induction and withdrawal to main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to main line from Inspection Shed / Repair-shop area. Movement from depot to the main line is so planned that the headway of main line is not affected. Simultaneous receipt and dispatch of trains from depot to main line is feasible in the present site scenario. Both of these activities will be done effectively without effecting the train operation on the main line. The stabling lines would be interlocked with the main line thereby induction of train from the stabling would be safe and without loss of time. The proposition for a transfer track on the incoming line as well as on the outgoing line to facilitate the movement of rake in the depot by Operation Control Centre (OCC) even though the further path inside the depot is not clear shall be explored in the detailed design stage depending on the actual availability of land.

An emergency line is also provided from which an emergency rescue vehicle may be dispatched to main line in the event of emergency if necessary.

### 11.10 Infrastructure Facilities at Hulimavu / Kothanur Depot



**I. Inspection Sheds**

As indicated in Paras 11.7.2

**II. Stabling Lines in Depots and terminals**

- a) The requirement of lines shall be in accordance with the table indicated at paras 11.5(iv) and 11.5 (iii). A part of stabling siding in the depot shall be covered with a roof in order to facilitate testing of air-conditioning of trains and their pre-cooling under controlled condition of temperature.
- b) Separate toilets adjacent to stabling lines shall be provided with small room for keeping cleaning aids and for utilization by the contractor's staff.

**III. Automatic Coach Washing Plants**

Provision to be made for Rolling Stock exterior surfaces to be washed using a fully automated Train Washing System, with a throughout capacity of approximately ten trains per hour. The AWP shall be situated at such a convenient point on the incoming route so that incoming trains can be washed before entry the depot and undesirable movement/shunting over ingress and egress routes within the depot is avoided. Additional space for plant room for AWP system shall be earmarked along-side the washing apron.

**IV. Train Operators Booking Office**

Suitable office facility adjacent to the stabling lines at each depot should be provided so that train operators reporting 'On' duty or going 'Off' duty can obtain updates regarding 'Special Notices', 'Safety Circulars' and other technical information in vogue. These offices should have an attached a cycle/scooter/car stand facility for convenience of the train operating staff.

**V. Heavy Cleaning Shed**

Monthly heavy cleaning of interior walls, floors, seats, windows glasses etc, outside heavy cleaning, Front/rear Face, Vestibule/ Buffer area, outside walls and roof shall be done manually in the interior cleaning plant designed for cleaning of one six car train at a time. A line adjacent to inspection shed should be so provided that placement of rakes is possible from workshop or inspection lines & vice – versa conveniently & with ease.

**VI. Power Supply**



Auxiliary substations are planned for catering to the power supply requirement of the whole depot. Details of connected load feeder shall be worked out. 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 will be adequate to supply all essential loads without over loading. In the depot, one auxiliary sub-station with DG set as standby is proposed to be provided.

**VII. Compressed Air Supply**

Silent type compressor units shall be suitably installed inside the depots at convenient location for the supply of compressed air to workshop and inspection sheds. Thus, the pneumatic pipeline shall run within the workshop and inspection bays as the case be lines should also have compressed air supply line at all convenient points.

**VIII. Water Supply, Sewerage and Drainage Works**

In house facilities shall be developed for the water supply of the depot. Sewerage, storm water drainage shall be given due care while designing the depots for efficient system functioning. Past records of Municipal Corporation shall be used to design the drainage system. Rainwater harvesting would be given due emphases to charge the under ground reserves.

**IX. Ancillary Workshop**

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 equipments.

**X. Watch Towers**

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

**XI. Administrative Building**



An administrative building close to the main entrance is planned. It can be suitably sized and architecturally designed at the detailed design stage. A time and security office is also provided close to main entrance. It shall be equipped with suitable Access control system for all the staff working in the complex.

## **XII. Parking Facilities**

Ample parking space shall be provided for the two wheelers and four wheelers at the following points.

- i. Close to the depot entry.
- ii. Close to the stabling lines.

## **XIII. Shed and Buildings**

The shed and buildings normally provided in the depot with their sizes and brief functions are indicated in Annexure-I. 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.

## **XIV. Plant and Machinery**

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 depositing of scrap.

**Requirement of buildings and major plants and machinery, is given at Annexure-I and II:**

Following Safety features should be incorporated in the design of all the Maintenance Depots

- a) 1.5 EOT cranes in the inspection bay should be interlocked with 25 KVAC rail feed system; the cranes become operational only when the system is isolated and grounded.
- b) Red flasher lights should be installed along the inspection lines at conspicuous location to indicate the isolation of rail feed system.
- c) Multi level wheel and TM stacking arrangement should be a inbuilt feature at the end of Workshop lines.





- d) Pillars in the inspection bay & workshop should have provision for power sockets.
- e) Placement of rakes from inspection/workshop lines on to washing lines for interior cleaning on their own power should be possible. Linking of supply system and its isolation at the cleaning area should be provided. Necessary requirements of safety should be kept in view.
- f) The roof inspection platform should have at least two open able doors to facilitate staff to go up the roof for cleaning of roof. Suitable safety interlock should be provided to ensure maintenance staff are enabled to climb on the roof safely.
- g) Control Centre, PPIO & store depot must be close to Workshop.
- h) Width of the doors of the sections wherein repairs of equipments are done should be at least 2 meters wide to allow free passage of equipment through them.
- i) Provision of water hydrants should be done in workshops stabling yards also.
- j) Compressed air points along with water taps should be available in interior of buildings for cleaning.
- k) Ventilation arrangement inside the inspection shed and workshop should be ensured. Arrangement for natural cross ventilation from one side to another of inspection & workshop bays to be incorporated along with optimum availability of natural light at floor level.

Both the depot and depot-cum-workshop will have all the facilities shown above.

**Annexure-I**

**List of Buildings at Depot at Hulimavu / Kothanur**

S.No.	Name of Building	Size	Brief Function
1.	Inspection Shed	160 x 28 m	Servicing of Cars for 10 days & 30 days inspection.
	Workshop*	160 x 63m	Lifting of cars for unit replacement of repaired bogies, wheels, under hung electric and mechanical equipments.
	Associated sections	160 x 8m	Rooms for carrying out the inspection & workshop activity.
	Pit Wheel lathe building	40 x 20m	For installation of PWL and related equipments



2.	Stores depot & offices including goods platform with ramp	40 x 40m	<ul style="list-style-type: none"> <li>i. Stocking of spares for regular &amp; emergency requirement including consumable items.</li> <li>ii. This store caters for the requirement of depot for rolling stock &amp; other disciplines.</li> <li>iii. To be provided with computerized inventory control.</li> <li>iv. Loading/unloading of material received by road.</li> </ul>
3.	Elect. Sub-station DG set room	40 x 20m 25 X 22m	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.	Traction repair depot and E&M repair shop	80 x 30m	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	40 x 6 m 40 x 6 m	<ul style="list-style-type: none"> <li>i. Close to the depot entry.</li> <li>ii. Close to the stabling lines.</li> </ul>
6.	(i) Auto coach washing plant (ii) Space for AWP machine room	40 x 10m 20 x 10	For automatic washing of coaches. Washing apron is for collection of dripping water and its proper drainage.
7.	Washing apron for Interior cleaning	35 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	<ul style="list-style-type: none"> <li>i. For track maintenance of section and depot.</li> <li>ii. To weld rails for construction period only.</li> <li>iii. To stable track Tamping machine.</li> </ul>
9.	Security office & time office garages (4 Nos.)	15 x 8m	<ul style="list-style-type: none"> <li>i. For security personnel.</li> <li>ii. For time punching.</li> <li>iii. For parking vehicle jeep, truck etc.</li> </ul>
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 centre & Crew booking centre	25x20m (double storey)	To control movement of trains in and out of the depot & out of the depot & for crew booking.
13.	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.	Dangerous goods Store	15m x 10m	For Storage of paints, inflammables & Lubricants
16.	Traction 25/33kV sub station	15m x 10m	Traction Power Supply
17.	Waste Collection Bin	10m x 10m	Garbage dumping
18.	Repair shops for S&T	40 x 20m	For the AFC gates, Signaling and telecom equipment.
19.	Work shop Manager Office	30 x 20m	Office of Depot in charge
20.	ATP & ATO Room	10 x 8m	To keep equipments of ATP/ATO
21.	Waste Water Treatment Plant	12 x 6m	For treating the discharge waters of the depot and remove the oil, acids etc. before discharging into the river, with U/G tank.



22.	Canteen	400 sqm.	Canteen to cater staff of depot and workshop staff should be in a separate building with modern kitchen ware and facilities. Obligatory as per statutory requirements
23.	Toilets (Gents) (Ladies)	8 x 7m	These toilets shall be approachable both from workshop as well as from inspection bay and ladies toilet shall be completely insulated from gent's toilet.
		8 x 7m	

Annexure-II

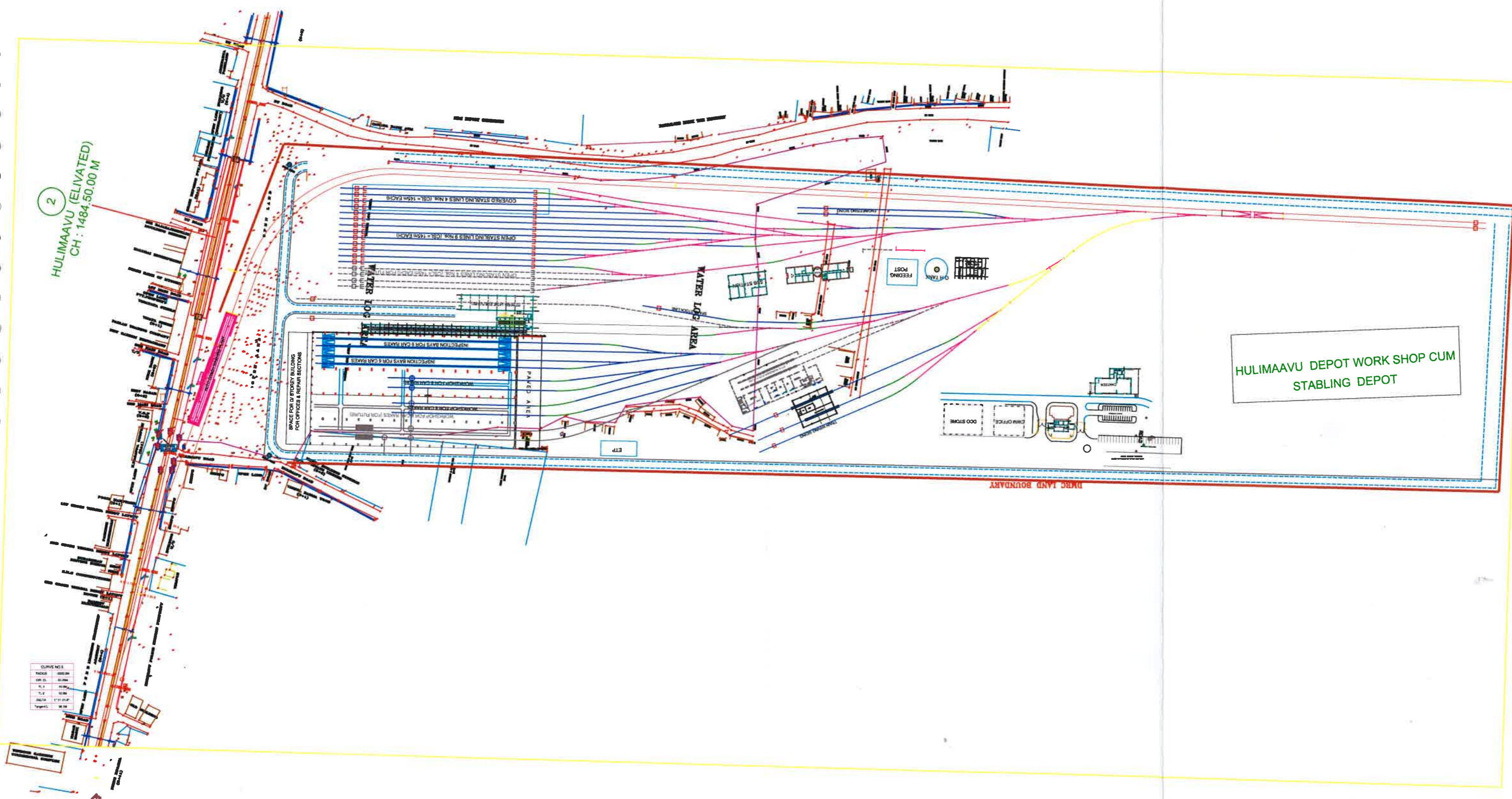
**List of Plants & Equipments at Hulimavu / Kothanur**

S.No.	Equipment	Qty	Unit	Imp. / Ind.
1	Mobile jacks 15T for lifting cars	12	Nos.	Imp
2	Pit jacks (complete set)	1	Set	Imp
3	Re-railing equipment consisting of rail cum road vehicle and associated jack system etc.	1	Set	Imp
4	Run through type Automatic Washing plant for Metro cars.	1	Nos.	Imp
5	Work lift platform	2	Nos.	Imp
6	Electric bogie tractor for pulling cars and bogies inside workshop	1	Nos.	Imp
7	Chemical cleaning tanks, ultrasonic cleaning tanks, etc	1	Set	Imp
8	Compressor for Inspection shed & shop air supply	2	Nos.	Ind
9	Travelling O/H crane Repair-shop 15 T / 3 T:- 4 Nos; 3 T :- 2 Nos	2+2	Nos.	Ind
10	Mobile jib crane	2	Nos.	Ind
11	Mobile lifting table	2	Nos.	Ind
12	Carbody stands	24	Nos.	Ind
13	Bogie turn tables	4	Nos.	Ind
14	Underframe & Bogie blowing plant	1		Ind
15	AC filter cleaning machine	1	Nos.	Ind
16	Portable cleaning plant for rolling stock	1	Nos.	Ind
17	High-pressure washing pump for front and rear end cleaning of car	1	Nos.	Ind
18	Shot blast cleaner	1	Set	Ind
19	Axle shaft inspection station	1	Set	Ind
20	Industrial furniture	1	L.s.	Ind
21	Minor equipment and collective tools	-	Set	Ind
22	Induction heater	1	No.	Ind
23	Oven for the motors	1	No.	Ind
24	EMU battery charger	3	Nos.	Ind
25	Welding equipments (Mobile welding, oxyacetylene, fixed arc welding)	2	Set	Ind
26	Electric and pneumatic tools	-	Set	Ind
27	Measuring and testing equipment	-	Set	Ind
28	Tool kits	-	Nos.	Ind
29	Mobile safety steps	4	Nos.	Ind
30	Fork lift tractor	2	Nos.	Ind
31	Pallet trucks	2	Nos.	Ind
32	Diesel/battery Shunting Locomotive	1	Nos.	Ind
33	Road vehicles (pickup van/ truck)	1	Set	Ind
34	Miscellaneous office equipments	-	Nos.	Ind
35	Special jigs and fixtures and test benches for Rolling Stock	-	-	Ind



36	Battery operated rail-cum-road shunter with suitable coupler	1	Nos	Ind
37	Under floor Pit lathe for wheel reprofiling chip crusher and conveyance for lathe on Pit & Electric tractor for movement of movement over lathe.	1	Nos	Ind

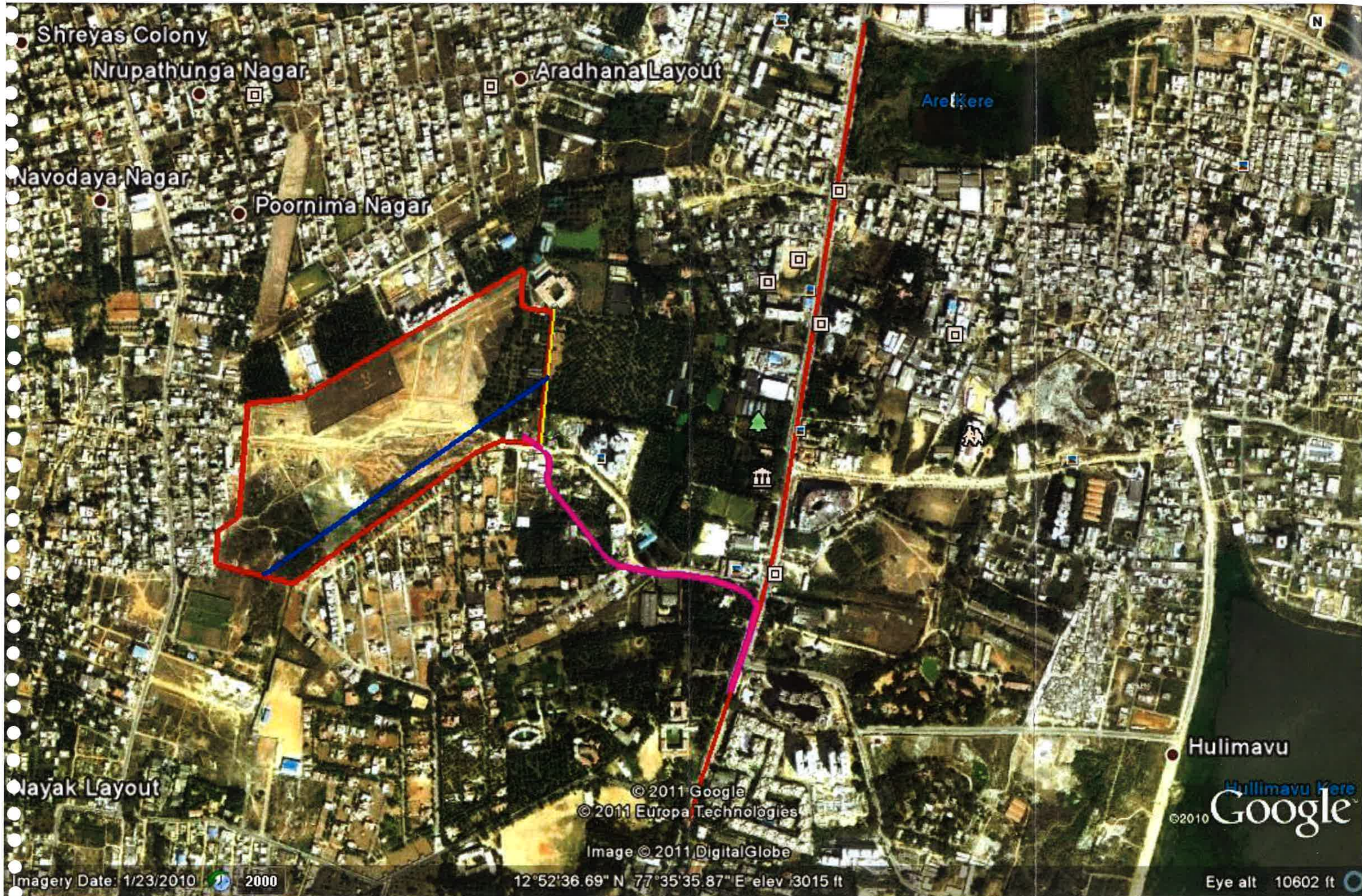
2  
HULIMAUVU (ELIVATED)  
CH : 1484.50.00 M



HULIMAUVU DEPOT WORK SHOP CUM  
STABLEING DEPOT

CURVE NO. 2	
RADIUS	1000.00 M
CH. ST.	1484.50 M
CH. EN.	1484.50 M
CH. L.	1484.50 M
CH. R.	1484.50 M
CH. S.	1484.50 M
CH. E.	1484.50 M
CH. W.	1484.50 M
CH. N.	1484.50 M
CH. S.	1484.50 M





Shreyas Colony

Nrupathunga Nagar

Aradhana Layout

Arel Kere

Navodaya Nagar

Poornima Nagar

Jayak Layout

Hulimavu

Hulimavu Kere  
Google

© 2011 Google  
© 2011 Europa Technologies

Image © 2011 DigitalGlobe

Imagery Date: 1/23/2010 2000

12°52'36.69" N 77°35'35.87" E elev 3015 ft

Eye alt 10602 ft



**CHAPTER-12**

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**ENVIORNMENT & SOCIAL  
IMPACT ASSESSMENT**





## **CHAPTER-12**

# **ENVIRONMENTAL IMPACT ASSESSMENT**

### **12.1.1 Background**

Bangalore is the fifth largest metropolitan city and the third most populous city in the country. It is located at 12°.59' North Latitude and 77°.56' East Longitude at an altitude of 920 m above Mean Sea Level, covering 741 Sq Km area of land. As per the 2001 census, total population of Bangalore was 5.6 million. With the formation of 'Greater Bangalore' in 2007, the city's population has exceeded to around 6.2 million according to CDP prepared by BDA. The Greater Bangalore comprises of 7 City Municipal Councils (CMC), 1 Town Municipal Council (TMC) and 111 Villages. The city has a flat topography except a ridge is found in the middle running in NNE-SSW direction. There are some freshwater lakes and water tanks while there are no rivers in the city. The city receives bimodal rainfalls during June to September and November to December. Around 54.18% of rainfall occurs due to southwestern monsoon and about 26.53% due to northeastern monsoon.

Bangalore is witnessing tremendous pressure on its infrastructure due to a rapid growth in industry, trade and commerce attributing to population growth. This development has evolved several crucial issues such as traffic congestion, air pollution, noise pollution, lack of open spaces, waste disposal, deterioration of water quality, sewerage, and health impacts. The prime concern at present scenario is traffic congestion and air pollution. With the advent of IT industries and educational institutions, people have occupied the intermediary spaces largely between the North- South and East - West of the City.

The city had a salubrious climate with a moderate temperature until early 80s. Now the situation is changing gradually from pollution free to pollution congest, chaotic with poor and overburdened infrastructure. There are hundreds of Multinational Companies, Information Technology Centers, Business Process Outsourcing units, BPO's mushrooming all over the city. The increased infrastructure and companies creating more job opportunities in various sectors, is a symbol of prestige for the city, because it increases purchasing power, increases investment, economic growth and development. The City population growth has been increasing very rapidly from the last two decades. On the other hand cost of living has more than doubled, intense competition in employment and education, severe traffic congestion, overpopulation, insufficient public transport, drinking water scarcity and



public health services, adverse environmental impacts are the frightening problems to city public.

Urban transportation systems are wilting under the pressure of ever growing demands on inadequate transportation facility and traffic congestions. The ever increasing population of the city has put a pressure on city transportation system. The widely used road transportation system resulted in traffic congestion and air pollution. The government has taken several measures/schemes to improve this traffic problem by widening existing roads, construction of flyovers etc but the problem still persist. The city has radial pattern road network covering about 3,500 Km with around 12 arterial roads forms the core traffic areas. Since, the existing transportation systems is also not able to keep pace with the rapid and substantial increase in the transportation demand of the commuters, Delhi Metro Rail Corporation (DMRC) is planning to extend Bangalore Metro Phase I and a new Phase II North - South alignment (Phase II) to other parts of city to resolve the vital transportation problem of the city. This report exclusively describes North-South alignment.

### 12.1.2 Objective of EIA Study

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.

Ministry of Environment and Forests (MoEF), New Delhi 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. However, Environment Impact Assessment is necessary to access the impacts and hence, the present study will fulfill this requirement.

#### ***Note of BMRCL:***

***EIA study has been carried out to assess the environmental impact.***

### 12.1.3 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.

#### 12.1.3.1 Legal Framework

##### – 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.

##### – 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.

##### – 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

– **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 (Asst 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 tree or 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.

– **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.

– **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 11<sup>th</sup> April 1994. Recently, NABET accreditation was



introduced for all environmental consultants and also introduced few additional parameters under air monitoring.

– **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-field 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 licence for the use of any such land or buildings for any other purposes shall be granted and any alienation made or licence 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.

– **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.

– **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.



– **Land Acquisition Act, 1894**

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

– **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 well being of the people. The noise quality standard in respect to different category of areas are based on weighted equivalent noise level (Leq)

– **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.

### 12.1.3.2 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.

– **National Forest Policy, 1988**

This policy applicable, when there 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.

– **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, organisations 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.

– **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.

– **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 minimise 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 lays down that the community to be displaced will have to be 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.

### 12.1.3.3 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.

#### – Ministry of Environment and Forest (MoEF)

In view of the growing importance of environmental affairs, the Government of India set up a Department in November 1980 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.

#### – Central Pollution Control Board (CPCB)

The Central Pollution Control Board (CPCB) is directly 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,

- The planning of comprehensive state programs for the prevention and control of air and water pollution and to ensure the implementation thereof.
- Inspection of control equipment, industrial plants, etc.
- 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.

#### – 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.

## 12.2 PROJECT DESCRIPTION

### 12.2.1 General

Mass Rapid Transport System (MRTS) is an elevated/underground suburban railway system which facilitates large commuters to travel any part of the city within short duration. The large capacities of such systems make them potentially more efficient in terms of cost and comfort journey than any other automobile transportation. In addition, it helps to decongest the crowded road corridors and offers a more environment friendly mass transportation alternatives.

The present study consists of one new alignment which is a Phase II North - South Metro Rail alignment. This alignment covers 21.255 km consisting of both elevated

and underground sections. The elevated stretch is  $\approx 7$  km, underground is  $\approx 13.8$  km and the ramp area is  $\approx 480$  m. The alignment starts from Gottigere (Meenakshi temple on Bannerghatta Road) to Nagavara (on Tannery Road) with 6 elevated stations and 12 underground stations. The salient features of the proposed alignment are given in Table 12.1.

**Table 12.1: Important salient features of Phase II North - South alignment**

<b>Salient Features</b>	<b>Gottigere to Nagavara</b>
Length of the alignment	21.255 Km
Nature of alignment	Elevated – 7 km Underground – 13.8 km
Number of stations	06 (Elevated) 12 (Underground)
Right of Way	20 m
Project implementation	
- Start Date	2012
- Completion Date	2017
Rail capacity	2000 passenger/trip (6 coach)
Frequency	1 train for every 4 minutes (Peak hours)
Connecting Areas	Gottigere, Hulimaavu, IIMB, JP Nagar, Jaynagar, Wilson garden, Richmond Town, MG Road, Shivajinagar, Benson Town, Pulikeshnagar, Govindapura and Nagavara
Industry/Companies along the proposed alignment	Intech Telecom Systems, Adobe system Pvt Ltd, Oracle, Dharmaram College, Bangalore Dairy, Accenture
Educational Institutions along the proposed alignment	IIMB, PSBB Learning Leadership Academy, Govt Institute of Training, Dharmaram College, Baldwin Boys School, Sacred Heart/Good Shepherd School, St. Joseph Educational Institution, Hafiziya High School, Niswan Urdu School, Quwahtul Islam School, Gem High School, Government urdu school, Dr. Ambedkar Medical College
Hospitals along the proposed alignment	Wockhard Hospital, Apollo Hospital, Jayadeva Hospital, Government Hospital, Dr. HM Honnur Dental Clinic, Dr. Ambedkar Medical College
Flyover along the alignment	Jayadeva Flyover, Dairy Circle Flyover, Phase I Metro viaduct
Major road approach the alignment	Marenahalli Road, Mari Gowda Road, Gen Thimmaiah Road, MG Road, Basaweshwara Main Road, Arabic College Road

**Table 12.2: Stations in Phase II North - South Alignment**

Sl.No.	Station Name	Chainage (m)	Type
1	Gottigere	411	Elevated
2	Hulimavu	1484.50	Elevated
3	Indian Institute of Management(IIM –B)	3204	Elevated
4	J P Nagar - IV Phase	4575	Elevated
5	Jayadeva Hospital	5414	Elevated
6	Swagath Road Cross	6777	Elevated
7	Dairy Circle	7929	Underground
8	MICO Industries	8961	Underground
9	Langford Town	9880.40	Underground
10	Vellara	10884	Underground
11	M G Road	12020	Underground
12	Shivajinagar	13241	Underground
13	Cantonment Rly Station	14405	Underground
14	Pottery Town	16023	Underground
15	Tannery Road	17182	Underground
16	Venkateshapura	18168	Underground
17	Arabic College	19592	Underground
18	Nagavara	20995	Underground
	End Of Chainage	21255	

### 12.2.2. Project Benefits

Bangalore City is one of the most cosmopolitan and commercially advanced cities in the country. It is home to many corporate giants like Infosys, Wipro, Biocon, Intel, IBM, HP, DELL, TCS, BHEL, BEML, HAL etc. A number of international standard research centers like ISRO, DRDO, NAL, NLS, IISc etc along with the technological centers like Electronic City & International Tech Park attract students and employees from all over the world. It is one of the major centers of education in the recent years with the help of the development in the infrastructure. In addition, increased employment opportunities further attract the work force resulting augmented migrants from all over the country. The increased population put greater pressure on existing transportation system which leads to various problems.

An ecologically sustainable alternative mode of transport system is required for better environment and better future. Thus, it is necessary to provide standardized transport network facilities in the form of Mass Rapid Transport System to



commuters. The new transport system gives a solution to the unprecedented increase in transport problems. The main objective of the proposed Metro alignment is to ease the traffic congestion by facilitating commuters to use public transport in minimal travel time and to reduce air pollution. It offers residents more transportation choices, reduces an overburdened road transport system and significantly improves environmental quality. The reduction in the number of vehicles will lower fuel costs, while shorter travel times and easier commutes from city one end to other. The proposed Metro Rail has many benefits few are listed below.

- Reduce the road traffic loads by reducing personalized transportation
- Reduce the fuel consumption
- Provide comfortable journey to public
- Sizable reduction in traveling time to public
- Reduce the number of accidents
- Reduce the vehicular pollution to a considerable extent
- Improve Trade and Commerce
- Improve the city aesthetic value
- Drastic cut in communication time
- Overall improvement in quality of life

## **12.3 ENVIRONMENTAL BASELINE STUDIES**

### **12.3.1 General**

The baseline environmental status of the project area is essential to assess the impacts on the neighboring environment. The study consist 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.

### **12.3.2 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 750 sq 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, Tumkur District in the northwest, Mandya District in the southwest, Ramanagaram District in the south and the neighboring state of Tamil Nadu in the southeast. 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.

### 12.3.3 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. Saugar group comprises ultramorphic rocks, amphibolites, Quartzite banded magnetites, quartzite occurring as small bands and lenses within the magmatites and gneisses. PGC is the dominant unit and covers about two-thirds of the area, which includes granites, gneisses and magmatites. The bed rocks essentially consist of granites and gneisses intruded by number of basic dykes.

### 12.3.4 Soils

The project area has Red Loamy and Laterite soils. Red loamy soils is 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.

### 12.3.5 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.

### 12.3.6 Land Use / Land Cover

There is substantial development in the North of Bangalore comprising of Banaswadi, Peenya Industrial Estate, Yashwantpur, Yelahanka and Bangalore International Airport. Banaswadi has many software companies, while Peenya is famous for manufacturing machine tools and it is one of the oldest and largest industrial areas in South-East Asia. The road from Bellary road to Yelahanka is witnessing rapid residential development. The trend is expected to remain positive in the area with development of International Airport acting as a catalyst for further growth. There are large IT companies like Hewlett Packard, Infosys, Siemens and Wipro etc in Electronic City which is spread in an area of 332 acres in South.



Sarjapur road is another promising area for industrial growth in the south of the city. Jaynagar, J.P Nagar, BTM layout are the areas adjoining to Electronic city developed primarily as residential areas.

East of Bangalore has grown till Whitefield and rapidly developing as a commercial area. Though the connectivity is not sufficient, initiatives were taken place by the government in the form of over bridges, underpass, road widened activities may not sufficient. Kormangala, Indiranagar and Hosur road are the prime areas. West of Bangalore has predominantly been the residential focus with prime areas being Rajajinagar, Vijayanagar, Basaveswarnagar, Magadi road. It is mainly comprised of residential areas. There is a massive population growth in North-East and in the South of the city along Hosur Road and Whitefield Road in the East.

