

DETAILED PROJECT REPORT

BANGALORE METRO PHASE – II (Four Extensions) Final DPR with BMRCL Comments

Client : Bangalore Metro Rail Corporation Ltd.



Delhi Metro Rail Corporation Ltd.

July - 2011

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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 of Delhi Metro Rail Project covering three lines aggregating to about 65 kms was completed and in operation. Large portion of Phase II of Delhi Metro Rail Project of about 128 kms is also commissioned except Airport Express Line.

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 the month of May 2010 as a part of Phase-II but for implementation as extension of Phase – I work itself. As desired the DPR for extensions of Phase-I N-S line and E-W line on both sides i.e. four extensions is now prepared and submitted as part of Phase II.

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 from 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



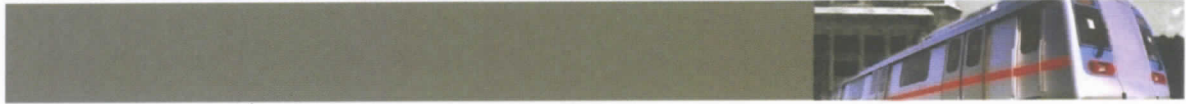
particularly the assistance rendered by BMRCL, who had made available some of the previous studies and relevant information needed for preparing this Report.

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 really 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
July 2011

(E. Sreedharan)
Managing Director
Delhi Metro Rail Corporation



SALIENT FEATURES

1. Gauge Standard Gauge (1435 mm)

2. Route Length

<u>Extension of Phase-1 Corridors (all elevated)</u>		Length (Km)	No. of Stations
(i)	Mysore Road Terminal - Kengeri	6.465	5
(ii)	Baiyappanahalli –ITPL - Whitefield	15.50	14
(iii)	Hesaraghatta Cross to BIEC	3.77	3
(iv)	Puttenahalli Cross to Anjanapura Township	6.29	5
Total		32.025	27

3. Traffic Forecast (Incremental Ridership)

	Extensions of East - West corridor (Mysore Road to Future Station + Baiyappanahalli to Whitefield)	Extensions of North-South corridor (Hesaraghatta cross to BIEC + Puttenahalli to Anjanapura Township)	Total for four extensions
2016			
Incremental Daily Ridership in lakhs	2.03	2.05	4.08
Average Lead in KM	18.7	15.2	16.9
2021			
Incremental Daily Ridership in lakhs	3.67	2.78	6.45
Average Lead in KM	16.7	13.3	15.2
2031			
Incremental Daily Ridership in lakhs	4.96	3.48	8.44
Average Lead in KM	16.3	14.2	15.5
2041			
Incremental Daily Ridership in lakhs	5.35	4.52	9.87
Average Lead in KM	16.8	13.6	15.4

**4. Train operation Plan**

North - South Corridor	Year	Headway (min)	Rake Consist
BIEC Terminal to Hesaraghatta	2016	7	3-car
Hesaraghatta to RV Road		3.5	Alternate 3-cars/ 6-car
RV Road to Anjanapura Township		7	3-car
BIEC Terminal to Hesaraghatta	2021	7	6-car
Hesaraghatta to RV Road		3.5	6-car
RV Road to Anjanapura Township		7	6-car

East - West Corridor	Year	Headway (min)	Rake Consist
Kengeri Terminal to Whitefield Section	2016	5.5	6-car
	2021	4	6-car
	2031	3	6-car
	2041	3	6-car

Coaches required for four extensions

Year	<u>2016</u>	<u>2021</u>	<u>2031</u>	<u>2041</u>
Coach Requirement	21+108=129	42+144=186	48+186=234	54+186=240

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

6. Traction Power Supply for all the extensions

- a) Traction system voltage 750V DC
b) Current Collection Third Rail bottom collection
c) Power supply source 220 KV GSSs at EPIP Park, Vrishabhavathi, Khoday's Factory
d) No. of Receiving Sub Stations 3
e) No. of Traction Sub Stations 14
f) SCADA system provided

7. Rolling Stock

- a) 2.88 m wide modern rolling stock with stainless steel body Standard Gauge.
b) Axle load - 15 t



Salient Features

- | | | | |
|----|--------------------------|---|----------------|
| c) | Seating arrangement | - | Longitudinal |
| d) | Capacity of 3 Coach unit | - | 786 Passengers |
| e) | Class of accommodation | - | One |
8. **Maintenance Facilities:** Kengeri Depot on E-W line
Augmentation of Peenya `` Depot on N-S line
9. **Signalling, Telecommunication & Train Control**
- | | | | |
|----|--------------------|--|--|
| a) | Type of Signalling | | Cab Signalling and continuous automatic train control with Automatic Train Protection (ATP) |
| b) | Telecommunication | | Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc.

Train information system, Control telephones and Centralized Clock System. |
10. **Fare Collection** Automatic Fare collection system with POM and Smart card etc.
11. **Construction Methodology**
Elevated viaduct consisting of prestressed concrete Box /"U" shaped Girders on Single pier/Portal with pile/Open foundations
12. a) Total estimated cost (at July, 2010 prices w/o taxes) **Rs. 5505 Crores**
b) Total estimated cost (at July, 2010 prices with taxes) **Rs. 6321 Crores**
c) Completion Cost with Central taxes (by 31.03.2016) **Rs. 7657Crores**
- Note by BMRCL:**
- | | | |
|----|--|------------------------|
| a) | <i>Total cost as per BMRCL(without taxes)</i> | Rs. 6945 crores |
| b) | <i>Total cost as per BMRCL (with taxes)</i> | Rs.1049 crores |
| c) | <i>Completion cost as per BMRCL with central taxes</i> | Rs.9647 crores |
13. **Financial Indices**



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 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 7 km is underground section and balance about 35 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 Baiyappanahalli where as for North – South Corridor a Maintenance Depot with full workshop facilities is being constructed at Peenya.

The Phase-1 Metro system is being implemented with 750 V DC Third Rail Traction System, Cab signaling with CATC, SCADA, and AFC. The rake interchange link is planned at Majestic Station.

Provision for extension had been kept at both ends of East – West and North –South Corridor.

0.1.1 Phase - II Corridors.

BMRCL vide their letter No. BMRCL/MD/PS/09-10/298 dt.25-03-2010 conveyed approval of HPC for preparation of DPRs in respect of the extensions/corridors as mentioned below.

Sl. No.	Corridor approved by HPC for inclusion in Phase-II	Length (Km)
1.	Extension of East-West Line: Mysore Road Terminal - Kengeri	6.10
2.	Extension of East-West Line: Baiyappanahalli - ITPL- Whitefield	15.50
3.	Extension of North-South Line: Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC)	4.00
4.	Extension of North-South Line: Puttenahalli Cross to Anjanapur Township(up to Nice Road)	6.00
5.	New North South Line: Indian Institute of Management, Bangalore (IIMB) to Nagawara	19.80
	Total	51.40



HPC in their supplementary meeting to the 8th High Power Committee meeting held on 06.05.2010 decided that DPR for R.V. Road – Bommasandra corridor (18.83 Km) should also be prepared. Copy of the letter and minutes of the supplementary meeting are placed as Annexure to Chapter 1.

The I.T industry organizations of Electronic City had come up with a strong plea to provide Metro Rail connection to Electronic City urgently under phase - I itself. The Government of Karnataka is keen to provide Metro connection to Electronic city on priority. Hence, in fitness of things this Metro line from RV Road Terminal to Electronic City has been studied and proposed as an extension of N-S Metro line of Phase – I towards South – East with provision for extension up to Bommasandra Industrial area in future. DPR for the same was submitted in May 2010.

This Report is prepared for the following extensions of the East-West Line and North - South Line of Phase-I in both directions. (four extensions) shown in Fig 0.1.

Sl. No	Extension of Phase -I Corridors in Phase-II	Length (Km)
i.	Extension of E-W line from Mysore Road to Kengeri	6.465
ii.	Extension of E-W line from Baiyappanahalli to ITPL - Whitefield	15.50
iii.	Extension of N-S line from Puttenahalli to Anjanapur Township	6.29
iv.	Extension of N-S line from Hesaraghatta Cross to BIEC	3.77
	TOTAL	32.025

0.2 Traffic Demand

The detailed traffic study was got done from M/s Wibursmith Associates, Bengaluru. Based on the detailed household surveys and traffic surveys carried out during DPR study in 2002 - 2003 and subsequent DPR Studies for extension of N-S line in October & December 2007 and the survey done now as a part of this study, the Transport Demand Model was developed. The network for all the four extensions have been developed from the primary database and used in the transport Demand Model. The traffic demand on these four extensions has been projected considering that the proposed R V Road – Electronic City/Bommasandra corridor and the new corridor between IIM(B) and Nagawara are in place.

0.2.1 TRAFFIC DEMAND

The entire study area has been delineated into 182 zones as shown in. 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

Population and Employment 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 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 Phase-II North - South Corridor between IIM (B) - Nagawara corridor and proposed R. V. Road - Electronic City corridor with total transport network of the city. Based on the final assignment of traffic on the total network, loading on the proposed four extensions with the Phase-I are as follows:

The Summary of the transport Demand for option extension of East West Corridor up to Whitefield on the proposed metro alignments is presented in Table 0.4.

Table 0.4 Summary of Transport demand (Extn of E-W Corridor upto Whitefield)

2016					
Routes	Length in KM	Max. Sectional Load (PPHPD)	Daily Passenger-KM in Lakhs	Daily Ridership in Lakhs	Average Lead (KM)
Metro Phase-1(N-S) (including extensions)	33.9	21,803	60.9	6.03	10.1
Metro Phase-1(E-W) (including extensions)	40.2	19,675	56.6	4.80	11.8
2021					
Metro Phase-1(N-S) (including extensions)	33.9	27,593	79.6	7.90	10.1
Metro Phase-1(E-W) (including extensions)	40.2	25,380	85.7	7.20	11.9
2031					
Metro Phase-1(N-S) (including extensions)	33.9	36,557	106.8	10.36	10.3



Metro Phase-1(E-W) (including extensions)	40.2	34,263	115.6	9.67	12.0
2041					
Metro Phase-1(N-S) (including extensions)	33.9	42,771	124.7	12.12	10.3
Metro Phase-1(E-W) (including extensions)	40.2	38,860	131.7	11.00	12.0

E-W Corridor extensions between Mysore road and Kengeri and Baiyappanahalli - Whitefield)

The phpdt (peak hour peak direction trips) on North South Corridor by 2016 will be 21,803 and will increase to 42771 by 2041. Similarly, the phpdt (peak hour peak direction trips) on East West Corridor by 2016 will be 19,675 and will increase to 38,860 by 2041.

The Incremental Ridership for option-2(extension of East West Corridor upto Whitefield) on the proposed metro alignments is presented in Table 0.5

Table 0.5 Incremental Ridership (Extension of E-W Corridor upto Whitefield)

2016				
Extensions	Incremental Length in Km	Incremental Daily Ridership in lakhs	Incremental Daily Passenger KM in Lakhs	Incremental Average Lead in KM
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	2.05	31.07	15.2
From Mysore Road to Kengeri+ Baiyapanhalli to Whitefield	22.7	2.03	38.05	18.7
Total	33.5	4.08	69.12	16.9
2021				
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	2.78	36.91	13.3
From Mysore Road to Kengeri+ Baiyapanhalli to Whitefield	22.7	3.67	61.13	16.7
Total	33.5	6.45	98.04	15.2
2031				
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	3.48	49.52	14.2
From Mysore Road to Kengeri+ Baiyapanhalli to Whitefield	22.7	4.96	80.94	16.3
Total	33.5	8.44	130.46	15.5
2041				
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	4.52	61.47	13.6
From Mysore Road to Kengeri+ Baiyapanhalli to Whitefield	22.7	5.35	90.05	16.8
Total	33.5	9.87	151.52	15.4



0.3 PLANNING AND DESIGN PARAMETERS

DMRC has already implemented Phase I and Phase-II of Delhi Metro project. Various design norms and parameters have been firmed up by DMRC after detailed studies of norms followed by Metro systems worldwide. However, Delhi being a much bigger Metropolitan City than Bangalore, its needs are different. 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 deck width of 9.54 m (track center 4.2 on 122.5 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.

15 t axle load, as adopted for Phase-I is proposed for these extensions also.

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 m/sec^2) and maximum deceleration (1.1 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 122.5 m. Other geometrical parameters are similar to that of Delhi Metro system.

It is proposed to provide 750 V dc, third rail traction system for all four extensions as being adopted for the phase-I under implementation. 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.

0.4 Alignment for the four extensions

Extension of Phase-I E-W line

0.4.1 Mysore Road Terminal to Kengeri

The line from Mysore road Terminal of Phase – I to Kengeri along Mysore road is an elevated standard gauge corridor with double line section having a route length of 7.09 km (up to dead end) and 6 stations (apart from Mysore road Terminal Station). Provision has been kept for extending the line beyond in future.

- Mysore Road Terminal station at the west end of E –W corridor of Ph-I is located on the Mysore road short of Outer Ring Road junction as elevated Terminal Station.



- This alignment is to be extended on the Mysore road up to Kengeri.
- The satellite town 'Kengeri' which has come up in the outskirts of southwestern part of Bengaluru has developed as a busy suburb and is further developing. The traffic on the Mysore road to Kengeri has also increased. Hence the necessity of extension of Mysore road Terminal to Kengeri.
- Provision has been kept for extending the line in future.

The line extending from the existing dead end of Mysore Road Terminal Station will be generally on the median of the Mysore road and traverse up to Kengeri. There are five stations on this extension of Mysore Road – Kengeri line namely Nayandahalli [Ch.(-)764.50], Rajarajeshwari Nagar [Ch.(-)1600], Bengaluru University Cross [Ch.(-)2400], R V College of ENGG [Ch.(-)4400], Kengeri [(-)6306]. Provision has been kept for extending the line beyond Kengeri in future either to Bidadi or towards the Satellite town of Kengeri.

0.4.2 Baiyappanahalli to ITPL/Whitefield

The extension of Mysore Road to Baiyappanahalli corridor to Whitefield will be elevated with route length of 15.50 km (up to dead end).

- Baiyappanahalli station along with the depot at the east end of E – W corridor is located on the NGEF land by the side of Old Madras Road as elevated Terminal Station.
- This alignment is to be extended towards east on Old Madras Road –up to Whitefield.
- The hub for the IT industry after Electronic City is the ITPL area. The Doddanekkundi Industrial Estate, Vishweshwaraiah Industrial Estate, KIADB Export Promotional Industrial Area etc are also existing along this line which caters for a large number of clientele. There has been a lot of development around Whitefield. The Whitefield Railway Station is being planned to make it a transportation hub on the eastern side. Sri. Sathya Sai Baba Ashram is near Whitefield Railway Station. All these cater for large ridership. Also as per the traffic survey, the traffic on the Phase-I E-W line is almost doubled by the extension of this line up to ITPL/Whitefield and hence the necessity of extension of Baiyappanahalli to ITPL/Whitefield.

The extension line starting from Baiyappanahalli Depot main line dead end is continued on the south side of Bangalore - Chennai line (out side the railway boundary). Then the metro line crosses Bangalore-Salem line and the loop railway line to Baiyappanahalli in one long span of about 40 mts and crosses the Kasturi Nagar road and then the outer ring road and reaches the median of the Old Madras road for a small length and then slightly shifted to the left side of the median to avoid the ramp of the Cable Stay Bridge and then the alignment crosses the approach of the Cable Stay Bridge and joins the Whitefield road. The metro alignment will also enter the Whitefield road at elevated level. The metro alignment continues between the Railway land and the outer ring road and reaches the median of Whitefield road. After crossing the flyover the alignment continues to be on the median of Whitefield road till the junction of Graphite India Road. Here the



alignment turns to right and reaches the median of Graphite India Road. The alignment will be on the median of Graphite India Road till the junction of Road 2 (opp to Graphite India Research & Development Centre) where it takes a turn to the left and reaches the median of Road 2 and runs on the median of Road 2 till opposite to SAP Labs India Ltd. After this the alignment runs on the median till approx Ch.26800 (where it has two H T line crossings), at this location the overhead High Tension (HT) lines of 220 KV are running along the median of the road hence the metro line is taken on the right side of the road till the crossing of Road 2 and Road 8 (Vyedehi Hospital). Here the metro alignment takes a left turn after crossing H T lines twice and taken on the right side of Road 8/1st Main Road till short of Whitefield road where the metro alignment turns right to reach Whitefield road. The alignment continues to be on the median up to the ITPL metro Station up to which the construction in first stage of extension is planned. The dead end of this station would be Ch.30100.

The line will be continued in stage 2 to Whitefield from the dead end of ITPL station along the median of Whitefield road till the junction of Whitefield Station road/Chennasandra Circle. Here the metro alignment turns to the left and reaches the median of Whitefield Station road and continues along the median up to short of the Road Over Bridge on the left side of the ROB and terminates before the railway lines.

Extension of Phase-I N-S line

0.4.3 Puttenahalli Cross to Anjanapur Township (Up to NICE Road)

The line from Puttenahalli Cross of Phase – I to Anjanapur Township (up to NICE Road Crossing) along Kanakapura Road is an elevated standard gauge corridor with double line section having a route length of 6.29 km (up to dead end) and 5 stations (apart from Puttenahalli Cross Station).

- Puttenahalli Cross station at the south end of N – S Phase-I corridor is located on the Kanakapura road after the Outer Ring Road junction as elevated Terminal Station.
- This alignment can be extended on the Kanakapura road up to Anjanapur Township (NICE Road Crossing).
- The Phase-I N-S line is already under construction up to Puttenahalli cross on Kanakapura road. In phase-II the same line is proposed for extension up to Anjanapur Township (NICE road x-ing) along Kanakapura road. There is good ridership from this part of the city who travel to & fro City Center. Therefore the necessity of extension of Phase-I N-S line on the southern side to Anjanapur Township (NICE road x-ing) is felt.

The line starting from the existing dead end of Puttenahalli Cross Station continues to be on the median of the Kanakapura road and traverse along the median up to Anjanapur Township (NICE road x-ing). There are five stations on this extension of Puttenahalli Cross – Anjanapur Township line namely Anjanapur Road Cross (Ch18900), Krishna Leela Park (ISKON) (Ch.20083), Vajara Halli (Ch.21400), Thalaghattapura (Ch.22285) and Anjanapur Township Terminal (24182). This extension is fully elevated line from Puttenahalli Cross to Anjanapur Township (NICE road x-ing).



0.4.4 Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC) [beyond NICE Road]

The line from Hesaraghatta Cross of Phase – I (N-S Metro Rail) to BIEC (beyond NICE Road) along RHS of Tumkur Road is an elevated standard gauge corridor with double line section having a route length of 3.77 km (up to dead end) and 3 stations (apart from Hesaraghatta Cross Station). Provision has been kept for extending the line beyond in the future.

- Hesaraghatta Cross station at the north end of N – S Phase-I Metro Rail corridor is located on the RHS of Tumkur road as elevated Terminal Station.
- This alignment can be extended on the RHS of Tumkur road up to BIEC now and even beyond in future. The Metro alignment will have to be continued on the RHS of Tumkur road as the tolled elevated/at grade High way is under construction on the existing median of the Tumkur road.
- The Phase-I N-S line is already under construction up to Hesaraghatta cross on RHS of Tumkur road. In phase-II the same line is proposed for extension up to BIEC (beyond NICE road x-ing) along the RHS of Tumkur road. Even though from the traffic point, this extension may not be wholly justified, but a lot of visitors who intend to go to the Exhibition Center from various parts of the city and outskirts are not going to BIEC as the travel time required by road as of now is too much and the travel time will be reduced if the existing N-S line from Hesaraghatta Cross is extended up to BIEC. Therefore the necessity of extension of Phase-I N-S line on the Northern side to BIEC is felt. Provision has been kept for extending the line in future.

The line starting from the existing dead end of Hesaraghatta Cross Station continues to be on the RHS of the Tumkur road and traverse along the RHS of Tumkur road up to BIEC (beyond NICE road x-ing). There are three stations on this extension of Hesaraghatta Cross – BIEC line namely Manjunatha Nagar [Ch.(-) 6825], Jindal Metro Station [Ch.(-)8074] and BIEC Terminal [Ch.(-)9224]. This extension is fully elevated line from Hesaraghatta Cross to BIEC (beyond NICE road x-ing). Provision has been kept for extending the line beyond BIEC in future.

0.4.5 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 extension of N-S line of Phase-I from Yeshwanthpur to Hesaraghatta Cross & R V Road Terminal to Puttenahalli cross of October 2007 & June 2008 has been used to plan all the 27 stations of the four extensions in Phase-II. Out of the total 27 stations, 19 stations are on the middle of the Road and balance 8 stations are off the road.



The proposed stations along all the four extensions of Phase-I are as follows:

Table 0.6 - Stations

NORTH-SOUTH CORRIDOR (BIEC Terminal-Anjanapur Township)				
S. No	Name of Stations	Change (in m)	Inter – Station Distance (in m)	Remarks
	Dead End	(-) 9674.00		
1	BIEC Terminal	(-) 9224	450	Elevated
2	Jindal	(-) 8074	1150	Elevated
3	Manjunatha Nagar	(-) 6825	1249	Elevated
4	Hessarghatta	(-)5400	1425	Elevated
5	T. Dasarahalli	(-)4497	903	Elevated
6	Jalahalli	(-)3747	750	Elevated
7	Peenya Ind Area	(-)3021	726	Elevated
8	Peenya	(-)1950	1071	Elevated
9	Outer Ring Road	(-)1138	812	Elevated
10	Yeshwantapur	0.00	1138	Elevated
11	Soap Factory	1103	1103	Elevated
12	Mahalakshmi	2102	999	Elevated
13	Rajaji Nagar	3069	967	Elevated
14	Kuvempu Road	3975	906	Elevated
15	Malleswaram	4728	753	Elevated
16	Swastik	5864	1136	Elevated
17	Majestic	7540	1676	Elevated
18	Chickpete	8559	1019	Elevated
19	City Market	9235	676	Elevated
20	K R Road	10427	1192	Elevated
21	Lal Bagh	11431	1004	Elevated
22	South End Circle	12386	955	Elevated
23	Jayanagar	13288	902	Elevated
24	R V Road	14180	892	Elevated
25	Banashankari	15540	1360	Elevated
26	J.P.Nagar	16413	873	Elevated
27	Puttenahalli Cross	17798	1385	Elevated
28	Anjanapura Road Cross	18900	1102	Elevated
28	Krishna Leela Park (ISKON)	20083	1183	Elevated
30	Vajarahalli	21400	1317	Elevated
31	Thalaghattapura	22285	885	Elevated
32	Anjanapura Township	24182	1897	Elevated

Phase-II Extension Hesarghatta to BIEC

Phase-I N-S line Hesarghatta to Puttenahalli presently under implementation

Phase-I N-S line Hesarghatta to Puttenahalli presently under implementation

Phase-II Extension Puttenahalli to Anjanapur Township



NORTH-SOUTH CORRIDOR (BIEC Terminal-Anjanapur Township)				
S. No	Name of Stations	Change (in m)	Inter - Station Distance (in m)	Remarks
	Dead End	24632	450	Elevated

EAST-WEST CORRIDOR with Whitefield (Future Station-Whitefield)				
S. No	Name of Stations	Change (in m)	Inter - Station Distance (in m)	Remarks
	Dead End	(-)6725	-	
2	Kengeri Terminal	(-) 6306	419	Elevated
3	RV College of Engineering	(-) 4400	1906	Elevated
4	Bangalore University Cross	(-) 2400	2000	Elevated
5	Rajarajeshwari Nagar	(-) 1600	800	Elevated
6	Nayandahalli	(-) 765	835	Elevated
7	Mysore Road Terminal	0	765	Elevated
8	Deepanjali Nagar	1117	1117	Elevated
9	Vijaya Nagar	2345	1228	Elevated
10	Hosahalli	3446	1101	Elevated
11	Toll Gate	4448	1002	Elevated
12	Magadi Road	5600	1152	Elevated
13	City Railway Station	6755	1155	Elevated
14	Majestic	7503	748	Elevated
15	Central College	8697	1194	Elevated
16	Vidhan Soudha	9318	621	Elevated
17	Cricket Stadium	10643	1325	Elevated
18	M G Road	11380	737	Elevated
19	Trinity Circle	12522	1142	Elevated
20	Ulsoor	13725	1203	Elevated
21	CMH Road	14610	885	Elevated
22	Old Madras Road	16419	1809	Elevated
23	Baiyappanahalli	17374	955	Elevated
24	Jyothipuram	19800	2426	Elevated
25	K R Puram	20625	825	Elevated
26	Narayanapura	21500	875	Elevated
27	Mahadevapura	22400	900	Elevated
28	Garudacharya Palya	23600	1200	Elevated
29	Doddanakundi Ind Area	24635	1035	Elevated



EAST-WEST CORRIDOR with Whitefield (Future Station-Whitefield)					
S. No	Name of Stations	Change (in m)	Inter - Station Distance (in m)	Remarks	
30	Vishweshwaraya Ind. Area	25635	1000	Elevated	
31	Kundanahalli	26500	865	Elevated	
32	Vydehi Hospital	27500	1000	Elevated	
33	Sathya Sai Hospital	28300	800	Elevated	
34	I T P L	29750	1450	Elevated	
35	Kadugodi	30800	1050	Elevated	
36	Ujwala Vidyalaya	31800	1000	Elevated	
37	Whitefield	32800	1000	Elevated	
38	Dead End	33250	450		

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.

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 Nayandanahalli & Kengeri Terminal Stations on Mysore Road Terminal – Kengeri line, Narayanapura, Mahdevapura, Garudacharpalya Stations, ITPL & Ujwala Vidyalaya on Baiyappanahalli – Whitefield line, Anjanapur Road Cross, Krishna Leela Park (ISKON) & Anjanapur Township Stations on Puttenahalli Cross – Anjanapur Township line and Manjunatha Nagara & BIEC Stations on Hesaraghatta Cross – BIEC line.

Location specific station plans for all the 27 stations on these four extensions have been prepared and being submitted with this DPR.

Geo Technical Investigation

Geo- technical Investigation has been carried out along all the four extensions at 54 locations up to a depth of 30 m in soil or up to a depth of 3 m 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, is a layer of soft rock and a layer of hard rock.

For the elevated section shallow foundation 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 in Vol-III.

Utility Diversions

The proposed alignments of (i) Mysore Road Terminal to Kengeri- Future Station, (ii) Baiyappanahalli to ITPL/Whitefield Terminal, (iii) Puttenahalli Cross to Anjanapura Township and (iv) Hesaraghatta Cross to BIEC extensions are traversing along the busy City Roads. Number of sub-surface, surface and overhead 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 alignments. 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.

The 12 major utility of 220/66/11 KV OHE lines detailed in chapter 4 are required to be shifted.