The land use pattern of the city depicts how various physical, social, economic factors have influenced the change over the past decades and the existing land use is essential for future planning of the project. Since the project is situated in the states capital, the core area of the city consists of administrative offices and it is also a traditional business areas. The land use status of city indicates that about 42 % area is used for residential purposes, 22 % land area is utilized for roads and 12 % land utilized for commercial purpose and rest area is covered by parks, water bodies, open spaces etc. The area is covered under residential and roads include large number of avenues.

### 12.3.7 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.

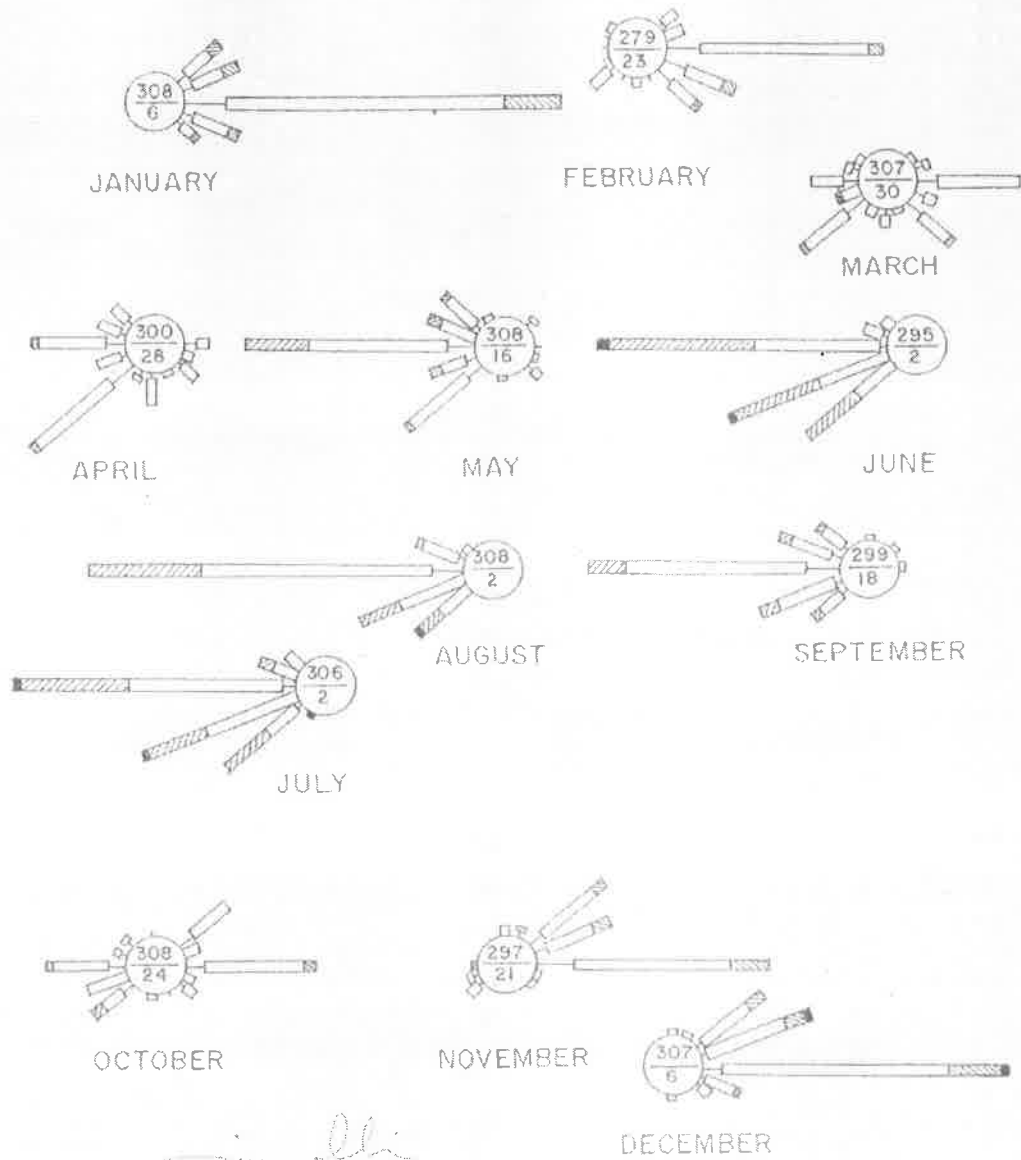
The wind rose diagrams available for the period 1976 – 1994 shows that easterly winds dominated over the months of December, January and February while, the westerly winds dominated over the months of May to July. The wind rose diagrams are given for day and night observations in Fig 3.1 and Fig. 3.2. 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.



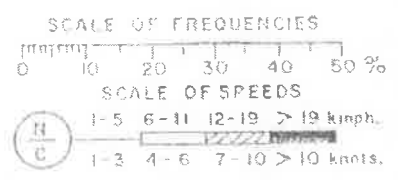
# WIND ROSES

R. BANGALORE

0830 HRS. I.S.T.



*S. S. Srinivasan*  
 28/3/07  
 Director, Planning  
 Department of Urban Planning  
 City and Regional Planning  
 Office No. 2, Training Road  
 Bangalore-560 001.



N: TOTAL NUMBER OF OBSERVATIONS.  
 C: TOTAL NUMBER OF CALMS IN PERCENTAGE FREQUENCIES

PERIOD: 1982 - 91

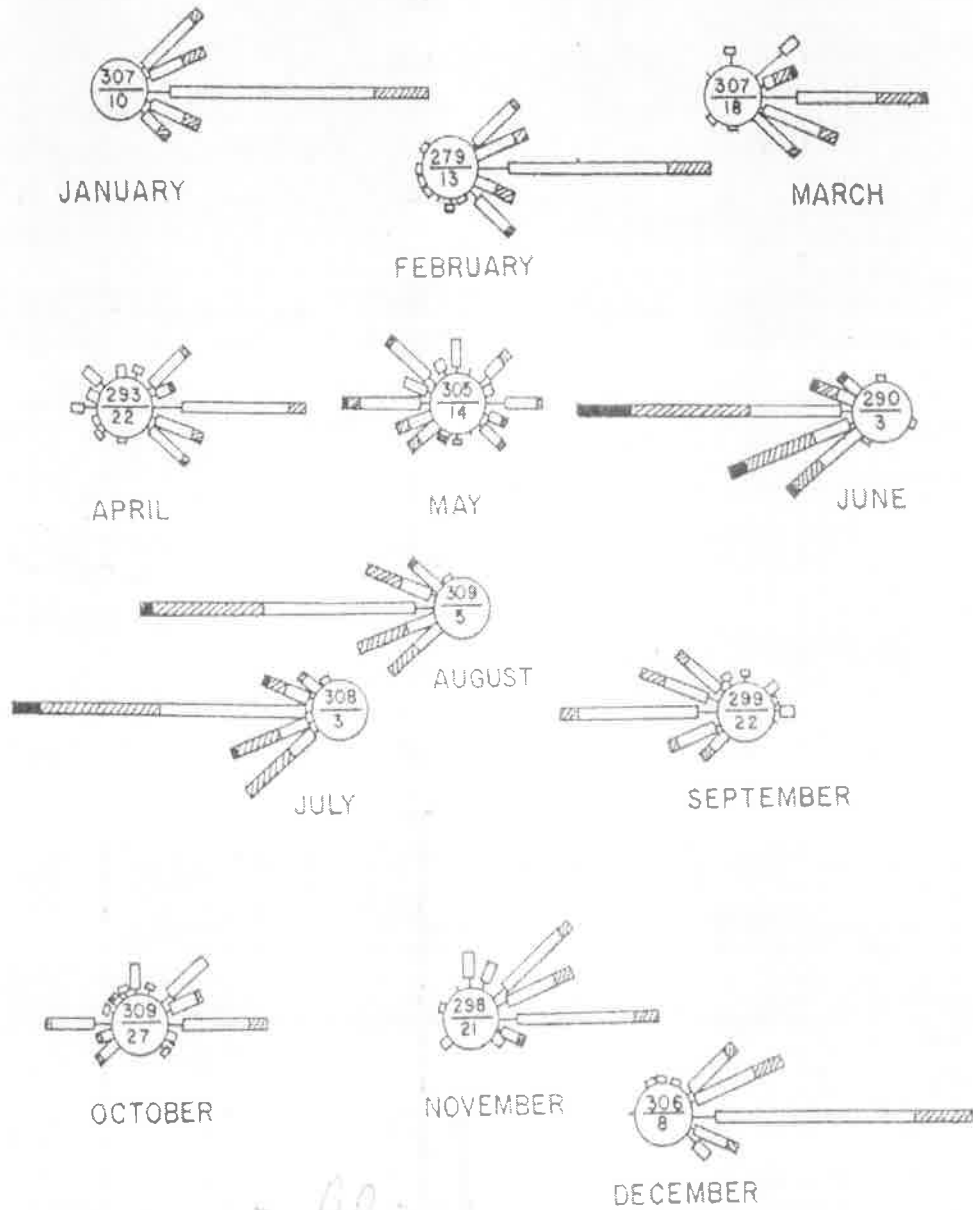
Figure 12.1: Wind rose diagram for Bangalore city (Morning observations)



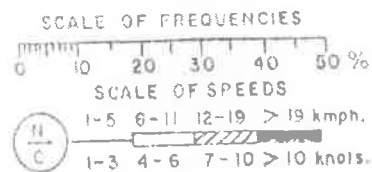
### WIND ROSES

BANGALORE

1730 HRS. I.S.T.



सहायक मौसम विज्ञान  
 ASSISTANT METEOROLOGIST  
 मौसम केंद्र / Meteorological Centre  
 पैलेस रोड / Palace Road  
 बंगलूर / Bangalore-560 001.



N: TOTAL NUMBER OF OBSERVATIONS.  
 C: TOTAL NUMBER OF CALMS IN PERCENTAGE FREQUENCIES

PERIOD: 1982 - 91

Figure 12.2: Wind rose diagram for Bangalore city (Evening observations)



### 12.3.8 Ambient Air Quality

The existing levels of ambient air quality parameters were assessed at various representative locations along the proposed alignment for Suspended Particulate Matter (SPM), Respirable Particulate Matter (RPM), Sulphur dioxide (SO<sub>2</sub>), Oxides of Nitrogen (NO<sub>x</sub>) and Carbon Monoxide (CO).

Respirable Dust Sampler 460 BL was deployed to monitor RPM, SPM, SO<sub>2</sub> and NO<sub>x</sub>. The sampler was placed to obtain 8 hourly average values of the above said parameters in the month of June - July 2009. The parameters were monitored and analyzed as per CPCB (Central Pollution Control Board) and NAQM (National Ambient Air Quality) standards.

One grab sample was collected at each ambient air quality monitoring station for analyzing CO and the spot concentration of CO was recorded using Indicator Tube Technique. The results of air quality measured in the study area in comparison with NAAQ standards are given in Table 3.1 and Figure 12.3

#### **Note of BMRCL:**

***The results of existing air quality have been noted. This should help in adopting measures to see that they do not become worse during construction phase.***

**Table 12.3: Air quality parameters along Phase II North - South alignment**

Monitoring Locations	Parameters Concentration ( $\mu\text{g}/\text{m}^3$ )				
	RPM	SPM	SO <sub>2</sub>	NO <sub>x</sub>	CO (mg/m <sup>3</sup> )
Near IIMB, Bannerghatta Road	255.23	358.07	8.5	60.97	1.7
Near Jayadeva Hospital	269.21	445.75	9.5	66.34	1.9
Richmond Circle	309.70	635.21	11.6	75.24	2.3
Nagavara Junction	305.47	605.64	11.2	63.26	1.9
National Ambient Air Quality Standards					
Standards	100	200	80	80	2.0

Air monitoring results clearly shows that, most of the monitoring locations in the proposed alignment were found to exceed the National Ambient Air Quality Standards (NAAQS). It is observed that, suspended and respirable particulate matter has been exceeded in most of the locations when compared to National Standards. The increased RPM and SPM is due to vehicular pollution which is increasing exponentially along the proposed alignment and bad maintenance of roads also influenced the rise in air pollutants.



The booming industries, software companies on Bannerghatta Road have indirectly influenced very higher concentration of RPM and SPM. However, the concentration of SO<sub>2</sub> and NO<sub>x</sub> is below permissible limits in sampling locations. The Bharat Stage-III emission norms have been introduced during 2005 drastically reduce SO<sub>2</sub> level in subsequent years. The decreased levels of NO<sub>x</sub> are due to banning of old vehicles in recent days, better traffic management, introduction of improved vehicular technology, etc. The concentration of CO was slightly higher at Richmond circle in compared to NAAQS Standards.

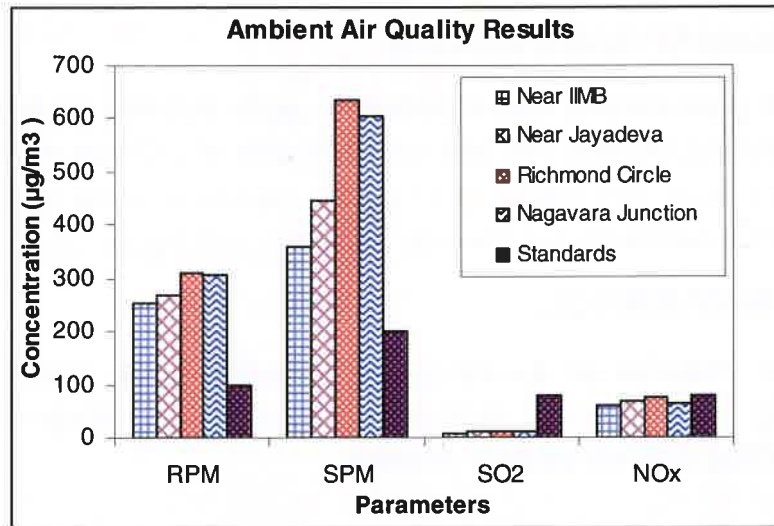


Figure 12.3: Status of Air quality along the Phase II North - South alignment

Air Quality Index (AQI) was characterized to know the quality of air at different locations. The higher the AQI value, greater is the level of air pollution and leads to greater damage to health. The air quality index and the criteria assigned to each index is depicted in Table 12.4 and Table 12.5

Table 12.4: Air Quality Values and Criteria

AQI Values	Air Quality Criteria
0-25	Clean Air
26-50	Light Air Pollution
51-75	Moderate Air Pollution
76-100	Heavy Air Pollution
>100	Severe Air Pollution

Table 12.5: Air Quality Index (AQI) values and Air Quality Criteria at Phase II North - South alignment

Monitoring Locations	AQI values	Air Quality Criteria
Near IIMB, Bannerghatta Road	130.28	Severe Air Pollution





Near Jayadeva Hospital	146.72	Severe Air Pollution
Richmond Circle	183.96	Severe Air Pollution
Nagavara Junction	175.34	Severe Air Pollution

It is observed that air quality index in almost all locations exceed 100 which fall under the category of "Severe Air Pollution". Therefore, immediate attention is required to reduce air pollutants at the city area.

### 12.3.9 Noise Quality

The ambient noise levels were 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 were computed with the help of  $L_{day}$  and  $L_{night}$  of the study area.  $L_{day}$  is defined noise level measured over a period of 16 hours during day (6 am to 10 pm).  $L_{night}$  is defined as noise level measured over a period of 8 hours during night (10 pm to 6 am) in the month of June - July 2009. The noise levels measured are given in Table 12.6

#### **Note of BMRCL:**

***The noise quality studies have been noted and this would help in adopting measures to see that they don't increase during construction phase.***

**Table 12.6: Noise levels along Phase II North - South alignment**

Monitoring Locations	Noise level dB (A) Leq	
	Day (Leq)	Night (Leq)
Near IIMB, Bannerghatta Road	74.5	68.3
Near Jayadeva Hospital	77.4	71.5
Richmond circle	79.5	72.6
Nagavara Junction	78.1	72.1
<b>Ambient Noise Standards</b>		
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45

Note: Day Time -- 0600 hour to 2200 hour (16 hours)  
Night time --2200 hour to 0600 hour (08 hours)

It is observed that noise equivalent levels along the proposed Phase II North - South alignment varied in the range 74.5 – 79.5 dB (A) in the day time and 68.3 – 72.6 dB (A) during night time. The increased noise level in the study area is mainly



due to commercial activities and vehicular movement round the clock. It is found that, noise levels in all the stations exceeded the permissible ambient noise levels. In addition, most of the locations even exceeded the industrial area standard limits also.

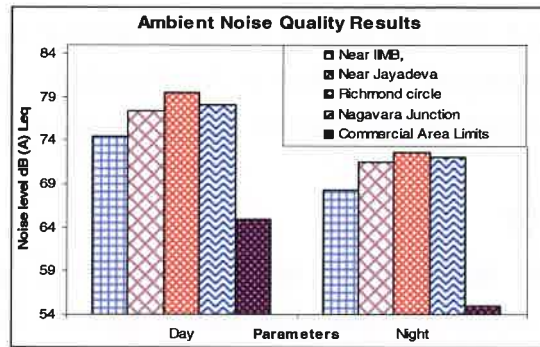


Figure 12.4: Measured noise level along the Phase II North - South alignment

### 12.3.10 Traffic Survey

#### 12.3.10.1 Transport Characteristics

Bangalore is well connected by road, rail and also has an international airport with flights to other locations in the country and abroad. The transportation system in the city is mainly dependent on road network. The city takes the second place for having the most number of vehicles per person (32 vehicles per 100 people) in the country. The efficiency of road network reflects on the urban standards and it also act as a catalyst in stimulating private investment, employment opportunity and income levels or revenue. On the contrary the boosting economic status among youngsters has induced preference of personal vehicles this has eventually weakened the commuters numbers to use public transportation. Simultaneously, the growth in the number of cars has been more than 10% every year during the last 10 years. In addition, the extensive development of urbanization and separation of functions, forces dependence on private means of transport.

#### **Note of BMRCL:**

***This study relating to road transport and number of vehicles in the city is noted. The study will help in integrating the metro rail network with other modes of transport like BMTc and KSRTC services.***

#### 12.3.10.2 Vehicle Statistics

The number of registered vehicles in Bangalore has increased rapidly from 1.68 lakhs in 1986 to 31.3 lakhs in 2008. The vehicular population and the vehicular growth is illustrated in Table 12.7 and Figure 12.5

**Note of BMRCL:**

**The study indicates the rapid increase in number of vehicles in the city in the last two decades and will help in designing metro rail service, capacity, frequency, etc.**

**Table 12.7: Vehicular population in Bangalore City**

Year	2-Wheelers	M/Cars	A/R. Cabs	Others	Total
	Lakhs				
1980	0.97	0.30	0.10	0.31	1.68
1985	1.89	0.47	0.11	0.30	2.77
1990	4.01	0.71	0.15	0.41	6.28
1995	5.94	1.07	0.34	0.62	7.97
1996	6.69	1.21	0.39	0.71	9.00
1997	7.58	1.38	0.47	0.80	10.23
1998	8.39	1.52	0.54	0.84	11.29
1999	9.10	1.64	0.55	0.94	12.23
2000	9.94	1.84	0.58	1.01	13.37
2001	10.92	2.07	0.62	1.12	14.73
2002	11.83	2.26	0.64	1.23	15.96
2003	13.23	2.53	0.69	1.37	17.83
2004	14.44	2.77	0.76	1.53	19.50
2005	15.70	3.18	0.75	1.67	21.30
2006	18.97	4.00	0.86	2.38	26.17
2007	21.11	4.69	0.92	2.86	29.55
2008	22.38	5.05	0.94	2.91	31.29

Source: Bangalore Traffic Police

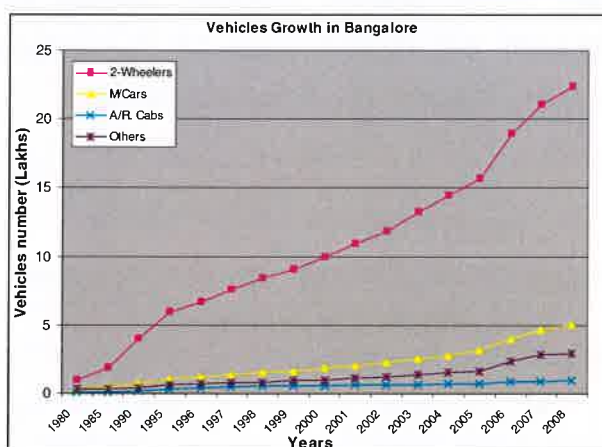


Figure 12.5: Increased Vehicular Traffic in Bangalore city over the period

The increase in vehicular traffic and inefficient road network has induced accidents. As per the traffic police report, Bangalore contributes nearly 18% of total accidents in Karnataka.

Even though there is slight decline in the accidents rate in recent years, still it is high compared to other cities in India. Thus it is one of the accident-prone cities in the country. The occurrence of



accidents in the study area from 2001 to 2007 is depicted in Table 12.8

**Table 12.8: Accidents in Bangalore**

Year	Fatal	Killed	Non-Fatal	Injured	Total
2001	668	703	8358	6929	9026
2002	783	820	9073	7577	9856
2003	843	883	9662	7980	10505
2004	875	903	8226	6921	9101
2005	796	836	6782	5899	7578
2006	880	915	6681	6048	7561
2007	957	981	7469	6591	8426

Source: Bangalore Traffic Police

### 12.3.10.3 Traffic study along the proposed alignment

Traffic in study area has become a serious problem due to increase in population leading to increased number of vehicles on road. Hence the present study emphasis on Traffic Studies along the proposed alignment. The vehicles on road have led to increasing congestion levels in the city and it is being observed that many roads are operating beyond their designed capacity. Hence a classified traffic volume count survey has been conducted at the selected locations by trained enumerators for 12 hours from 08.00 am to 08.00 pm on working days. The vehicle data has been collected in 15 minutes time interval as per the vehicle classification mentioned by Indian Road Congress (IRC). Though the survey was conducted for 12 hrs, peak hour traffic details are considered to assess the congestion index of each alignment because the traffic congestion on roads is at its 12.9. The traffic compositions of light motor vehicles are found to be high in almost all roads.

#### **Note of BMRCL:**

**The study gives us peak hour traffic details along the metro alignment and the same will be made use of for planning the running of the metro services, capacity, frequency, etc.**

**Table 12.9:**

#### **Peak hour traffic movement along Phase II North - South alignment**

Vehicle Type	IIMB to Nagavara					
	VC-1		VC-2		VC-3	
	NOs	%	NOs	%	NOs	%
Two Wheeler	1805	38.10	4135	59.03	1462	44.93



Auto Rickshaw	1058	22.33	1050	14.99	710	21.82
Car/Jeep/Van/Taxi	1511	31.89	1604	22.90	449	13.80
Mini-Bus	80	1.69	17	0.24	10	0.31
Bus	112	2.36	64	0.91	85	2.61
LCV	117	2.47	44	0.63	53	1.63
2 - Axle Trucks	29	0.61	2	0.03	2	0.06
3 - Axle Trucks	9	0.19	0	0.00	0	0.00
Tractor with/without Trailor	2	0.04	0	0.00	0	0.00
Bicycles	15	0.32	89	1.27	483	14.84
<b>Total Vehicles</b>		<b>100.0</b>		<b>100.0</b>		<b>100.0</b>
	<b>4738</b>	<b>0</b>	<b>7005</b>	<b>0</b>	<b>3254</b>	<b>0</b>
<b>Total PCU</b>	<b>5602</b>	<b>-</b>	<b>7071</b>		<b>3488</b>	<b>-</b>

VC-1: Near Shopper Stop, Bannerghatta Road

VC-2: Baldwin Boys School, Hosur Road

VC-3: Near DJ Halli Bus Stop, Tannery Road

Bannerghatta Road is the preferred access to reach Bannerghatta National Park and city outskirts like Jigini and Anekal. The national park is rich in natural zoological reserves hence it has added onto tourist attraction. There are many software companies, institutions and super specialty hospitals along the alignment.

It is observed that, two wheelers density is more dominated in the proposed alignment ranging from 38 % to 59 %. The vehicular density at Hosur Road near Baldwin Boys School is high because this is the only route for North Bangalore towards Bannerghatta.

Overall, 2 wheelers and 4 wheelers are more dominant when compared to other vehicles on road. It is observed that, trucks are found to be less in this alignment because it is restricted in city core areas. There is still glimpse of usage of bicycles in highly populated area and in city outskirts. The variation in traffic is observed in the roads and this depends on various factors such as human behavior, design service volume, importance of the area and deviations of traffic towards adjoining areas based on their importance of activities. These increasing number of vehicles leads to traffic congestion. Traffic congestion is the key issue of the city. Hence evaluating the congestion index will give a correct picture as to which road is congested and the necessity of alternative modes.

To evaluate the congestion index for the proposed corridor, the design volume of the road and the maximum capacity of the road have been considered. The Congestion Index (CI) was worked out for the proposed alignment and presented in Table 12.10

**Table 12.10: Congestion Index for Phase II North - South alignment**

Location	Peak Hour Traffic Volume in PCU	Designed Service Volume PCU	Maximum Capacity PCU	Congestion Index (CI) Based on	
				Design Service Volume	Maximum Capacity
1	VC-1	5602	3600	1.56	1.09
2	VC-2	7071	3600	1.96	1.37
3	VC-3	3488	1500	2.33	1.63

Note: PCU – Passengers Car Unit

The Designed Service Volume and the Maximum Capacity of the road have been considered based on the type of carriageway and category of road as mentioned in IRC: 106-1990 – “Guidelines for Capacity of Urban Roads in Plain Areas”. The data indicates the present CI on the Design Service Volume and Maximum Capacity of the roads.

As per the CI results, the traffic survey locations viz., Shopper Stop at Bannerghatta Road (VC-1), Baldwin Boys School at Hosur Road (VC-2) and DJ Halli Bus Stop at Tannery Road (VC-3) exceeded the congestion index limit. This clearly indicates that the road is not sufficient to cater any more vehicular population. Overall, the entire road stretch is overcrowded by vehicles with higher congestion index shows prime necessary of Metro transport system.

### 12.3.11 Water Quality

The Ground water samples were collected from borewells at different locations along the proposed alignment for analysis of Physico-chemical characteristics. The collected samples were analysed as per the CPCB drinking water standards. The physico-chemical characteristics of ground water samples collected are summarized in Table 12.11

#### **Note of BMRCL:**

***The results of soil and water quality have been noted and these will be monitored during the construction phase, so that the water quality is not allowed to deteriorate. It would help in designing concrete structures against sulphate attack, etc.***



**Table 12.11: Physico-chemical characteristics of ground water along the Phase II North - South alignment**

Parameters	Observed range	CPCB Limits (Drinking water)
pH	6.95 - 7.51	<b>6.5-8.5</b>
Total Chlorides (mg/l)	112.14 – 265	<b>250</b>
Total Hardness (mg/l)	105.6 – 221	<b>300</b>
Calcium as Ca (mg/l)	35.27 – 60.74	<b>75</b>
Magnesium as Mg (mg/l)	13.15 – 32.14	<b>30</b>
Sulphate as SO <sub>4</sub> (mg/l)	8.75 – 28.65	<b>200</b>
Nitrate as NO <sub>3</sub> (mg/l)	11.25 – 20.33	<b>45</b>
Total Dissolved Solids (mg/l)	415 – 518	<b>500</b>

The ground water samples were collected in the proposed alignment shows that, most of the parameters analyzed were below the CPCB standards. However, the total Chlorides, Magnesium and Total Dissolved Solids are slightly higher in compare to CPCB standards. This may be due to industrial and high domestic discharge may lead to ground water contamination at city area. There is no lake nearing to the alignment hence Physico-chemical characteristics of surface water was omitted.

### 12.3.12 Soil Quality

The surface soil samples from a depth of 0 - 20 cm were collected along the proposed alignment and collected samples were analysed for soil physico-chemical properties (Table 12.12).

The bulk density of soils ranged from 1.25 - 1.63 g/cm<sup>3</sup>. Thus, the porosity and water holding capacity also varied largely and found in the range of 38.1 - 51.7 % and 40.5 - 50.3 % respectively. The soil pH ranges from 6.21 - 7.89 while Electrical Conductivity (EC) ranges 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 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 and varied to a great extent depending on the land use. Similarly, the available N, P<sub>2</sub>O<sub>2</sub> and K<sub>2</sub>O are also in lesser range compare to productive soils.



**Table 12.12:**  
**Physico-chemical characteristics of soil along the alignment**

Sl. No	Parameters	Measured Range
1	pH	6.21 – 7.89
2	EC (dS/m)	0.321 – 0.885
3	Bulk Density (g/cm <sup>3</sup> )	1.25 - 1.63
4	Porosity (%)	38.1 – 51.7
4	Water Holding Capacity (%)	40.5 – 50.3
5	Organic Carbon (%)	0.23 - 0.46
6	Available Nitrogen (kg ha <sup>-1</sup> )	223 - 378
7	Available P <sub>2</sub> O <sub>5</sub> (kg ha <sup>-1</sup> )	15.6 - 31.5
8	Available K <sub>2</sub> O (kg ha <sup>-1</sup> )	156 – 321

### 12.3.13 Green Cover Assessment

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.

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 varying distance *viz.* 0-5 m and 5-10 m was recorded. The trees present at a distance of 19 m from the central line and 140 m length was recorded for the proposed elevated stations. At underground stations trees were monitored at a distance of 20 m from the central line and 200 m length of the station corridor.

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 1.3 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.

#### **Note of BMRCL:**

***This study relating to green cover assessment has been noted and environment management plan for planting saplings as part of compensatory afforestation will be implemented in the report.***



### 12.3.13.1 Baseline Tree Resources

There is no forest area existing along the proposed alignment. The green cover on either side of the alignment was assessed and trees to be affected were identified and recorded. Furthermore, the tree species girth and approximate height was recorded and biomass has been quantified. Tree population for the proposed alignment is given in Table 12.13. Trees to be cut and trimmed at stations, curves and alignment were studied as per the maps provided by DMRC.

**Table 12.13: Tree population along Phase II North - South alignment**

Sl. No.	Metro Alignment	Trees found along the alignment			
		0-5m		5-10m	
		Left	Right	Left	Right
1	IIMB to Nagavara	1	0	10	15
<b>Total</b>		<b>1</b>		<b>25</b>	

A total of 26 trees were recorded in the proposed alignment of which only 1 tree is recorded at 0-5 m alignment and 25 at 5-10 m respectively. The survey result clearly indicates that only one tree will be cut due to the proposed project while a significant number of trees will be affected due to trimming. The common tree species found along the alignment were *Peltophorum ferrugineum*, *Swietenia macrophylla*, *Spathodea companulata*, *Terminalia arjuna*, *Azadirachta indica*, *Delonix regia*, *Cocus nucifera* and *Eucalyptus*. Overall affected tree population along the proposed alignment are given in Table 12.14

**Table 12.14: Overall affected trees along the Phase II North - South alignment**

Sl. No	Locations	No. of trees to be cut	No. of trees to be trimmed	Canopy area loss (m <sup>2</sup> )
1	Stations			
	a. Elevated Stations	83	18	121
	b. Underground Stations	99	0	0
2	Road median & Alignment	24	26	217
<b>Total</b>		<b>206</b>	<b>44</b>	<b>338</b>

A total of 206 trees will have to be cut and 44 trees will have to be pruned in proposed alignment. The 44 trees being trim will contribute about 338 m<sup>2</sup> canopy cover. It is observed that, more trees are going to be cut at the proposed stations area than alignment.



It is estimated that, out of 206 trees to be cut along the corridor, 93 trees are big canopy trees followed by medium canopy of 69 and small canopy trees of 44 respectively. The majority of the smaller canopy trees belong to Ashoka trees and *Cocus nucifera*, planted along the proposed alignment. Maximum number of trees is going to be removed at stations than alignment. Underground alignment drastically reduces any tree loss at alignment and only we can expect at stations. Tree cutting will be minimized by proper utilization of open land for station construction. The proposed affected tree biomass is depicted in Table 12.15.

**Table 12.15: Affected tree canopy along the proposed alignment**

Sl. No	Tree canopy	Alignment, Curves & Median		Stations	
		Number	Biomass (t)	Number	Biomass (t)
1	Big canopy trees with girth >70cm at GBH	8	10.91	85	581.96
2	Medium canopy trees with girth 40 to 70 cm at GBH	13	2.95	56	13.96
3	Small canopy trees and shrubs with girth <40 cm	3	0.15	41	3.18
<b>Total</b>		<b>24</b>	<b>14.01</b>	<b>182</b>	<b>599.1</b>

In Phase II North - South alignment around 24 trees need to be cut in alignment, curves & median resulting 14.01 tonnes of biomass is going to be affected. Similarly, about 182 trees are going to be affected at stations resulting nearly 599 tonnes of biomass will be affected. Maximum biomass is going to be affected at underground stations compare to elevated station area.

Since, maximum trees are going to be affected at stations; the station area will be restricted as per the minimum land requirement. However, compensatory afforestation will be taken care without any much damage to ecosystem.

### 12.3.14 Socio Economic Assessment

The proposed alignment runs on existing road dissecting developed areas in the city. People tend to loose their property or other assets leading to legal and political sensitivities. As a part of the study, socio-economic survey was conducted in residential and commercial areas along the alignment through questionnaire to assess the impacts on socio economic status of the people and their perception about the proposed project. This survey was carried out on people living within (20m) Right of Way (ROW). The perception of people was summarized

According to the inception conducted in the proposed alignment a few commercial structures, educational institutions and a few residential structures are partially



affected. The alignment is designed in such a way that most of the open lands and/or service roads and/or road median have been utilized rather than structures. In addition, proper planning of underground alignment will also reduce any major property loss.

**Note of BMRCL:**

***The trees required to be cut are noted and action will be taken to plant saplings at the ratio of 1:10***

**12.3.14.1 Features Identified along the Alignment**

The alignment starting from Gottigere upto Bangalore Dairy Circle is flooded with software companies, commercial areas and few super specialty hospitals. The rail track is at the centre of the existing road; hence shoulder area of the road will be acquired. The alignment from the center of the road moves gradually to the left end at the location where Jayadeva and dairy circle flyover premises. There are a few shops which are likely to be affected due to the change in the alignment.

As the alignment moves beyond Dairy Circle Flyover near Laljinagar the road is narrower ahead upto Nagavara. In addition to the road being narrower, it is also populated. To avoid any bigger loss of properties, the proposed alignment is planned maximum at underground.

**Note of BMRCL:**

***As indicted in the study the alignment partially runs as a elevated line and as such the land requirement is minimized. People who are affected due to acquisition of their property will be compensated in accordance with law.***

**12.3.14.2 Features Identified along the Stations**

There are 18 stations in this alignment. Most of the stations are planned on service road and open land. Out of the 18 stations, 06 are elevated while 12 are underground. The underground stations will reduce the land acquisition and tree felling at considerable extent. The underground stretch starts near Bangalore Dairy Company and terminates near to Nagavara junction.

**12.3.14.3 Socio Economic Profile of the PAPs**

The proposed alignment require narrow strip of land if the road width is insufficient for Metro rail. Hence the project neither displaces scattered populations nor relocates community. It is observed that most of the people along the alignment are of residential and commercial sectors while few are industrial, institutions and



religious places. Residential and commercial sectors are matter of concern as the narrow strip of land being acquired by project is of great value in terms of their livelihood. Industries or Institutions will not be much affected as the narrow strip of land is found to be either compound wall or open land. The acquisition of religious sector will lead to sensitive issues among community. In view of this impact, DMRC has proposed the alignment to be underground approximately about 14.50 km to avoid land acquisition and tree felling.

#### 12.3.14.4 Perception of PAPs (Rehabilitation & Resettlement)

The perception of the people collected by personal interview covering three areas based on the intensity of impacts and the following inferences were observed.

People along the alignment from IIMB to Dairy Circle flyover supported the project as they understood the project requirement. Directly affected people residing near the ramp area at Tannery road did not fully favor on the proposed Metro is due to their land acquisition. However, people residing above the underground stretch had a mixed opinion. However most of them gave a positive response because they were assured that the proposed alignment will not displace much of the people community. People residing along the alignment are aware of present air pollution level, traffic situation in the road and spending hours of time in traveling. A series of public consultation reveals that the Metro rail project would act as a better mode of transport, reduce air pollution, quick service, and wide range of benefits to the surrounding community by increasing property values, business, and employment opportunities. In addition, elevated stretch provides aesthetic look and also increases the land value at the surrounding places.

### 12.4 IMPACT IDENTIFICATION

An initial environmental examination has been carried out to identify the positive and negative impacts from various activities due to proposed Phase II North - South alignment. A typical checklist identifying the anticipated environmental impacts is shown in Table 12.16.

**Table 12.16: Checklist for impact identification**

SI No	Parameters	No Impact	Negative Impact	Positive Impact	Remarks
<b>Impacts Due to Project Location</b>					
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





SI No	Parameters	No Impact	Negative Impact	Positive Impact	Remarks
					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 diverse effect
1.5	Aesthetics	*			
1.6	Natural Disasters	**			
<b>Impacts due to Project Construction</b>					
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
<b>Impacts due to Project Operation</b>					
3.1	Oil Pollution		*		Waste management plan will be adapted
3.2	Noise Pollution		*		Not much envisaged
3.3	Water Supply and Sanitation at Stations		*		Water and waste management plan will be adapted



SI No	Parameters	No Impact	Negative Impact	Positive Impact	Remarks
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			**	

\* Less Impact; \*\* More Impact

## 12.4.1 Negative Environmental Impacts

### 12.4.1.1 Impacts due to Project Location

#### 12.4.1.1.1 Land Acquisition

Land acquisition in the proposed project is of two types, one is for permanent usage and the other is for temporary usage. Permanent land is the land to be acquired throughout the life of the project it cannot be retrieved by the occupants. Temporary land is the land which is needed in addition to permanent land during construction phase. This can be retrieved by the occupant once the project is completed.

The right of way of the alignment is 20m while the elevated station area is 140m x 19m underground station area is 200m x 20m. The land situated within ROW was identified as Residential, Commercial, Industrial, Institutional, Religious and the category with negligible information as others.

The alignment consists of both elevated and underground stretch. Elevated stretch and the ramp area is considered for land acquisition. In underground stretch there won't be any land acquisition. The following table depicts the type of land and its area to be acquired for the proposed alignment.

**Note of BMRCL:**

**The compensation will be paid as per the law for the land/ property to be acquired.**

**Table 12.17: Area to be acquired along Phase II North - South alignment**

Type	North - South alignment *	
	Area in sq m	Area in %
Residential	8694.49	9.05
Commercial	34039.64	35.45
Industrial	1092.10	1.14
Religious places	4453.48	4.64
Institutional	19504.25	20.31
Others	28236.94	29.41
<b>Total</b>	<b>96020.91</b>	<b>100.00</b>

\* Excluding underground alignment

It is observed that land acquisition is found to be minimal in Phase II North - South alignment because the alignment is planned on the existing road and the road width meets its requirement. Where there is populated area with less availability of open space, underground corridor has been proposed. The above acquisition land has been categorized under open and structure area at station as well as alignment wise.

**12.4.1.1.2 Loss of Trees/Forests**

Tree enumeration was carried out along the proposed alignment. There were no rare or endangered species noticed during field studies. Most of the trees were far away from the existing road and only few tree species existing in the proposed alignment especially in stations. The common species observed are *Peltophorum ferruginea*, *Spathodea companulata*, *Azadirachta indica*, *Pongamia pinnata*, *Samanea saman* etc. The proposed alignment is situated in urban area and will not pass through any forests or protected parks. Hence there is no loss of forest land due to the proposed project.

The proposed corridor will affect only 24 trees at alignment and about 182 trees will affect at stations while 44 trees are required to be pruned at both stations and alignment. In the underground section, the tunnels will be at a minimum depth of about 5 to 6 meters from the surface. Hence construction of tunnel at this depth will not affect any tree loss. .



It is observed that one third of tree population is exotic species viz. Ashoka and Silver oak and very few indigenous/native tree species viz. *Pongamia pinnata*, *Ficus religiosa* and *Azadirachta indica* are going to be lost in the proposed alignment. The average height and girth of the trees to be cut is 10-12 m and 0.8 to 1.0 m respectively. The biomass is dominated by big trees belong to *Samanea saman* and *Peltophorum ferruginea* which have been planted during British period.

**Note of BMRCL:**

**As noted in the study, majority of the trees that are required to be cut are ornamental species. As suggested in this chapter, for 432 trees that will be cut 4320 saplings will be planted as per the guidelines of MoEF. Care will also be taken to plant indigenous species like *Samanea saman*, *Pongamia pinnata*, *Ficus religiosa* and *Azadirachta indica* as part of compensatory afforestation**

#### 12.4.1.1.3 Utility/Drainage Problems

The proposed alignment is generally planned on road center line (divider), service roads and vacant lands. As per the land availability and topography, alignment is planned both above ground and below ground. The proposed alignment will cross drains and utility services such as sewer, storm water drains, water mains, telephone cables, overhead electrical transmission lines, electric poles, traffic signals etc. These utilities/ services are essential and have to be maintained in working condition even during construction phase also and required to shift temporarily or permanently without any adverse effects. The utilities/drainage which is likely to be affected due to stations and alignment are listed in Table 12.18

**Note of BMRCL:**

**The study has listed the surface utilities that are required to be shifted and maintained in working condition. Action will be taken to shift these utilities temporarily/ permanently as required.**

**Table 12.18: List of public utilities to be shifted along the proposed alignment**

Location	Utilities (In numbers)					
	Lamp Post	Bus Stop	Manhole	Telephone cable	Power line	Drain
Stations	13	4	2	-	-	-
Alignment	74	9	-	1	4	2
<b>Total</b>	<b>87</b>	<b>13</b>	<b>2</b>	<b>1</b>	<b>4</b>	<b>2</b>



It is observed that, since the alignment is situated in urban city lots of utilities have to be diverted. The drain, power lines and telephone cables are a matter of concern in the above alignment. Utilities below ground and at the ramp area will have to be diverted for construction of underground section.

#### **12.4.1.2 Impacts due to Project Construction**

##### **12.4.1.2.1 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 100 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.

***Note of BMRCL:***

***Steps will be taken to reduce air pollution during construction period.***

##### **12.4.1.2.2 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.

***Note of BMRCL:***

***Steps will be taken to reduce/minimize noise pollution during construction period.***

##### **12.4.1.2.3 Soil Erosion and Health Risk at Construction Site**

Land leveling and excavation leads to soil erosion. The proposed alignment is both elevated and underground, there are 6 elevated stations and 12 underground stations with one ramp. Soil excavation is found at the ramp area and the underground alignment. From the estimations made on the basis of preliminary



drawings and literature study it is estimated that the total quantum of soil to be excavated at proposed alignment is about 10.81 lakh cubic meters. The excavated soil can be used for backfilling.

Human 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.

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.

**Note of BMRCL:**

***Dumping of construction waste will be done at sites provided by the Municipal body. The carrying of such material will be done in accordance with civic body norms. The provision of facilities for labour will be done as per prescribed norms.***

#### 12.4.1.2.4 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.

**Note of BMRCL:**

***Traffic diversion and traffic control during construction phase will be done in consultation in City Traffic Police.***

#### 12.4.1.2.5 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 total length of the alignment is 22.195 km covering 18 stations. Hence the construction activity require 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  $\approx 700 \text{ m}^3$ . 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.

### **12.4.1.3 Impacts due to Project Operation**

#### **12.4.1.3.1 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.

#### **12.4.1.3.2 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 80 km per hour and the average speed is about 35 km per hour. 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.

#### **12.4.1.3.3 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 30 nos, therefore around 1,350 liters/day of water will be required for railway staff for one station. The water requirement for the proposed alignment having 18 stations is 24,000 liters/day. In addition, water demand at stations for cleaning, sanitation, fire fighting and washing purpose will be about  $400 \text{ m}^3/\text{day}$ . Municipal water or ground water supply will be tapped for drinking purposes. The sewage treated water is proposed for toilets cleaning, washing etc. As per the waste water discharge about 0.5 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.

**Note of BMRCL:**

***Noted and action will be taken for water supply at each station. On site sewerage treatment will be organized as required, based on site conditions.***

**12'4.1.3.4 Solid Waste Generation**

The waste generated from stations and rail includes garbage, rubbish from wrappers, discarded boxes, rags etc are the solid waste sources. Based on the data generated, it is estimated that about 6g 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 proposed Metro stations. By considering 3.5 lakhs passengers per day, solid waste generation can be expected around 1 tonne / day. 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.

**12.4.2 Positive Environmental Impacts****12.4.2.1 Employment Opportunities**

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 opportunities. It is estimated that, about 2000 people per day are expected to be deployed during the peak period of construction activity for the proposed project. On an average 2.4 lakh mandays are required annually. During operational phase, there will be employment generation for about 250 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 as expected to create substantial direct and indirect employment opportunities during construction and operational phases.

**12.4.2.2 Benefits of Economy**

The proposed alignment will facilitate the commuters to use public transportation, this adds in to the states 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.

#### 12.4.2.3 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. According to the survey carried out on Phase II North - South alignment from IIMB to Nagavara, the vehicle movement of two wheelers at peak hours ranges from 1462 to 4135, three wheelers ranges from 710 to 1058, four wheelers ranges from 449 to 1604 and buses ranges from 64 to 112 respectively.

The factors responsible for the rise in vehicles are due to increase in income levels, preference of people of 20-35 year age group to use personalized vehicles, and the absence of an adequate public transport system. Since the proposed alignment carries around 2000 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.

The present peak hour traffic data collected during traffic survey conducted along the proposed alignment has been projected upto 2016 (Metro commencing date) with an annual growth rate of 5%. The details of the projected traffic by 2016 are summarized in Table 12.19

**Table 12.19: Present and projected traffic volume in Phase II North - South Alignment**

Place	Year	Vehicle Type						
		Two Wheeler	Auto Rickshaw	Car/Jeep /Van/Taxi	Mini-Bus	Bus	Other Four Wheelers	Total Vehicles*
		Vehicles / day**						
VC-1	2009	15875	2627	13560	844	3820	4783	41509
	2016	22338	3697	19081	1188	5376	6730	58410
VC-2	2009	13892	2115	10904	816	4479	4354	36560
	2016	19548	2976	15342	1148	6302	6126	51442
VC-3	2009	23608	3587	19584	2329	1987	5191	56286
	2016	33219	5047	27557	3277	2796	7304	79200

Note: Annual 5% traffic growth is considered as per norms of Planning commissions

\* Bicycles excluded \*\*12- hours data has been utilized



The reduction of vehicles plying on road after Metro Commissioning is predicted based on the people perception. On the basis of this, about 45-50% of the commuters expressed their willingness to shift to Metro rail. According to number of vehicles plying on road with and without Metro by 2016 on the proposed alignment around 35% of two wheelers, 20% of three wheelers, 25% four wheelers and 20% of commuters traveling in public/private transport are likely to shift to Metro rail. The expected reduction of vehicles on road due to proposed alignment is given Table 12.20

**Table 12.20: Expected reduction of vehicles due to the proposed alignment**

Place	Year	Vehicle Type						
		Two Wheeler	Auto Rickshaw	Car/Jeep/ Van/Taxi	Mini-Bus	Bus	Other Four Wheelers	Total
		Vehicles / day						
% Shift to Metro		35	20	25	5	20	0	-
VC-1	2016*	22338	3697	19081	1188	5376	6730	58410
	2016**	14519	2957	14310	1129	4300	6730	43945
VC-2	2016*	19548	2976	15342	1148	6302	6126	51442
	2016**	12706	2381	11507	1091	5042	6126	38853
VC-3	2016*	33219	5047	27557	3277	2796	7304	79200
	2016**	21593	4037	20668	3113	2237	7304	58952

**Note:** 2016\* -No. of Vehicles without Metro 2016

2016\*\* - No. of Vehicles with Metro 2016

#### 12.4.2.4 Less Fuel Consumption

The main fuels used in vehicles are petrol, diesel and CNG. About two million vehicles has been registered in Bangalore and running on city roads. Annual consumption of diesel and petrol is in the range of 4,50,000 and 2,50,000 tonnes 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 and depicted in Table 12.21.



The projected vehicles in the proposed alignment from IIMB to Nagavara will save 18966 liters / day of petrol and 8933 liters/ day of diesel after initiation of Metro rail.

**Table 12.21: Expected fuel cost savings from the proposed alignment**

<b>Savings</b>	<b>VC-1</b>	<b>VC-2</b>	<b>VC-3</b>	<b>Total</b>
Total Petrol (lt) saved / day	5791	4769	8406	<b>18966</b>
Total Diesel (lt) saved / day	3088	3402	2444	<b>8933</b>
Total Petrol Cost (Rs.) saved / day	301123	247992	437104	<b>986219</b>
Total Diesel Cost (Rs.) saved / day	114238	125868	90433	<b>330539</b>
Total Petrol Cost (crores) saved / year	10.99	9.05	15.95	<b>36.00</b>
Total Diesel Cost (crores) saved / year	4.17	4.59	3.30	<b>12.06</b>
Total Fuel Cost (crores) savings / year	<b>15.16</b>	<b>13.65</b>	<b>19.26</b>	<b>48.06</b>

Due to the reduction in the number of vehicles, the consumption of petrol and diesel will reduce significantly and it will directly influence State economy. Considering the present cost of petrol (Rs. 52/lit) and diesel (Rs. 37/lit), an amount of Rs 36.00 crores from petrol and Rs. 12.06 crores from diesel can be saved per year. Overall, the proposed alignment annually will save nearly Rs. 48.06 crores fuel cost. In addition, there will be reduction of traffic congestion on road thus increasing the speed of the vehicles plying on road. The increase in speed of vehicles due to reduction of vehicles improves mileage efficiency. Similarly, Metro will reduce regular road maintenance and traffic management cost effectively.

#### **12.4.2.5 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 (NO<sub>x</sub>), Sulphur Dioxide (SO<sub>2</sub>) 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, NO<sub>x</sub> and HC of vehicles plying on road is within the CPCB standard while particulate matter found to be

exceeded the permissible limit. An attempt as been made to estimate the pollution load by colligating exhaust emission factor and the fuel consumption and the reduction in air pollution after commissioning of Metro is depicted in Table 12.22. It is observed that the proposed project will reduce nearly 8.49 tonnes of pollutants per day.

**Table 12.22: Estimated reduction of air pollutants in the proposed alignment**

Pollutants	Exhaust factor for petrol in kg/1000*	Reduction of air pollutants / day due to Metro by 2016 (in tonnes)			
		VC-1	VC-2	VC-3	Total
Carbon Monoxide	391	2.26	1.86	3.29	<b>7.42</b>
Hydrocarbons	34	0.20	0.16	0.29	<b>0.64</b>
Oxides of Nitrogen	19.2	0.11	0.09	0.16	<b>0.36</b>
Oxides of sulphur	1.5	0.01	0.01	0.01	<b>0.03</b>
Particulate matter	1.9	0.01	0.01	0.02	<b>0.04</b>
<b>Total</b>		<b>2.59</b>	<b>2.13</b>	<b>3.76</b>	<b>8.49</b>

\* Exhaust emission factor as per H.B. Mathur, 1984.

#### 12.4.2.6 Reduction in Passenger Time

The train is designed to travel around 80 kmph with an average speed of 35 kmph. The carrying capacity of 6 coach train would carry 2000 passengers with 50 seating capacity per coach. The frequency of the train is 4 minutes during peak hour i.e. 8.00 am to 11.00 am and 4.00 pm to 8.00 pm (7 hours) accounting for 105 trips. The frequency of train is 8 minutes during nonpeak hours i.e. 11.00 am to 4:00 pm and 8.00 pm to 12.00 am (9 hours) accounts to 67 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 3.5 lakhs passenger/day is expected.

The existing transportation system on the city roads takes 2.0 to 2.5 hours to reach IIMB to Nagavara (Bangalore South to North) while the estimated travel time using Metro rail takes < 1 hour to cover the same distance. Considering an average 30 minutes time savings / passenger / trip, per day can save approximately 1.72 lakhs man hours. 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.

#### 12.4.2.7 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 were at 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 has shot up from Rs 14 crore in 2003 to Rs 38 crore in 2009.

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 grater public safety.

#### 12.4.2.8 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.

### 12.5.1 ENVIRONMENT IMPACT EVALUATION

The impact evaluation for Phase II North - South alignment 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.

$$EIU = \sum_{i=1}^n EQ_{ij} \cdot PIU_i$$

EIU = Environmental Impact Unit

$EQ_{ij}$  = Environmental Quality Relative Scale value for  $i^{\text{th}}$  factor of  $j^{\text{th}}$  alternative

$PIU_i$  = Parameter Importance Unit for  $i^{\text{th}}$  factor

Environmental parameters have been identified under three categories viz Physical Environment, Biological Environment and Socio Economic Environment. The changes in EIU have been calculated for baseline (as on date) as well as environmental status with EMP after the project implementation is presented in Table 12.23



Table 12.23: Evaluation of the Environmental Quality and Benefits (in terms of PIU) of proposed project.

Environmental Aspect and Components	PIU Assigned (Ideal)	EIU without Project (As on 2009 baseline)	EIU with Project (With EMP)	EIU Change due to project (With EMP)
<b>i. Physical</b>				
Air Quality	345	182	244	+62
Water Quality	114	111	113	+2
Land	65	62	61	-1
<b>ii. Biological</b>				
Terrestrial Ecosystem	205	187	200	+13
Aquatic Ecosystem	22	21	22	+1
<b>iii. Socio economic</b>				
Traffic Congestion, Fossil Fuels, Quality of life, Comforts etc	249	42	221	+179
<b>Total EIU</b>	<b>1000</b>	<b>605</b>	<b>861</b>	<b>+256</b>

It is observed that the initiation of Phase II North - South alignment would be beneficial against an ideal of 1000 units. Currently, the EIU stands at 605 units in Phase II North - South alignment with the absence of Metro while there is an increase up to 861 units following the introduction of Metro rail with comprehensive Environmental Management Plan. Therefore, a net gain of +256 (42.31 % gain) EIU units with respect to baseline (2009) is observed which demonstrates a positive benefit to the surrounding community.

Incidentally, the prevailing baseline EIU value of 605 units in Phase II North - South alignment (as on 2009) is likely to degrade over the next 7 years (up to 2016), till the Metro inception due to persistent growth of vehicles. The predicated value of EIU for the year 2016 is around 535 from the present 605 units. The overall benefits in EIU due to Metro will be =  $861 - 535 = 326$  with reference to predicted EIU value of 535 after 7 years, i.e. the improvement of 61 % gives clear positive indication of Metro benefits.

### 12.6.1 ENVIRONMENTAL MANAGEMENT PLAN

As discussed in the earlier sections, the proposed alignment has positive as well as 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 affects 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). 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 carry out post monitoring activities. 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.

## 12.6.2 Mitigation Measures

### 12.6.2.1 Compensation for Loss of Land

The alignment is predominantly along the busy roads and over head. The alignment and stations is sited preferably in the open land and government property to nullify the impact on private public. However the land private property which has to be acquired for the purpose of alignment/station will be given compensation with respect to the Land acquisition norms. PAPs will be provided with suitable rehabilitation and resettlement compensation as mentioned in National Rehabilitation and Resettlement Policy.

The area of open land and structures to be acquired for the proposed alignment is 3.21 Ha. Since the project occupies linear area of land/property, compensation will be given for property holder of structures to be acquired in the form of cash. The cost will be given based on property cost in Bangalore Development Authority (BDA) Gazetteer. The compensation varies with respect to the property cost. Individual beneficiaries will be identified and their compensation will be taken care without any misuse.

#### **Note of BMRCL:**

**Compensation for land including structures will be paid as per market value and rehabilitation package norms will be same as in Phase-I**

### 12.6.2.2 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.

It is estimated that 206 trees are likely to be lost due to the proposed corridor and the total value of these trees lost is Rs. 1.65 lakhs. According to the MoEF guidelines for compensatory afforestation, ten trees have to be planted for each tree cut. Hence, 2060 trees will be planted along the corridor. These trees would have occupied about 2.06 ha area @ Rs. 1000 /tree. The cost includes saplings, tree guard, watering, control of pest and weed, thinning and maintenance for 5 years excluding the land cost. Thus, the compensatory reforestation cost for the proposed alignments will be 20.60 lakhs which includes road side plantation.

The alignment is predominantly along 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, ten trees have to be planted for each tree cut.

Environmentally beneficial tree species such as *Michelia champaca*, *Bauhinia variegata*, *Plumeria alba*, *Muntingia calabura*, *Ficus religiosa*, *Dendrocalamus strictus*, *Caryota urens*, *Azadirachta indica*, *Pongamia pinnata* has been proposed all along the station borders under compensatory afforestation. Apart from the above trees species few climbers and flower bearing 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 100 metric tones carbon. Therefore, it is estimated that planting 2060 trees in 5.08 acres of land under compensatory afforestation can sequester 508 metric tonnes of carbon in 50 years, thus the proposed project can sequester an average 10.16 metric tonnes of carbon in a year.

**Note of BMRCL:**

**Compensatory afforestation will be taken up as per the guide lines of MoEF.**

### 12.6.2.3 Green Belt Development

In addition to the compensatory plantation, green belt area can be developed for the total 7.50 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.

Cost estimates for 1 km Green belt development under the elevated track (width of ribbon = 1.5m) is calculated and presented in Table 12.24.

- a. 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**
- b. 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 2000 = **Rs. 133300.00**
- c. Grasses and perennial herbs on both the sides of 1000 m @ Rs. 50/m<sup>2</sup> to cover balance 0.75 m width

Rs. 50 x 0.75 m x 2000 m = **Rs. 75000.00**

**Table 12.24:**  
**Cost Estimate for Green Belt Development along the proposed alignment**

Green belt type	Establishment cost for 1 km	Gottigereto Nagavara (7.50 km)
Small trees	41600	312000
Shrubs	133300	999750
Grass/herbs	75000	562500
<b>Total</b>	<b>2,49,900</b>	<b>18,74,250</b>

The total cost for green belt development under the elevated track for the entire 07.50 km stretch is about 18.74 lakhs.

#### 12.6.2.4 Translocation of trees

About 65 trees need to translocate to nearby park, which are having shallow root systems. This requires Rs. 3,000 tree towards translocation expense resulting a total Rs. 2.0 lakhs is required to translocate 65 trees without any damage.

#### **Note of BMRCL:**

**The proposal to translocate 65 trees is found to be not feasible. The cost of translocation of each tree comes nearly to Rs.1 lakh**



***and survival rate of translocated trees is also very less. Compensatory Afforestation of trees at the rate of 1:10 will be taken up for each of the 65 trees that are proposed for translocation.***

#### **12.6.2.5 Compensation for Rehabilitation/Resettlement**

The rehabilitation and resettlement was confined to the provision of Land Acquisition Act for several years. However, in recent years national rehabilitation and resettlement policy have issued instruction for compensation of project affected people. The proposed project involves displacement of 83 residential of about 8694.49 Sqm of land and 34039.63 commercial and other properties is about 53286.77 Sqm. Compensatory land records for each person have been updated to give compensation to the right persons and to avoid misuse of any property. As per the BDA Gazetteer 2007, the average land cost has been worked out at Rs. 2500/sq ft from IIMB to Nagavara. Approximately Rs. 254.94 crores will be paid towards compensation for property loss due to the proposed project.

About 500 workers per day will be employed during construction period and during peak working days it may reach 2000. Provisions will be made to enhance the female employment opportunities by encouraging female workers to participate even in the construction activities. To prevent possible traffic congestion, temporary access roads will be used during construction phase for transportation of personnel/ materials /equipment. However, the traffic congestion is less likely to be observed as the proposed construction activity is in service road.

#### **12.6.2.6 Water Supply and Sanitation**

The water demand for the proposed project is expected to be around 450 m<sup>3</sup> and 300 m<sup>3</sup> 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.

#### **12.6.2.7 Oil Pollution Control**

There should be provision for the collection of oil and grease generated from construction equipments 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.

#### **12.6.2.8 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 muffers, 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 equipments to have minimal disturbances. The construction equipments 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.

#### **12.6.2.9 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.

#### **12.6.2.10 Soil Disposal**

The construction activities will generate approximately 10.81 lakh cubic meters 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. Since there is bulk quantity of soil is generating at the underground alignment area, 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.





### 12.6.2.11 Rain Water Harvesting

Roof top rain water harvesting can be carried out at elevated 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. As per the rainfall characteristics, generally the annual rainwater harvesting potential for 1000 sqm roof area will be 7,68,000 liters. Therefore around 50400 sqm area at 18 elevated stations can harvest approximately 38.70 million liters of rainwater annually in the proposed alignment from IIMB to Nagavara (Table 12.25).

**Table 12.25: Rain Water Harvesting potential along the proposed alignment**

Items	IIMB to Nagavara
Stations Roof area (sq m)	50400
Total rainfall available for harvest (Million liters)	38.70

Note: Avg. annual rainfall - 850 mm; Rainfall availability for harvest – 70 %

### 12.6.2.12 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 *Azadirachta indica*, *Terminalia chebula* and *Dalbergia sissoo*, *Albizia amara* and *Mangifera indica* are proposed under greenery development.



### **12.6.2.13 Utility Restoration**

There are many utilities such as water supply and sewer pipe lines, storm water drains, telephone cables, over head 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.

### **12.6.2.14 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 follow 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 any water spills, adopt disease control measures and employment of local labour.

## **12.7 ENVIRONMENT MONITORING PROGRAM**

### **12.7.1 Introduction**

Environmental monitoring program is a vital process of any management plan in any project. It is an integral part of any environmental assessment process and helps to ensure if the management plans are carried out regularly and to identify the potential problems that emerge from the proposed project.



Monitoring of existing project provides a better understanding of the factual impacts rather than the impacts projected. Monitoring must begin during the planning and designing of the project and continue through the construction. As soon as the project becomes operational, its impact and the effectiveness of mitigation measures must be monitored at regular intervals. The results are evaluated and implemented continuously. To improve the project operation it must be compared with the current environmental standards.

The execution of these activities needs an exclusive environmental monitoring wing in the form of a Project Management Cell. This cell will be responsible to monitor and implement EMP in the project area at regular interval.

### 12.7.2 Monitoring activity

Monitoring activity must begin during planning and designing of the project and should continue throughout the construction stage. During operational stage the effectiveness of mitigation measures must be monitored at regular intervals. The results are evaluated and implemented to improve the functioning of the project. The results of environmental parameters must be compared with that of the current environmental standards.

**Air monitoring:** Air quality monitoring should be carried out during construction and operational phases at regular interval. Post- monitoring should also be carried out from time to time. The main environmental parameters to be monitored are SPM, NO<sub>x</sub> and SO<sub>2</sub> at six months interval. All parameters will be analyzed as per CPCB standards.