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 four extensions works out to:

Mysore Road Terminal – Kengeri	= 1.46 ha
Baiyappanahalli – Whitefield	= 7.79 ha
Puttenahalli Cross – Anjanapura Township (Up to NICE Road x-ing)	= 2.23 ha
Hesaraghatta Cross – BIEC	= 4.58 ha
Maintenance Depot at Kengeri	=12.00 ha
Stabling facilities at Anjanapura Township	=4.00 ha

The land cost for the four extensions of alignment & stations

Mysore Road Terminal – Kengeri	= Rs. 87 Crores
Baiyappanahalli – ITPL - Whitefield	= Rs. 250 Crores
Puttenahalli Cross – Anjanapura Township	= Rs. 93 Crores
	(Up to NICE Road x-ing)
Hesaraghatta Cross – BIEC	= Rs. 82 Crores

The project involves displacement of about 311 properties out of which 153 are commercial, 39 residential, 03 religious and 116 others.

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



0.5 TRAIN OPERATION PLAN AND MAINTENANCE DEPOT

Train Operation Plan

Any public transport system, particularly a Metro system, is made attractive and useful by providing suitable high frequency service during peak and off-peak hours. For this purpose for all the four extension lines short trains (3 coach trains) are proposed initially at 5.5 minutes frequency during peak periods and 15 minutes frequency during slack periods of the day. The frequency can be changed gradually to 3 minutes with 6-cars in future depending upon the demand.

Salient features of the proposed train operation plan are:

- Running of services for 19 hours of the 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 these corridors has been assumed as:
 - North-South Corridor (BIEC Terminal-Anjanapura Township') : 34 kmph
 - North- South Corridor ('Hessarghatta Cross-RV Road loop) : 33 kmph
 - East-West Corridor ('Future Station-ITPL') : 34 kmph
 - East-West Corridor ('Mysore Road Terminal-Baiyappanahalli'): 34 kmph

0.5.1 Train Formation

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

The basic unit of 3-car train comprising of DMC + TC + DMC and 6-car train comprising of DMC + TC + MC + MC + TC + DMC configurations are selected for the year 2016 and 6-car train comprising of DMC + TC + MC + MC + TC + DMC configurations is selected for the year 2021, 2031 & 2041.

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.

Composition

DMC : Driving Motor Car

MC : Motor Car

TC : Trailer Car

3 Car Train Compositions: DMC + TC + DMC

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

Capacity (with standees @6 passengers per sqm of standee area)

DMC : 253 Passengers (Sitting-43, Crush Standing-210)

TC/MC : 280 Passengers (Sitting-50, Crush Standing-230)

3 Car Train: 786 Passengers (Sitting-136, Crush Standing-650)

6 Car Train: 1626 Passengers (Sitting-286, Crush Standing-1340)



0.5.2 Train Operation Plan

Train operation plan (headway and train composition) for the year 2016,2021,2031 and 2041 during the peak hours has been worked out for the following two options.

North South Corridor	BIEC – Hesseragatta- Puttenahalli Cross- Anjanapura Township	33.400 Km
East West Corridor	Kengeri – Mysore Road – Baiyappanahalli – ITPL- WhiteField	39.106` Km

Capacity Provided for North-South Corridor

North - South Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
BIEC Terminal to Hasseragatta Section	2016	7	21 Rakes of 3-car and 14 Rakes of 6-car	3-car	147	3161	6737 (8571*)
Hasseragatta to RV Road Section		3.5		Alternate 3-cars/ 6-car		21803	20674 (26297*)
RV Road to Anjanapura Township Section		7		3-car		11241	6737 (8571*)
BIEC Terminal to Hasseragatta Section	2021	7	35 Rakes of 6-car	6-car	210	8807	13937 (17726*)
Hasseragatta to RV Road Section		3.5		6-car		27593	27874 (35451*)
RV Road to Anjanapura Township Section		7		6-car		14389	13937 (17726*)
BIEC Terminal to Hasseragatta Section	2031	6	39 Rakes of 6-car	6-car	234	10913	16260 (20680*)
Hasseragatta to RV Road Section		3		6-car		36557	32520 (41360*)
RV Road to Anjanapura Township Section		6		6-car		19137	16260 (20680*)
BIEC Terminal to Hasseragatta Section	2041	5	47 Rakes of 6-car	6-car	282	12769	19512 (24816*)
Hasseragatta to RV Road Section		2.5		6-car		42771	39024 (49632*)
RV Road to Anjanapura Township Section		5		6-car		22391	19512 (24816*)

**Capacity Provided for East-West corridor**

East - West Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
Kengeri Terminal to Whitefield Section	2016	5.5	32	6-car	192	19675	17738 (22560*)
	2021	4	43	6-car	258	25380	24390 (31020*)
	2031	3	56	6-car	336	34263	32520 (41360*)
	2041	3	56	6-car	336	38860	32520 (41360*)

* @ 8 persons per square meter of standee area

0.6 ROLLING STOCK

Rolling stock for all the four extensions of Phase-I 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;
- ◆ Optimised scheduled speed;
- ◆ Aesthetically pleasing Interior and Exterior;
- ◆ Low life cycle cost; and
- ◆ Flexibility to meet increase in traffic demand.

As these run on 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 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 same as that taken for Phase-I lines i.e. 15 t for which the structures are to be designed.

0.7 POWER SUPPLY, SYSTEM OF TRACTION AND POWER TARIFF**Power Supply arrangements**

Electricity is the only source of energy for operation of Metro system. The electric power supply is required by Metro system for the following purposes:-



- For running trains
- For station services e.g. lighting, ventilation and air-conditioning (only in underground stations), lifts, escalators, signalling & telecom, fire fighting and pumping etc.
- For workshops, depots and other maintenance infrastructure within premises of metro system.

The major component of power supply is traction requirements for elevated section and auxiliary requirements for underground section.

0.7.1 Selection of Traction System:-

Existing system of electric traction on all the corridors of Bangalore Metro constructed in Phase – 1 is at 750 V DC. This is based on techno economic studies for Bangalore. The same traction system for the proposed extension of the existing corridors and new corridors has been considered, viz 750 V DC third rail bottom current collections.

0.7.2 Design Criteria for Power Supply and Traction System:

Power requirement has been evaluated considering Train operation plan, which envisages running of trains as summarized below:-

Corridor	Year	
	2016	2041
E – W Corridor - Train composition - Headway	6 car 5.5 minutes	6 car 3 minutes
N-S Corridor - Train composition - Headway	3 car 7 minutes	6 car 5 minutes

In train bunching situation, headway may get reduced to 150 seconds for short durations. Accordingly, traction power supply system has been planned to cater for 6-car train operation at 150 seconds headway in year 2041 under bunching conditions in part of the corridor. However, initially equipment will be installed to cater the expected power requirement during initial years of operations. As and when the traffic builds up in year 2031 & 2041, the power supply system may need slight augmentation by way of adding main power transformers & traction transformer-rectifier sets.

0.7.3 Power Demand Estimation

The power requirement of a metro system is determined by peak-hour demands of power for traction and auxiliary applications. Broad estimation of auxiliary and traction power demand is made based on the following requirements:-

- (i) Specific energy consumption of rolling stock – 75KWh/1000 GTKM
- (ii) Regeneration by rolling stock – 20%



- (iii) Elevated/at –grade station load – initially 200KW, which will increase to 500 KW in the year 2041
- (iv) Depot auxiliary load - initially 2250 KW in the year 2016, which will increase to 2750 KW in the year 2041.

Keeping in view of the train operation plan and demand of auxiliary and traction power, power requirement have been worked out for the year 2016, 2021, 2031 and 2041 which is briefly summarized in Table 0.7 below:-

Table 0.7:- Power Demand Estimation (MVA)

Corridor		Year			
		2016	2021	2031	2041
Extension of N – S corridor BIEC to Hesarghatta	Traction	0.7	1.4	1.7	2.0
	Auxiliary	0.7	0.90	1.1	1.9
	Sub Total (A)	1.4	2.3	2.8	3.9
Extension of N – S corridor Puttenahalli to Anjanapura Township	Traction	0.7	1.4	1.6	1.9
	Auxiliary	1.2	1.5	1.9	3.1
	Sub Total (B)	1.9	2.9	3.5	5.0
Total (A+B)		3.3	5.2	6.3	8.9
Extension of E – W corridor Kengeri Station to Mysore Road Terminal	Traction	2.9	4.0	5.4	5.4
	Auxiliary	1.2	1.5	1.9	3.1
	Sub Total (C)	4.1	5.5	7.3	8.5
Extension of E – W corridor Byappanahalli to White field (OPTION – II)	Traction	7.3	10.1	13.4	13.4
	Auxiliary	3.5	4.3	5.2	8.6
	Sub Total (D)	10.8	14.4	18.6	22.0
Total (C+D)		14.9	19.9	25.9	30.5

0.7.4 Selection of Inputs Supply Voltage and the Locations of Receiving Sub-Stations

The high voltage power supply network of Bangalore city was studied in brief. The city has got 220kV, 66kV and 11kV network to cater to the various types of demand. 220kV sub-stations are generally located at outskirts of the city. 66kV sub-stations are located near to the alignment of E-W and N-S corridor. Keeping in view of the reliability requirements, 2 input sources of 66kV voltage level have already been considered for each corridor and accordingly, 2 receiving sub-stations (66/33kV) are proposed to be set up each for existing E-W and N-S corridors. The existing E-W corridor from Mysore Terminal to Byappanahalli is 17.37 km, whereas N-S Corridor from Hasargatta to Puttenhalli is 23.19 km section having RSS's at following locations:-

S. No.	Corridor	Grid sub-station (Input source)	Location of RSS of Metro Authority	Approx. length of 66kV cables
1.	E-W corridor	NGEF sub-station (66kV)	Baiyyappanahalli depot	1km. (Double circuit)
2.		REMCO sub-station (66kV)	Mysore Road Terminal	1km. (Double circuit)



3.	N-S Corridor	SRS Peenya sub-station (220/66kV)	Yeshwantpur Depot	4km. (Double circuit)
4.		SARAKKI sub-station (66kV)	R.V. Road Terminal	4km. (Single circuit)

The 4 RSS's of phase – I corridors are being provided with 2 transformers each having capacity of 20 / 25 MVA based on the simulation studies carried out for BMRCL in phase-I. The 66 KV will be stepped down to 33 KV level at the above RSS's of metro authority.

In case of failure of one RSS, the other RSS of the same line will feed entire corridor. If both the RSS's of any corridor fail, then the power can be supplied through RSS's of other corridor through 33 KV link provided at Majestic station.

Since the proposed corridors in Phase – 2, are extension of the existing corridors of E-W and N-S, the efforts have been made to minimise the need of additional RSS. In Phase – 2 following extensions have been proposed:-

(a) **E – W corridor:-**

East side extension:-

Further extension of 3.05 Km up to Whitefield flyover.

West side extension:-

Further extension 15.50 Km to Future city or satellite town.

(b) **N – S corridor:-**

South side extension:- 3.62 km extension up to Anjanapura Township,

North side extension:- 3.82 km extension up to BIEC Terminal.

The East – West corridor is likely to be extended beyond Kengeri up to Future city / Satellite town, therefore it is essential to have one more RSS towards East (up to ITPL) & one RSS towards West if the extension is also considered.

Similarly 3.62 km extension towards south also requires one RSS to improve reliability of the North – South corridor. 3.82 km extension towards North can be fed from the existing RSS at Peenya existing RSS and no new RSS will be required.

Keeping in view the above, the discussions were held with Director/ KPTCL and following sources have been identified:-

S. No.	Corridor	Grid sub – station (Input Source)	Location of RSS of Metro Authority	Approx. length of 66kV cables
1.	E-W corridor	EPIP Park 220 kV GSS (2 no. 66 kV bays)	Near ITPL station	2km. (Double circuit)
2.		Vrishabhavathi 220kV GSS (2 no. 66kV bays)	Kengeri Depot	4km. (Double circuit)
3.	N-S Corridor	Khodays factory 220kV GSS (2 no. 66kV bays)	Anjanapura Depot	5km. (Double circuit)



The detailed calculation and power required etc can be finalized through simulation studies during detailed design stage.

M/s KPTCL in the minutes of meeting issued vide memo no:- KPTCL/CEE/P&C/KCO – 88/25958, dated:- 28.10.2010 (Annexure – 7.3) have indicated that metro authorities (BMRCL) may confirm the requirement of power requirements at 66kV level from already planned EPIP Park 220/66 KV GIS Grid sub-station, 220 / 66 kV Khoday factory GSS and existing 220/66kV Vrishabhavathi GSS.

If additional power requirement is a certainty, BMRCL may indicate and deposit money so that the GSSs can be designed and equipment procured now itself.

0.7.5 AUXILIARY SUPPLY ARRANGEMENTS FOR STATIONS & DEPOT

Auxiliary sub-stations (ASS) are envisaged to be provided at each station. A separate ASS is required at each depot. The ASS will be located at mezzanine or platform level inside a room. Wherever TSS is required, ASS & TSS will be housed together inside a room. The auxiliary load requirements have been assessed to be about 500 kW for elevated/at-grade stations and accordingly two dry type cast resin transformers (33/0.415kV) of 630 kVA for elevated / at grade stations (with one transformer as standby) are proposed to be installed. Both the Depot ASSs will also be provided with 2 x 3000 kVA auxiliary transformers

0.7.6 STANDBY DIESEL GENERATOR (DG) SETS

In the unlikely event of simultaneous tripping of all the four RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby DG set of 100 / 150 KVA capacity at elevated/at-grade stations to cater the following essential services:

- (i) Lift operation
- (ii) Essential lighting
- (iii) Signaling & telecommunications
- (iv) Fire fighting system.

Capacity may be fine-tuned depending on S&T requirement for Interlock stations. Silent types of DG sets are proposed which have low noise levels and do not require separate room for installation.

0.7.7 Utility diversion:-

The extension of East corridor is having around 3 Km 220 KV double circuit transmission line physically infringing the alignment. The transmission line needs to be shifted or replaced through equivalent cable network. The estimated cost of this work will be around Rs 80 Cr. The fund provision is to be kept separately.

0.8 SIGNALLING AND TRAIN CONTROL

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. Signalling & Train Control system on the line shall be designed to meet the required headway during peak hours. These are detailed in chapter 8.

0.9 TELECOMMUNICATION

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.

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
- Integrated Passenger Announcement System and Passenger Information and Display System within the station and from Central Control to each station.
- Centralised 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.

0.10 Maintenance Depot for Bangalore Metro

Detailed Project Report of Phase-I of Bangalore Metro provides for the Depots at Baiyappanahalli and Yeswantpur respectively for East-West and North-South Corridors. Subsequently, the location of Yeshwantpur Depot was changed to Peenya. The existing capacities of these two Depots and additional requirement is furnished in the Table below:

S.No	Depot Location	Corridor	Available capacity	Requirement for 2041 (including Extensions)	Additional requirement
1	Peenya	North - South	30 of 6 Car	47 of 6 Car	17 of 6 Car
2	Baiyappanahalli	East-West	19 of 6 Car	56 of 6 Car	37 of 6Car



It is proposed to augment the depot capacity at peenya depot for stabling the additional 17 rakes. The planning has been done and the drawing is available in depot chapter. A plot of land with 4 Hect. area is identified at Anjanapura for any further requirement in future.

Baiyyappanahalli Depot is located in the congested area and any further expansion is not possible. It has to continue with the already planned capacity as per Phase-I DPR. The additional depot at Kengeri/station side for stabling and maintaining 37 rakes of 6 car to be planned for which 12 Hect. of land is identified. Workshop will also be provided at Kengeri depot.

0.11 Environmental Impact Assessment/Environmental Management Planning (EIA/EMP)

The EIA and EMP studies were entrusted to M/s SECON Pvt Ltd, Bangalore and their report is enclosed as separate volume. However, the numbers of properties and trees affected due are given below.

Number of properties affected due to proposed Metro Corridor/extension

Commercial Property	Residential Property	Religious Property	Others	Total
(i) Mysore Road Terminal - Kengeri				
32	07	01	17	57
(ii) Baiyyappanahalli – ITPL - Whitefield				
87	21	01	42	151
(iii) Puttenahalli Cross – Anjanapura Township (Up to NICE Road x-ing)				
26	10	01	34	17
(iv) Hesaraghatta Cross - BIEC				
08	01	-	23	32
TOTAL	153	39	116	311

Number of Trees affected due to proposed Metro Corridor/extension

Sl. No.	Metro Corridor/Extension	No. of trees affected in 10m strip of alignment and within the station area.
1.	Mysore Road - Kengeri –Future Station	50
2.	Baiyyappanahalli to ITPL/Whitefield Terminal	385
3.	Puttenahalli – Anjanapura Township (NICE Road x-ing)	253
4.	Hesaraghatta Cross - BIEC	26



0.12 COST ESTIMATES

The Cost Estimates for the four extensions have been prepared at July 2010 prices and works out to **Rs.6361 Crores** including land, taxes & duties(856 crores. The same is summarized as below.

Cost Estimate for Bangalore Phase – II extensions								
EXTENSION OF PHASE - I LINES (four Extensions)								
(i) Extension of E-W line from Mysore Road to Kengeri								
Total length = 6.465 km(completely elevated) No. of Stations = 5								
	Item	Unit	As per Final DPR			As per BMRCL		
			Rate	Qty	Amount (Rs. in crores)	Rate	Qty	Amount (Rs. in crores)
1.0	Land							
1.1	(a) land for alignment and stations	Ha	13.45	1.46	19.63	30.00	1.46	43.80
	(b) (i) Land for Depot Pvt. Land	Ha.	13.45	4.00	53.80	13.45	4.00	53.80
	(c) Land for Construction Depot (Land on lease for four years)	Ha.	3.23	4.00	12.91	3.23	4.00	12.92
	Sub Total (1)				86.34			110.52
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R.Km	32.55	6.47	210.44	31.50	6.47	203.81
	Sub Total (2)				210.44			203.81
3.0	Station Buildings							
3.1	Elevated Stations							
A	Type (A) Way side	Each	14.15	4	56.60	30.60	4	122.40
B	Type (c) Terminal & Junction	Each		1	16.97	34.20	1	34.20
C	Architectural finishing	Each	4.00		20.00			
	Sub Total (3)				93.57			156.60
4.0	E & M Works							
4.1	Elevated Stations							
C	Type (A) Way side – E & M works	Each	6.47	5	32.35	6.47	4	25.88
D	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total				38.82			32.35



Executive Summary

	(4)							
5.0	Depot at Kengeri /Future Station							
	Civil Works				24.00			24.00
	E & M Works				16.00			16.00
	Sub Total				40.00			40.00
	(5)							
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	6.47	41.51	6.42	6.47	41.51
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	2.00	4.00	2.00	2.00	4.00
	Sub Total				45.51			45.54
	(6)							
7.0	Traction & Power Supply							
7.1	Traction & Power supply including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	6.47	60.51	13.00	6.47	84.11
	Sub Total				60.51			84.11
	(7)							
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	6.47	51.85	9.89	6.47	63.99
8.2	Telecom	Each Stn.	2.76	6.00	16.56	5.04	5.00	25.20
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	6.00	17.58	2.93	5.00	14.65
	Sub Total				85.99			103.84
	(8)							
9.0	R & R including Hutments and road restoration etc	LS			26.00			26.00
	Sub Total				26.00			26.00
	(9)							
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	6.47	20.18	3.12	6.47	20.19
10.2	Electrical Utilities	LS			25.00			18.00
10.3	Telecom Utilities	LS			4.00			4.00
	Sub Total				49.17			42.19
	(10)							
11.0	Rolling Stock (SG)	Each	10.40	30.00	312.00	9.50	38.00	361.00
	Sub Total				312.00			361.00
	(11)							



12.1	Barracks for CISF including Security equipments	LS			3.00			3.00
12.2	Staff Quarters for O & M	LS			13.00			36.10
	Sub Total (12)				16.00			39.10
13.0	Total of all items except Land				978.00			1134.54
14.0	General Charges incl. Design charges @ 5% on all items except land				48.90			56.73
15.0	Total of all items including General charges				1026.90			1191.27
16.0	Total of Cost inclusive land cost				1113.24			1301.79
17.0	Contingencies @ 3%				33.40			39.05
18.0	Gross Total				1146.64			1340.84

(ii) Extension of Phase-I E-W line Baiyyappanahalli to White Field

Total length = 15.5 km No. of Stations = 14

Sl. No.	Item	As per Final DPR				As per BMRCL		
		Unit	Rate	Qty	Amount Rs. in crores)	Rate	Qty	Amount Rs. in crores)
1.0	Land							
1.1	(a) land for alignment and stations	Ha	16.13	7.79	125.61	30.00	7.79	233.70
	(b) Land for RSS	Ha.	16.13	0.40	6.45	16.13	0.40	6.45
	(c) Land for Depot	Ha.	13.45	8.00	107.60	13.45	8.00	107.60
	(d) Land for construction Depot (on lease for four years)	Ha.	3.87	4.00	15.48	3.87	4.00	15.48
	Sub Total (1)				255.15			363.23
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R. Km	32.55	15.50	504.53	31.50	15.50	488.25
	Sub Total (2)				504.53			488.25
3.0	Station Buildings							
3.1	Elevated Stations							
a	Type (A) Way side	Each	14.15	11	155.65	30.60	11	336.60



Executive Summary

b.	Type (b) Way side with signaling	Each	15.56	2	31.12	32.40	2	64.80
C	Type (c) Terminal & Junction	Each	16.97	1	16.97	34.20	1	34.20
d	Architectural finishing	Each	4.00	14.00	56.00			
	Sub Total (3)				259.74			435.60
4.0	E & M Works							
4.1	Elevated Stations							
d	Type (A) Way side – E & M works	Each	6.47	11	71.17	6.47	11	71.17
e	Type (B) Way side with signaling E & M works	Each	6.47	2	12.94	6.47	2	12.94
F	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				90.58			90.58
5.0	Depot at Kengeri /Future Station							
	Civil Works				48.00			48.00
	E & M Works				32.00			32.00
	Sub Total (5)				80.00			80.00
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	15.50	99.51	6.42	15.50	99.51
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	3.00	6.00	2.00	3.00	6.00
	Sub Total (6)				105.51			105.51
7.0	Traction & Power Supply							
7.1	Traction & Power supply including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	15.50	145.08	10.00	15.50	155.00
	Sub Total (7)				145.08			155.00
8.0	Signaling and Telecom							
8.1	Signaling	R.K m	8.02	15.50	124.31	9.89	15.50	153.30
8.2	Telecom	Each Stn.	2.76	14.00	38.64	5.04	14.00	70.56
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	14.00	41.02	2.93	14.00	41.02
	Sub Total (8)				203.97			264.88



9.0	R & R including Hutments and road restoration etc	LS			42.00			42.00
	Sub Total (9)				42.00			42.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.K m	3.12	15.50	48.36	3.12	15.50	48.36
10.2	Electrical Utilities	LS			41.50			125.81
10.3	Telecom Utilities	LS			6.50			6.50
	Sub Total (10)				96.36			180.67
11.0	Rolling Stock (SG)	Each	10.40	78	811.20	9.50	100.00	950.00
	Sub Total (11)				811.20			950.00
12.1	Barracks for CISF including Security equipments	LS			4.75			4.75
12.2	Staff Quarters for O & M	LS			21.00			77.90
	Sub Total (12)				25.75			82.65
13.0	Total of all items except Land				2364.72			2875.14
14.0	General Charges incl. Design charges @ 5% on all items except land				118.24			143.76
15.0	Total of all items including General charges				2482.95			3018.90
16.0	Total of Cost inclusive land cost				2738.10			3382.13
17.0	Contingencies @ 3%				82.14			101.46
18.0	Gross Total				2820.24			3483.59



(ii) Extension of Phase-I N-S line Puttenahalli Cross to Anjanapur Township

Total length = 6.29 km No. of Stations = 5

Sl.No.	Item	Unit	As per Final DPR			As per BMRCL		
			Rate	Qty	Amount (Rs. in crores)	Rate	Qty	Amount (Rs. in crores)
1.0	Land							
1.1	(a) land for alignment and stations	Ha	15.05	2.23	33.62	30.00	2.23	66.90
	(b) Land for Depot Pvt. Land	Ha.	15.05	3.00	45.15	15.05	3.00	45.15
	(c) Land for construction Depot (on lease for four years)	Ha.	3.61	4.00	14.45	3.61	4.00	14.44
	Sub Total (1)				93.22			126.49
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R. Km	32.55	6.29	204.80	31.50	6.29	198.14
	Sub Total (2)				204.80			198.14
3.0	Station Buildings							
3.1	Elevated Stations							
a	Type (A) Way side	Each	14.15	4	56.60	30.60	4	122.40
b	Type (c) Terminal & Junction	Each	16.97	1	16.97	34.20	1	34.20
C	Architectural finishing	Each	4.00		20.00			
	Sub Total (3)				93.57			156.60
4.0	E & M Works							
4.1	Elevated Stations							
c	Type (A) Way side – E & M works	Each	6.47	4	25.88	6.47	4	25.88
d	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				32.35			32.35
5.0	Stabling Depot at Anjanapura with washing facilities							
	Civil Works				36.00			36.00
	E & M Works				24.00			24.00
	Sub Total (5)				60.00			60.00
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	6.29	40.39	6.42	6.29	40.38
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	2.00	4.00	2.00	2.00	4.00
	Sub Total (6)				44.39			44.38
7.0	Traction & Power Supply							
7.1	Traction & Power supply							



	including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	6.29	58.89	10.00	6.29	62.90
	Sub Total (7)				58.89			62.90
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	6.29	50.46	11.64	6.29	73.22
8.2	Telecom	Each Stn.	2.76	5.00	13.80	5.68	5.00	28.40
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	5.00	14.65	2.93	5.00	14.65
	Sub Total (8)				78.92			116.27
9.0	R & R including Hutments and road restoration etc	LS			22.00			22.00
	Sub Total (9)				22.00			22.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	6.29	19.63	3.12	6.29	19.63
10.2	Electrical Utilities	LS			22.00			21.00
10.3	Telecom Utilities	LS			3.50			3.50
	Sub Total (10)				45.13			44.13
11.0	Rolling Stock (SG)	Each	10.40	12.00	124.80	9.50	30	285.00
	Sub Total (11)				124.80			285.00
12.1	Barracks for CISF including Security equipments	LS			2.50			2.50
12.2	Staff Quarters for O & M	LS			11.00			32.30
	Sub Total (12)				13.50			34.80
13.0	Total of all items except Land				778.36			1056.57
14.0	General Charges incl. Design charges @ 5% on all items except land				38.92			52.83
15.0	Total of all items including General charges				817.27			1109.40
16.0	Total of Cost inclusive land cost				910.49			1235.89
17.0	Contingencies @ 3%				27.31			37.08
18.0	Gross Total				937.81			1272.97