**Noise monitoring:** Noise monitoring should be carried during construction phase once in two months each time during day and night while in the operational phase it has to be carried out once in six months. It has to be ensured that it is in compliance of prescribed CPCB standards.

**Water and Soil quality monitoring:** The ground and surface water should be monitored during construction and operational phases till the completion of the project. Soil quality also needs to be monitored at regular interval.

**Land monitoring:** The land use pattern has to be carefully monitored for muck disposal areas, borrow pits, temporary camp sites, waste dump etc during construction.

**Ecology Monitoring:** Ecological study has to be carried out and implementation of afforestation programme should be monitored.

**Note of BMRCL:**

***Suitable mechanism will be introduced to monitor the various activities during construction and operational phases.***



## 12.8 ENVIRONMENTAL COST ESTIMATE

### 12.8.1 General

The cost is postulated to minimize the impact resulting due to the environment is highlighted in the following section. The environmental cost of the project is estimated based on management plan proposed. Overall cost for implementing environmental management plans is depicted in Table 12.26

**Table 12.26:**  
**Overall cost for implementing environmental management plans\***

Sl. No.	Item	IIMB to Nagavara
		Cost in lakhs
1	Compensatory Afforestation	20.60
2	Green Belt Development beneath the elevated track	18.74
3	Translocation of trees	2.00
4	Disposal of excavated soil	200.00
5	Shifting of utilities/Drainage	50.00
6	Rain Water Harvesting	35.00
7	Water Quality/ Epimidiological	40.00
8	Air & Noise Monitoring	35.00
9	Establishment of Environmental Management Cell	50.00
<b>TOTAL</b>		<b>451.34</b>

\* Establishment cost only

A total of Rs. 451.34 Lakhs is required to implement the Environmental Management Plan suggested for Phase II North - South alignment. The major cost will be invested to shift the excavated soil of the underground stretch to low laying area. The cost above mentioned is excluding land acquisition. The Environmental Management Plan should be implemented in phases so that optimum benefit could be achieved and should be synchronized with the construction schedules.

Similarly periodic Environmental Auditing is proposed to ensure the Environmental Management Plans and corrective measures at appropriate time during operation phase.



## 12.9 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 discussed below,

- Reduction in air pollution level is the single most important indications due to Metro Rail alignment. Air pollution reduction predicted that, the proposed Metro alignment will reduce nearly 8 - 9 tonnes of air pollutants per day.
- BEES model indicates, a net gain of 42 % EIU units with respect to baseline, which demonstrates a positive benefit to the surrounding community.
- Metro Rail would effectively bring down the traffic congestion problems on city's roads to an extent of nearly about 32 %. In addition, this will also ensure reduction in accidents and provides safety transport facility in lesser time.
- The reduction of vehicles will manifest in reduced fossil-fuel consumption and it will directly influence State Economy. However, the fuel reduction can save fuel cost nearly about Rs. 48 crores/ annually due to proposed Metro commissioning.
- Metro rail used 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 can save approximately 1.72 lakhs man hours.
- 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.

The proposed Metro will improve socio-economic benefits of the common public through employment, trade and tourism.

**CHAPTER-13**

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**COST ESTIMATES**



## CHAPTER 13

### COST ESTIMATES

#### 13.1 INTRODUCTION

131.1 Detailed cost estimates for Bangalore Metro Phase-II 2<sup>nd</sup> N-S line have been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, etc. considering 25 KV OHE Traction at January 2011 price level.

13.1.2 While preparing the capital cost estimates, various items have generally been grouped under three major heads on the basis of (i) route km length of alignment, (ii) number of units of that item and (iii) item being an independent entity. All items related with elevated alignment, permanent way, traction, Signalling & Telecommunication, whether in main lines or in maintenance depot, have been estimated at rate per route km/km basis. Cost of station structures, other electrical services at these stations and automatic fare collection (AFC) installations at all stations have been assessed in terms of each station as a unit. Similarly for items like Rolling stock, lifts, escalators etc. costs have been estimated in terms of number of units required for each item. In remaining items, viz. land, utility diversions, rehabilitation, etc. the costs have been assessed on the basis of each item, taken as an independent entity.

**Note of BMRCL:**

***These observations are noted and wherever differences have arisen they have been noted in the paras concerned.***

13.1.3 In order to arrive at realistic cost of various items, costs have been assessed based on the rates adopted for DMRC Ph-III DPR. The element of customs duty and works tax has been excluded for working out the project cost and details thereof are worked out separately.

**Note of BMRCL:**

***The cost estimates of items have been revised based on Bangalore Metro phase-1 rates. The cost estimates proposed in the DPR have been duly considered with reference to the cost of similar works in Bangalore Metro Phase-1. There are major differences in the cost estimates of station buildings, viaduct, cost of depot and the cost of land. The details of these are given in paras concerned.***



13.1.4 The overall capital cost for Bangalore Metro Phase-II North – South line, at January 2011 price level, works out to:

**Option 1( With Hulimavu Depot): Rs.6537 Crores.**

**Option 2 (With Kothanur Depot): Rs.7077 Crores.**

These are figures excluding taxes and duties, but including general charges @ 5% on all items except land and 3% contingencies on all items and also inclusive of octroi & insurance. The abstract capital cost estimates are shown at Table 13.1

In the Draft DPR submitted, the proposed depot was in the Hulimavu area. BMRCL vide letter dt.02-09-11 & 20-09-11 had insisted to change the depot area stating that the Hulimavu area is on tank bed. However, no suitable Govt land could be identified for locating this depot and a private land could only be located for this purpose which will be costlier by more than Rs.550 Crores as compared to Option 1. It is seen that the Govt Order regarding Hulimavu tank bed i.e. No.PWD 82 IMB 85 dt 11-02-1988 recommended for "Foreshore Planting, water sheet to be retained" by forest department. However, in spite of this order, nothing has happened since 1988. As of now there are sizable unauthorized encroachments in this tank bed area and is dirty and has become a breeding space for mosquitoes and hence health hazard. If this area is developed as a depot, the whole area will get a face lift with proper landscaping and open area in this locality. In addition the extra cost of more than Rs.550 Crores for acquisition of Pvt lands will be saved. Therefore it is recommended that the depot of Hulimavu area is confirmed after getting proper Governments clearance.

**Note of BMRCL:**

**BMRCL's cost estimate is Rs.7526.00 crores**

**TABLE 13.1**

**ABSTRACT OF COST ESTIMATE FOR PHASE-II NORTH – SOUTH LINE  
(inclusive of land cost for alignment & Stations)**

Sl. No.	Description	Cost excluding taxes & Duties in Rs. Crores	Details of taxes & Duties in Rs. Crores	TOTAL in Rs. Crores
1	Phase-II North – South line	6537	1097	7634

	<b>{Option 1}</b>			
1	Phase-II North – South line (Gottigere - IIMB to Nagavara) <b>{Option 2}</b>	7077	1111	8188

<b>Abstract Cost Estimate of Ph-II N-S line Gottigere - IIMB – Nagavara (Option 1)</b> <b>Total length = 21.255 km,</b> <b>Under Ground Length= 13.79 km</b> <b>Elevated length= 06.98 km</b> <b>Ramp length= 0.48 km</b> <b>Total Station = 18nos ( UG = 12 , Elv = 06 )</b> <b>(Cost Without Taxes &amp; Duties) Rs. In crores</b>					
S. No.	Item	Unit	Rate as per Price level Jan 2011	Qty.	Amount (Rs in Cr.)
<b>1.0</b>	<b>Land</b>				
1.1	Private land	Hect.	16.13	4.100	66.13
1.2	Govt.Land	Hect.	5.00	15.16	75.80
1.4	Temporary land for casting yard, working spaces etc.	Hect.	3.87	29.000	112.23
1.6	Cost of land for rehabilitation ( to be identified)	LS			10.00
	<b>Sub Total (1)</b>				<b>264.16</b>
<b>2.0</b>	<b>Alignment and Formation</b>				
2.1	Underground section by Cut & Cover excluding Station length	R. km.	101.16	0.000	0.00
2.1	Tunneling by TBM	R. km.	144.31	10.910	1574.42
2.2	Ramp (Underground)	R. km.	0.24	44.670	10.72
2.3	Elevated viaduct section	R. km.	29.87	6.980	208.49
2.4.1	Special Spans	R. km.	41.90	0.500	20.95
2.5	Ramp (Elevated)	R. km.	18.33	0.240	4.40
2.6	Civil work for Mid Section Ventilation Shaft	each	2.00	1.000	2.00
	<b>Sub Total (2)</b>				<b>1820.98</b>
<b>3</b>	<b>Station Buildings</b>				
3.1	Underground Station	Each	120.75	12.000	1449.00
3.2	Elevated stations (including finishes)				
a	Type (A) way side	Each	20.59	4.000	82.36
b	Type (B) Way side with signaling	Each	22.02	1.000	22.02

c	Type (C), Terminal station	Each	23.44	1.000	23.44
3.3	Interchange facilities at interchange stations	Each	5.25	2.000	10.50
	<b>Sub total (3)</b>				<b>1587.32</b>
<b>4</b>	<b>E&amp;M Works</b>				
4.1	Underground station (E&M ,Lifts ,Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	12.000	618.36
4.2	Elevated station (E&M ,Lifts ,Escalators, DG sets etc.)	Each	6.53	6.000	39.18
4.3	Mid Section Ventilation Shaft	Each	5.00	1.000	5.00
	<b>Sub total (4)</b>				<b>662.54</b>
<b>5.0</b>	<b>Depot</b>				
5.1	Depot at Hulimavu (i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			175.00
5.2	Stabling and inspection facilities at Nagavara side( i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			40.00
	<b>Sub total (5)</b>				<b>215.00</b>
<b>6.0</b>	<b>Permanent Way</b>				
6.1	Ballastless track for elevated , underground and at grade alignment	R. km.	6.48	21.255	137.73
6.2	Ballasted track for sidings etc in depots	R. km.	2.08	3.000	6.24
	<b>Sub total (6)</b>				<b>143.97</b>
<b>7</b>	<b>Traction &amp; power</b>				
<b>7.1</b>	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>				
7.1.1	Under Ground Section	R. km.	12.74	13.790	175.68
7.1.2	Elevated & at grade section	R. km.	8.56	6.980	59.75
	<b>Sub total (7)</b>				<b>235.43</b>
<b>8.0</b>	<b>Signalling and Telecom.</b>				
8.1	Signalling	R. km.	9.73	21.255	206.81
8.2	Telecom	Each Stn.	4.36	18.000	78.48
8.3	Automatic fare collection				
8.3.1	Underground stations	Each	2.96	12.000	35.52
8.3.2	Elevated stations	Each	2.96	6.000	17.76

	<b>Sub Total (8)</b>				<b>338.57</b>
<b>9.0</b>	<b>R &amp; R incl. Hutments and road restoration etc.</b>	LS			50.00
	<b>Sub Total (9)</b>				<b>50.00</b>
<b>10.1</b>	<b>Misc. Utilities, other civil works such as median, road signages etc.</b>	R. km.	3.15	21.255	66.95
10.2	Electrical Utilities	LS			60.00
10.3	Telecom Utilities	LS			14.00
	<b>Sub Total (10)</b>				<b>140.95</b>
<b>11</b>	<b>Rolling Stock (SG)</b>	Each	8.40	69.000	579.60
	<b>Sub Total (11)</b>				<b>579.60</b>
<b>12.1</b>	<b>Barracks for CISF including security equipments</b>	LS			5.58
<b>12.2</b>	<b>Staff Quarters for O&amp;M</b>	LS			13.00
	<b>Sub Total (12)</b>				<b>18.58</b>
<b>13</b>	<b>Total of all items except Land</b>				<b>5792.94</b>
<b>14</b>	<b>General Charges incl. Design charge @ 5% on all items except land</b>				<b>289.65</b>
<b>15</b>	<b>Total of all items including General charges</b>				<b>6082.59</b>
<b>16</b>	<b>Total of cost inclusive land cost</b>				<b>6346.75</b>
<b>17</b>	<b>Contingencies @ 3 %</b>				<b>190.40</b>
<b>18</b>	<b>Gross Total</b>				<b>6537.15</b>

**Abstract Cost Estimate of Ph-II N-S line Gottigere - IIMB – Nagavara (Option 2)****Total length = 22.455 km,****Under Ground Length= 13.79 km****Elevated length= 8.18 km****Ramp length= 0.48 km****Total Station = 18nos ( UG = 12 , Elv = 06 )****(Cost Without Taxes & Duties) Rs. In crores**

Sl. No.	Item	Unit	As per DPR			As per BMRCL		
			Rate as per Price level Jan 2011	Qty.	Amount (Rs in Cr.)	Rate	Qty.	Amount (Rs in Cr.)
<b>1.0</b>	<b>Land</b>							
1.1	Private land – for station building & viaduct	Hect.	24.84	20.460	508.23	30.00	4.10	123.00
	Private land for Depot					15.00	15.16	227.40
1.2	Govt. Land	Hect.	5.00	0.800	4.00	5.00	0.80	4.00
1.3	Temporary land for casting yard, working spaces etc.	Hect.	5.96	29.000	172.84	5.96	29.00	172.84
1.4	Cost of land for rehabilitation ( to be identified)	LS			10.00			10.00
	<b>Sub Total (1)</b>				<b>695.07</b>			<b>537.24</b>
<b>2.0</b>	<b>Alignment and Formation</b>							
2.1	Underground section by Cut & Cover excluding Station length	R. km.	101.16	0.000	0.00	100.00	0.00	0.00
2.2	Tunneling by TBM	R. km.	144.31	10.910	1574.42	150.00	10.910	1636.50
2.3	Ramp (Underground)	R. km.	44.67	0.240	10.72	45.00	0.48	21.60
2.4.1	Elevated viaduct section – Main line	R. km.	29.87	8.180	244.34	31.50	6.980	219.87
	Elevated viaduct section – Single line to Depot					22.05	1.20	26.46
2.4.2	Special Spans	R. km.	41.90	0.500	20.95	41.90	0.500	20.95
2.5	Ramp (Elevated)	R. km.	18.33	0.480	8.80	18.33	0.240	4.40
2.6	Civil work for Mid Section Ventilation Shaft	each	2.00	1.000	2.00	2.00	1.00	2.00
	<b>Sub Total (2)</b>				<b>1861.23</b>			<b>1931.78</b>
<b>3</b>	<b>Station Buildings</b>							
3.1	Underground Station	Each	120.75	12.000	1449.00	135.00	12.00	1620.00
3.2	Elevated stations (including finishes)							
a	Type (A) way side	Each	20.59	4.000	82.36	30.60	4.00	122.40
b	Type (B) Way side with signaling	Each	22.02	1.000	22.02	32.40	1.00	32.40
c	Type (C), Terminal station	Each	23.44	1.000	23.44	34.20	1.00	34.20

3.3	Interchange facilities at interchange stations	Each	5.25	2.000	10.50	5.25	2.00	10.50
	<b>Sub total (3)</b>				<b>1587.32</b>			<b>1819.50</b>
<b>4</b>	<b>E&amp;M Works</b>							
4.1	Underground station (E&M, Lifts, Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	12.000	618.36	51.53	12.00	618.36
4.2	Elevated station (E&M, Lifts, Escalators, DG sets etc.)	Each	6.53	6.000	39.18	6.53	6.00	39.18
4.3	Mid Section Ventilation Shaft	Each	5.00	1.000	5.00	5.00	1.00	5.00
	<b>Sub total (4)</b>				<b>662.54</b>			<b>662.54</b>
<b>5.0</b>	<b>Depot</b>							
5.1	Depot at Hulimavu (i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			175.00			238.00
5.2	Stabling and inspection facilities at Nagavara side( i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			40.00			50.00
	<b>Sub total (5)</b>				<b>215.00</b>			<b>288.00</b>
<b>6.0</b>	<b>Permanent Way</b>							
6.1	Ballastless track for elevated , underground and at grade alignment	R. km.	6.48	22.455	145.51	6.42	21.255	136.46
6.2	Ballasted track for sidings etc in depots	R. km.	2.08	3.000	6.24	2.08	3.00	6.24
	<b>Sub total (6)</b>				<b>151.75</b>			<b>142.70</b>
<b>7</b>	<b>Traction &amp; power</b>							
<b>7.1</b>	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>							
7.1.1	Under Ground Section	R. km.	12.74	13.790	175.68	12.74	13.79	175.68
7.1.2	Elevated & at grade section	R. km.	8.56	8.180	70.02	8.56	9.38	80.29
	<b>Sub total (7)</b>				<b>245.70</b>			<b>255.97</b>
<b>8.0</b>	<b>Signalling and Telecom.</b>							
8.1	Signalling	R. km.	9.73	22.455	218.49	11.37	22.455	255.31
8.2	Telecom	Each Stn.	4.36	18.000	78.48	5.04	19.00	95.76
8.3	Automatic fare collection							
8.3.1	Underground stations	Each	2.96	12.000	35.52	2.50	12.00	30.00
8.3.2	Elevated stations	Each	2.96	6.000	17.76	2.50	6.00	15.00
	<b>Sub Total (8)</b>				<b>350.25</b>			<b>396.07</b>

9.0	R & R incl. Hutments and road restoration etc.	LS			52.00			50.00
	<b>Sub Total (9)</b>				<b>52.00</b>			<b>50.00</b>
10.1	Misc. Utilities, other civil works such as median, road signages etc.	R. km.	3.15	22.455	70.73	3.12	22.455	70.06
10.2	Electrical Utilities	LS			60.00			60.00
10.3	Telecom Utilities	LS			15.00			15.00
	<b>Sub Total (10)</b>				<b>145.73</b>			<b>145.06</b>
11	Rolling Stock (SG)	Each	8.40	69.000	579.60	10.00	69.00	690.00
	<b>Sub Total (11)</b>				<b>579.60</b>			<b>690.00</b>
12.1	Barracks for CISF including security equipments	LS			5.58			5.58
12.2	Staff Quarters for O&M	LS			24.55			60.00
	<b>Sub Total (12)</b>				<b>30.13</b>			<b>65.58</b>
13	Total of all items except Land				<b>5881.25</b>			<b>6447.20</b>
14	General Charges incl. Design charge @ 5% on all items except land				<b>294.06</b>			<b>322.36</b>
15	Total of all items including General charges				<b>6175.31</b>			<b>6769.56</b>
16	Total of cost inclusive land cost				<b>6870.38</b>			<b>7306.80</b>
17	Contingencies @ 3%				<b>206.11</b>			<b>219.20</b>
18	Gross Total				<b>7076.49</b>			<b>7526.00</b>

**Say 7077 Crores.**

**Note of BMRCL:**

- The cost of 4.10 hectare of land for viaduct and stations at the rate of Rs.30.00 crores per hectare comes to Rs.123.00 crores

## 13.2 CIVIL ENGINEERING WORKS

### 13.2.1 Land

- i) Land requirements have been kept to the barest minimum & worked out on area basis.

**Option 1 (With Hulimavu Depot):**

- ii ai) Total land requirements for the alignment & Stations of Phase-II N-S line have been worked out to **3.10 Ha** of private land on permanent basis and **9.0 Ha** on temporary basis for underground station during construction.
- aii) **15.16 Ha** (Govt land) for Car Maintenance Depot, **1.0 Ha** for RSS and **20.0 Ha** for Construction depots on temporary basis.



**Option 2 (With Kothanur Depot):**

- ii ai) Total land requirements for the alignment & Stations of Phase-II N-S line have been worked out to **20.46 Ha** of private land on permanent basis for alignment & depot and **9.0 Ha** on temporary basis for underground station during construction.
- aii) **0.8 Ha** (Govt land) for depot.  
**1.0 Ha** for RSS and **20.0 Ha** for Construction depots on temporary basis.

**Note:** *The cost of land proposed for acquisition for alignment, station buildings and depot proposed in the DPR is Rs 24.84 crores per hectare. It may be noted here that the alignment of this line runs along NH-7 which is already well developed. The cost of land proposed in the DPR comes to Rs.24,840/- per sqm (Rs. 2,308/- per sft). The guidance value as approved by the State Government ranges from Rs.1000 / sft to Rs.3000 / sft. As it is a compulsory acquisition we have to add 30% Solatium and 12% additional market value to this basic price to arrive at the cost of the land. So in our view the land cost will not be less than Rs.3000 / sft. In fact the average cost of land in Phase-1 of Bangalore Metro is Rs.2800 / sft. Now Government of India is likely to amend the Land Acquisition Act 1894. As per the draft bill of the new land acquisition law, the solatium is proposed to be increased to 100% from the existing rate of 30%. If the new law comes into effect, the cost of land will further go up.*

*So considering all these factors, cost of the land required for viaduct and station buildings is calculated at the rate of Rs 30 crores per hectare as against Rs.24.84 crores per hectare given in the DPR. However the land proposed for depot is either agricultural or undeveloped N.A. land which will not command the same value as that of developed land. Hence the value of the land proposed for depot is considered at Rs.15.00 crores per hectare*

- iii) The summary of the land cost is placed at Table 13.2

**Note of BMRCL:**

**Agree with the extent of land required for viaduct, station buildings and property development.**

**The rate proposed in the DPR is Rs.24.84 Crores. This is found to be low and the same has been revised as Rs.30/- Crores per hectare.**

### 13.2.2 Alignment

- i) **Elevated Section:** Rates are based on rates for works of Delhi Metro Ph-III. Cost of viaduct length for station has been included in elevated section.
- ii) **Underground Section:** Rates are based on rates for works of Delhi Metro Ph-III.

**Note of BMRCL:**

**The rates have been revised as shown in the Annexure. The cost of elevated section proposed in the DPR is Rs.29.87 crores per km. In our view the cost would be Rs.31.50 crores per km. This cost is also based on the contract value of this work in Bangalore Metro Phase-1 works.**

### 13.2.3 Station Buildings

- i) **Elevated Stations:** Estimated rate is based on rates for stations by DMRC for Ph-III works of Delhi Metro. The cost includes the general services at the stations but excludes the cost of viaduct, lifts & escalators, which have been considered separately under, respective items.
- ii) **Underground Stations:** Estimated rate is based on rates for stations by DMRC for Ph-III works of Delhi Metro. The cost includes the general services at the stations, lifts & escalators.

**Note: The cost of 'A' type station building as per DPR is Rs20.59 crores and for terminal station, it is Rs.23.44 crores. Whereas the cost of 'A' type station in Bangalore Metro Phase-1 is Rs.30.60 crores. Similarly the cost of terminal / junction station is Rs.34.20 crores. Hence the cost estimate of station buildings proposed in DPR is not realistic and as such cannot be adopted. So the cost estimate as proposed by BMRCL may be accepted.**

**13.2.4 Permanent Way -** For elevated & underground sections, ballast less track has been planned. Rates adopted are based on rates of Delhi Metro Ph-III for ballast less tracks.

### 13.3 UTILITY DIVERSIONS

13.3.1 The costs of utility diversions have been considered under head utility diversions. In addition to sewer/drainage/water pipelines other important utilities works considered are road diversions, road restoration etc. Over and above the cost provision made on route km basis based on experience of Delhi Metro, additional provision has been made for this Corridor towards diversion of HT lines crossing the alignment.

#### **13.4 ENVIRONMENTAL IMPACT ASSESSMENT**

13.4.1 Provision for environmental impacts of this Metro corridor has been made to cover various protection works, additional compensatory measures, and compensation for loss of trees, compensatory a forestation and fencing, monitoring of water quality, air/noise pollution during construction, establishment of Environmental Division.

***Note of BMRCL:***

***Agree with observations except for the proposal regarding translocation of trees.***

#### **13.5 REHABILITATION & RESETTLEMENT**

13.5.1 **Private Structures** - Provision towards compensation/rehabilitation of properties on private land, likely to be affected has been assessed after site inspection. Sufficient provision is kept in the estimate to cover the cost of shifting various structures.

#### **13.6 TRACTION & POWER SUPPLY**

13.6.1 Provisions have been made to cover following subheads:

- 25 KV OHE
- Receiving-cum-Traction Sub-stations including cables.
- ASS for elevated and at-grade stations.
- Service connection charges for Receiving Sub-stations.
- Scada augmentation.
- Traction maintenance vehicle
- Miscellaneous items e.g. illumination, lifting T&P, etc.

13.6.2 The rates adopted for various items are based on the accepted contract rates for similar works being done for Delhi Metro.

#### **13.7 ELECTRICAL SERVICES AT STATIONS**

13.7.1 These are included in estimated costs of stations on elevated alignment section. Cost of escalators, lifts for elevated stations have not been included in station costs, but provided under electrical estimates & shown separately. Cost for elevated stations cover all electrical works like internal & external lighting etc., but does not include 25 KV OHE.

***Note of BMRCL:***

***The rates for traction & power supply have been revised based on the actual cost of similar items for Phase – I.***

### **13.8 SIGNALLING & TELECOMMUNICATION WORKS**

13.8.1 The rates adopted are based on accepted rates of underground and elevated corridors of Delhi Metro. These rates include escalation during manufacture & supply of equipment and their installation at site.

***Note of BMRCL:***

***The rates adopted by BMRCL are slightly higher because it is proposed to have CBTS signaling and communication system which is modern and more advanced.***

### **13.9 AUTOMATIC FARE COLLECTION**

13.9.1 Adopted rates are based on accepted contract rates of Delhi Metro Corridors. These rates include escalation during the period of equipment manufacture and their supply, including installation.

### **13.10 ROLLING STOCK**

13.10.1 The base cost is taken based on rates for works of Delhi Metro Ph-III

***Note of BMRCL:***

***The cost of Rolling Stock shown in the DPR is Rs.8.4 crores per coach. This is found to be inadequate and the BEML, the manufacturers of coaches, have been consulted and in their view the cost of each coach would be Rs.10 crores. Accordingly, the same rates have been adopted.***

### **12.2 STAFF QUARTERS**

***Note of BMRCL:***

***The next major item where there is a substantial cost variation pertains to staff quarters. The cost of this item of work is Rs.24.55 Crores as per DPR. As the number of staff quarters to be provided will be substantially more the cost in our view will be Rs.60 Crores.***

### **13.11 TAXES AND DUTIES**

Estimate for taxes and duties are given in **Table 13.3**. It is estimated that the taxes and duties will amount to

**Option 1: Rs.1097 Crores** and the total cost inclusive of taxes and duties is **Rs.7634 Crores**.

**Option 2: Rs.1111 Crores** and the total cost inclusive of taxes and duties is **Rs.8188 Crores**.

**Note of BMRCL:**

**As per our due diligence the cost of the project comes to Rs.7526.00 Cr. Consequently the taxes & duties come to Rs.1204.00 Cr. So the total cost of this corridor comes to Rs.8730.00 Cr.**

**Table 13.3**  
**Details of Taxes and Duties B M PHASE- 2<sup>nd</sup> II N-S line**

Phase II N-S line Gottigere - IIMB – Nagavara (Option1)						
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1587.14	99.73	80.10	107.23	<b>287.06</b>
	Elevated, at grade & entry to Depot	233.84		16.86	22.57	<b>39.43</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1464.75	92.04	73.93	98.96	<b>264.93</b>
	b) Underground station-EM works	623.36	65.29	27.29	36.53	<b>129.10</b>
	c) Elevated station - civil works	159.32		11.49	15.38	<b>26.86</b>
	d) Elevated station-EM works	39.18	1.64	2.74	3.67	<b>8.06</b>
<b>5</b>	<b>Depot</b>					
	Civil works	86.00	5.40	4.34	5.81	<b>15.55</b>
	EM works	129.00	5.40	9.04	12.09	<b>26.53</b>
<b>6</b>	<b>P-Way</b>	143.97	24.13	2.52	3.37	<b>30.02</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	235.43	19.73	12.37	16.55	<b>48.65</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	285.29	47.81	5.88	7.87	<b>61.55</b>
	AFC	53.28	8.37	1.37	1.84	<b>11.58</b>
<b>9</b>	<b>R &amp; R hutments</b>	50.00			3.13	<b>3.13</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	66.95		4.83	6.46	<b>11.29</b>

	EM works	75.00		6.57	8.79	<b>15.36</b>
<b>11</b>	<b>Rolling stock</b>	579.60	106.84	4.66	6.23	<b>117.73</b>
	<b>Total</b>	<b>5812.11</b>	<b>476.38</b>	<b>263.97</b>	<b>356.47</b>	<b>1096.82</b>
	<b>Total taxes &amp; Duties</b>					<b>1097</b>

**Phase II N-S line Gottigere - IIMB – Nagavara (Option 2) As per DPR**

<b>Details of Taxes and Duties</b>						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1587.14	99.73	80.10	107.23	<b>287.06</b>
	Elevated, at grade & entry to Depot	274.09		19.76	26.45	<b>46.22</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1464.75	92.04	73.93	98.96	<b>264.93</b>
	b) Underground station-EM works	623.36	65.29	27.29	36.53	<b>129.10</b>
	c) Elevated station - civil works	159.32		11.49	15.38	<b>26.86</b>
	d) Elevated station-EM works	39.18	1.64	2.74	3.67	<b>8.06</b>
<b>5</b>	<b>Depot</b>					
	Civil works	86.00	5.40	4.34	5.81	<b>15.55</b>
	EM works	129.00	5.40	9.04	12.09	<b>26.53</b>
<b>6</b>	<b>P-Way</b>	151.75	25.43	2.66	3.56	<b>31.64</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	245.70	20.59	12.91	17.28	<b>50.77</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	296.97	49.76	6.12	8.19	<b>64.07</b>
	AFC	53.28	8.37	1.37	1.84	<b>11.58</b>

<b>9</b>	<b>R &amp; R hutments</b>	52.00			3.25	<b>3.25</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	70.73		5.10	6.83	<b>11.93</b>
	EM works	75.00		6.57	8.79	<b>15.36</b>
<b>11</b>	<b>Rolling stock</b>	579.60	106.84	4.66	6.23	<b>117.73</b>
	<b>Total</b>	<b>5887.87</b>	<b>480.50</b>	<b>268.06</b>	<b>362.07</b>	<b>1110.63</b>
	<b>Total taxes &amp; Duties</b>					<b>1111</b>

## Phase II N-S line Gottigere - IIMB – Nagavara As per BMRC

Details of Taxes and Duties						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1636.50	102.84	82.59	110.56	<b>295.99</b>
	Elevated, at grade & entry to Depot	295.28		21.29	28.50	<b>49.79</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1620.00	101.80	81.76	109.45	<b>293.01</b>
	b) Underground station-EM works	618.36	64.76	27.07	36.23	<b>128.06</b>
	c) Elevated station - civil works	199.50		14.38	19.25	<b>33.64</b>
	d) Elevated station-EM works	44.18	1.85	3.09	4.14	<b>9.09</b>
<b>5</b>	<b>Depot</b>					
	Civil works	120.00	7.54	6.06	8.11	<b>21.70</b>
	EM works	118.00	4.94	8.26	11.06	<b>24.27</b>
<b>6</b>	<b>P-Way</b>	142.70	23.91	2.50	3.34	<b>29.76</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	255.97	21.45	13.45	18.00	<b>52.89</b>



<b>8</b>	<b>S and T Works</b>					
	S & T	396.07	66.37	8.16	10.92	<b>85.45</b>
	AFC	45.00	7.07	1.16	1.55	<b>9.78</b>
<b>9</b>	<b>R &amp; R hutments</b>	<b>50.00</b>			<b>3.13</b>	<b>3.13</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	70.06		5.05	6.76	<b>11.81</b>
	EM works	75.00		6.57	8.79	<b>15.36</b>
<b>11</b>	<b>Rolling stock</b>	<b>690.00</b>	<b>127.19</b>	<b>5.54</b>	<b>7.42</b>	<b>140.15</b>
	<b>Total</b>	<b>6376.62</b>	<b>529.72</b>	<b>286.94</b>	<b>387.22</b>	<b>1203.87</b>
	<b>Total taxes &amp; Duties</b>					<b>1204</b>