(iv) Extension of Phase-I N-S line Hesaraghatta Cross to BIEC								
Total length = 3.774km (entire Corridor is elevated) No. of Stations = 3								
			As per Final DPR			As per BMRCL		
Sl. No.	Item	Unit	Rate	Qty	Amount	Rate	Qty	Amount (Rs. In crores)
1.0	Land							
1.1	(a) land for alignment and stations							
	Govt. Land	Ha	5.00	0.49	2.44	5.00	0.49	2.45
	Pvt. Land	Ha	12.90	4.09	52.78	30.00	4.09	122.70
	(b) Land for Depot Pvt. Land	Ha.	15.05	1.00	15.05	15.05	1.00	15.05
	(c) Land for construction Depot (on lease for four years)	Ha.	3.10	4.00	12.38	3.10	4.00	12.40
	Sub Total (1)				82.66			152.60
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R. Km	32.55	3.77	122.84	31.50	3.77	118.76
	Sub Total (2)				122.84			118.76
3.0	Station Buildings							
3.1	Elevated Stations							
a	Type (A) Way side	Each	14.15	2	28.30	30.60	2	61.20
b	Type (c) Terminal & Junction	Each	16.97	1	16.97	34.20	1	34.20
C	Architectural finishing	Each	4.00	3	12.00			
	Sub Total (3)				57.27			95.40
4.0	E & M Works							
4.1	Elevated Stations							
c	Type (A) Way side – E & M works	Each	6.47	2	12.94	6.47	2	12.94
d	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				19.41			19.41
5.0	Stabling Depot at Anjanapura with washing facilities							
	Civil Works				18.00			18.00
	E & M Works				12.00			12.00
	Sub Total (5)				30.00			30.00



6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	3.77	24.23	6.42	3.77	24.20
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	2.00	4.00	2.00	2.00	4.00
	Sub Total (6)				28.23			28.20
7.0	Traction & Power Supply							
7.1	Traction & Power supply including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	3.77	35.32	9.36	3.77	35.29
	Sub Total (7)				35.32			35.29
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	3.77	30.27	9.89	3.77	37.29
8.2	Telecom	Each Stn.	2.76	3.00	8.28	5.04	3.00	15.12
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	3.00	8.79	2.93	3.00	8.79
	Sub Total (8)				47.34			61.20
9.0	R & R including Hutments and road restoration etc	LS			11.00			11.00
	Sub Total (9)				11.00			11.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	3.77	11.77	3.12	3.77	11.76
10.2	Electrical Utilities	LS			11.00			6.00
10.3	Telecom Utilities	LS			1.70			1.70
	Sub Total (10)				24.47			19.46
11.0	Rolling Stock (SG)	Each	10.40	9.00	93.60	9.50	21	199.50
	Sub Total (11)				93.60			199.50
12.1	Barracks for CISF including Security equipments	LS			1.25			1.25
12.2	Staff Quarters for O & M	LS			5.50			19.00
	Sub Total (12)				6.75			20.25
13.0	Total of all items except Land				476.24			638.47
14.0	General Charges incl. Design charges @ 5% on all items except land				23.81			31.92



15.0	Total of all items including General charges				500.05			670.39
16.0	Total of Cost inclusive land cost				582.71			822.99
17.0	Contingencies @ 3%				17.48			24.69
18.0	Gross Total				600.19			847.68

**ABSTRACT OF COST ESTIMATE FOR FOUR EXTENSIONS
(inclusive of land cost for alignment & Stations)**

Sl. No.	Description	As per DPR			As per BMRCL			
		Cost excluding taxes & Duties Rs. Crores	Details of taxes & Duties Rs. Crores	TOTAL in Rs. Crores	Cost excluding taxes & Duties Rs. Crores	Details of taxes & Duties Rs. Crores	TOTAL in Rs. Crores	
1	Mysore Road Terminal – Kengeri	1146.64	182.00	1328.64	1340.84	207.00	1547.84	
2	Baiyyappanahalli – ITPL – White field	2820.24	444.000	3264.24	3483.59	532	4015.59	
3	Puttenahalli Cross – Anjanapura Township (up to NICE Road crossing)	937.81	142.00	1079.81	1272.97	193.00	1465.97	
4	Hesaraghatta Cross - BIEC	600.19	88.00	688.19	847.68	117.00	964.68	
GRAND TOTAL		5504.88	856.00	6360.88	6945.08	1049.00	7994.08	
				Say Rs.6361 Crores				Say Rs.7994.08 Crores

0.13 FINANCIAL ANALYSIS AND FINANCING PLAN

The East West & North South Corridor Bengaluru Phase-II Metro is proposed to be constructed with an estimated cost of Rs 5505 Crore at July 2010 price level without taxes but including land cost. The estimated cost with taxes is Rs. 6361 crore.

**Year wise Investment-With Central Taxes – As per DPR**

Financial Year	Estimated Cost	Completion Cost
2012-13	823.00	895.00
2013-14	1379.00	1587.00
2014-15	1391.00	1733.00
2015-16	1113.00	1456.00
2016-17	556.00	763.00
2017-18	556.00	802.00
2018-19	278.00	421.00
Total	6096.00	7657.00

Year wise Investment-With Central Taxes – As per BMRCL

Financial Year	Estimated Cost	Completion Cost
2012-13	1036.87	1127.32
2013-14	1737.33	1999.37
2014-15	1752.71	2183.65
2015-16	1402.48	1834.66
2016-17	700.48	961.24
2017-18	700.48	1010.40
2018-19	350.23	530.41
Total	7680.58	9647.05

Financing Plan: -

The four extensions 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: -

Particulars	Government of India		Government of Karnataka		Total	
	%	Rs/Crore	%	Rs/Crore	%	Rs/Crore
Equity by GOI & GO Karnataka	20%	1532.00	20%	1532.00	40%	3064.00
SD for land cost by GO Karnataka	0%	0.00	7%	533.00	7%	533.00
Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	8%	594.00	2%	148.00	10%	742.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	43%	3318.00	0%	0.00	43%	3318.00
Total	71.00%	5444.00	29.00%	2213.00	100.00%	7657.00

**Financial Internal Rate of Return (FIRR)**

The FIRR with Central taxes only is given below:

Particulars	Completion Cost With Central Taxes (Without additional PD)	Completion Cost With Central Taxes (With Additional PD income from 15 Ha.)
FIRR (%)	-3.10%	2.23%

0.14 ECONOMIC ANALYSIS

Implementation of the proposed four extensions 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.

Sl. No.	Parameter	Value
1	EIRR (%)	16%

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 2016. However these sections get priority as these are the extensions to the on going Phase-I E-W and N-S lines of Phase-I and cater for the outskirts traffic to/fro the city center.

A suggested project implementation schedule is given below. The proposed date of commissioning of the section with suggested dates of important milestones is given in below.

Implementation Schedule

S. No.	Item of Work	Completion Date
1.	Date of Submission of Final DPR to Karnataka State Government	D
2.	Approval of DPR by Karnataka State Government	D+ 6 Months
3.	Approval of DPR by Central Government	D+ 12 Months
4.	Appointment of Interim Consultant for preliminary works	D+ 6 Months
5.	Appointment of General Consultant	D+ 18 Months
6.	Tendering, execution of works and procurement of equipment, coaches and installations	D+60 Months
7.	Testing and Commissioning	D+62 Months
8.	Revenue Operation	From D+63 rd Month



*D : Date of submission of Final DPR

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.

The implementation of the two corridors of Bangalore Metro is already in progress by BMRCL. Based on the details as furnished in the Detailed Project Report the project may be implemented on priority basis, as extension to Phase-I.

* * * * *

LEGEND

- Phase-1 UNDERGROUND SECTION
- Phase-1 ELEVATED SECTION (N-S LINE)
- Phase-1 ELEVATED SECTION (E-W LINE)
- Extension of Phase-1 ELEVATED SECTION
- Phase-2 ELEVATED SECTION (N-S LINE)
- Phase-2 ELEVATED SECTION (E-W LINE)
- METRO STATIONS

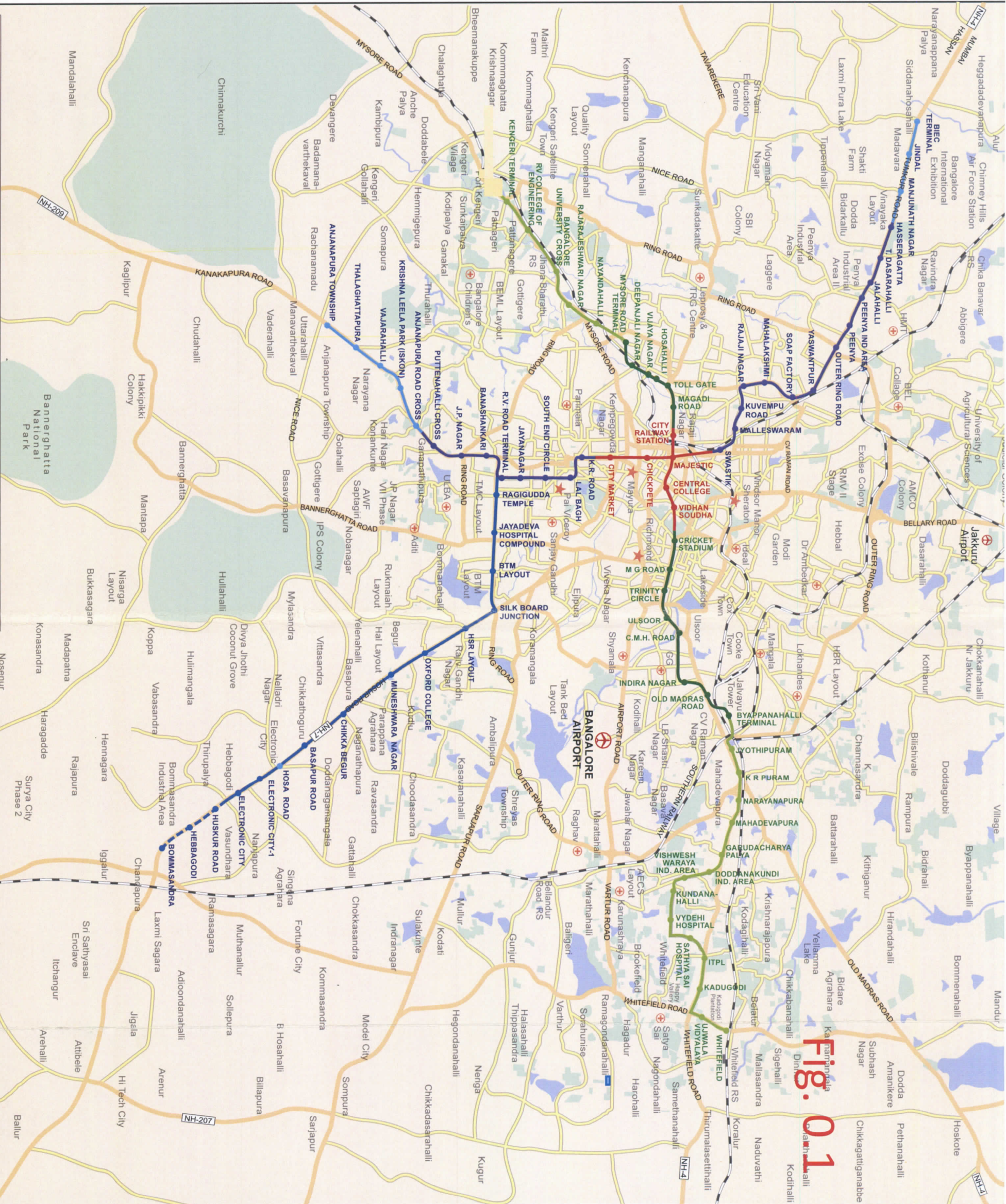


Fig. 01
Bangalore Metro



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 Phase-I 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 N-S 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 was proposed 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 14th June 2008.

1.1.4 The details of North – South line including extensions as sanctioned in Phase-I are given in table 1.1 and 1.2 and the implementation is in progress.

Table 1.1
DETAILS OF NORTH – SOUTH CORRIDOR IN PHASE-I

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)
	TOTAL	24.165	24 (21 elevated & 3 underground)



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	CMH Road	14610	885
16	Old Madras Road	16419	1809
17	Byappanahalli	17374	955

1.2 Phase - II Corridors.

BMRCCL vide their letter No.BMRCCL/MD/PS/09-10/298 dt.25-03-2010 conveyed approval of HPC for preparation of DPRs in respect of the extensions/corridors as mentioned below.

Sl. No.	Corridor approved by HPC for inclusion in Phase-II	Length (Km)
1.	Extension of East-West Line: Mysore Road Terminal - Kengeri	6.10
2.	Extension of East-West Line: Baiyappanahalli - ITPL- Whitefield	15.50
3.	Extension of North-South Line: Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC)	4.00
4.	Extension of North-South Line: Puttenahalli Cross to Anjanapura Township(upto Nice Road)	6.00
5.	New North South Line: Indian Institute of Management, Bangalore (IIMB) to Nagavara	19.80
Total		51.40

HPC in their supplementary meeting to the 8th High Power Committee meeting held on 06.05.2010 decided that DPR for R.V. Road – Bommasandra corridor (18.83 Km) should also be prepared. Copy of the letter and minutes of the supplementary meeting are placed as Annexure to this Chapter.

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

1.2.1 The I.T industry organizations of Electronic City had come up with a strong plea to provide Metro Rail connection to Electronic City urgently under phase - I itself. The Government of Karnataka is keen to provide Metro connection to Electronic city on priority. Hence, in fitness of things this Metro line from RV Road Terminal to Electronic City has been studied and proposed as an extension of N-S Metro line of Phase – I towards South – East with provision for extension up to Bommasandra Industrial area in future. DPR for the same was submitted in May 2010.

1.2.2 This Report is being prepared for the following extensions of the East-West Line and North -South Line of Phase-I in both directions. (four extensions).