Table 13.2  
LAND REQUIREMENT FOR B M PHASE- 2<sup>nd</sup> II N-S line

Sl No	Location	Chainage		Area in (Sqm)				Rate for Private Land (on Perm acqn) (Per Sqm)	Amount for Govt/Private Land on perm acqn( Rate Rs 5000/16130/- Per Sqm)	Amount for Pvt land on temp acqn Land (Rate Rs 3870 Per Sqm)	Total Land cost
		From	To	Alignment		Station					
				Private (on Permanent Acqn)	Govt (on Permanent Acqn)	Private (on Permanent acqn)	Pvt on Temporary acquisition				
	<b>Gottigere - IIM (B) - Nagavara</b>										
	<b>Alignment (excluding Stations)</b>										
1	Alignment	0	1000	54.75	0	-	-	16130.00	883117.50	0	883117.50
2	Alignment	1000	2000	0	0	-	-	16130.00	0	0	0.00
3	Alignment	2000	3000	0	0	-	-	16130.00	0	0	0.00
4	Alignment	3000	4000	0	0	-	-	16130.00	0	0	0.00
5	Alignment	4000	5000	0	0	-	-	16130.00	0	0	0.00
6	Alignment	5000	6000	5744.02	0	-	-	16130.00	92651042.60	0	92651042.60
7	Alignment	6000	7000	5645.81	0	-	-	16130.00	91066915.30	0	91066915.30
8	Alignment	7000	8000	930.07	0	-	-	16130.00	15002029.10	0	15002029.10
9	Alignment	8000	9000	0	0	-	-	16130.00	0	0	0.00
10	Alignment	9000	10000	0	0	-	-	16130.00	0	0	0.00
11	Alignment	10000	11000	0	0	-	-	16130.00	0	0	0.00
12	Alignment	11000	12000	0	0	-	-	16130.00	0	0	0.00
13	Alignment	12000	13000	0	0	-	-	16130.00	0	0	0.00
14	Alignment	13000	14000	0	0	-	-	16130.00	0	0	0.00
15	Alignment	14000	15000	0	0	-	-	16130.00	0	0	0.00
16	Alignment	15000	16000	0	0	-	-	16130.00	0	0	0.00

17	Alignment	16000	17000	0	0	-	-	16130.00	0	0	0	0.00
18	Alignment	17000	18000	0	0	-	-	16130.00	0	0	0	0.00
19	Alignment	18000	19000	0	0	-	-	16130.00	0	0	0	0.00
20	Alignment	19000	20000	0	0	-	-	16130.00	0	0	0	0.00
21	Alignment	20000	21000	0	0	-	-	16130.00	0	0	0	0.00
22	Alignment	21000	21255	105.20	0	-	-	16130.00	1696876.00	0	0	1696876.00
	<b>Total</b>			<b>12479.9</b>	<b>0</b>	<b>-</b>	<b>-</b>	<b>16130.00</b>	<b>201299980.50</b>	<b>0</b>	<b>0</b>	<b>201299980.50</b>
												<b>say 20.13</b>
												<b>Crores</b>
<b>II</b>	<b>Stations</b>											
1	Gottigere			-	-	2539.00	0	16130.00	40954070.00	0	0	40954070.00
2	Hulimavu			-	-	3237.00	0	16130.00	52212810.00	0	0	52212810.00
3	IIMB			-	-	2568.00	0	16130.00	41421840.00	0	0	41421840.00
4	J P Nagar - IV Phase			-	-	1832.00	0	16130.00	29550160.00	0	0	29550160.00
5	Jayadeva Hospital			-	-	3149.00	0	16130.00	50793370.00	0	0	50793370.00
6	Swagath Road Cross			-	-	2766.00	0	16130.00	44615580.00	0	0	44615580.00
7	Dairy Circle			-	-	200.00	5129.21	16130.00	3226000.00	19850042.7	23076042.70	
8	MICO Industries			-	-	200.00	6206.48	16130.00	3226000.00	24019077.6	27245077.60	
9	Langford Town			-	-	200.00	7805.97	16130.00	3226000.00	30209103.9	33435103.90	
10	Vellara			-	-	200.00	6443.11	16130.00	3226000.00	24934835.7	28160835.70	
11	M G Road			-	-	200.00	4543.06	16130.00	3226000.00	17581642.2	20807642.20	
12	Shivaji Nagar			-	-	200.00	10781.33	16130.00	3226000.00	41723747.1	44949747.10	
13	Cantonment Railway Station			-	-	200.00	11769.88	16130.00	3226000.00	45549435.6	48775435.60	
14	Pottery Town			-	-	200.00	8533.55	16130.00	3226000.00	33024838.5	36250838.50	
15	Tannery Road			-	-	200.00	6893.91	16130.00	3226000.00	26679431.7	29905431.70	
16	Venkateshpura			-	-	200.00	7072.77	16130.00	3226000.00	27371619.9	30597619.90	

17	Arabic College					200.00	7913.73	16130.00	3226000.00	30626135.1	33852135.10
18	Nagavara					200.00	6958.24	16130.00	3226000.00	26928388.8	30154388.80
	For Construction Depots						200000	0	0.00	774000000	
	For RSS	10000						16130.00	161300000.00		161300000.00
	<b>Total</b>	<b>22479.90</b>			<b>18491.00</b>	<b>18491.00</b>	<b>290051.24</b>		<b>660846100.00</b>	<b>1122498298.80</b>	<b>1783344398.80</b>
	For Car Maintenance Depot										
	Option 1 (Hulimavu)		151600					5000.00		758000000.00	758000000.00
	Option 2 (Kothanur)	163600	8000					24840.20	3567052720.00	40000000.00	3607052720.00
	<b>Total (Option 1){With Hulimavu Depot}</b>	<b>22479.9</b>	<b>-</b>		<b>18491.00</b>	<b>18491.00</b>	<b>290051.24</b>		<b>660860617.00</b>	<b>1122498299.00</b>	<b>2540058128.98</b>
	<b>Total (Option 2) {With Kothanur Depot}</b>	<b>186079.9</b>	<b>80000</b>		<b>18491.00</b>	<b>18491.00</b>	<b>290051.24</b>	<b>24840.20</b>	<b>5121582070.00</b>	<b>1728705390.00</b>	<b>6850287460.00</b>
	<b>Add for land for rehabilitation L.S</b>										
	<b>OPTION 1 (With Hulimavu Depot)</b>										
										Say	264.1Crores
	<b>OPTION 2 (with Kothanur Depot)</b>										
										Say	695.03 Crores

(Option 1)

<b>Abstract Cost Estimate of Ph-II N-S line Gottigere - IIMB - Nagavara</b>						
Total length = 21.255 km,						
Under Ground Length= 13.79 km						
Elevated length= 06.98 km						
Ramp length= 0.48 km						
Total Station = 18nos ( UG = 12 , Elv = 06 )						
(Cost Without Taxes & Duties)						
S. No.	Item	Unit	Rate as per Price level Jan 2011 ( . In Crores)	Qty.	Amount (Rs in Cr.)	Remarks
<b>1.0</b>	<b>Land</b>					
1.1	Private land	Hect.	16.13	4.100	66.13	
1.2	Govt.Land	Hect.	5.00	15.160	75.80	
1.4	Temporary land for casting yard, working spaces etc.	Hect.	3.87	29.000	112.23	
1.6	Cost of land for rehabilitation ( to be identified)	LS			10.00	
	<b>Sub Total (1)</b>				<b>264.16</b>	
<b>2.0</b>	<b>Alignment and Formation</b>					
2.1	Tunneling by TBM	R. km.	144.31	10.910	1574.42	
2.2	Ramp (Underground)	R. km.	0.24	44.670	10.72	
2.3	Elevated viaduct section	R. km.	29.87	6.980	208.49	
2.4.1	Special Spans	R. km.	41.90	0.500	20.95	
2.5	Ramp (Elevated)	R. km.	18.33	0.240	4.40	
2.6	Civil work for Mid Section Ventilation Shaft	each	2.00	1.000	2.00	
	<b>Sub Total (2)</b>				<b>1820.98</b>	
<b>3</b>	<b>Station Buildings</b>					
3.1	Underground Station	Each	120.75	12.000	1449.00	
3.2	Elevated stations (including finishes)					
a	Type (A) way side	Each	20.59	4.000	82.36	
b	Type (B) Way side with signaling	Each	22.02	1.000	22.02	
c	Type (C), Terminal station	Each	23.44	1.000	23.44	
3.3	Interchange facilities at interchange stations	Each	5.25	2.000	10.50	
	<b>Sub total (3)</b>				<b>1587.32</b>	

<b>4</b>	<b>E&amp;M Works</b>					
4.1	Underground station (E&M ,Lifts ,Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	12.000	618.36	
4.2	Elevated station (E&M ,Lifts ,Escalators, DG sets etc.)	Each	6.53	6.000	39.18	
4.3	Mid Section Ventilation Shaft	Each	5.00	1.000	5.00	
	<b>Sub total (4)</b>				<b>662.54</b>	
<b>5.0</b>	<b>Depot</b>					
5.1	Depot at Hulimavu (i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			175.00	
5.2	Stabling and inspection facilities at Nagavara side (i/c Civil works, E & M, P&M, Track work, OHE etc.)	LS			40.00	
	<b>Sub total (5)</b>				<b>215.00</b>	
<b>6.0</b>	<b>Permanent Way</b>					
6.1	Ballastless track for elevated , underground and at grade alignment	R. km.	6.48	21.255	137.73	
6.2	Ballasted track for sidings etc in depots	R. km.	2.08	3.000	6.24	
	<b>Sub total (6)</b>				<b>143.97</b>	
<b>7</b>	<b>Traction &amp; power</b>					
7.1	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>					
7.1.1	Under Ground Section	R. km.	12.74	13.790	175.68	
7.1.2	Elevated & at grade section	R. km.	8.56	6.980	59.75	
	<b>Sub total (7)</b>				<b>235.43</b>	
<b>8.0</b>	<b>Signalling and Telecom.</b>					
8.1	Signalling	R. km.	9.73	21.255	206.81	
8.2	Telecom	Each Strn.	4.36	18.000	78.48	
8.3	Automatic fare collection					
8.3.1	Underground stations	Each	2.96	12.000	35.52	
8.3.2	Elevated stations	Each	2.96	6.000	17.76	
	<b>Sub Total (8)</b>				<b>338.57</b>	
<b>9.0</b>	<b>R &amp; R incl. Hutments and road restoration etc.</b>	LS			50.00	
	<b>Sub Total (9)</b>				<b>50.00</b>	
<b>10.1</b>	<b>Misc. Utilities, other civil works such as median, road signages etc.</b>	R. km.	3.15	21.255	66.95	
10.2	Electrical Utilities	LS			60.00	
10.3	Telecom Utilities	LS			14.00	
	<b>Sub Total (10)</b>				<b>140.95</b>	

<b>11</b>	<b>Rolling Stock (SG)</b>	Each	8.40	69.000	579.60	
	<b>Sub Total (11)</b>				<b>579.60</b>	
<b>12.1</b>	<b>Barracks for CISF including security equipments</b>	LS			5.58	
<b>12.2</b>	<b>Staff Qutarters for O&amp;M</b>	LS			13.00	
	<b>Sub Total (12)</b>				<b>18.58</b>	
<b>13</b>	<b>Total of all items except Land</b>				<b>5792.94</b>	
<b>14</b>	<b>General Charges incl. Design charge @ 5% on all items except land</b>				<b>289.65</b>	
<b>15</b>	<b>Total of all items including General charges</b>				<b>6082.59</b>	
<b>16</b>	<b>Total of cost inclusive land cost</b>				<b>6346.75</b>	
<b>17</b>	<b>Contingencies @ 3 %</b>				<b>190.40</b>	
<b>18</b>	<b>Gross Total</b>				<b>6537.15</b>	



**Phase II N-S line Gottigere - IIMB - Nagavara  
Details of Taxes and Duties**

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1587.14	99.73	80.10	107.23	<b>287.06</b>
	Elevated, at grade & entry to Depot	233.84		16.86	22.57	<b>39.43</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1464.75	92.04	73.93	98.96	<b>264.93</b>
	b) Underground station-EM works	623.36	65.29	27.29	36.53	<b>129.10</b>
	c) Elevated station - civil works	159.32		11.49	15.38	<b>26.86</b>
	d) Elevated station-EM works	39.18	1.64	2.74	3.67	<b>8.06</b>
<b>5</b>	<b>Depot</b>					
	Civil works	86.00	5.40	4.34	5.81	<b>15.55</b>
	EM works	129.00	5.40	9.04	12.09	<b>26.53</b>
<b>6</b>	<b>P-Way</b>	143.97	24.13	2.52	3.37	<b>30.02</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	235.43	19.73	12.37	16.55	<b>48.65</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	285.29	47.81	5.88	7.87	<b>61.55</b>
	AFC	53.28	8.37	1.37	1.84	<b>11.58</b>
<b>9</b>	<b>R &amp; R hutments</b>	50.00			3.13	<b>3.13</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	66.95		4.83	6.46	<b>11.29</b>
	EM works	74.00		6.48	8.67	<b>15.15</b>
<b>11</b>	<b>Rolling stock</b>	579.60	106.84	4.66	6.23	<b>117.73</b>
	<b>Total</b>	<b>5811.11</b>	<b>476.38</b>	<b>263.88</b>	<b>356.36</b>	<b>1096.62</b>
	<b>Total taxes &amp; Duties</b>					<b>1097</b>

<b>OPTION 2 (With Depot at Kothanur)</b>						
<b>Abstract Cost Estimate of Ph-II N-S line Gottigere - IIMB - Nagavara</b>						
Total length = 22.455 km,						
Under Ground Length= 13.79 km						
Elevated length= 08.18 km						
Ramp length= 0.48 km						
Total Station = 18nos ( UG = 12 , Eiv = 06 )						
(Cost Without Taxes & Duties)						
S. No.	Item	Unit	Rate as per Price level Jan 2011 (In Crores)	Qty.	Amount (Rs in Cr.)	Remarks
<b>1.0</b>	<b>Land</b>					
1.1	Private land	Hect.	24.84	20.460	508.23	
1.2	Govt. Land	Hect.	5.00	0.800	4.00	
1.4	Temporary land for casting yard, working spaces etc.	Hect.	5.96	29.000	172.84	
1.6	Cost of land for rehabilitation ( to be identified)	LS			10.00	
	<b>Sub Total (1)</b>				<b>695.07</b>	
<b>2.0</b>	<b>Alignment and Formation</b>					
2.1	Tunneling by TBM	R. km.	144.31	10.910	1574.42	
2.2	Ramp (Underground)	R. km.	44.67	0.240	10.72	
2.3	Elevated viaduct section	R. km.	29.87	8.180	244.34	
2.4.1	Special Spans	R. km.	41.90	0.500	20.95	
2.5	Ramp (Elevated)	R. km.	18.33	0.480	8.80	
2.6	Civil work for Mid Section Ventilation Shaft	each	2.00	1.000	2.00	
	<b>Sub Total (2)</b>				<b>1861.23</b>	
<b>3</b>	<b>Station Buildings</b>					
3.1	Underground Station	Each	120.75	12.000	1449.00	
3.2	Elevated stations (including finishes)					
a	Type (A) way side	Each	20.59	4.000	82.36	
b	Type (B) Way side with signaling	Each	22.02	1.000	22.02	
c	Type (C), Terminal station	Each	23.44	1.000	23.44	
3.3	Interchange facilities at interchange stations	Each	5.25	2.000	10.50	
	<b>Sub total (3)</b>				<b>1587.32</b>	

<b>4</b>	<b>E&amp;M Works</b>					
4.1	Underground station (E&M ,Lifts ,Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	12.000	618.36	
4.2	Elevated station (E&M ,Lifts ,Escalators, DG sets etc.)	Each	6.53	6.000	39.18	
4.3	Mid Section Ventilation Shaft	Each	5.00	1.000	5.00	
	<b>Sub total (4)</b>				<b>662.54</b>	
<b>5.0</b>	<b>Depot</b>					
5.1	Depot at Kothanur (i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			175.00	
5.2	Stabling and inspection facilities at Nagavara side (i/c Civil works, E & M, P&M, Track work, OHE etc.)	LS			40.00	
	<b>Sub total (5)</b>				<b>215.00</b>	
<b>6.0</b>	<b>Permanent Way</b>					
6.1	Ballastless track for elevated , underground and at grade alignment	R. km.	6.48	22.455	145.51	
6.2	Ballasted track for sidings etc in depots	R. km.	2.08	3.000	6.24	
	<b>Sub total (6)</b>				<b>151.75</b>	
<b>7</b>	<b>Traction &amp; power</b>					
7.1	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>					
7.1.1	Under Ground Section	R. km.	12.74	13.790	175.68	
7.1.2	Elevated & at grade section	R. km.	8.56	8.180	70.02	
	<b>Sub total (7)</b>				<b>245.70</b>	
<b>8.0</b>	<b>Signalling and Telecom.</b>					
8.1	Signalling	R. km.	9.73	22.455	218.49	
8.2	Telecom	Each Stn.	4.36	18.000	78.48	
8.3	Automatic fare collection					
8.3.1	Underground stations	Each	2.96	12.000	35.52	
8.3.2	Elevated stations	Each	2.96	6.000	17.76	
	<b>Sub Total (8)</b>				<b>350.25</b>	
<b>9.0</b>	<b>R &amp; R incl. Hutments and road restoration etc.</b>	LS			52.00	
	<b>Sub Total (9)</b>				<b>52.00</b>	
<b>10.1</b>	<b>Misc. Utilities, other civil works such as median, road signages etc.</b>	R. km.	3.15	22.455	70.73	
10.2	Electrical Utilities	LS			60.00	
10.3	Telecom Utilities	LS			15.00	
	<b>Sub Total (10)</b>				<b>145.73</b>	

<b>11</b>	<b>Rolling Stock (SG)</b>	Each	8.40	69.000	579.60	
	<b>Sub Total (11)</b>				<b>579.60</b>	
<b>12.1</b>	<b>Barracks for CISF including security equipments</b>	LS			5.58	
<b>12.2</b>	<b>Staff Qutarters for O&amp;M</b>	LS			24.55	
	<b>Sub Total (12)</b>				<b>30.13</b>	
<b>13</b>	<b>Total of all items except Land</b>				<b>5881.25</b>	
<b>14</b>	<b>General Charges incl. Design charge @ 5% on all items except land</b>				<b>294.06</b>	
<b>15</b>	<b>Total of all items including General charges</b>				<b>6175.31</b>	
<b>16</b>	<b>Total of cost inclusive land cost</b>				<b>6870.38</b>	
<b>17</b>	<b>Contingencies @ 3 %</b>				<b>206.11</b>	
<b>18</b>	<b>Gross Total</b>				<b>7076.49</b>	

## OPTION 2 (With Depot at Kothanur)

## Phase II N-S line Gottigere - IIMB - Nagavara

Details of Taxes and Duties						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	1587.14	99.73	80.10	107.23	<b>287.06</b>
	Elevated, at grade & entry to Depot	274.09		19.76	26.45	<b>46.22</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	1464.75	92.04	73.93	98.96	<b>264.93</b>
	b) Underground station-EM works	623.36	65.29	27.29	36.53	<b>129.10</b>
	c) Elevated station - civil works	159.32		11.49	15.38	<b>26.86</b>
	d) Elevated station-EM works	39.18	1.64	2.74	3.67	<b>8.06</b>
<b>5</b>	<b>Depot</b>					
	Civil works	86.00	5.40	4.34	5.81	<b>15.55</b>
	EM works	129.00	5.40	9.04	12.09	<b>26.53</b>
<b>6</b>	<b>P-Way</b>	151.75	25.43	2.66	3.56	<b>31.64</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	245.70	20.59	12.91	17.28	<b>50.77</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	296.97	49.76	6.12	8.19	<b>64.07</b>
	AFC	53.28	8.37	1.37	1.84	<b>11.58</b>
<b>9</b>	<b>R &amp; R hutments</b>	52.00			3.25	<b>3.25</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	70.73		5.10	6.83	<b>11.93</b>
	EM works	75.00		6.57	8.79	<b>15.36</b>
<b>11</b>	<b>Rolling stock</b>	579.60	106.84	4.66	6.23	<b>117.73</b>
	<b>Total</b>	<b>5887.87</b>	<b>480.50</b>	<b>268.06</b>	<b>362.07</b>	<b>1110.63</b>
	<b>Total taxes &amp; Duties</b>					<b>1111</b>

**Land Requirement (in Ha. ) Gottigere - IIMB - Nagavara line (2nd N-S line, BM PH-II)  
Option 1 (with Hulimavu Depot)**

S. No.	Item	
1	Land	
1.1	Private land	4.1
1.2	Govt.Land (for Depot)	15.16
1.3	Temporary land for casting yard, working spaces, U/G stations etc.	29
Total		48.26

**Land Requirement (in Ha. ) Gottigere - IIMB - Nagavara line (2nd N-S line, BM PH-II)  
(Option 2, With Kothanur Depot)**

S. No.	Item	
1.0	Land	
1.1	Private land	20.46
1.2	Govt.Land (for Depot)	0.80
1.3	Temporary land for casting yard, working spaces, U/G stations etc.	29.00
	Total	50.26

**CHAPTER-14**

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**FINANCIAL VIABILITY, FARE  
STRUCTURE & FINANCING OPTIONS**





## CHAPTER 14

### FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

#### 14.1 INTRODUCTION

The North South Corridor of Bengaluru Phase-II Metro from Gottigere-IIMB-Nagavara corridor is proposed to be constructed with following two options.

- Option-I with Depot at Hulimavu
- Option-II with Depot at Kothanur

The route lengths with estimated cost at January 2011 price level are tabulated below:-

Particulars	Option-I	Option-II
Route Length	21.255 KM	22.455 KM
Estimated Cost without Land Cost, taxes & duties	6272.99 Crore	6381.12 Crore
Estimated Cost With Central Taxes	7277.41 Crore	7795.05 Crore

The estimated cost at January-2011 price level includes an amount of Rs.18.58 Crore as one-time charges of security personal towards cost of weapons, barricades, hand held and door detector machine etc. However, the recurring cost towards salary and allowances of security personal have not taken in to account in FIRR calculation.

**Note of BMRCL:**

**After detailed analysis the cost estimate comes to Rs.7526.00 crores (without central taxes). The cost with central taxes will be Rs.8730.00 crores**

**14.2 Costs****14.2.1 Investment Cost**

14.2.1.1 For the purpose of calculating the Financial Internal Rate of Return (FIRR), the completion cost with central taxes have been calculated by taking escalation factor @5% PA. It has been assumed that Government of Karnataka will exempt local taxes or reimburse the same. The impact of proposed Goods & Service Tax Act (GST) has not been considered in the calculation.

The project will be taken up for construction in April-2012 and expected to be completed on 31.03.2017 and Revenue Opening Date (ROD) has been assumed as 01.04.2017. The total completion costs duly escalated and shown in the table 14.1 have been taken as the initial investment. The cash flow of investments separately is placed in Table –14.1 as below.

**Table 14.1 Corridor-wise & Year wise Investment-With Central Taxes**

Figs in Rs. Cr.

Financial Year	Option-I		Option-II	
	Estimated Cost	Completion Cost	Estimated Cost	Completion Cost
2012-13	701	890	711	1123
2013-14	1401	1720	1422	1965
2014-15	1751	2077	1777	2108
2015-16	1401	1745	1422	1771
2016-17	701	917	711	930
2017-18	701	963	711	976
2018-19	349	503	355	512
Total	<b>7005</b>	<b>8815</b>	<b>7109</b>	<b>9385</b>

**Note of BMRCL:**

**The completion cost as per BMRCL would be Rs.11014.00 crores and the year wise break up of investment is shown below.**

Figs in Rs. Cr.

Financial Year	Estimated Cost	Completion Cost
2012-13	834.34	1317.82
2013-14	1668.80	2305.97
2014-15	2085.40	2473.92



2015-16	1668.76	2078.26
2016-17	834.38	1091.38
2017-18	834.38	1145.37
2018-19	416.60	600.84
<b>Total</b>		

**Say 11014.00**

14.2.1.2 Although the construction is expected to get over by 31<sup>st</sup> March 2017, the cash flow spills up to March 2019 on account of payment normally required to be made to the various contractors up to that period necessitated by contractual clauses.

14.2.1.3 The land cost is divided in initial two years during which it is expected that the land acquisition work would be over and related payments would have to be released.

14.2.1.4 The escalation factor used is 5% p.a.

#### 14.2.2 Additional Investment

Total investment provided in the FIRR calculation towards requirement of additional rolling stock duly escalated @5% PA is placed in table 14.2 as under: -

**Table 14.2 Additional Investment towards Rolling Stock (Rs/Crore)**

<b>With Taxes &amp; Duties</b>			
<b>2021-22</b>		<b>2031-32</b>	
<b>No of Cars</b>	<b>Amount</b>	<b>No of Cars</b>	<b>Amount</b>
24	1161.00	48	1287.00

#### Operation & Maintenance (O&M) Costs

14.2.3.1 The Operation & Maintenance costs can be divided into three major parts: -

- (i) Staff costs
- (ii) Maintenance cost which include expenditure towards upkeep and maintenance of the system and consumables
- (iii) Energy costs



The staff is assumed to be provided @ 35 persons per kilometre. The escalation factor used for staff costs is 9% per annum to provide for both escalation and growth in salaries.

The cost of other expenses is based on the actual O & M unit cost for the Delhi Metro Phase-2 project. The rate of electricity assumed in the Delhi Metro study is about Rs. 3.80 per unit whereas at present in Bengaluru the applicable rate is Rs. 4.00 per unit. The latter has been used for all calculations. The O&M cost (excluding staff cost) has been obtained by providing an escalation of 5% per annum towards energy cost, 5% towards Maintenance cost.

14.2.3.4 The total O&M cost of both the corridors have been tabulated in Table 14.3 as below:

**Table 14.3 Operation and Maintenance Costs**

Figs in Rs. Cr.

YEAR			Staff	Mainten nce Expenses	Energy	Total
2016	-	2017	57.93	29.94	6.77	94.64
2017	-	2018	63.14	31.44	7.11	101.69
2018	-	2019	68.82	33.01	7.46	109.30
2019	-	2020	75.02	34.66	7.84	117.52
2020	-	2021	81.77	36.39	8.61	126.77
2021	-	2022	89.13	38.21	9.04	136.38
2022	-	2023	97.15	40.12	9.49	146.76
2023	-	2024	105.89	42.13	9.97	157.99
2024	-	2025	115.42	44.24	10.47	170.12
2025	-	2026	125.81	46.45	11.00	183.25
2026	-	2027	137.13	48.77	11.55	197.45
2027	-	2028	149.48	51.21	12.13	212.81
2028	-	2029	162.93	53.77	12.74	229.43
2029	-	2030	177.59	56.46	13.37	247.42
2030	-	2031	193.57	59.28	17.34	270.20
2031	-	2032	211.00	62.24	18.21	291.45
2032	-	2033	229.99	65.36	19.12	314.46
2033	-	2034	250.68	68.62	20.08	339.39
2034	-	2035	273.25	72.05	21.09	366.39
2035	-	2036	297.84	75.66	22.15	395.65
2036	-	2037	324.64	79.44	23.26	427.34
2037	-	2038	353.86	83.41	24.42	461.69
2038	-	2039	385.71	87.58	25.64	498.93
2039	-	2040	420.42	91.96	26.93	539.31
2040	-	2041	458.26	96.56	31.23	586.05
2041	-	2042	499.50	101.39	32.80	633.69



#### 14.2.4 Depreciation

Although depreciation does not enter the FIRR calculation (not being a cash outflow) unless a specific depreciation reserve fund has been provided, in the present calculation, depreciation calculations are placed for purpose of record.

#### 14.2.5 Replacement Cost

The replacement costs are provided for meeting the cost on account of replacement of equipment due to wear and tear. With the nature of equipment proposed to be provided, it is expected that only 50% of the Signalling and Telecom and 25% of electrical works would require replacement after 20 years. Further, 50% of the Signalling and Telecom and 25% of electrical works would require replacement after 30 years. These costs have been provided duly escalated @ 5% per annum.

### 14.3 Revenues

The Revenue of Bangalore metro mainly consists of fare box collection and other incomes from property development, advertisement, parking etc.

#### 14.3.1 Fare box

The Fare box collection is the product of projected ridership per day and applicable fare structure based on trip distribution at different distance zones.

#### **Note of BMRCL:**

***The Fare box revenue as calculated by BMRCL works to Rs.220.54 crores. This is based on average fare of BMRCL, with 5% escalation every year.***

#### 14.3.2 Traffic

14.3.1.1 a. The projected ridership figures years are as indicated in table 14.4 as below: -

**Table 14.4 Projected Ridership**

Year	Trips per day (lakhs)
2016-17	2.75
2021-22	4.03
2031-32	5.58
2041-42	6.19



14.3.1.1 b. The corridor-wise growth rate for traffic is assumed at 11% Per Annum up to 2021-22, @ 2.75% upto 2031-32 and thereafter @ 1.50% per annum.

#### 14.3.1.2 Trip Distribution

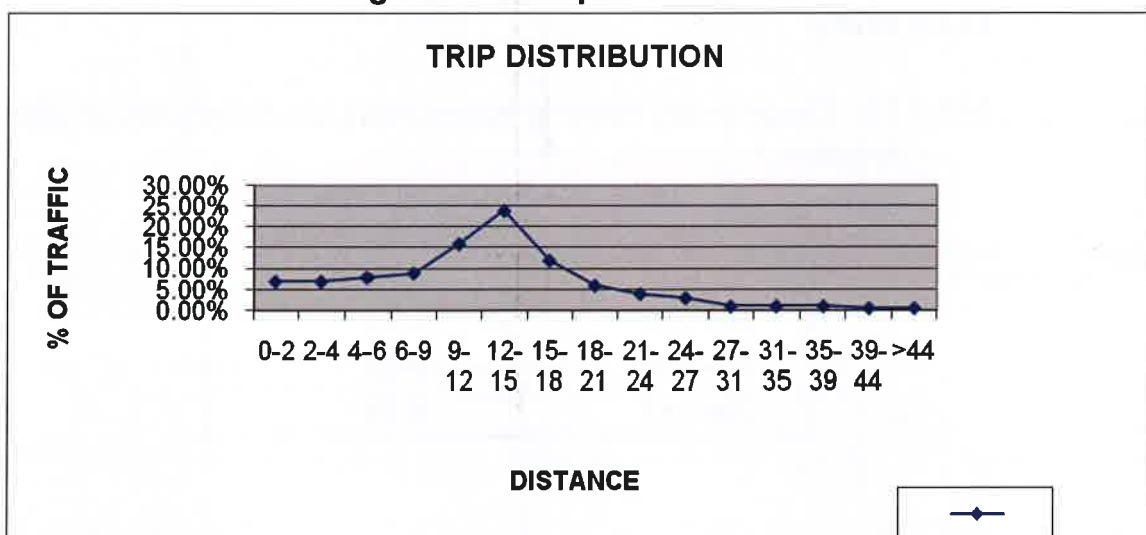
The trip distribution has been worked out by considering average lead of 12.40 KM, which is placed in Table 14.5 below: -

**Table 14.5 Trip Distribution**

Distance in kms.	Percent distribution
0-2	7.00%
2-4	7.00%
4-6	8.00%
6-9	9.00%
9-12	16.00%
12-15	24.00%
15-18	12.00%
18-21	6.00%
21-24	4.00%
24-27	3.00%
27-31	1.00%
31-35	1.00%
35-39	1.00%
39-44	0.50%
>44	0.50%
Total	100.00%

The graphic presentation of the same is placed below in Figure-14.1.