Sl. No	Extension of Phase -I Corridors in Phase-II	Length (Km)
i.	Extension of E-W line from Mysore Road to Kengeri – Future Station	6.465
ii.	Extension of E-W line from Baiyappanhalli to ITPL - Whitefield	15.50
iii.	Extension of N-S line from Puttenahalli to Anjanapura Township	6.29
iv.	Extension of N-S line from Hesarghatta Cross to BIEC	3.77
	TOTAL	32.025

The details of proposed extensions of Phase – I lines (four extensions) are as under:

(i) Extension of Phase – I E-W line on the west side from Mysore road Terminal to Kengeri- Future Station.

The satellite town 'Kengeri' which has come up in the outskirts of south-western part of Bangalore has developed and further is a fast developing suburb. The traffic on the Mysore road up to Kengeri has also increased a lot in the recent past. Conveniently, passengers from/to Mysore may terminate/originate here. Therefore the necessity of extension of Mysore road Terminal to Kengeri.

(ii) Extension of Phase – I E-W line on the East side from Baiyappanhalli to ITPL/Whitefield.

The hub for the IT industry after Electronic City is the ITPL area. Also the Doddanekkundi Industrial Estate, KSIIDC Industrial Estate, Visveshwaraiah Industrial Estate, KIADB Export Promotional Industrial Area etc also exist along this line which caters for a large number of ridership. Also the Whitefield Railway Station which the Railways are planning to make a transportation hub on the eastern side, the Sri Sathya Sai Baba Ashram near the Whitefield Railway Station and a large number of Real Estate projects in Whitefield area caters for large number of ridership. As per the traffic survey, the traffic on the Phase-I E-W line is almost doubled by the extension of this line up to ITPL/Whitefield. Therefore the necessity of extension of Baiyappanhalli to ITPL/Whitefield.

(iii) Extension of Phase – I N – S line on south side from Puttenahalli Cross to Anjanapura Township (NICE road x-ing)

The Phase-I N-S line is already under construction up to Puttenahalli cross on Kanakapura road. In phase-II the same line is proposed for extension up to Anjanapura Township (NICE road x-ing) along Kanakapura road. There is a large number of ridership from this part of the city travelling to & fro from City. Therefore the necessity of extension of Phase-I N-S line on the southern side to Anjanapura Township (NICE road x-ing).

**(iv) Extension of Phase – I N-S line on north side from Hesarghatta Cross to Bangalore International Exhibition Center (BIEC)**

The Phase-I N-S line is already under construction up to Hesarghatta Cross on Tumkur road. In phase-II the same line is proposed for extension up to Bangalore International Exhibition Center (BIEC) (beyond NICE road x-ing) along Tumkur road. A lot of visitors who intend to go to the Exhibition Center from various parts of the city will be benefitted to visit the BIEC as the travel time required as of now is too much. Therefore the necessity of extension of Phase-I N-S line on the Northern side to BIEC.

1.2.3 Draft Detailed Project Report (DPR) for IIM(B) - Nagavara (North-South Line) as approved in Phase-II is already submitted in May 2011.**1.3 This Report is structured in 16 Chapters as below:**

Chapter - 1	INTRODUCTION
Chapter - 2	TRAFFIC DEMAND ANALYSIS
Chapter - 3	PLANNING & DESIGN PARAMETERS
Chapter - 4	CIVIL ENGINEERING WORKS
Chapter - 5	TRAIN OPERATION PLAN
Chapter - 6	ROLLING STOCK
Chapter - 7	POWER SUPPLY SYSTEM
Chapter - 8	SIGNALLING SYSTEM
Chapter - 9	TELECOMMUNICATION & AUTOMATIC FARE COLLECTION SYSTEM
Chapter - 10	TRAIN MAINTENANCE DEPOT
Chapter - 11	ENVIRONMENT & SOCIAL IMPACT ASSESSMENT
Chapter - 12	COST ESTIMATES
Chapter - 13	FINANCIAL VIABILITY, FARE STRUCTURE & FINANCING OPTIONS
Chapter - 14	ECONOMICAL INTERNAL RATE OF RETURN
Chapter - 15	IMPLEMENTATION PLAN
Chapter - 16	CONCLUSIONS

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



Chapter 1 - Introduction

- 1.4 This DPR has been prepared subsequent to the remarks of BMRCL put up at annexure II to this chapter. The DPR, now includes only one option i.e. extension of East West Corridor from Baiyappanhalli to Whitefield and North –South corridor as given in the earlier DPR.



Annexure I

Chapter 1 - Introduction

N. SIVASAILAM, IAS
Managing Director



Bangalore Metro Rail Corporation Ltd.
(A Joint Venture of Govt. of India & Govt. of Karnataka)
3rd Floor, BMTCL Complex, K.H. Road,
Shanthinagar, Bangalore - 560 027, INDIA
Phone: 080-2296 9202, 2296 9203, Fax: 2296 9204
Web : www.bmrc.co.in e-mail : md@bmrc.co.in

No. BMRCL/MD/PS/09-10/298
March 25, 2010

Dr. E. Sreedharan
Managing Director
Delhi Metro Rail Corporation Ltd.
Metro Bhawan, 13, Fire Brigade Lane
Barakhamba Road
New Delhi-110 001.

Respected Sir,

Sub: Bangalore Metro Rail Project Phase-II – Preparation of DPRs – Reg

Enclosed please find a copy of the Extract of the Proceedings further to the 8th High Power Committee Meeting held under the Chairmanship of Chief Secretary, Govt. of Karnataka, on 20th March 2010 on the above subject, for your information. The HPC has cleared the proposal for preparation of DPRs in respect of following lines :

Sl. No.	Alignment	Length of the line
1.	Extension of EW line: -Mysore Road Terminal to Kengeri	6.10 KMs
2.	Extension of EW Line: -Baiyappanahalli to ITPL -Whitefield	15.50 KMs
3.	Extension of NS Line: Hesaraghatta Cross to Bangalore International Exhibition Centre (BIEC)	4.00 KMs
4.	Extension of NS Line: - Puttenahalli Cross to Anjanapura Township (Upto NICE Road)	6.00 KMs
5.	New Line – NS Line: - Indian Institute of Management, Bangalore (Meenakshi Temple on Bannerghatta Road) to Nagavara	19.8 KMs

I, therefore, request you to kindly forward the DPRs within the next 2 months positively to enable its consideration by the Government of Karnataka and the Govt. of India.

With kind regards,

Yours sincerely,


(N. SIVASAILAM)

Encls. Extract of 8th HPC Minutes – 4 pages.



ಬೆಂಗಳೂರು ಮೆಟ್ರೋ ರೈಲ್ ನಿಗಮ ನಿಯಮಿತ

(ಸಹಭಾಗಿತ್ವ - ಕರ್ನಾಟಕ ಸರ್ಕಾರ ಹಾಗೂ ಕೇಂದ್ರ ಸರ್ಕಾರ ಉದ್ಯಮ)

ಬಿ.ಎಂ.ಟಿ.ಸಿ. ಕಾಂಪ್ಲೆಕ್ಸ್, 3ನೇ ಮಹಡಿ, ಕೆಂಗಲ್ ವಸುಮಂತಯ್ಯ ರಸ್ತೆ, ಶಾಂತಿನಗರ, ಬೆಂಗಳೂರು - 560 027, ಭಾರತ

Bangalore Metro Rail Corporation Ltd.

(A Joint Venture of Government of Karnataka & Government of India)

B.M.T.C. Complex, 3rd Floor, K.H. Road, Shanthinagar, Bangalore - 560 027, INDIA

No.BMRCL/EO/HPC/2010-11

May 14, 2010

Sir,

Sub : Proceedings of the 2nd supplementary meeting to the 8th High Power Committee meeting held on 6th May, 2010.

Kindly find enclosed copy of the Proceedings of the 2nd supplementary meeting to the 8th High Power Committee meeting held on 6th May, 2010 at 11:00 A.M. under the Chairmanship of the Chief Secretary to Govt., GoK, at Committee Room No.313, Vidhana Soudha, Bangalore.

Thanking you,

Yours faithfully,

For Bangalore Metro Rail Corporation Limited,

(Anil B. Shedbal)
Company Secretary & General Manager

Encl : Copy of the Proceedings of the
2nd Supplementary meeting to the
8th HPC meeting.

To:

- 1) Additional Chief Secretary to Govt., Urban Development Department, Vikasa Soudha, Bangalore.
- 2) Principal Secretary to Govt., Finance Department, Vidhana Soudha, Bangalore.
- 3) Principal Secretary to Govt., Public Works Department, Vikasa Soudha, Bangalore.
- 4) Principal Secretary to Govt., Transport Department, M.S. Building, Bangalore.
- 5) Sri M.Mohsin, Additional Secretary, Urban Development Department, Vikasa Soudha, Bangalore.
- 6) Metropolitan Commissioner, Bangalore Metropolitan Region Development Authority, Bangalore.
- 7) Commissioner, Bangalore Development Authority, T. Chowdaiah Road, Kumarapark West, Bangalore-560 020.
- 8) Commissioner, Bruhat Bangalore Mahanagara Palike, Bangalore.
- 9) Additional Commissioner of Police (Traffic), Shivajinagar, Bangalore.
- 10) Sri S.N. Venkata Rao, Advisor, Delhi Metro Rail Corporation Ltd., No.4A, 'Bharath Apartments', Fairfield Layout, Race Course Road, Bangalore-560 001.
- 11) Sri R. Gopinathan Nair, Project Director, Delhi Metro Rail Corporation Ltd., No.4A, 'Bharath Apartments', Fairfield Layout, Race Course Road, Bangalore-560 001.
- 12) Managing Director, BMTCL.
- 13) Managing Director, BARL.
- 14) Director, Town Planning, Bangalore.
- 15) Director, DULT, Bangalore.
- 16) Sri M. Shivakumara Swamy, Dy. Secretary, Infrastructure Development Department, Vikasa Soudha, Bangalore.
- 17) Sri T. Parvateesam, Mgr(T), National Highways Authority of India, (Ministry of Shipping, Road, Transport & Highways), Project Implementation Unit, #52, 6th Cross, 38th Main, BTM 2nd Stage, Bangalore-560 068.
- 18) Sri K.S. Vishwanath, Chief Traffic Manager (Operations), BMTCL, Bangalore.
- 19) PS to the Chief Secretary, Govt. of Karnataka, Vidhana Soudha, Bangalore.



PROCEEDINGS OF THE 2nd SUPPLEMENTARY MEETING TO THE 8TH HIGH POWER COMMITTEE MEETING HELD ON 6TH MAY 2010 AT 11.00 AM UNDER THE CHAIRMANSHIP OF CHIEF SECRETARY TO GOVERNMENT OF KARNATAKA IN THE CHAMBERS OF CHIEF SECRETARY, VIDHANA SOUDHA, BANGALORE.

MEMBERS PRESENT: As mentioned in the Annexure.

The Chief Secretary welcomed all the members present in the meeting and thanked all for attending the meeting at short notice.

The meeting is in continuation of the 8th HPC held on 17.2.2010 wherein the alignment from RV Road – BTM Layout and Central Silk Board – Hosur Road – Electronic City – Bommasandra Industrial Area was presented with a request seeking the assistance of the State Government to approach NHAI for facilitating construction of Metro line on portals over the service road of the existing Highway on Hosur Road. During the meeting it was suggested that since Electronic City has already been connected directly with the present elevated expressway, the alignment to Electronic City via Bannerghatta Road (IIMB) – Jigani Industrial Area - Bommasandra Industrial Area – Electronic City may be explored, so that the commuters of Jigani and Bommasandra Industrial areas can utilise Metro Rail besides commuters of Electronic City. The Metro alignment to Electronic City was deferred to a later date for detailed discussion after consideration of suggestions made in the meeting. The matter has been examined in detail. The alignment along Bannerghatta road to Electronic City via DLF enclave and via Jigani & Bommasandra is not viable on account of poor ridership to Bommasandra and becomes Electronic City a circuitous route with poor rider preference, involving traversing a distance of additional 20 Kms & 25 Kms. respectively from IIM-B on Bannerghatta Road making Metro an unviable option both on distance travelled and travel time criteria.

Another alignment considered is from Bannerghatta (Meenakshi Temple) to the backside of Electronic City. Here the patrons in Electronic City have to walk a long



Chapter 1 - Introduction

distance to reach Metro Station at Electronic City thereby making it a less preferred option to more comfortable and efficient options. The alignment passes through areas that are presently under intermittent development along a length of about 6 to 7 kms while about 3 to 4 kms (in multiple stretches) would pass through lands without high ridership potential, in the short and medium term upto 15 years. Further the alignment reaches the rear of the Electronic City without offering much potential to take it further towards Bommasandra Industrial Area and beyond and the alignment would therefore be an optimal alignment. MD, BMRCL, informed that he has held extensive discussions with representatives of ELCIA (representing with other industry associations) who have expressed the view that the alignment to Electronic City via Hosur Road will be appropriate.

The alignment from Bannerghatta (Meenakshi temple) to Jigani is not viable in the short to medium term and hence not recommended. Hence, as suggested by DMRC, the Metro Rail alignment on Hosur Road from Central Silk Board junction to Bommasandra Industrial area and beyond is feasible both in the short and long run. The construction is feasible, the economics very favourable and the only issue is administrative sanction (NOC) from institutions having existing Right of Way.