**Figure 14.1 –Trip Distribution**



Fare Structure



The Delhi Metro Fares structures as fixed by a fare fixation committee in 2009 have been assumed, which have been duly escalated @5% for every two years, which is placed in table 14.6.

**Table 14.6 Fare Structure in 2017-18**

<b>Distance in kms.</b>	<b>Metro Fare (Rs.)</b>
0-2	9.00
2-4	12.00
4-6	14.00
6-9	18.00
9-12	19.00
12-15	21.00
15-18	23.00
18-21	25.00
21-24	26.00
24-27	27.00
27-31	30.00
31-35	32.00
35-39	33.00
39-44	34.00
>44	36.00

**Note of BMRCL:**

**The fares fixed by BMRCL are as shown below.**

<b>Dist km</b>	<b>Fare</b>
<b>1</b>	<b>10.00</b>
<b>2</b>	<b>10.00</b>
<b>3</b>	<b>12.00</b>
<b>4</b>	<b>12.00</b>
<b>5</b>	<b>14.00</b>
<b>6</b>	<b>14.00</b>
<b>7</b>	<b>15.00</b>
<b>8</b>	<b>17.00</b>
<b>9</b>	<b>17.00</b>
<b>10</b>	<b>19.00</b>
<b>11</b>	<b>19.00</b>
<b>12</b>	<b>21.00</b>
<b>13</b>	<b>21.00</b>
<b>14</b>	<b>23.00</b>
<b>15</b>	<b>23.00</b>
<b>16</b>	<b>25.00</b>
<b>17</b>	<b>26.00</b>
<b>18</b>	<b>27.00</b>





<b>19</b>	<b>28.00</b>
<b>20</b>	<b>29.00</b>
<b>21</b>	<b>30.00</b>
<b>22</b>	<b>31.00</b>
<b>23</b>	<b>32.00</b>
<b>24</b>	<b>33.00</b>
<b>25</b>	<b>34.00</b>

### 14.3.1 Other sources of revenues

Other revenues from Property Development and advertisement have been estimated at 10% of the fare box revenues during operations. Apart from development of property on metro stations and depot it is possible to raise resources through leasing of parking rights at stations, advertisement on trains and tickets, advertisements within stations and parking lots, advertisements on viaducts, columns and other metro structures, co-branding rights to corporates, film shootings and special events on metro premises. The FIRR is negative if additional residual rental income as detailed in the table 14.7 accrue from Property Development is not considered. Therefore, the State Government should provide sufficient land for PD activity to the Bangalore Metro Phase-II as detailed below: -

Bangalore Metro requires 20 Hectors of lands for the proposed corridor, which can be exploited for Real Estate Development with the involvement of established Developers. The property development models can be designed in a way that not only the upfront receipts but also the regular receipts in the development of lease rentals can be ensured to supplement the fare box collection and reduce the fare structure.

The SPV i.e., BMRC will give the land free of cost to the developer or develop the same on its own. The developer will bring equity to the extent of Rs.361 crore and the balance amount towards construction and upfront money to be given to JMRC as 12% Market Debt. The estimated development cost will be Rs.361 crore. It is assumed that the rental revenue (assumed @ Rs. 70/Sq. ft.) will accrue to the developer from the FY 2017-18 which has been escalated @2.5% every year. Out of the estimated rental income, apart from meeting maintenance expenditure, the developer will repay the loan and interest. After meeting these obligations and retaining 14% return on his equity with an escalation @5% every year, the residual rental earnings will accrue to JMRC, which has been taken into account in the FIRR calculations.



The details of PD income accrue to JMRC is tabulated as under; -

**Table 14.7 Estimated generation of Rental Income from PD  
(Rs/Crore)**

Year			Const ructio n cost	Rental Income	Mainte nance Expen diture	Loan	IDC	Loan repa yme nt	Bal Loan Amo unt	Inter est on Loan @15 %	Return @14% to the develo per	Residual rental income to LMRC
2012	-	2013	0			0	0		0		-180.5	
2013	-	2014	0			0	0		0		-180.5	
2014	-	2015	458			278	17		295			
2015	-	2016	481			578	53		631			
2016	-	2017	505			1083	108		1191			0
2017	-	2018		52	5	0	0	0	1191	143	36	-132
2018	-	2019		105	11			0	1191	143	38	-87
2019	-	2020		165	17			79	1112	143	40	-114
2020	-	2021		225	45			79	1033	133	42	-74
2021	-	2022		288	58			79	954	124	44	-17
2022	-	2023		296	59			79	875	114	46	-2
2023	-	2024		364	73			79	796	105	48	59
2024	-	2025		435	87			79	717	96	50	123
2025	-	2026		509	102			79	638	86	53	189
2026	-	2027		588	118			79	559	77	56	258
2027	-	2028		669	134			79	480	67	59	330
2028	-	2029		686	137			79	401	58	62	350
2029	-	2030		703	141			79	322	48	65	370
2030	-	2031		721	144			79	243	39	68	391
2031	-	2032		739	148			79	164	29	71	412
2032	-	2033		757	151			79	85		75	452
2033	-	2034		776	155			85	0		79	457
2034	-	2035		795	159						83	553
2035	-	2036		815	163						87	565
2036	-	2037		836	167						91	578
2037	-	2038		857	171						96	590
2038	-	2039		878	176						101	601
2039	-	2040		900	180						106	614
2040	-	2041		922	184						111	627
2041	-	2042		945	189						117	639
<b>Total</b>			<b>1444</b>	<b>15026</b>	<b>2974</b>	<b>1939</b>	<b>178</b>	<b>1191</b>		<b>1405</b>	<b>1724</b>	<b>7732</b>

#### 14.4 Financial Internal Rate of Return (FIRR)

The FIRR with Central taxes only is produced in Table 14.8.



**Table 14.8 FIRR:**

Particulars	Completion Cost With Central Taxes (Without additional PD)	FIRR (%) - Completion Cost With Central Taxes (With Additional PD income from 20 Ha.)
Option-I	Net Cash Flow Negative by Rs.7116 Crore	0.40%
Option-II	Net Cash Flow Negative by Rs.8053 Crore	-0.20%

**Note of BMRCL:**

**On the basis of revised cost and the BMRCL's estimated fare box revenue of Rs.220.54 crores + property development revenue as in DPR, the FIRR works to 4.41% (This is after taking into consideration the full additional cost of Rolling Stock + Replacement cost as in DPR).**

**The FIRR as per cost estimate for option – 2 will be .....%**

14.4.1 The Financial Internal Rate of Return (FIRR) obtained with the above revenues and costs for 30 years are placed in table 14.9: -

**Table 14.9 –FIRR (with Central taxes)**

**Option-I**

**Figs in cr. (Rs.)**

Year		Outflow				Inflow			Net Cash Flow	
		Completion Cost	Additional Cost	Running Expenses	Replac e-ment costs	Total Costs	Fare Box Revenue	PD & ADVT	Total Revenue	IRR
2012	- 2013	890		0		890	0	0	0	-890
2013	- 2014	1720		0		1720			0	-1720
2014	- 2015	2077		0		2077			0	-2077
2015	- 2016	1745		0		1745			0	-1745
2016	- 2017	917		95		1012	197.81	20	218	-794
2017	- 2018	963		102		1065	219.57	-110	110	-955
2018	- 2019	503		109		612	256.11	-61	195	-417
2019	- 2020	0	0	118		118	284.29	-86	199	81
2020	- 2021	0	0	127		127	319.26	-42	277	150
2021	- 2022	0	396	136		532	328.04	16	344	-188
2022	- 2023	0	0	147		147	352.67	33	386	239
2023	- 2024	0	0	158		158	362.37	95	458	300
2024	- 2025	0	0	170		170	389.32	162	551	381



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2025 - 2026	0	0	183		183	400.03	229	629	446
2026 - 2027	0	0	197		197	429.70	301	731	534
2027 - 2028	0	0	213		213	441.52	374	816	603
2028 - 2029	0	0	229		229	474.49	397	872	643
2029 - 2030	0	0	247		247	487.54	419	906	659
2030 - 2031	0	0	270		270	552.07	446	998	728
2031 - 2032	0	1287	291		1578	560.35	468	1028	-549
2032 - 2033	0	0	314		314	595.39	512	1107	793
2033 - 2034	0	0	339		339	604.32	518	1122	783
2034 - 2035	0	0	366		366	640.97	617	1258	892
2035 - 2036	0	0	396		396	650.58	630	1281	885
2036 - 2037	0	0	427	1735	2162	694.62	647	1342	-820
2037 - 2038	0	0	462	1822	2284	705.04	661	1366	-918
2038 - 2039	0	0	499		499	740.10	675	1415	916
2039 - 2040	0	0	539		539	740.10	688	1428	889
2040 - 2041	0	0	586		586	778.47	705	1483	897
2041 - 2042	0	0	634		634	790.15	718	1508	874
<b>Total</b>	<b>8815</b>	<b>1683</b>	<b>7354</b>	<b>3557</b>	<b>21409</b>	<b>12995</b>	<b>9032</b>	<b>22028</b>	<b>0.40%</b>

**Option-II**

**Figs in cr. (Rs.)**

Year	Outflow					Inflow			Net Cash Flow
	Completion Cost	Additional Cost	Running Expenses	Replacement costs	Total Costs	Fare Box Revenue	PD & ADVT	Total Revenue	IRR
2012 - 2013	1123		0		1123	0	0	0	-1123
2013 - 2014	1965		0		1965			0	-1965
2014 - 2015	2108		0		2108			0	-2108
2015 - 2016	1771		0		1771			0	-1771
2016 - 2017	930		99.00		1029	197.81	20	218	-811
2017 - 2018	976		107.00		1083	219.57	-110	110	-973
2018 - 2019	512		115.00		627	256.11	-61	195	-432
2019 - 2020	0	0	123.00		123	284.29	-86	199	76
2020 - 2021	0	0	133.00		133	319.26	-42	277	144
2021 - 2022	0	396	143.00		539	328.04	16	344	-195
2022 - 2023	0	0	154.00		154	352.67	33	386	232
2023 - 2024	0	0	166.00		166	362.37	95	458	292
2024 - 2025	0	0	178.00		178	389.32	162	551	373
2025 - 2026	0	0	192.00		192	400.03	229	629	437
2026 - 2027	0	0	207.00		207	429.70	301	731	524
2027 - 2028	0	0	223.00		223	441.52	374	816	593
2028 - 2029	0	0	241.00		241	474.49	397	872	631
2029 - 2030	0	0	260.00		260	487.54	419	906	646
2030 - 2031	0	0	284.00		284	552.07	446	998	714
2031 - 2032	0	1287	306.00		1593	560.35	468	1028	-564
2032 - 2033	0	0	330.00		330	595.39	512	1107	777
2033 - 2034	0	0	356.00		356	604.32	518	1122	766
2034 - 2035	0	0	385.00		385	640.97	617	1258	873
2035 - 2036	0	0	415.00		415	650.58	630	1281	866



2036	-	2037	0	0	449.00	1735	2184	694.62	647	1342	-842
2037	-	2038	0	0	485.00	1822	2307	705.04	661	1366	-941
2038	-	2039	0	0	524.00		524	740.10	675	1415	891
2039	-	2040	0	0	567.00		567	740.10	688	1428	861
2040	-	2041	0	0	616.00		616	778.47	705	1483	867
2041	-	2042	0	0	666.00		666	790.15	718	1508	842
Total			9385	1683	7724	3557	22349	12995	9032	22028	-0.20%

The various sensitivities with regard to increase/decrease in capital costs, O&M costs and revenues are placed in Table 14.10 below :-

**Table 14.10 –FIRR Sensitivity**

**Option-I**

<b>CAPITAL COSTS with Central Taxes</b>			
10% increase in capital cost	20% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
-0.17%	-0.67%	1.03%	1.75%
<b>REVENUE</b>			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue
-1.51%	-0.49%	1.18%	1.88%
<b>O&amp;M COSTS</b>			
10% increase in O&M cost		10% decrease in O&M cost	
-0.08%		0.84%	

**Option-II**

<b>CAPITAL COSTS with Central Taxes</b>			
10% increase in capital cost	20% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
-0.76%	-1.26%	0.42%	1.14%
<b>REVENUE</b>			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue



-2.17%	-1.11%	0.59%	1.31%
<b>O&amp;M COSTS</b>			
10% increase in O&M cost		10% decrease in O&M cost	
-0.72%		0.27%	

These sensitivities have been carried out independently for each factor.

### 14.5 Financing Options

**Objectives of Funding:** - The objective of funding metro systems is not necessarily enabling the availability of funds for construction but coupled with the objective of financial closure are other concerns, which are of no less importance: -

- Ensuring low project cost
- Ensuring debt funds at low rates of interest
- Creating self sustainable system in the long run by
  - Low infrastructure maintenance costs
  - Longer life span
  - Setting fares which minimise dependence on subsidies
- Recovering returns from both direct and indirect beneficiaries

Rail based mass transit systems are characterised by heavy capital investments coupled with long gestation period leading to low financial rates of return although the economic benefits to the society are immense. Such systems generate externalities, which do not get captured in monetary terms and, therefore, do not flow back to the system. However, experience all over the world reveals that both construction and operations of metro are highly subsidised. Government involvement in the funding of metro systems is a foregone conclusion. Singapore had a 100% capital contribution from the government, Hong Kong 78% for the first three lines and 66% for the later 2 lines.

#### 14.5.1 ALTERNATIVE MODELS OF FINANCING

14.5.2 The financing option shall depend upon selection of the dedicated agency created to implement the project. The prominent models are: -

- (i) Special Purpose Vehicle under the State Control (Delhi Metro Rail Corporation (Metro model)
- (ii) Public-Private Partnership (PPP) mode
  - Built Operate and Transfer (BOT) model
  - Other PPP Model



- a) **DMRC/BMRC/CMRC pattern of Financing:** - A Special Purpose Vehicle (SPV) is set up for the implementation of the project and for its subsequent Operation & Maintenance. Under this arrangement Government of India and Government of Karnataka shall make equal equity contribution and run SPV as a commercial enterprise. As per the prevalent practice, Central Government may be willing to contribute 20% of the project cost as their equity contribution. An equal amount can be contributed by Government of Karnataka aggregating the total equity to 40%. With the equal ownership of the SPV, both the governments nominate their representatives as members of the Board of Directors, which in turn select functional directors. Such a SPV has a benefit of independent management under the aegis of Indian Companies Act, 1956. Delhi Metro Rail Corporation is a shining example of success of such a SPV. For the balance 60% funding requirement, options available are as follows: -

**(i) Subordinate Debt:** - For Delhi Metro, land and rehabilitation and resettlement cost have been borne by GOI & GNCTD equally as interest free subordinate debt. Now, MOUD have changed the policy under which the cost of land for Bangalore and Chennai has been borne by Government of Karnataka and Tamilnadu as interest free subordinate debt. Similarly, the cost of Land amounting to Rs.272.00 Crore under option-I & Rs.716.00 Crore under option-II has to be contributed as interest free subordinate debt by Government of Karnataka. This mezzanine financing is of extreme help in quickening the pace of land acquisition, since the compensation amount is released to evacuate instantaneously. The loan is of longer duration and becomes repayable only after other loans raised for the project is repaid.

**(ii) Debt:** - The balance cost is to be met through loans from various institutions namely JICA, Local borrowing, loans from ADB/World Bank and Suppliers Credit.

**JICA Loan:** - The total amount of loan required is Rs. 4120 Crore under option-I and Rs. 4016 Crore under option-II. Overseas Development Loan from Japan International Cooperation Agency (JICA) can be availed of for metro rail projects with interest rate @ 1.40% PA. The loan is repayable in 30 years including moratorium period of 10 years. The loan is to be provided to Central Government





which in turn releases the same to SPV under a Pass Through Assistance (PTA) mechanism. Normally, JICA agrees to fund for underground civil works, Electrical, Signalling & Telecom and Rolling Stock only. Since the loan will be in Japanese Yen any fluctuation in exchange rate at the time of repayment shall be borne by the Government of Karnataka in line with recent guidelines of Department of Economic Affairs of Ministry of Finance, GOI. Alternatively, JICA can release the loan to the SPV for which a sovereign guarantee will be required from Central Government. Foreign exchange variation in such eventuality will be borne by the SPV. The State Government need to hedge the foreign currency fluctuation so minimise its loss. In either case loan shall be repaid by SPV from the income streams of metro operations.

**Loan from Asian Development Bank (ADB)/World Bank:** - The Loan shall be available from ADB/World Bank, but as per the experience its processing and approval normally takes 8-12 months. This may delay the implementation of the project resulting in avoidable increase in the completion cost.

**Loan from Bank and Financial Institutions:** - Funds can be arranged from Indian Financial Institutions like India Infrastructure Finance Company Limited (IIFCL), India Development Financing Corporation (IDFC), Life Insurance Corporation of India (LIC), IDBI Bank, ICICI Bank Ltd etc. These institutions are increasingly engaged to fund infrastructure projects subject to their commercial viability. There are many models available under which the funds can be arranged by these financial institutions with or without syndicating with other commercial banks. IIFCL e.g. fund 20% of the project cost and arrange balance through the syndication of commercial banks with a lead banker among the consortium of bankers. Also, IIFCL funds full loan requirement subject to approval by the Board/their Empowered Committee. The loan can be given for a period of 20-30 years with interest rate ranging from 9.50% to 12% PA. The funding arrangement may require submission of central government guarantee as well. Since the rate of interest of these financial institutions is much higher than the interest rates of soft loan provided by JICA, Central Government and Government of Karnataka shall have to bear the interest difference and provide suitable subsidy to the SPV.



**Suppliers Credit:** - Suppliers Credit is an established method to secure funding of imports. It is backed by EXIM banks of exporting countries and is often a much better instrument than bilateral aid. While bilateral aid ties the borrowing entity, Suppliers Credit can be used intelligently and effectively to spur competition in competitive international tendering method. In case of Rolling Stock, where market is truly competitive (unlike S&T) an attractive rate of interest for suppliers credit is possible. However, the supplier will load the amount of interest in cost of supply due to which the effective completion cost will be very high.

**Note of BMRCL:**

**Appropriate decision will be taken by the Govt. regarding alternate modes of financing.**

14.5.2 The funding pattern assumed under this model (SPV) is placed in table 14.11 as under: -

**Table 14.11 Funding pattern under DMRC model (with central taxes)**

**Option-I**

Particulars	Government of India		Government of Karnataka		Total	
	%	Rs/Crore	%	Rs/Crore	%	Rs/Crore
Equity by GOI & GO Karnataka	20%	1764.00	20%	1764.00	40%	3528.00
SD for land cost by GO Karnataka	0%	0.00	3%	272.00	3%	272.00
Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	8%	717.00	2%	178.00	10%	895.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	47%	4120.00	0%	0.00	47%	4120.00
<b>Total</b>	<b>75.00%</b>	<b>6601.00</b>	<b>25.00%</b>	<b>2214.00</b>	<b>100.00%</b>	<b>8815.00</b>

**Option-II**

Particulars	Government of India		Government of Karnataka		Total	
	%	Rs/Crore	%	Rs/Crore	%	Rs/Crore
Equity by GOI & GO Karnataka	20%	1878.00	20%	1878.00	40%	3756.00



SD for land cost by GO Karnataka	0%	0.00	8%	716.00	8%	716.00
Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	8%	717	2%	180.00	10%	897.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	42%	4016.00	0%	0.00	42%	4015.00
<b>Total</b>	<b>70.00%</b>	<b>6611.00</b>	<b>30.00%</b>	<b>2774.00</b>	<b>100.00%</b>	<b>9385.00</b>

**Note of BMRCL:**

**As per BMRCL, the sharing pattern of capital cost would be as given below**

	<b>GOK</b>	<b>GOI</b>	<b>Fin. Institutions</b>
<b>Equity</b>	<b>15%</b>	<b>15%</b>	
<b>Sub debt</b>	<b>15%</b>	<b>10%</b>	
<b>Sr Term debt</b>			<b>45%</b>

**The completion cost of BMRCL will be Rs.11014.00 Cr.**

**14.5.4 Public Private Partnership:** - Public Private Partnership (PPP) arrangements are steadily growing in use particularly in road, power, and telecom sectors which are more of commercial nature rather than in a social sector project. PPP models are arrayed across a spectrum ranging from BOT where the private sectors have total involvement to other tailor made models where both public and private sector assume separate responsibilities. BOT model is explained as under-

**14.5.5 BOT Model:** - In this model, the private firm will be responsible for financing, designing, building, operating and maintaining of the entire project. The contribution of Government of Karnataka will be limited to cost of land only. Such a project become eligible for Viability Gap Funding (VGF) upto 20% from the Central Government provided the state government also contribute same or more amount towards the project. The metro being a social sector project not much private parties are available to bid for such a project. Besides quite expectedly the private operator may demand assured rate of return in the range of 16% to 18% or a comfort of guaranteed ridership.

**14.5.6** The funding pattern assumed under this model including the cost of land to ensure 16% post tax return on operators equity i.e. Equity



Internal Rate of Return (EIRR) is placed in table 14.12 tabulated as under: -

**Table 14.12 Funding pattern under BOT model  
(With central taxes but excluding state taxes)**

**Option-I**

Particulars	% Of contribution	Amount (Rs/Crore)
VGF by GOI 20% (Excluding Land Cost)	20%	1764.00
VGF by Karnataka State Government	60%	5304.00
Land to be provided free of cost by State	3%	272.00
Equity by Concessionaire	6%	492.00
Concessionaire's debt @11% PA	11%	983.00
<b>Total</b>	<b>100%</b>	<b>8815.00</b>

**Option-II**

Particulars	% Of contribution	Amount (Rs/Crore)
VGF by GOI 20% (Excluding Land Cost)	20%	1764.00
VGF by Karnataka State Government	59%	5570.00
Land to be provided free of cost by State	7%	716.00
Equity by Concessionaire	5%	445.00
Concessionaire's debt @11% PA	9%	890.00
<b>Total</b>	<b>100%</b>	<b>9385.00</b>

**14.6.1 Recommendations: -**

**Option-I:-**The FIRR of subject metro with taxes is 0.40% & the cumulative cash balance at the end of 30 years (including construction period) is positive to the extent of Rs.4281 crore with JICA loan and with market borrowing @11% per annum is Rs.32 crore after meeting all the operational expenses, interest payment and repayment of loan. Hence, the corridors are recommended for implementation.



**Option-II:-**The FIRR of subject metro with taxes is -0.20% & the cumulative cash balance at the end of 30 years (including construction period) is positive to the extent of Rs.4044 crore with JICA loan and with market borrowing @11% per annum is Rs.(-)25 crore after meeting all the operational expenses, interest payment and repayment of loan.

**Therefore, option-I with FIRR 0.40% is recommended for implementation i.e. the depot to be constructed on tank bed at Hulimavu (Govt land).**

**14.6.2 Option-I:-**The total contribution of GOI & Government of Karnataka under the SPV model excluding PTA to be repaid latter is Rs.4696 Crore only (excluding state taxes to be exempted of Rs.356 Crore at Jan-2011 level) as against Rs. 7340 crore under BOT model. Since the Bangaluru Metro is primarily a social project and the total contribution of funds to be made by GOI and Karnataka Government is less under SPV model, it is recommended that it should be implemented by the existing SPV.

**Option-II:-**The total contribution of GOI & Government of Karnataka under the SPV model excluding PTA to be repaid latter is Rs.5370 Crore only (excluding state taxes to be exempted of Rs.362 Crore at Jan-2011 level) as against Rs. 8050 crore under BOT model. Since the Bangaluru Metro is primarily a social project and the total contribution of funds to be made by GOI and Karnataka Government is less under SPV model, it is recommended that it should be implemented by the existing SPV.

**Note of BMRCL:**

***Appropriate decision will be taken by the State Govt. in this regard.***

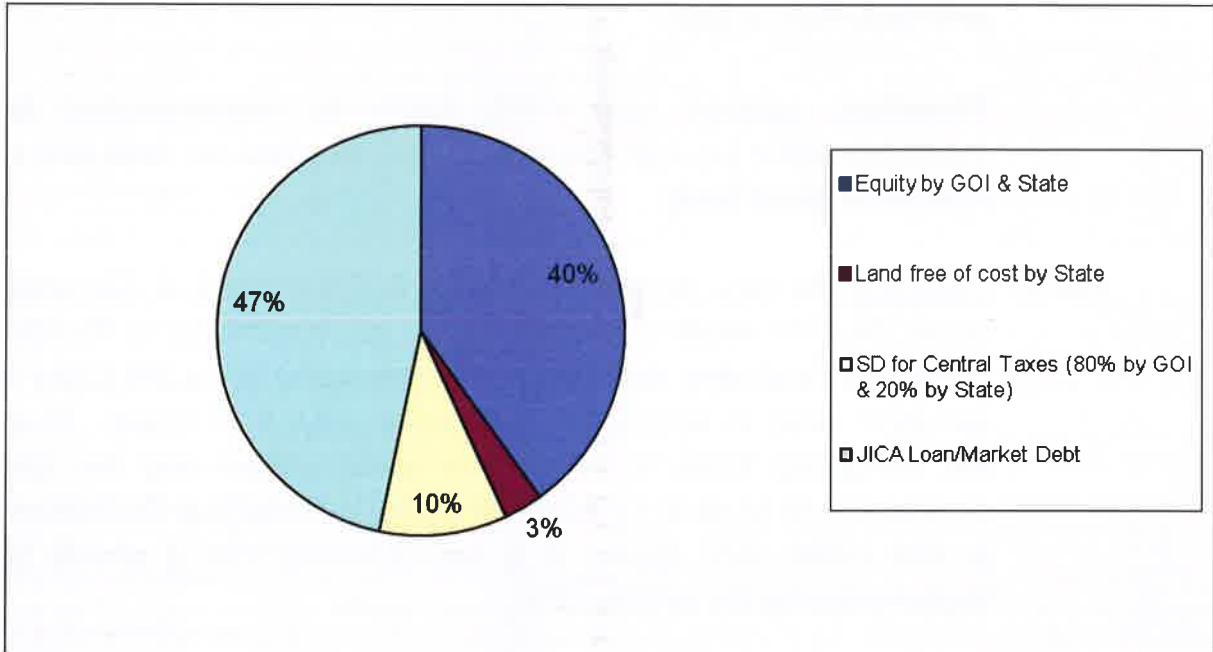
**14.6.3** The details showing cash flow under JICA Loan, Market Borrowing and BOT model when the project cost is with central taxes only are shown respectively in table 14.13.1, 14.13.2 and 14.13.3. The cash flow of PD is shown in table 14.13.4 and with JICA Loan without additional PD is shown in table 14.13.5.



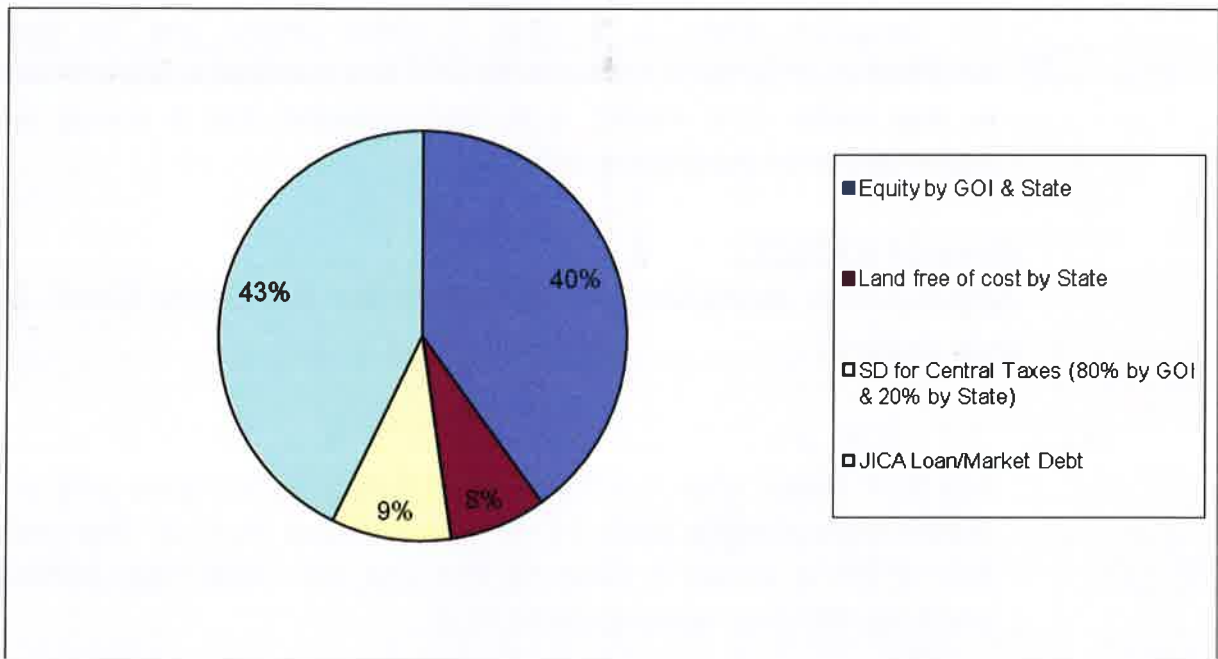
14.6.4 The funding pattern assumed under DMRC/BMRC/CMRC model is depicted in the pie chart i.e., Figure 14.2 as under.