The issue for consideration is the location of the Viaduct of the alignment over the service road in Hosur Road. The contention of NHAI representative is that the Viaduct may run beyond the service road rather than over it so that NHAI right of way on the service road is not affected. This contention has been considered in the present setting. The proposal to locate the Viaduct over the service road is on account of the fact that land acquisition beyond the service road is practically not feasible since it would involve demolition of a large number of properties over a continuous distance of 8



less present and valued presently at over Rs. 3000 Crores making the project and facility unviable through any road or rail infrastructure project. It was further contended by NHAI that 6 to 7 km of the road will be operational with a limited width. This is correct because a portion of the service road only has to be closed during construction. This is unavoidable. However, the construction over the service road does not affect NHAI right of way over it (road surface) except that the road width will be reduced to 3.5 M from the present 7.5 M during construction allowing one lane traffic against two lane presently. The service road on the other side of the NHAI corridor will be totally without any disturbance. Further, the utility duct on either side of the service road will not be affected. The Metro alignment will cater to developments all along Hosur Road while the Road expressway caters to Electronic City only.

DMRC Principal Secretary, Finance Department, enquired about the ridership in the alignment to Electronic City via Bannerghatta. It was explained that the alignment passes through areas that are presently under intermittent development along a length of about 6 to 7 kms while for about 3 to 4 kms (in multiple stretches) it would pass through lands without any ridership potential, in the short and medium term. It is estimated that the ridership on the Metro to Electronic City via Central Silk Board Junction and Hosur Road will be around 2 lakhs per day which will further increase later.

Principal Secretary, PWD, pointed out that when large investments of about Rs.900 Crores has been made for the road expressway which has reduced the travel time to Electronic City to about 10 minutes, further investment for providing Metro connectivity to Electronic City needs to be viewed in the light of above. However, he mentioned that there is no better alternative to the proposed alignment via Hosur Road to reach



Bommasandra & beyond effectively. The Chief General Manager (T) of NHAI expressed the opinion that the NHAI Concessionaire will be affected by the development. BMRCL, clarified that there is no stipulation in the Expressway agreement regarding allowing other parallel developments during the concession period.

Commissioner, BDA, opined that the Metro alignment along Hosur Road to Electronic City, Bommasandra and beyond in future helps development of the nearby localities in view of metro stations all along the alignment.

Mr. Gopinathan Nair, Project Director, DMRC, informed that while the NHAI expressway caters to Electronic City only, Metro will have 9 metro stations before reaching Electronic City and will cater to substantial developments from and before RV Road to Electronic City – Bommasandra and beyond.

MD, BMRCL, stated that the present proposal is for preparation of DPR for Bommasandra Industrial Area covering Electronic City, with further scope for extension to other areas in future. The construction work may be taken up in phases, starting from Electronic City in the first stage, then upto Bommasandra Industrial Area in the second stage and so on, depending on funds availability.

MD, BMTC, apprehended that with the proposed Metro alignment along Hosur Road to Electronic City, the earnings of BMTC buses running to Electronic City will be substantially reduced. Chief Secretary stated that in view of large developments in the area creating huge ridership in the route, both BMTC and Metro Rail services will be viable and bus services will only increase to cater to increased demand in the area. Hence, there is no need for any apprehension of overall revenue loss to BMTC if Metro rail services are provided in this stretch.



After detailed deliberations taking the opinions and suggestions of all the Members present and taking into consideration the overall development of Electronic City, Bommasandra Industrial Area and surrounding areas, it was felt that there is a necessity of providing Metro Rail services to these areas to cater to the demand for a quick and efficient service to the concerned areas.

Chief Secretary finally summarized up the discussions as follows:

- (a) The proposed Metro alignment from RV Road – BTM Layout and Central Silk Board – Hosur Road – Electronic City – Bommasandra Industrial Area will cater to the transport requirement of commuters of these areas besides covering the future development of Electronic City and Bommasandra Industrial Areas and beyond.
- (b) It will help develop the areas all along the Metro alignment substantially.
- (c) In the long run, Bangalore City will require all modes of transportation such as Road transport, Expressway, Metro rail connectivity etc., when we look at the speed at which the developments are taking place. The construction over the service road is the only cost effective feasible alternative without impairing NHAI Right of way, temporary curtailment of it during construction, notwithstanding.
- (d) During construction of Metro alignment, inconvenience to the public must be kept to minimum and the project authorities shall take steps to that effect.

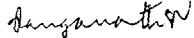
With the above observations, HPC approved the Metro alignment from RV Road – BTM Layout and Central Silk Board – Hosur Road – Electronic City – Bommasandra Industrial Area and to take up alignment from Central Silk Board Junction to Electronic City and beyond upto Bommasandra Industrial Area at this stage over the service road of NHAI on Hosur Road to avoid large scale



Chapter 1 - Introduction

acquisition of land and demolition of properties. Further HPC authorised BM to go ahead with preparation of DPR from RV Road to Bommasandra Industrial Area. Further, the State Government will write to NHAI to seek their permission for construction of Metro line on the western side above the service road of Hosur Road.

Meeting concluded with vote of thanks from the Chair.


(S.V.RANGANATH)
CHIEF SECRETARY TO GOVERNMENT



ದಿನಾಂಕ 06.05.2010 ರಂದು ಸರ್ಕಾರದ ಮುಖ್ಯ ಕಾರ್ಯದರ್ಶಿ, ಇವರ
ಅಧ್ಯಕ್ಷತೆಯಲ್ಲಿ ನಡೆದ ಸಭೆಯಲ್ಲಿ ಹಾಜರಿದ್ದ
ಅಧಿಕಾರಿಗಳ ಹಾಜರಾತಿ

ಕ್ರ.ಸಂ	ಹೆಸರು ಮತ್ತು ಪದನಾಮ	ಸಹಿ
1	ಸರ್ಕಾರದ ಮುಖ್ಯ ಕಾರ್ಯದರ್ಶಿಯವರು	ಅಧ್ಯಕ್ಷರು
2	ಸರ್ಕಾರದ ಅಪರ.ಮುಖ್ಯ ಕಾರ್ಯದರ್ಶಿ ಯವರು ನಗರಾ ಟಿವೈಡಿ ಇಲಾಖೆ	
3	LV Nagasayeri Pr Secy (D)	
4	R.B. AGAWANE - Pr. Secy. PWD	
5	S. Z. pasha MD, BMTC	
6	R. Gopinathan Nair Project Director / DMRC	
7	S. H. Venkatesh Rao Asstt. Dir. (P) BICA	
8	B. S. SUDHAR CHANDR Asstt. Dir. (P) BICA	
9	N. Saraswatham MD BMRCL	
10	Siddiah. Commissioning BDA	

i) A. K. H. A. S.



12. M. Mohsin
Addl. Secy. UDD.

MB

13. T. PARVATEESAM
M&CT) NHAI

TR

14. BHARAT LAL COMMR
BBMP

3205 CW

15. H.B. Mukunda
Director of Town and Country
Planning

whites sign

16. K. S. Vishwanath
Chief Traffic Manager (Ops)
B. M. T. C.

Doc. 2 6/5/10

17. ಎಂ. ಶಶಿವರ್ಷಪ್ಪ
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A. Shetty



DMRC's Remarks to BMRCL Comments on Detailed Project Report – Phase II (four extensions)

SI No.	Chapter / Page No/Para	Comment/Suggestion of BMRCL	DMRC's Remarks
1	Salient Features Point no -3 Page no 1 of 3	Average lead, is it average trip length? It is not clear. As in chapter -2, 56 of 59, the values are different and in executive summary table 0.4	Yes, it is average trip length for the incremental ridership. The table appearing at page 56 of chapter 2 presents the ridership details of N-S and E-W corridors with extensions at both ends for option 2, while it seems that comparison has been done with option 1 in table 0.4. In this DPR, The Option I is deleted and figures given only for option II(i.e. the extension of East-West corridor up to Kengeri on one side and up to Whitefield on other side.
2	Salient Features Point no -4 Page no 2 of 3	Coaches required 2016, 57 nos is it additional to already projected coaches for Phase-I and Phase-II extensions? As per para 10 of Executive summary it is only 48 additional cars	57 coaches are additional requirement in Phase II extensions in 2016. The break-up of the coaches are as under: (refer page 44,46 of chapter 5) Byappanahalli-Whitefield =24 Mysore Road-Future Station =12 Puttenahalli-Anjanapura=12 Hessarghatta-BIEC=9 However , The TOP chapter is now revised and the requirement of coaches has increased.
3	Executive Summary Page 6 and 7	The incremental average lead in Km has decreased from 2016 to 2041. Is it correct?	Para 10 last column of table of Executive Summary indicates the additional capacities required for stabling the trains in depot. Therefore, it is different from the requirement of trains for the extensions. It can be observed that the overall average lead is increasing during 2010-2041. However, the development pattern which has been envisaged in the study illustrate that the city growth is very less compared to the rest of BBMP area in the 2021-2041 period. This results in more opportunities in outer city area and has led to shorter trips in the rest of BBMP



Chapter 1 - Introduction

			area in the 2021-2041 period. This has resulted in lower incremental lead.
4	Executive Summary Point no 0.2 Page 2 of 33	R.V.Road to Electronic City report is submitted in draft and comments have been given already vide letter no Bmrcl D&UG C186 2010 3268 dated 6 th September 2010.. Final report awaited	Final DPR for R V Road-Bommasandra in place of Electronic City has already been submitted.
5	Executive summary Table no 0.1 Page no 3 of 33	The Projections are from CDP? If any other method is used - to be indicated, what is the growth rate assumed as CDP is only up to 2015	Population & employment figures are based on Census 2001 and projected for future with reference to CDP and revised Structural Plan for BMR for the horizon year 2031(ref para 2.1.3 of chapter 2).
6	Executive summary Planning Parameters Table no 0.3 Page no 7 of 33	The over all deck width recommended is 9.84m which is not adequate as experienced in Phase I. This comment was given in the R.V.Road to Electronic City terminal draft DPR. But it is not here. But not addressed here. DMRC is not addressing the third rail issues and the related cables, third rail brackets etc.	The deck width of 9.54 m with over all width of 10.520 has been recommended for Bommasandra extension. The same is recommended even for these four extensions.
7	Executive Summary Page 7 of 33 . Para 0.3 Para-2	However, provision of deck width of 9.84m and 10.04m is not clear	The deck width of 9.54 m even with track centers of 4.2 m on 120 m radius curve(with SE of 110 mm) is adequate.
8	Executive Summary Page 8 of 33 Para 0.4.2	In this stretch of the alignment, the alignment should be so designed that the new TTMC building of BMTC is not affected.	The TTMC building line edge is about 2.5 m from the parapet of proposed BMRCL deck.
9	Executive Summary Page 14 of 33	<u>Geo Technical Investigation</u> The intervals of the bores taken shall be mentioned. It looks too far apart.	Interval is already mentioned in the Stratigraphy. These intervals are considered sufficient for elevated stretches in the DPR stage. Distances of boreholes are 500 m on an average.
10	Executive Summary Page 15 of 33	<u>Land requirement</u> The provision of 01.5 hectares of land for PD is very less. More land shall be identified and earmarked for PD (Property Development)	The total land for PD is 9.82 Ha, which is shown as per Chapter 12, Cost Estimate clause 12.2.1 (iii), page 11/25.The figure of (01.52) in the bracket is the additional land if the alignment is extended upto Whitefield. The para is now accordingly revised.
11	Executive Summary Page 16 of 33 Top para	<u>Schedule speed</u> Why operational speed is only 33km less than in North-South 34 in East West	The operational scheduled speeds mentioned in the DPR for the different corridors/sections are the estimated speeds based on the average inter-station distances in the sections and DMRC's past experience.



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			Road Terminal is estimated as lower than the other sections due to smaller inter-station distances.
12	Executive Summary Point 0.5.1 Page 16 of 33	The capacity is calculated based on 6 passengers per Sqmtr for standee area. In Phase-I crush load is calculated based on 8 passengers per Sqmtr of Standee area. This works out to 2068 passengers instead of 1626 passengers. Why this change?	<p>It is DMRC's experience that crush load of standees @ 6 passengers per sqm of standee area in itself is a densely packed condition and hence the available PHPDT capacity is calculated based on this dense load condition. DMRC has also worked out the requirements for its Phase – II and Phase – III networks based on PHPDT capacity @ 6 passengers per sqm of standee area.</p> <p>It may further be noted that the Rolling Stock is designed for carrying higher density loading @ 8 passengers per sqm of standee area and the sections where the PHPDT demand exceeds the planned PHPDT capacity @ 6 passengers per sqm, overloading permissible @ 8 passengers per sqm of standee area will help in optimizing the requirements and reducing the demand for increased deployment of Rolling Stock.</p>
13	Executive Summary Page 21 of 33 Top portion	Power supply has been suggested to be augmented in future years and in train bunching situation head way reduces to 150 seconds for short durations. In Phase – I 2 cables ASS are suggested by DDC (Traction) Why not designed likewise here?	Please refer chapter 7 (related to Power Supply) where it has already been stated that during the detailed design stage, schemes developed in Phase I and the related experiences should be considered (ref. para-7.2, 7.8.5).
14	Executive summary Table no.0.7.6 Page no 24 of 33	The cost of shifting (80crs) for 220 kv double circuit transmission line shifting should be included in the project cost itself.	Total 100 crores for shifting of electrical utilities has already been provided vide item no. 10.2 of estimate of all the extensions. Hence, no need is felt for additional provision. Any additional requirement can be met with contingency head.
15	Executive Summary Page 26 of 33 Point 0.11	Trees – Pruning and uprooting show separately	Table 11.15 of chapter 11 provides the details.
16	Executive Summary Page 27 of 33 Point – 0.12	Cost Estimates 127crs for 6 Stations appears low. (i.e Rs 21 crores / Station) We have platform membrane also	Cost of finishing work (@ Rs 4 crores for each station is now added in this DPR.