Fig 14.2

**Option-I**



**Option-II**



Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option I											WITH CENTRAL TAXES ONLY											Table 14.13.1		
CAPITAL COST-FIXED				7277																			1.40%	
CAPITAL COST - CURRENT				8815																				
Year	Completion Cost	Additional Capital	Running Expenses	DEPREC IATION	REPLACEM ENT COSTS	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT	TOTAL REVENUE	NET CASH FLOW FOR IRR	Funds other than loan i.e., Equity & SD	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl. IDC	INTERE ST	PROFIT BEFORE TAX	CASH BALANCE S	CUMULATI VE CASH		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23		
2012 - 2013	890		0	0		890	0	0	0	-890	1289	399	399	0	0	0	0.00	0			399	399		
2013 - 2014	1720		0	0		1720			0	-1720	1289	-431	-32	32	32	0	0.00	32	0		-399	0		
2014 - 2015	2077		0	0		2077			0	-2077	705	-1372	-1404	1404	1372	0	10.28	1414	0		0	0		
2015 - 2016	1745		0	0		1745			0	-1745	705	-1040	-2444	2444	1040	0	27.08	2481	0		0	0		
2016 - 2017	917		95	256.00		1012	197.81	20	218	-794	707	-210	-2654	2654	210	0	36.21	2728	0	-133	123	123		
2017 - 2018	963		102	256.00		1065	219.57	-110	110	-955	0	-963	-3617	3617	963	0	44.93	3735	0	-248	8	130		
2018 - 2019	503		109	256.00		612	256.11	-61	195	-417	0	-503	-4120	4120	503	0		4238	56	-226	30	160		
2019 - 2020	0	0	118	256.00		118	284.29	-86	199	81	0	0	-4120	4120	0	0		4238	59	-235	21	181		
2020 - 2021	0	0	127	256.00		127	319.26	-42	277	150	0	0	-4120	4120	0	0		4238	59	-165	91	272		
2021 - 2022	0	396	136	256.00		532	328.04	16	344	-188	0	0	-4120	4120	0	0		4238	59	-107	-247	25		
2022 - 2023	0	0	147	256.00		147	352.67	33	386	239	0	0	-4120	4120	0	212		4238	59	-76	-32	-7		
2023 - 2024	0	0	158	256.00		158	362.37	95	458	300	0	0	-4120	4120	0	212		4027	59	-16	28	21		
2024 - 2025	0	0	170	256.00		170	389.32	162	551	381	0	0	-4120	4120	0	212		3815	56	69	113	134		
2025 - 2026	0	0	183	256.00		183	400.03	229	629	446	0	0	-4120	4120	0	212		3603	53	137	181	315		
2026 - 2027	0	0	197	256.00		197	429.70	301	731	534	0	0	-4120	4120	0	212		3391	50	227	271	586		
2027 - 2028	0	0	213	256.00		213	441.52	374	816	603	0	0	-4120	4120	0	212		3179	47	299	343	929		
2028 - 2029	0	0	229	256.00		229	474.49	397	872	643	0	0	-4120	4120	0	212		2967	45	342	387	1316		
2029 - 2030	0	0	247	256.00		247	487.54	419	906	659	0	0	-4120	4120	0	212		2755	42	362	406	1722		
2030 - 2031	0	0	270	256.00		270	552.07	446	998	728	0	0	-4120	4120	0	212		2543	39	434	478	2199		
2031 - 2032	0	1287	291	256.00		1578	560.35	468	1028	-549	0	0	-4120	4120	0	212		2331	36	446	-797	1402		
2032 - 2033	0	0	314	256.00		314	595.39	512	1107	793	0	0	-4120	4120	0	212		2119	33	504	548	1951		
2033 - 2034	0	0	339	256.00		339	604.32	518	1122	783	0	0	-4120	4120	0	212		1907	30	497	541	2492		
2034 - 2035	0	0	366	256.00		366	640.97	617	1258	892	0	0	-4120	4120	0	212		1695	27	609	653	3145		
2035 - 2036	0	0	396	256.00		396	650.58	630	1281	885	0	0	-4120	4120	0	212		1483	24	605	649	3794		
2036 - 2037	0	0	427	308.05	1735	2162	694.62	647	1342	-820	0	0	-4120	4120	0	212		1272	21	586	-1053	2742		
2037 - 2038	0	0	462	362.71	1822	2284	705.04	661	1366	-918	0	0	-4120	4120	0	212		1060	18	523	-1148	1594		
2038 - 2039	0	0	499	362.71		499	740.10	675	1415	916	0	0	-4120	4120	0	212		848	15	539	689	2283		
2039 - 2040	0	0	539	362.71		539	740.10	688	1428	889	0	0	-4120	4120	0	212		636	12	515	665	2948		
2040 - 2041	0	0	586	362.71		586	778.47	705	1483	897	0	0	-4120	4120	0	212		424	9	526	676	3625		
2041 - 2042	0	0	634	362.71		634	790.15	718	1508	874	0	0	-4120	4120	0	212		212	6	506	656	4281		
	<b>8815</b>	<b>1683</b>	<b>7354</b>	<b>7242</b>	<b>3557</b>	<b>21409</b>	<b>12995</b>	<b>9032</b>	<b>22027</b>	<b>0.40%</b>	<b>4695</b>				<b>4120</b>	<b>4238</b>	<b>118</b>	<b>71849</b>	<b>913</b>	<b>6518</b>	<b>4281</b>			
<b>Funding Pattern</b>																								
	Items	GOI	State	Total	%																			
	Equity by GOI & State	1764	1764	3528	40.02%																			
	Land free of cost by State	0	272	272	3.09%																			
	SD for Central Taxes (B)	717	179	896	10.16%																			
	JICA Loan/Market Debt	4120	0	4120	46.73%																			
	<b>Total</b>	<b>6601</b>	<b>2215</b>	<b>8816</b>	<b>100.00%</b>																			



Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option I											WITH CENTRAL TAXES ONLY							Table 14.13.2				
CAPITAL COST-FIXED					7277													11.00%				
CAPITAL COST - CURRENT					8815																	
Year	Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT COSTS	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT	TOTAL REVENUE	NET CASH FLOW FOR IRR	Funds other than loan i.e., Equity & SD	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl. IDC	INTEREST	PROFIT BEFORE TAX	CASH BALANCES	CUMULATIVE CASH
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2012 - 2013	890		0	0		890	0	0	0	-890	1289	399	399	0	0	0	0.00	0			399	399
2013 - 2014	1720		0	0		1720			0	-1720	1289	-431	-32	32	32	0	0.00	32	0		-399	0
2014 - 2015	2077		0	0		2077			0	-2077	705	-1372	-1404	1404	1372	0	80.74	1485	0		0	0
2015 - 2016	1745		0	0		1745			0	-1745	705	-1040	-2444	2444	1040	0	220.52	2745	0		0	0
2016 - 2017	917		94.64	256.00		1012	197.81	20	218	-794	707	-210	-2654	2654	210	0	313.53	3269	0	-133	123	123
2017 - 2018	963		101.69	256.00		1065	219.57	-110	110	-955	0	-963	-3617	3617	963	0	412.53	4644	0	-248	8	131
2018 - 2019	503		109.30	256.00		612	256.11	-61	195	-418	0	-503	-4120	4120	503	0		5147	539	-709	-453	-322
2019 - 2020	0	0	117.52	256.00		118	284.29	-86	199	81	0	0	-4120	4120	0	515		5147	566	-741	-1000	-1322
2020 - 2021	0	0	126.77	256.00		127	319.26	-42	277	150	0	0	-4120	4120	0	515		4632	566	-672	-931	-2253
2021 - 2022	0	396	136.38	256.00		532	326.04	16	344	-188	0	0	-4120	4120	0	515		4117	510	-558	-1213	-3466
2022 - 2023	0	0	146.76	256.00		147	352.67	33	386	239	0	0	-4120	4120	0	515		3602	453	-470	-720	-4195
2023 - 2024	0	0	157.99	256.00		158	362.37	95	458	300	0	0	-4120	4120	0	515		3087	396	-353	-612	-4806
2024 - 2025	0	0	170.12	256.00		170	389.32	162	551	381	0	0	-4120	4120	0	515		2572	340	-214	-473	-5280
2025 - 2026	0	0	183.25	256.00		183	400.03	229	629	446	0	0	-4120	4120	0	515		2057	283	-93	-352	-5632
2026 - 2027	0	0	197.45	256.00		197	429.70	301	731	533	0	0	-4120	4120	0	515		1542	226	51	-208	-5840
2027 - 2028	0	0	212.84	256.00		213	441.52	374	816	603	0	0	-4120	4120	0	515		1027	170	177	-82	-5922
2028 - 2029	0	0	229.43	256.00		229	474.49	397	872	643	0	0	-4120	4120	0	512		512	110	274	17	-5905
2029 - 2030	0	0	247.42	256.00		247	487.54	419	908	659	0	0	-4120	4120	0	0		0	56	347	603	-5302
2030 - 2031	0	0	270.20	256.00		270	552.07	446	998	728	0	0	-4120	4120	0	0		0	0	472	728	-4574
2031 - 2032	0	1287	291.45	256.00		1578	560.35	468	1028	-550	0	0	-4120	4120	0	0		0	0	481	-550	-5124
2032 - 2033	0	0	314.46	256.00		314	595.39	512	1107	792	0	0	-4120	4120	0	0		0	0	536	792	-4332
2033 - 2034	0	0	339.39	256.00		339	604.32	518	1122	783	0	0	-4120	4120	0	0		0	0	527	783	-3549
2034 - 2035	0	0	366.39	256.00		366	640.97	617	1258	892	0	0	-4120	4120	0	0		0	0	636	892	-2657
2035 - 2036	0	0	395.65	256.00		396	650.58	630	1281	885	0	0	-4120	4120	0	0		0	0	629	885	-1772
2036 - 2037	0	0	427.34	308.05	1735	2162	694.62	647	1342	-820	0	0	-4120	4120	0	0		0	0	607	-820	-2593
2037 - 2038	0	0	461.69	362.71	1822	2284	765.04	661	1366	-918	0	0	-4120	4120	0	0		0	0	541	-918	-3511
2038 - 2039	0	0	498.93	362.71		499	740.10	675	1415	916	0	0	-4120	4120	0	0		0	0	553	916	-2595
2039 - 2040	0	0	539.31	362.71		539	740.10	688	1428	889	0	0	-4120	4120	0	0		0	0	526	889	-1706
2040 - 2041	0	0	586.05	362.71		586	778.47	705	1483	897	0	0	-4120	4120	0	0		0	0	535	897	-809
2041 - 2042	0	0	633.69	362.71		634	790.15	718	1508	874	0	0	-4120	4120	0	0		0	0	512	874	66
		<b>8815</b>	<b>1683</b>	<b>7356</b>	<b>7242</b>	<b>3557</b>	<b>21411</b>	<b>12995</b>	<b>9032</b>	<b>22027</b>	<b>0.40%</b>	<b>4695</b>			<b>4120</b>	<b>5147</b>	<b>1027</b>	<b>45621</b>	<b>4218</b>	<b>3211</b>	<b>66</b>	
<b>Funding Pattern</b>																						
Items																						
GOI																						
State																						
Total																						
%																						
Equity by GOI & State																						
Land free of cost by State																						
SD for Central Taxes (8)																						
PD																						
JICA Loan/Market Debt																						
Total																						

Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option I  
 Completion Cost (Total) 8815  
 CAPITAL COST - COMPLETION (Concessio 1475 Concess. Equity

**BOT (WITH CENTRAL TAX)**

**Table 14.13.3**

492

Grant

7340

83%

Market Loan 11.00%  
for Debt

Year	Completi on Cost	Additional Cost	Running Expenses	Depreciati on	Replacem ent Costs	Total Costs	Fare Box Revenue	PD & ADVT- Metro	Total Revenue	Net Cashflow for FIRR	Concessi on, Equity	Funds Available	govt support	Loan	Cumul Loan	IDC (Conce Loan)	Repaym entn of Loan	Repaym ent of Con Loan	Interest (Conces sionaire)	PBT	Cash Balances	Cumulativ e cash	Return on Equity - PRE TAX	Tax on Profit @33.99 %	Equity IRR		
1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	22	23	24	26	27	28	29	30	31		
2012 - 2013	156.00				0.00	890.00	0.00	0.00	0.00	-890.00	123.00	-33.00	0.00	33.00	33.00	0.00	0.00				0.00		-123.00		-123.00		
2013 - 2014	252.00				0.00	1720.00	0.00	0.00	0.00	-1720.00	123.00	-162.00	0.00	129.00	162.00	3.63	0.00				0.00		-123.00		-123.00		
2014 - 2015	315.00				0.00	2077.00	0.00	0.00	0.00	-2077.00	123.00	-354.00	0.00	192.00	357.63	17.82	0.00				0.00		-123.00		-123.00		
2015 - 2016	277.00				0.00	1745.00	0.00	0.00	0.00	-1745.00	123.00	-508.00	0.00	154.00	529.45	39.34	0.00				0.00		-123.00		-123.00		
2016 - 2017	183.00	0.00	95.00	256.00	0.00	1012.00	197.81	19.78	217.59	-794.41	0.00	-691.00	0.00	183.00	751.79	58.24	0.00			-133.41	122.59	122.59	122.59	0.00	122.59		
2017 - 2018	229.00	0.00	102.00	256.00	0.00	1065.00	219.57	-110.04	109.53	-955.47	0.00	-920.00	0.00	229.00	1039.03	82.70				-248.47	7.53	7.53	7.53	0.00	7.53		
2018 - 2019	63.00	0.00	109.00	256.00	0.00	612.00	256.11	-61.39	194.72	-417.28		-983.00	0.00	63.00	1184.73					79.00	114.29	-284.57	-107.57	-107.57	0.00	-107.57	
2019 - 2020	0.00	0.00	118.00	256.00	0.00	118.00	284.29	-85.57	198.71	80.71		0.00	0.00	0.00	1105.73					79.00	130.32	-305.61	-128.61	-128.61	0.00	-128.61	
2020 - 2021	0.00	0.00	127.00	256.00	0.00	127.00	319.26	-42.07	277.19	150.19		0.00	0.00	0.00	1026.73					79.00	121.63	-227.44	-50.44	-279.09	-50.44	0.00	-50.44
2021 - 2022	0.00	395.82	136.00	256.00	0.00	531.82	328.04	15.80	343.84	-187.98		0.00	0.00	0.00	947.73					79.00	112.94	-161.10	-379.92	-659.01	-379.92	0.00	-379.92
2022 - 2023	0.00	0.00	147.00	256.00	0.00	147.00	352.67	33.27	385.94	238.94		0.00	0.00	0.00	868.73		0.00			79.00	104.25	-121.31	55.69	-603.32	55.69	0.00	55.69
2023 - 2024	0.00	0.00	158.00	256.00	0.00	158.00	362.37	95.24	457.60	299.60		0.00	0.00	0.00	789.73		0.00			79.00	95.56	-51.96	125.04	-478.28	125.04	0.00	125.04
2024 - 2025	0.00	0.00	170.00	256.00	0.00	170.00	389.32	161.93	551.26	381.26		0.00	0.00	0.00	710.73		0.00			79.00	86.87	38.39	215.39	-262.89	215.39	13.00	202.39
2025 - 2026	0.00	0.00	183.00	256.00	0.00	183.00	400.03	229.00	629.03	446.03		0.00	0.00	0.00	631.73		0.00			79.00	78.18	111.85	288.85	25.96	288.85	38.00	250.85
2026 - 2027	0.00	0.00	197.00	256.00	0.00	197.00	429.70	300.97	730.67	533.67		0.00	0.00	0.00	552.73		0.00			79.00	69.49	208.18	385.18	411.15	385.18	71.00	314.18
2027 - 2028	0.00	0.00	213.00	256.00	0.00	213.00	441.52	374.15	815.67	602.67		0.00	0.00	0.00	473.73		0.00			79.00	60.80	285.87	462.87	874.01	462.87		462.87
2028 - 2029	0.00	0.00	229.00	256.00	0.00	229.00	474.49	397.45	871.94	642.94		0.00	0.00	0.00	394.73		0.00			79.00	52.11	334.83	511.83	1385.84	511.83		511.83
2029 - 2030	0.00	0.00	247.00	256.00	0.00	247.00	487.54	418.75	906.29	659.29		0.00	0.00	0.00	315.73	0.00	0.00			79.00	43.42	359.87	536.87	1922.72	536.87		536.87
2030 - 2031	0.00	0.00	270.00	256.00	0.00	270.00	552.07	446.21	998.28	728.28		0.00	0.00	0.00	236.73		0.00			79.00	34.73	437.55	614.55	2537.27	614.55		614.55
2031 - 2032	0.00	1286.85	291.00	256.00	0.00	1577.85	560.35	468.04	1028.39	-549.46		0.00	0.00	0.00	157.73		0.00			79.00	26.04	455.35	-654.50	1882.77	-654.50		-654.50
2032 - 2033	0.00	0.00	314.00	256.00	0.00	314.00	595.39	511.54	1106.93	792.93		0.00	0.00	0.00	78.73		0.00			78.73	17.35	519.58	696.85	2579.62	696.85		696.85
2033 - 2034	0.00	0.00	339.00	256.00	0.00	339.00	604.32	517.59	1121.90	782.90		0.00	0.00	0.00	0.00		0.00			0.00	8.66	518.25	774.25	3353.86	774.25		774.25
2034 - 2035	0.00	0.00	366.00	256.00	0.00	366.00	640.97	617.10	1258.07	892.07		0.00	0.00	0.00	0.00		0.00			0.00	0.00	636.07	892.07	4245.93	892.07		892.07
2035 - 2036	0.00	0.00	396.00	256.00	0.00	396.00	650.58	630.06	1280.64	884.64		0.00	0.00	0.00	0.00		0.00			0.00	0.00	628.64	884.64	5130.57	884.64		884.64
2036 - 2037	0.00	0.00	427.00	308.05	1735.00	2162.00	694.62	647.46	1342.08	-819.92		0.00	0.00	0.00	0.00		0.00			0.00	0.00	607.03	-819.92	4310.65	-819.92		-819.92
2037 - 2038	0.00	0.00	462.00	362.71	1822.00	2284.00	705.04	660.50	1365.54	-918.46		0.00	0.00	0.00	0.00		0.00			0.00	0.00	540.83	-918.46	3392.19	-918.46	184.00	-1102.46
2038 - 2039	0.00	0.00	499.00	362.71	0.00	499.00	740.10	675.01	1415.11	916.11		0.00	0.00	0.00	0.00		0.00			0.00	0.00	553.40	916.11	4308.30	916.11	188.00	728.11
2039 - 2040	0.00	0.00	539.00	362.71	0.00	539.00	740.10	688.01	1428.11	889.11		0.00	0.00	0.00	0.00	0.00	0.00			0.00	0.00	526.40	889.11	5197.41	889.11	179.00	710.11
2040 - 2041	0.00	0.00	586.00	362.71	0.00	586.00	778.47	704.85	1483.32	897.32		0.00	0.00	0.00	0.00		0.00			0.00	0.00	534.61	897.32	6094.72	897.32	182.00	715.32
2041 - 2042	0.00	0.00	634.00	362.71	0.00	634.00	790.15	718.01	1508.16	874.16		0.00	0.00	0.00	0.00		0.00			0.00	0.00	511.45	874.16	6968.89	874.16	174.00	700.16
<b>Total</b>	<b>1475</b>	<b>1683</b>	<b>7354</b>	<b>7242</b>	<b>3557</b>	<b>21409</b>	<b>12995</b>	<b>9032</b>	<b>22027</b>	<b>0.40%</b>	<b>492</b>		<b>0.00</b>	<b>983</b>	<b>12349</b>	<b>201.73</b>	<b>0</b>	<b>1184.7</b>	<b>1157</b>	<b>6274.3</b>	<b>7091.5</b>		<b>14.68%</b>	<b>1029</b>	<b>14.00%</b>		

Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option I											WITH CENTRAL TAXES ONLY								Table 14.13.5							
CAPITAL COST-FIXED				7277																			1.40%			
CAPITAL COST - CURRENT				8815																						
Year	Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT COSTS	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT	TOTAL REVENUE	NET CASH FLOW FOR IRR	Funds other than loan i.e., Equity & SD	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl. IDC	INTEREST	PROFIT BEFORE TAX	CASH BALANCES	CUMULATIVE CASH				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23				
2012 - 2013	890		0	0		890	0	0	0	-890	1289	399	399	0	0	0	0.00	0			399	399				
2013 - 2014	1720		0	0		1720			0	-1720	1289	-431	-32	32	32	0	0.00	32	0		-399	0				
2014 - 2015	2077		0	0		2077			0	-2077	705	-1372	-1404	1404	1372	0	10.28	1414	0		0	0				
2015 - 2016	1745		0	0		1745			0	-1745	705	-1040	-2444	2444	1040	0	27.08	2481	0		0	0				
2016 - 2017	917		94.64	256.00		1012	197.81	20	218	-794	707	-210	-2654	2654	210	0	36.21	2728	0	-133	123	123				
2017 - 2018	963		101.69	256.00		1065	219.57	22	242	-823	0	-963	-3617	3617	963	0	44.93	3735	0	-116	140	263				
2018 - 2019	503		109.30	256.00		612	256.11	26	282	-331	0	-503	-4120	4120	503	0		4238	56	-139	117	379				
2019 - 2020	0	0	117.52	256.00		118	284.29	28	313	195	0	0	-4120	4120	0	0		4238	59	-120	136	515				
2020 - 2021	0	0	126.77	256.00		127	319.26	32	351	224		0	-4120	4120	0	0		4238	59	-91	165	680				
2021 - 2022	0	396	136.38	256.00		532	328.04	33	361	-171		0	-4120	4120	0	0		4238	59	-91	-231	450				
2022 - 2023	0	0	146.76	256.00		147	352.67	35	388	241		0	-4120	4120	0	212		4238	59	-74	-30	420				
2023 - 2024	0	0	157.99	256.00		158	362.37	36	399	241		0	-4120	4120	0	212		4027	59	-75	-31	389				
2024 - 2025	0	0	170.12	256.00		170	389.32	39	428	258		0	-4120	4120	0	212		3815	56	-54	-10	379				
2025 - 2026	0	0	183.25	256.00		183	400.03	40	440	257		0	-4120	4120	0	212		3603	53	-53	-9	370				
2026 - 2027	0	0	197.45	256.00		197	429.70	43	473	275		0	-4120	4120	0	212		3391	50	-31	13	383				
2027 - 2028	0	0	212.81	256.00		213	441.52	44	486	273		0	-4120	4120	0	212		3179	47	-31	13	397				
2028 - 2029	0	0	229.43	256.00		229	474.49	47	522	293		0	-4120	4120	0	212		2967	45	-8	36	433				
2029 - 2030	0	0	247.42	256.00		247	487.54	49	536	289		0	-4120	4120	0	212		2755	42	-9	35	468				
2030 - 2031	0	0	270.20	256.00		270	552.07	55	607	337		0	-4120	4120	0	212		2543	39	43	87	555				
2031 - 2032	0	1287	291.45	256.00		1578	560.35	56	616	-962		0	-4120	4120	0	212		2331	36	33	-1209	-655				
2032 - 2033	0	0	314.46	256.00		314	595.39	60	655	340		0	-4120	4120	0	212		2119	33	52	96	-559				
2033 - 2034	0	0	339.39	256.00		339	604.32	60	665	325		0	-4120	4120	0	212		1907	30	40	84	-475				
2034 - 2035	0	0	366.39	256.00		366	640.97	64	705	339		0	-4120	4120	0	212		1695	27	56	100	-375				
2035 - 2036	0	0	395.65	256.00		396	650.58	65	716	320		0	-4120	4120	0	212		1483	24	40	84	-291				
2036 - 2037	0	0	427.34	308.05	1735	2162	694.62	69	764	-1398		0	-4120	4120	0	212		1272	21	8	-1631	-1922				
2037 - 2038	0	0	461.69	362.71	1822	2284	705.04	71	776	-1508		0	-4120	4120	0	212		1060	18	-67	-1738	-3660				
2038 - 2039	0	0	498.93	362.71		499	740.10	74	814	315		0	-4120	4120	0	212		848	15	-62	88	-3571				
2039 - 2040	0	0	539.31	362.71		539	740.10	74	814	275		0	-4120	4120	0	212		636	12	-100	51	-3520				
2040 - 2041	0	0	586.05	362.71		586	778.47	78	856	270		0	-4120	4120	0	212		424	9	-101	49	-3471				
2041 - 2042	0	0	633.69	362.71		634	790.15	79	869	235		0	-4120	4120	0	212		212	6	-133	18	-3453				
	<b>8815</b>	<b>1683</b>	<b>7356</b>	<b>7242</b>	<b>3557</b>	<b>21411</b>	<b>12995</b>	<b>1299</b>	<b>14294</b>	<b>#DIV/0!</b>	<b>4695</b>				<b>4120</b>	<b>4238</b>	<b>118</b>	<b>71849</b>	<b>913</b>	<b>-1217</b>	<b>-3453</b>					
										-7116																
	<b>Funding Pattern</b>																									
				GOI	State	Total			%																	
				Equity by GOI & State	1764	1764	3528		40.02%																	
				Land free of cost by State	0	272	272		3.09%																	
				SD for Central Taxes (8%)	717	179	896		10.16%																	
				JICA Loan/Market Debt	4120	0	4120		46.73%																	
				<b>Total</b>		6601	2215		8816		100.00%															

Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option II												WITH CENTRAL TAXES ONLY										Table 14.13.1			
CAPITAL COST-FIXED				7825																				1.40%	
CAPITAL COST - CURRENT				9385																					
Year		Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT COSTS	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT	TOTAL REVENUE	NET CASH FLOW FOR IRR	Funds other than loan i.e., Equity & SD	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl. IDC	INTEREST	PROFIT BEFORE TAX	CASH BALANCES	CUMULATIVE CASH		
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23		
2012	-	2013	1123	0	0		1123	0	0	0	-1123	1558	435	435	0	0	0	0.00	0			435	435		
2013	-	2014	1965	0	0		1965			0	-1965	1558	-407	28	0	0	0	0.00	0	0		-407	28		
2014	-	2015	2108	0	0		2108			0	-2108	751	-1357	-1329	1329	1329	0	9.30	1338	0		-28	0		
2015	-	2016	1771	0	0		1771			0	-1771	751	-1020	-2349	2349	1020	0	25.88	2384	0		0	0		
2016	-	2017	930	99.00	260.00		1029	197.81	20	218	-811	751	-179	-2528	2528	179	0	34.63	2598	0	-141	119	119		
2017	-	2018	976	107.00	260.00		1083	219.57	-110	110	-973	0	-976	-3504	3504	976	0	43.20	3617	0	-257	3	121		
2018	-	2019	512	115.00	260.00		627	256.11	-61	195	-432	0	-512	-4016	4016	512	0		4129	54	-234	26	147		
2019	-	2020	0	123.00	260.00		123	284.29	-86	199	76	0	0	-4016	4016	0	0		4129	58	-242	18	165		
2020	-	2021	0	133.00	260.00		133	319.26	-42	277	144	0	0	-4016	4016	0	0		4129	58	-174	86	251		
2021	-	2022	0	396	143.00	260.00	539	328.04	16	344	-195	0	0	-4016	4016	0	0		4129	58	-117	-253	-2		
2022	-	2023	0	154.00	260.00		154	352.67	33	386	232	0	0	-4016	4016	0	206		4129	58	-86	-32	-34		
2023	-	2024	0	166.00	260.00		166	362.37	95	458	292	0	0	-4016	4016	0	206		3923	58	-26	27	-7		
2024	-	2025	0	178.00	260.00		178	389.32	162	551	373	0	0	-4016	4016	0	206		3716	55	58	112	105		
2025	-	2026	0	192.00	260.00		192	400.03	229	629	437	0	0	-4016	4016	0	206		3510	52	125	179	284		
2026	-	2027	0	207.00	260.00		207	429.70	301	731	524	0	0	-4016	4016	0	206		3303	49	215	268	552		
2027	-	2028	0	223.00	260.00		223	441.52	374	816	593	0	0	-4016	4016	0	206		3097	46	286	340	892		
2028	-	2029	0	241.00	260.00		241	474.49	397	872	631	0	0	-4016	4016	0	206		2890	43	328	381	1273		
2029	-	2030	0	260.00	260.00		260	487.54	419	906	646	0	0	-4016	4016	0	206		2684	40	346	399	1672		
2030	-	2031	0	284.00	260.00		284	552.07	446	998	714	0	0	-4016	4016	0	206		2477	38	417	470	2142		
2031	-	2032	0	1287	306.00	260.00	1593	560.35	468	1028	-564	0	0	-4016	4016	0	206		2271	35	428	-806	1337		
2032	-	2033	0	330.00	260.00		330	595.39	512	1107	777	0	0	-4016	4016	0	206		2065	32	485	539	1876		
2033	-	2034	0	356.00	260.00		356	604.32	518	1122	766	0	0	-4016	4016	0	206		1858	29	477	531	2406		
2034	-	2035	0	385.00	260.00		385	640.97	617	1258	873	0	0	-4016	4016	0	206		1652	26	587	641	3047		
2035	-	2036	0	415.00	260.00		415	650.58	630	1281	866	0	0	-4016	4016	0	206		1445	23	583	636	3683		
2036	-	2037	0	449.00	312.05	1735	2184	694.62	647	1342	-842	0	0	-4016	4016	0	206		1239	20	561	-1069	2614		
2037	-	2038	0	485.00	366.71	1822	2307	705.04	661	1366	-941	0	0	-4016	4016	0	206		1032	17	496	-1165	1449		
2038	-	2039	0	524.00	366.71		524	740.10	675	1415	891	0	0	-4016	4016	0	206		826	14	510	670	2119		
2039	-	2040	0	567.00	366.71		567	740.10	688	1428	861	0	0	-4016	4016	0	206		619	12	483	643	2762		
2040	-	2041	0	616.00	366.71		616	778.47	705	1483	867	0	0	-4016	4016	0	206		413	9	492	652	3414		
2041	-	2042	0	666.00	366.71		666	790.15	718	1508	842	0	0	-4016	4016	0	206		206	6	470	630	4044		
			<b>9385</b>	<b>1683</b>	<b>7724</b>	<b>7346</b>	<b>3557</b>	<b>22349</b>	<b>12995</b>	<b>9032</b>	<b>22028</b>	<b>-0.20%</b>	<b>5369</b>			<b>4016</b>	<b>4129</b>	<b>113</b>	<b>69808</b>	<b>890</b>	<b>6067</b>	<b>4044</b>			
<b>Funding Pattern</b>																									
			Items	GOI	State	Total	%																		
			Equity by GOI & State	1878	1878	3756	40.02%																		
			Land free of cost by State	0	716	716	7.63%																		
			SD for Central Taxes (8)	718	180	898	9.57%																		
			JICA Loan/Market Debt	4016	0	4016	42.79%																		
			Total	6612	2774	9386	100.00%																		



Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option II											WITH CENTRAL TAXES ONLY											Table 14.13.2	
CAPITAL COST-FIXED					7825													11.00%					
CAPITAL COST - CURRENT					9385																		
Year		Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT COSTS	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT	TOTAL REVENUE	NET CASH FLOW FOR IRR	Funds other than loan i.e., Equity & SD	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl. IDC	INTEREST	PROFIT BEFORE TAX	CASH BALANCES	CUMULATIVE CASH
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2012	-	2013	1123	0	0		1123	0	0	0	-1123	1558	435	435	0	0	0	0.00	0			435	435
2013	-	2014	1965	0	0		1965			0	-1965	1558	-407	28	0	0	0	0.00	0	0		-407	28
2014	-	2015	2108	0	0		2108			0	-2108	751	-1357	-1329	1329	1329	0	73.10	1402	0		-28	0
2015	-	2016	1771	0	0		1771			0	-1771	751	-1020	-2349	2349	1020	0	210.33	2632	0		0	0
2016	-	2017	930	99.11	260.00		1029	197.81	20	218	-812	751	-179	-2528	2528	179	0	299.41	3111	0	-142	118	118
2017	-	2018	976	106.51	260.00		1083	219.57	-110	110	-973	0	-976	-3504	3504	976	0	395.87	4483	0	-257	3	121
2018	-	2019	512	114.50	260.00		627	256.11	-61	195	-432	0	-512	-4016	4016	512	0		4995	521	-701	-441	-320
2019	-	2020	0	123.14	260.00		123	284.29	-86	199	76	0	0	-4016	4016	0	499		4995	549	-734	-973	-1292
2020	-	2021	0	132.84	260.00		133	319.26	-42	277	144	0	0	-4016	4016	0	499		4496	549	-665	-904	-2196
2021	-	2022	0	396	260.00		539	328.04	16	344	-195	0	0	-4016	4016	0	499		3997	495	-554	-1188	-3385
2022	-	2023	0	153.85	260.00		154	352.67	33	386	232	0	0	-4016	4016	0	499		3498	440	-468	-707	-4091
2023	-	2024	0	165.65	260.00		166	362.37	95	458	292	0	0	-4016	4016	0	499		2999	385	-353	-592	-4683
2024	-	2025	0	178.41	260.00		178	389.32	162	551	373	0	0	-4016	4016	0	499		2500	330	-217	-456	-5139
2025	-	2026	0	192.22	260.00		192	400.03	229	629	437	0	0	-4016	4016	0	499		2001	275	-98	-337	-5476
2026	-	2027	0	207.15	260.00		207	429.70	301	731	524	0	0	-4016	4016	0	499		1502	220	43	-196	-5672
2027	-	2028	0	223.30	260.00		223	441.52	374	816	592	0	0	-4016	4016	0	499		1003	165	167	-72	-5744
2028	-	2029	0	240.79	260.00		241	474.49	397	872	631	0	0	-4016	4016	0	504		504	110	261	17	-5727
2029	-	2030	0	259.71	260.00		260	487.54	419	906	647	0	0	-4016	4016	0	0		0	55	331	591	-5135
2030	-	2031	0	283.50	260.00		284	552.07	446	998	715	0	0	-4016	4016	0	0		0	0	455	715	-4421
2031	-	2032	0	1287	305.85	260.00	1593	560.35	468	1028	-564	0	0	-4016	4016	0	0		0	0	463	-564	-4985
2032	-	2033	0	330.06	260.00		330	595.39	512	1107	777	0	0	-4016	4016	0	0		0	0	517	777	-4208
2033	-	2034	0	356.29	260.00		356	604.32	518	1122	766	0	0	-4016	4016	0	0		0	0	506	766	-3443
2034	-	2035	0	384.71	260.00		385	640.97	617	1258	873	0	0	-4016	4016	0	0		0	0	613	873	-2569
2035	-	2036	0	415.49	260.00		415	650.58	630	1281	865	0	0	-4016	4016	0	0		0	0	605	865	-1704
2036	-	2037	0	448.86	312.05	1735	2184	694.62	647	1342	-842	0	0	-4016	4016	0	0		0	0	581	-842	-2546
2037	-	2038	0	485.01	366.71	1822	2307	705.04	661	1366	-941	0	0	-4016	4016	0	0		0	0	514	-941	-3487
2038	-	2039	0	524.22	366.71		524	740.10	675	1415	891	0	0	-4016	4016	0	0		0	0	524	891	-2596
2039	-	2040	0	566.73	366.71		567	740.10	688	1428	861	0	0	-4016	4016	0	0		0	0	495	861	-1735
2040	-	2041	0	615.79	366.71		616	778.47	705	1483	868	0	0	-4016	4016	0	0		0	0	501	868	-868
2041	-	2042	0	665.95	366.71		666	790.15	718	1508	842	0	0	-4016	4016	0	0		0	0	475	842	-25
			<b>9385</b>	<b>1683</b>	<b>7723</b>	<b>7346</b>	<b>3557</b>	<b>22347</b>	<b>12995</b>	<b>9032</b>	<b>22027</b>	<b>-0.20%</b>	<b>5369</b>			<b>4016</b>	<b>4995</b>	<b>979</b>	<b>44115</b>	<b>4095</b>	<b>2863</b>	<b>-25</b>	
<b>Funding Pattern</b>																							
			Items		GOI	State	Total	%															
			Equity by GOI & State		1878	1878	3756	40.02%															
			Land free of cost by State		0	716	716	7.63%															
			SD for Central Taxes (8		718	180	898	9.57%															
			PD		0		0	0.00%															
			JICA Loan/Market Debt		4016	0	4016	42.79%															
			Total		6612	2774	9386	100.00%															

Bangalore Phase-II NS Line Gottigre - IIMB-Nagavara Option II  
 Completion Cost (Total) 9385  
 CAPITAL COST - COMPLETION (Concessisr 1335 Concess. Equity

**BOT (WITH CENTRAL TAX)**

Table 14.13.3

Market Loz 11.00%  
 for Debt

445 Grant 8050 86%

Year	Completi on Cost	Additional Cost	Running Expenses	Depreciati on	Replacem ent Costs	Total Costs	Fare Box Revenue	PD & ADVT- Metro	Total Revenue	Net Cashflow for FIRR	Concessi on. Equity	Funds Available	govt support	Loan	Cumul Loan	IDC (Conce Loan)	Repaym entn of Loan	Repaym ent of Con Loan	Interest (Conces sionaire)	PBT	Cash Balances	Cumulativ e cash	Return on Equity - PRE TAX	Tax on Profit @33.99 %	Equity IRR
1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	22	23	24	26	27	28	29	30	31
2012 - 2013	318.00				0.00	1123.00	0.00	0.00	0.00	-1123.00	111.00	-207.00	0.00	207.00	207.00	0.00	0.00				0.00		-111.00		-111.00
2013 - 2014	355.00				0.00	1965.00	0.00	0.00	0.00	-1965.00	111.00	-451.00	0.00	244.00	451.00	22.77	0.00				0.00		-111.00		-111.00
2014 - 2015	176.00				0.00	2108.00	0.00	0.00	0.00	-2108.00	111.00	-516.00	0.00	65.00	538.77	49.61	0.00				0.00		-111.00		-111.00
2015 - 2016	161.00				0.00	1771.00	0.00	0.00	0.00	-1771.00	112.00	-565.00	0.00	49.00	637.38	59.26	0.00			0.00	0.00		-112.00		-112.00
2016 - 2017	125.00	0.00	99.00	260.00	0.00	1029.00	197.81	19.78	217.59	-811.41	0.00	-690.00	0.00	125.00	821.64	70.11	0.00			-141.41	118.59	118.59	118.59	0.00	118.59
2017 - 2018	171.00	0.00	107.00	260.00	0.00	1083.00	219.57	-110.04	109.53	-973.47	0.00	-861.00	0.00	171.00	1062.76	90.38				-257.47	2.53	2.53	2.53	0.00	2.53
2018 - 2019	29.00	0.00	115.00	260.00	0.00	627.00	256.11	-61.39	194.72	-432.28		-890.00	0.00	29.00	1182.14			79.00	116.90	-297.18	-116.18	-113.65	-116.18	0.00	-116.18
2019 - 2020	0.00	0.00	123.00	260.00	0.00	123.00	284.29	-85.57	198.71	75.71		0.00	0.00	0.00	1103.14			79.00	130.04	-314.32	-133.32	-246.97	-133.32	0.00	-133.32
2020 - 2021	0.00	0.00	133.00	260.00	0.00	133.00	319.26	-42.07	277.19	144.19		0.00	0.00	0.00	1024.14			79.00	121.35	-237.16	-56.16	-303.13	-56.16	0.00	-56.16
2021 - 2022	0.00	395.82	143.00	260.00	0.00	538.82	328.04	15.80	343.84	-194.98		0.00	0.00	0.00	945.14			79.00	112.66	-171.81	-386.63	-689.76	-386.63	0.00	-386.63
2022 - 2023	0.00	0.00	154.00	260.00	0.00	154.00	352.67	33.27	385.94	231.94		0.00	0.00	0.00	866.14		0.00	79.00	103.97	-132.03	48.97	-640.79	48.97	0.00	48.97
2023 - 2024	0.00	0.00	166.00	260.00	0.00	166.00	362.37	95.24	457.60	291.60		0.00	0.00	0.00	787.14		0.00	79.00	95.28	-63.67	117.33	-523.46	117.33	0.00	117.33
2024 - 2025	0.00	0.00	178.00	260.00	0.00	178.00	389.32	161.93	551.26	373.26		0.00	0.00	0.00	708.14		0.00	79.00	86.59	26.67	207.67	-315.79	207.67	9.00	198.67
2025 - 2026	0.00	0.00	192.00	260.00	0.00	192.00	400.03	229.00	629.03	437.03		0.00	0.00	0.00	629.14		0.00	79.00	77.90	99.14	280.14	-35.65	280.14	34.00	246.14
2026 - 2027	0.00	0.00	207.00	260.00	0.00	207.00	429.70	300.97	730.67	523.67		0.00	0.00	0.00	550.14		0.00	79.00	69.21	194.47	375.47	339.81	375.47	66.00	309.47
2027 - 2028	0.00	0.00	223.00	260.00	0.00	223.00	441.52	374.15	815.67	592.67		0.00	0.00	0.00	471.14		0.00	79.00	60.52	272.15	453.15	792.97	453.15		453.15
2028 - 2029	0.00	0.00	241.00	260.00	0.00	241.00	474.49	397.45	871.94	630.94		0.00	0.00	0.00	392.14		0.00	79.00	51.83	319.11	500.11	1293.08	500.11		500.11
2029 - 2030	0.00	0.00	260.00	260.00	0.00	260.00	487.54	418.75	906.29	646.29		0.00	0.00	0.00	313.14	0.00	0.00	79.00	43.14	343.16	524.16	1817.24	524.16		524.16
2030 - 2031	0.00	0.00	284.00	260.00	0.00	284.00	552.07	446.21	998.28	714.28		0.00	0.00	0.00	234.14		0.00	79.00	34.45	419.83	600.83	2418.07	600.83		600.83
2031 - 2032	0.00	1286.85	306.00	260.00	0.00	1592.85	560.35	468.04	1028.39	-564.46		0.00	0.00	0.00	155.14		0.00	79.00	25.76	436.63	-669.22	1748.86	-669.22		-669.22
2032 - 2033	0.00	0.00	330.00	260.00	0.00	330.00	595.39	511.54	1106.93	776.93		0.00	0.00	0.00	76.14		0.00	76.14	17.07	499.86	683.72	2432.58	683.72		683.72
2033 - 2034	0.00	0.00	356.00	260.00	0.00	356.00	604.32	517.59	1121.90	765.90		0.00	0.00	0.00	0.00		0.00	0.00	8.38	497.53	757.53	3190.11	757.53		757.53
2034 - 2035	0.00	0.00	385.00	260.00	0.00	385.00	640.97	617.10	1258.07	873.07		0.00	0.00	0.00	0.00		0.00	0.00	0.00	613.07	873.07	4063.18	873.07		873.07
2035 - 2036	0.00	0.00	415.00	260.00	0.00	415.00	650.58	630.06	1280.64	865.64		0.00	0.00	0.00	0.00		0.00	0.00	0.00	605.64	865.64	4928.82	865.64		865.64
2036 - 2037	0.00	0.00	449.00	312.05	1735.00	2184.00	694.62	647.46	1342.08	-841.92		0.00	0.00	0.00	0.00		0.00	0.00	0.00	581.03	-841.92	4086.90	-841.92		-841.92
2037 - 2038	0.00	0.00	485.00	366.71	1822.00	2307.00	705.04	660.50	1365.54	-941.46		0.00	0.00	0.00	0.00		0.00	0.00	0.00	513.83	-941.46	3145.44	-941.46	175.00	-1116.46
2038 - 2039	0.00	0.00	524.00	366.71	0.00	524.00	740.10	675.01	1415.11	891.11		0.00	0.00	0.00	0.00		0.00	0.00	0.00	524.40	891.11	4036.55	891.11	178.00	713.11
2039 - 2040	0.00	0.00	567.00	366.71	0.00	567.00	740.10	688.01	1428.11	861.11		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	494.40	861.11	4897.66	861.11	168.00	693.11
2040 - 2041	0.00	0.00	616.00	366.71	0.00	616.00	778.47	704.85	1483.32	867.32		0.00	0.00	0.00	0.00		0.00	0.00	0.00	500.61	867.32	5764.97	867.32	170.00	697.32
2041 - 2042	0.00	0.00	666.00	366.71	0.00	666.00	790.15	718.01	1508.16	842.16		0.00	0.00	0.00	0.00		0.00	0.00	0.00	475.45	842.16	6607.14	842.16	162.00	680.16
<b>Total</b>	<b>1335</b>	<b>1683</b>	<b>7724</b>	<b>7346</b>	<b>3557</b>	<b>22349</b>	<b>12995</b>	<b>9032</b>	<b>22027</b>	<b>-0.20%</b>	<b>445</b>		<b>0.00</b>	<b>890</b>	<b>13156</b>	<b>292.14</b>	<b>0</b>	<b>1182.1</b>	<b>1155</b>	<b>5801.9</b>	<b>6725.7</b>		<b>14.73%</b>	<b>962</b>	<b>14.07%</b>





**CHAPTER-15**

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**ECONOMICAL INTERNAL RATE OF RETURN**



## CHAPTER 15

### ECONOMIC ANALYSIS

#### 15.1 Introduction:

The objective of the cost- benefit analysis is to identify and quantify the economic benefits and costs associated with the project (implementation of 21.25 kms of metro corridor: Gottigere-IIMB-Nagavara Corridor in Bangalore), in order to select the optimum solution along with the economic viability in terms of its likely investment return potential.

The cost – benefit analysis is carried out by using the Discounted Cash Flow (DCF) technique to obtain the economic internal rate of return (EIRR %) and economic net present value (ENPV) for the proposed investments linked with the project. This is followed by a 'sensitivity analysis' carried out by increasing or decreasing the critical factors affecting the cost and benefit streams of the proposed project, in order to ascertain their effect on the economic feasibility indicators i.e. ENPV, EIRR.

#### 15.2 Economic Analysis Approach

The economic appraisal of the metro system 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 factors. The annual streams of project costs and benefit 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.

#### 15.3 Analysis Period

The analysis period of the project is taken as 37 years from the base year 2009 as follows:

Base Year 2009

Construction period – 2012 to 2017 (5 years)



Project opening for traffic – 01.04.2017

End of the analysis period –2046

No. of operating years, considered for economic analysis – 30 years

Thus, 30 years of operation, in effect, from the start of operation i.e. 2017, has been considered for economic evaluation for the project.

#### 15.4 Estimation of Costs

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 project cost is taken as Rs. 6185 Crores. The Operation & Maintenance Cost (O & M cost) is assumed as 3% of the project cost/annum. This cost has been converted to economic price by applying a factor of 0.85.

The development of metro is proposed in four years. The proposed phasing of construction is explained in Table 15.1.

Table 15.1: Phasing of Construction

Year	Phasing	Cost (Rs. In Crores) in Financial price
2012	15%	928
2013	30%	1855
2014	30%	1855
2015	15%	928
2016	10%	619
Total		6185

#### **Note of BMRCL:**

**The cost estimates as per BMRC calculation comes to Rs.7526.00 crores (without central tax).**

#### 15.5 Estimation of Benefits

The proposed metro will yield tangible and non-tangible savings due to equivalent reduction in road traffic and certain socio-economic benefits. Introduction of metro will result in reduction in number of buses, usage of private vehicles, air pollution and increase the speed of road-based vehicles. This, in turn, will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers. Reduction in accidents, pollution and road maintenance costs are the other benefits to the society in general.



The benefit stream that has been evaluated and quantified includes:

Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing bus system and private vehicles in case the metro project is not taken up.

Savings in operating costs of all buses and other vehicles due to de-congestion including those that would continue to use the existing transport network even after the metro is introduced.

Savings in time of commuters using the metro over the existing transport modes because of faster speed of metro.

Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.

Savings in fuel consumption on account of less number of vehicles on road and decongestion effect with introduction of metro are included in those of vehicle operating cost.

Quantification of some of the social benefits has not been attempted because universally acceptable norms do not exist to facilitate such an exercise. However, it has been considered appropriate to highlight the same, as given below:

Reduction in accidents and pollution from vehicles

Reduced road stress

Better accessibility to facilities in the influence area

Economic stimulation in the micro region of the infrastructure

Increased business opportunities

Overall increased mobility

Facilitating better planning and up-gradation of influence area.

Improving the image of the city.

### 15.6 Transport Demand on Metro Corridor

At present mostly bus system is meeting the transport demand in the study area. Part of the demand is also met by IPT modes and private modes. As given in traffic chapter, the estimated transport demand on metro is given in Table 15.2.

**Table 15.2 Transport Demand Forecast on the proposed metro corridor**

ITEM	2016	2021	2031	2041
Trips on metro / day (Lakh)	2.62	4.03	5.58	6.19



### 15.7 Reduction in Traffic Congestion and Fuel Consumption

The traffic on the metro is expected to shift from buses, auto rickshaw, car, taxi and two wheelers. It has been estimated that the number of buses and other private modes are likely to decrease with the introduction of the metro corridors. This will save Rs. 520.39 Crores in the year 2017 towards the vehicle operating cost (VoC).

### 15.8 Passenger Time Saving

With the introduction of metro, there will be reduction in traffic congestion on the roads and correspondingly, there will be saving in time of commuters travelling by various modes of road transport. Similarly, metro System itself being faster than conventional road transport modes, will also lead to considerable saving in time of commuters travelling on metro. With the implementation of the project, the annual passenger time savings are estimated at Rs. 579.64 Crore for the year 2017.

### 15.9 Results of Economic Analysis

The cost and benefit streams for 30-year period in the economic prices have been worked out and presented in Annexure 1. The residual value of the metro facilities in last year has not been taken into account as benefit in these tables.

In the analysis, the 'with project' alternative of providing metro system is compared with the base option of 'without project (Do- nothing scenario)' alternative of using the existing transport facilities. This is to arrive the net economic benefits, which consist of reduction in vehicle operation cost and reduction in travel time. The total cost worked out on the above basis is then subtracted from the total benefits to estimate the net benefit of the project. This flow is then subjected to the process of discounting to work out the EIRR and ENPV on the project, to examine the viability of the Project in Economic terms. The results are given in Table 15.3.

**Table 15.3: Results of Economic Analysis**

Sl. No.	Parameter	Results
1	EIRR (%)	13.2%
2	ENPV (Rs. In crores @ 12% discount rate)	416.2



The EIRR for the proposed metro project is worked out to be 13.2%.

**Note of BMRCL:**

***The EIRR will be 11.43% as per the revised completion cost as against 13.2%.***

The EIRR of BMRCL is shown below:

Sl. No.	Parameter	Results
1	EIRR (%)	13.2%
2	ENPV (Rs. In crores @ 12% discount rate)	416.2

### 15.10 Sensitivity Analysis

A sensitivity analysis is carried out for the following scenarios;

Increase in cost by 10%

Decrease in benefits by 10%

Combined scenario of Increase in cost by 10% and Decrease in benefits by 10%

The EIRR under these scenarios are given in Table 15.4. Details are presented in Annexure 15.1.

**Table 15.4 Results of Sensitivity Analysis**

Scenario	EIRR (%)	ENPV (Rs. in crores @ 12% discount rate)
<b>Normal Scenario</b>	<b>13.2%</b>	<b>416.2</b>
Sensitivity I: 10% increase in cost	12.1%	37.3
Sensitivity II: 10% reduction in benefits	15.99%	-4.3
<b>Sensitivity III: 10% increase in cost and 10% reduction in Benefits</b>	<b>10.9%</b>	<b>-383.2</b>

In the sensitivity analysis, the EIRR is found to be at 16%, under the combined scenario of increase in cost by 10% and decrease in benefits by 10%. Hence the project is found to be economically viable.



## Annexure 15.1

Cost and Benefit Stream : Normal Scenario							(RS. In crores)
YEAR	CAPITAL	Operation & Maintenance Cost	TOTAL COSTS	SAVINGS FROM		TOTAL SAVINGS	NET CASH FLOW
				TIME	VOC		
2009	0.00	0.00	0.00	0.00	0.00	0.00	0
2010	0.00	0.00	0.00	0.00	0.00	0.00	0
2011	0.00	0.00	0.00	0.00	0.00	0.00	0
2012	-825.72	0.00	-825.72	0.00	0.00	0.00	-826
2013	-1523.26	0.00	-1523.26	0.00	0.00	0.00	-1523
2014	-1743.85	0.00	-1743.85	0.00	0.00	0.00	-1744
2015	-1395.08	0.00	-1395.08	0.00	0.00	0.00	-1395
2016	-697.54	0.00	-697.54	0.00	0.00	0.00	-698
2017	0.00	-185.56	-185.56	579.64	520.39	1100.03	914
2018	0.00	-185.56	-185.56	598.20	537.06	1135.26	950
2019	0.00	-185.56	-185.56	616.77	553.73	1170.50	985
2020	0.00	-185.56	-185.56	635.33	570.40	1205.73	1020
2021	0.00	-185.56	-185.56	653.90	587.06	1240.96	1055
2022	0.00	-185.56	-185.56	665.25	597.25	1262.50	1077
2023	0.00	-185.56	-185.56	676.60	607.44	1284.04	1098
2024	0.00	-185.56	-185.56	687.95	617.63	1305.58	1120
2025	0.00	-185.56	-185.56	699.29	627.82	1327.12	1142
2026	0.00	-185.56	-185.56	710.64	638.01	1348.66	1163
2027	0.00	-185.56	-185.56	721.99	648.20	1370.20	1185
2028	0.00	-185.56	-185.56	733.34	658.39	1391.73	1206
2029	0.00	-185.56	-185.56	744.69	668.58	1413.27	1228
2030	0.00	-185.56	-185.56	756.04	678.77	1434.81	1249
2031	0.00	-185.56	-185.56	767.39	688.96	1456.35	1271
2032	0.00	-185.56	-185.56	775.42	696.17	1471.59	1286
2033	0.00	-185.56	-185.56	783.45	703.38	1486.83	1301
2034	0.00	-185.56	-185.56	791.48	710.58	1502.06	1316
2035	0.00	-185.56	-185.56	799.51	717.79	1517.30	1332
2036	0.00	-185.56	-185.56	807.54	725.00	1532.54	1347
2037	0.00	-185.56	-185.56	815.57	732.21	1547.77	1362
2038	0.00	-185.56	-185.56	823.59	739.42	1563.01	1377
2039	0.00	-185.56	-185.56	831.62	746.62	1578.25	1393
2040	0.00	-185.56	-185.56	839.65	753.83	1593.48	1408
2041	0.00	-185.56	-185.56	847.68	761.04	1608.72	1423
2042	0.00	-185.56	-185.56	856.16	768.65	1624.81	1439
2043	0.00	-185.56	-185.56	864.72	776.34	1641.05	1455
2044	0.00	-185.56	-185.56	873.37	784.10	1657.47	1472





2045	0.00	-185.56	-185.56	882.10	791.94	1674.04	1488	
2046	0.00	-185.56	-185.56	890.92	799.86	1690.78	1505	
<b>Total</b>	<b>-6185.45</b>	<b>-5566.91</b>	<b>11752.36</b>	<b>22729.80</b>	<b>20406.63</b>	<b>43136.43</b>	<b>31384.07</b>	
						<b>IRR %</b>	<b>13.2%</b>	
ENPV (Rs. in crores @ 12% discount rate)								<b>416.2</b>

**CHAPTER-16**

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**IMPLEMENTATION PLAN**



## CHAPTER 16

### IMPLEMENTATION PLAN

#### 16.0 WAY FORWARD

On receipt of the Detailed Project Report, following actions are required to be taken for implementing 2nd North-South corridor of Bangalore Metro project Ph-II:

- Approval of the Detailed Project Report by Board of Directors (BoD), Karnataka State Government and the Central Government, for taking up this 2<sup>nd</sup> N-S line of Ph-II Project and the two Governments committing to an investment decision.

BMRCL can go ahead with the following preliminary works:

- Reservation of land along the corridors, identification and survey for acquisition.
- Preliminary action for diversion of utility and preparation of estimates thereof.

***Note of BMRCL:***

***BMRCL has already carried out due diligence study and proposal will be submitted to Govt. for approval of DPR. After State Govt.'s approval, proposal will be submitted to GOI for their approval.***

#### 16.1 IMPLEMENTATION SCHEDULE

The implementation of the two corridors of Bangalore Metro is already in progress by BMRCL. Detailed Implementation programme for this line

may be drawn so as to commission this line by March 2017. This may necessitate to even start the work on this line in parallel to Phase-I corridors presently under Implementation.

## 16.2 PROPOSED CONTRACTS

### 16.2.1 Civil Works

Civil contracts can be taken up on “Design and Built” basis for expediting the implementation of the project. For civil works, it is suggested that the one contract package of the viaduct and two contract packages for elevated stations independently and two contract packages for the underground stretch including stations are recommended.

#### ***Note of BMRCL:***

***Necessary steps will be taken in this regard in due course of time.***

#### **A. Check on Designs of Contractual firms.**

All designs of the contractors should be checked by BMRCL either in house or by keeping a Detailed Design Agency.

#### **B. Construction Contracts**

The exact chainages for various Contract packages of viaduct and similarly the number of stations in the each contract packages of station are to be decided by BMRCL

### 16.2.2 System Contracts

System contracts for the under mentioned activities are also to be finalized

- Design, construct and installation for Traction and Power Supply.
- Design, construct and installation of Signal and Telecommunication works.
- Design, construct and installation of lifts.
- Design, construct and installation of escalators.

- Design, construct and commissioning of Automatic Fare Collection System.
- Installation of track in Depot and on main line.
- Design and installation of Signage.
- Design, supply & commissioning of rolling stock

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**CHAPTER-17**

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**CONCLUSIONS AND  
RECCOMENDATIONS**



## CHAPTER 17

### CONCLUSIONS AND RECOMMENDATIONS

- 17.1** Bangalore is the fifth largest metropolitan city and the third most populous city in the country. As per the 2001 census, total population of Bangalore was 5.6 million. With the formation of 'Greater Bangalore' in 2007, the city's population has become 8.4 million in the Census of 2011.

Bangalore City is one of the most cosmopolitan and commercially advanced cities in the country. It is home to many corporate giants like Infosys, Wipro, Biocon, Intel, IBM, HP, DELL, TCS, BHEL, BEML, HAL etc. A number of international standard research centers like ISRO, DRDO, NAL, NLS, IISc, IIMB etc along with the technological centers like Electronic City & International Tech Park attract students and employees from all over the world. It is one of the major centers of education in the recent years with the help of the development in the infrastructure. In addition, increased employment opportunities further attract the work force resulting augmented migrants from all over the country. The increased population put greater pressure on existing transportation system which leads to various problems.

With the advent of IT industries and educational institutions, people have occupied the intermediary spaces largely between the North-South and East - West of the City. The existing transportation systems are not sufficient to meet the need of the commuters. Hence, extensions to the already planned and on going Bangalore Metro on North- South and East – West corridors are considered. Further a 2<sup>nd</sup> North – South line Gottigere - IIMB - Nagavara is considered in this DPR.

#### **17.2 Project Description**

Bangalore Metro Phase II 2<sup>nd</sup> N-S line consists of the following:

The proposed route is 21.25 km starting from Gottigere on Bannerghatta Road to Nagavara on Tannery road. The initial alignment from Gottigere to Swagath Road Cross (Short of Dairy Circle) is elevated with 6 stations and from short of Dairy Circle to the





end i.e. Nagavara is underground with 12 stations. The alignment runs initially on Bannerghatta Road connecting many populated areas such as Hulimavu, IIMB, J P Nagar IV Phase, Jayadeva Hospital, Swagath Road Cross, Dairy circle, MICO Industries. It then turns left and runs below the Hosur road via Langford Town, Vellara; then traverses below Brigade Road, the commercial hub; then crosses below BM Ph-I elevated E-W line and reaches below Kamraj Road where the M G Road underground station of this line is situated which is integrated with the elevated M G Road station of Ph-I. After this the underground alignment passes by the side of busy Shivaji Nagar Bus-stand where the Shivaji Nagar underground station of this line is located. After this the alignment traverses below the built up areas by the side of Queens Road and cuts across the Queens Road and then turns right to reach the front side car parking area of Bangalore Cantonment Railway Station. Here the Cantonment Railway Metro Station is planned. This station is integrated with the Bangalore Cantonment Railway Station. From here the alignment crosses below the Cantonment Railway Station area on to the Millers road, Nandi Durg road and traverses below Benson Town area and reach Pottery Town open ground area. Here the Pottery Town underground Station is planned (This station will be connected to the Netaji road through suitable under pass below the SWR line to provide access to the surrounding Frazer town areas). From here the underground alignment turns left to reach below the Tannery road and continues almost below the Tannery road and crosses the Salem Railway line and then Outer Ring Road (ORR) to reach the last Station of this line namely Nagavara, which is located immediately after the crossing of the ORR. The route length is 21.255 km (up to dead end) and there are 18 (06 Elevated + 12 Underground) Stations in this 2nd N-S line of Phase-II. Provision has been kept to extend the line later beyond Nagavara as Elevated line to whichever side it is required as the city is growing in these parts.

- 17.3** A detailed Environmental Impact Assessment Study has been carried out for the project. As a part of this Study, comprehensive environmental baseline data was collected, and both positive and negative impacts of the project were assessed in detail. The project has many positive environmental impacts like reduction in traffic congestion, saving in travel time, reduction in air and noise pollution, lesser fuel consumption, lesser road accidents etc, with a few negative impacts (especially during implementation phase of the project) for which Environmental Management Plan has been suggested.



**17.4** After examining the various options for execution of Bangalore Metro Project, it has been recommended that the project should be got executed through the institutional arrangements existing for Phase-I of Bangalore Metro.

**17.5** The fare structure has been estimated based on Delhi Metro fares duly escalating the same for year 2014. Subsequently, for the purpose of assessing returns from the project, the fares have been revised every second year with an escalation of 5% every two years with an addition of Rs 2.00 at every distance zone.

***Note of BMRCL:***

***BMRCL has it's own fare structure and will take appropriate decision on periodical increase of fare.***

**17.6** The State Government should exempt/reimburse the Karnataka Value Added Tax (VAT) to Bangalore Metro. It should also exempt the following: -

- Tax on electricity required for operation and maintenance of the metro system.
- Municipal Taxes.

***Note of BMRCL:***

***A suitable decision will be taken by the State Govt. in this regard***

**17.7** As per the present policy 80% of the Central Taxes will be paid by GOI as subordinate Debt and balance 20% will be paid by the concerned State Government. Karnataka State Government may pursue the Central government to extend the same benefit to Bangalore Metro.

**17.8** While the Financial Internal Rate of Return (FIRR) for the project has been assessed as 0.40% (Option 1 with depot at Hulimavu); (-)0.20% {Option 2 with depot at Kothanur) and the Economic Internal Rate of Return (EIRR) works out to 13.2 %.



In the Draft DPR submitted, the proposed depot was in the Hulimavu area. BMRCL vide letter dt.02-09-11 & 20-09-11 had insisted to change the depot area stating that the Hulimavu area is on tank bed. However, no suitable Govt land could be identified for locating this depot and a private land could only be located for this purpose which will be costlier by more than Rs.550 Crores as compared to Option 1. It is seen that the Govt Order regarding Hulimavu tank bed i.e. No.PWD 82 IMB 85 dt 11-02-1988 recommended for "Foreshore Planting, water sheet to be retained" by forest department. However, in spite of this order, nothing has happened since 1988. As of now there are sizable unauthorized encroachments in this tank bed area and is dirty and has become a breeding space for mosquitoes and hence health hazard. If this area is developed as a depot, the whole area will get a face lift with proper landscaping and open area in this locality. In addition the extra cost of more than Rs.550 Crores for acquisition of Pvt lands will be saved. Therefore it is recommended that the depot of Hulimavu area is confirmed after getting proper Governments clearance.

**Note of BMRCL:**

**As per BMRCL's calculation the FIRR will be 4.41% and EIRR would be 11.43%**

- 17.9 To avoid delays in processing the clearance for the Project, It is suggested that immediately on receipt of the DPR, the State Government should approve it 'in principle' and forward the DPR to the Secretary, Ministry of Urban Development, Government of India, advising the GOI of the State Government's intention to take up the Project on DMRC pattern requesting for the latter's "in principle" clearance to go ahead with the Project.
- 17.10 Meanwhile the State Government should freeze all future developments along the proposed route of metro corridors to avoid infructuous expenditure.
- 17.11 To start with BMRCL may engage Interim Consultants for the first one year who will do this job on behalf of the BMRCL in preparation of land plans, transferring the alignment from drawing to the ground, fixing the contracts for some of the selected elevated packages and depots. Interim consultant will also help in finalization of General Consultants.



**17.12** To keep a check on the work of General Consultants and to ensure that the Metro is being constructed to meet the appropriate specifications and safety standards, the BMRCL will also need the services of Prime Consultants who will keep over-all watch over the execution of the project.