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17	Chapter-1 introduction Table no.1.2 Page no 2 of 17	Check the final chain ages as per final station Plans of Phase-I	Phase-I DPR Chainages have been adopted. If the Chainages have been revised, the same may please be furnished so that suitable changes, if any, may be done.
18	Table no.1.3 Page no 2 of 17 if we are following DPR Phase-I names of Stations	Indiranagar should be written as CMH Road	This change is now made in this DPR.
19	Chapter -1 Page no 10 of 17 Introduction Proceedings HPC on NHAI Alignment with Metro	NHAI has agreed to close main carriage way Road during Construction, if we indemnify the loss in toll collection. However, service Road shall be operational during construction also.	Please refer to this office No.DMRC/BM Ph-II/ 244/260 dt.24-11-2010
20	1.Chapter-2 Traffic forecast Annexure -1 Page 27 of 59 2.Chapter 2 Traffic forecast -The Boarding Alighting at Peenya Industrial Area seems to be less check Page no 31 of 59	<ul style="list-style-type: none">Only zone Names are given, Population of each zone and Employment of each zone in base years horizon years may be given. Also vehicle ownership zone wise may also be given.From each zone, total originating and destination trips by Public Transport and Private transport may also be givenSeparately CD containing softcopy of OD matrix by mode and purpose base and horizon years, years may be given	Population and employment of each zone is enclosed as Annexure I. CD containing OD matrix is enclosed
21	Chapter-2 Traffic Forecast Page 32 of 59	In table, years have to be mentioned.	Now corrected in this DPR.
22	Chapter 3 Page no. 1 of 11 Horizontal curves minimum radius 120m	The centre line minimum radius shall be kept as 122.5m.	This has been already complied.
23	Chapter – 3 Page – 1of 11	Following shall be adopted Maximum Cant deficiency=100mm Desirable Cant deficiency=85mm	DMRC recommends for the adoption of only desirable cant deficiencies.
24	Chapter – 3 Page – 2 of 11 Point – 3.2.1	Track centers mentioned is 3.7m, 4m and 4.15m for Straight, Curved and Underground? sections it doesn't tally with Executive Summary	Paragraph has been modified.
25	Chapter -3 Page 2 of 11	Changing track centers from 3.11m to 4.15m is not practical in Bangalore, as the curves occur	Paragraph has been revised. A constant c/c distance of 4.2 m will be provided, if the large number of



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	Point no. 3.2.1 Vertical alignment	very frequently and number of reverse curves has to be introduced. Generally 4.2m constant track centre shall be adopted as done in Phase I.	curves are on 120 m radius.
26	Chapter – 3 Page – 3 of 11 Point – 3.2.3	Minimum Vertical Curved radius shall be 1500mtrs for all sections.	Yes, agreed. Change has been made in the planning chapter.
27	Chapter 3 Page – 4 of 11 Point no. 3.4.2	Typical cross section of viaduct on single pillar/portal showing the rail, track plinth, 3 rd rail, guard rail, parapet, cable ducts are not shown . This cross section accommodating all the cable ducts, tuning boxes of signaling with parapet may be included	Incorporated in this DPR in chapter 4.
28	Chapter -3 Page – 4 of 11 Point no. 3.4.3	Vossloh-336 fastening system naming performance specification of Railway Board may be referred to and not Vossloh – 336 system	Para has been modified.
29	Chapter – 3 Page no 5 of 11 Point no.3.4.5	1 in 7 turnout shall be 140m radius and not 400m radius	Yes, agreed. Now it is corrected.
30	Chapter – 3 Page no 6 of 11 Fig -3.1	Show Anchor bolt correctly.	DPR gives only conceptual drawing.
31	Chapter -3 Page no 6 of 11 Fig – 3.2	Vossloh 336 naming; Vossloh turnouts why don't we take what is supplied for Phase-I already for fig 3.1 and 3.2	DPR recommends any suitable system of fastening. However, Performance criteria of Railway Board has now been mentioned.
32	Chapter – 4 Page 1 of 44 Point no. 4.1.3	Down line , Up line just reverse in our convention	There is no specific convention of naming the line 'Up/ Down'. However, in DMRC the line which leads to Depot is named as 'Up' and other line as 'Down'.
33	Chapter – 4 Page 4 of 44 Table 4.2	3.48% Gradients is very steep for segmental launching of as approved in Phase -I girder. Future Station Chainage (-) 6989. Table of chainage is not through	Table 4.2 has been corrected and included in this DPR.
34	Chapter -3 Page no 5 of 44 Point no. 4.1.11	<ul style="list-style-type: none"> Land requirement shall be finalized after fitting the concept plan of stations site wise. Land for Telecom Tower as per signaling requirement may be identified. Land for any pocket track not identified 	Land requirement has been worked out taking into account the exit/entry, ancillary buildings required for the stations. At the time of final location survey, there may be minor changes.



35	Chapter 4 Page no 7 of 44 Point no.4.1.16	Examine the feasibility of Rajarajeshwarinagar station in median, since there is a curve ahead, off road station is more feasible and land on either side is available. Otherwise Road width will not be sufficient.	Station has been proposed on the median and the road is required to be shifted and adequate land is available for redesigning road geometry.
36	Chapter -4 Page no 10 of 44 Point no. 4.2.3	Up line, Down line nomenclature may be corrected as mentioned above.	There is no specific convention of naming the line 'Up/ Down'. However, in DMRC the line which leads to Depot is named as 'Up' and other line as 'Down'.
37	Chapter -4 Page 23 of 44 Point no. 4.3.3	-do-	There is no specific convention of naming the line 'Up/ Down'. However, in DMRC the line which leads to Depot is named as 'Up' and other line as 'Down'.
38	Chapter -4 Page no. 37 of 44 Table 4.19	The estimate for HT line shifting of Rs. 80crs shall be confirmed from BESCOM	Total 100 crores for shifting of electrical utilities has already been provided vide item no. 10.2 of estimate of all the extensions. Hence, no need is felt for additional provision. Any additional requirement can be met with contingency head.
39	Chapter -4 Page no. 44 of 44 Fig 4.5 (a)	Font size of the letters may be increased	Soft copy will also be furnished.
40	Chapter 5 5.2 station Page no -2 of 47 and 3 of 47 The inter station distance between RV college and Bangalore University 2000m and Byappanahalli to Jyothis Puram 2426km	If any intermediate station is possible, future provision may be kept. If not, to be explained why intermediate station is not required	Provision of future intermediate Station between Bangalore University & R V College of Engg is not planned since one side of the road is railway track and on the other side there is barren land and there is no habitation and no justifiable ridership. Further due to road curvature the proposed track will go away from the median of road involving additional unnecessary acquisition. Intermediate station between Baiyyappanahalli & Jyothipuram is not possible as there is SWR lines on



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one side and the crossing of elevated ORR etc.

41	Chapter 5 Page no.5 of 47 Point 5.3.4	<ul style="list-style-type: none">6 car trains may be required from 2016 itself. At extensions beyond Hesaraghatta and Banashankari alternate trains.This may affect procurement of rolling stock.Has mentioned earlier 6 persons per sqmt is considered.Under capacity in more than 3 sections 10-minutes -7 minutes – 5 minutes head way, that means will there be intermediate terminal? Station facilities are remaining same for all Stations. No additional Stabling lines given. Clarify.	<p>The observations of BMRCL are not clear.</p> <p>However, as mentioned in the DPR, the train operation is planned in two loops in such a way that in 2016, in one loop 3-car trains run in section 'BIEC Terminal – Anjanapura Township' at 7 min headway and in the second loop 6-car trains run in section 'Hessaragatta – R V Road' at 7 min headway, resulting in effective headway of 7/2 = 3.5 min with alternate 3-car/6-car trains in 'Hessaragatta – R V Road' Section and headway of 7 min with 3-car trains in 'BIEC Terminal – Hesaragatta' and 'R V Road – Anjanapura Township' Sections. This operation plan would need suitable reversing facilities at Hesaragatta and R V Road.</p> <p>In subsequent years, all trains of 6-car consist have been suggested and headways reduced based on traffic projections.</p> <p>It is reiterated that the train operation plan is based on the calculations based on traffic projections. In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by adjusting the headway or train consist.</p>
42	Chapter – 5 Page no.31 of 47 Table 1.1B	The changing of frequency alternate 3 minutes to 6 minutes not desirable from commuters point of view also. Check up the S&T requirements	As per the Hourly Train Operation Plan mentioned in Table 1.1B, the frequency is not being altered at 3 min and 6 min as mentioned by BMRCL. The frequency of operation in the Section 'Hessaragatta – R V Road' remains at 3.5 min in the peak hour but with alternate 3-car and 6-car trains.
43	Chapter – 7 Page no. 7 of 17 Point no 7.8	Antistatic Platform Membranes shall be provided as being done in Phase-I	This is for BMRCL to decide.
44	Signalling Scheme Chapter -8 figures at the end of the chapter	S&T team to study emergency additional cross over requirements (6 Stations) between Byappanahalli and ITPL, Puttenahalli and Anjanapura Road (5 Stations).	1. In Metro Rail Project for smooth train operation and to take out defective trains out of system, cross-overs are essentially required. This is operational requirement.



			<p><u>Signaling Plan</u> Mysore Road existing Station cross over not shown correctly</p>	<p>2. An interlocking station covers around 4 km section on either side. Therefore, distance between two adjacent interlocking stations is considered 8 km approximately.</p> <p>3. Cross-overs shown in the said Signalling Scheme plans are correct and as planned in Phase I.</p>
45	Chapter -9 Telecom		<p>Identification of Telecom towers not done</p>	<p>Tentatively Radio Towers are required at R V College of Engineering, Vijay Nagar, Majestic, Trinity Circle, Jyothipuram, Gurudacharyapalya, Vydehi Hospital (7 places). With inclusion of Whitefield, additional tower at Kadugodi is required. The Tower base requires 5x5 m clear space. However, the final locations can only be decided after a detailed RF survey when actual construction starts, as additional buildings which come up upon the route till that time will have impact on present day survey.</p>
46	Chapter - 10 Page no.3 of 16 Table 10.3		<p>The land required for additional Stabling line in future may be acquired now itself. Acquiring land at a later date may be difficult.</p>	<p>Now since Car maintenance depots are being proposed in these locations, no need for provision of additional stabling lines. Accordingly, the foot note to the table in paragraph 10.3 is being deleted.</p>
47	Chapter - 10 Page no. 9 of 16 Point no. 10.6		<p>Why 160 mtrs long. Inspection line and Stabling lines is provided</p>	<p>The length of the stabling / inspection lines has been arrived at as indicated below:-</p> <ul style="list-style-type: none"> • Total length of 6 car coach = 134 mtrs • Length upto fouling marks on either side of rake on stabling lines = 10x2=20 mtr • Space required between two 3-car rakes when placed on same stabling / inspection line = 5 mtrs <p style="text-align: right;">Total length = 134+20+5 = 159 mts (say 160 mtrs)</p>
48	Chapter -10 Page no. 11 of 16 Roman no. XII		<p>Watch Towers may be deleted; Electronic surveillance system may be adopted.</p>	<p>Electronic surveillance system may be adopted instead of watch towers. This may be decided by BMRCL's safety guidelines.</p>



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49	Chapter – 10 Page no. 13 of 16	<ul style="list-style-type: none"> At Byappanahalli and Peenya facilities already provided in Phase-I Peenya Depot plan - updated plan may be incorporated. The details of Kengeri Depot plan not shown. How is the Depot cost arrived, is not clear? 	<ul style="list-style-type: none"> Year-wise requirements of SBLs, IBLs and WSL at Byappanahalli, Peenya and other terminal stations has been shown in Depot chapter. Provision of depot has been made at Kengeri. Provision of stabling depot at Anjanapura is also made. 																																				
50	Chapter 11	Any separate detailed EIA report will be submitted?	EIA report is already submitted.																																				
51	Chapter 12 Page 1 of 25 Table 12.1.3 Abstract of Phase-I lines. Based on LAR of DMRC Page no 2 of 25	<ul style="list-style-type: none"> LAR of Bangalore Metro to be adopted Rs. 21crs / Station include E&M is in lower side In Phase-I costs are about 38crs excluding Viaduct in Station. 	<ul style="list-style-type: none"> The station cost (civil works) is increased by Rs 4 crores which is normally the cost of architectural works for each station. The E & M cost provided in DPR is considered reasonable. DMRC does not agree to the cost of Rs 38 crores per station as indicated in this para. 																																				
52	Chapter – 12 Page 5 of 20	Provision of Rs.80 crores for Depot is on lower side. It will be atleast Rs.120 crores.	Provision of Rs 120 crores in East-West line and Rs 90 crores has been made for depot. This is considered adequate.																																				
53	Chapter -12 Kindly check the calculations provided on the right hand side table	<p>Energy Trains Consumption of</p> <table border="1"> <thead> <tr> <th>Energy round trip (Byappanahalli and MEGR)</th> <th>Consumption per trip between</th> <th>Consumption per day</th> <th>Cost per day @</th> <th>Rs.4/- per unit cost per month</th> <th>Cost per month</th> </tr> </thead> <tbody> <tr> <td>No of trips per day</td> <td></td> <td>205.73 units</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Consumption per day</td> <td></td> <td></td> <td>36</td> <td></td> <td></td> </tr> <tr> <td>Cost per unit cost per month</td> <td></td> <td></td> <td></td> <td>7406.28 units</td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td>29,625/-</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td>888,750/-</td> </tr> </tbody> </table>	Energy round trip (Byappanahalli and MEGR)	Consumption per trip between	Consumption per day	Cost per day @	Rs.4/- per unit cost per month	Cost per month	No of trips per day		205.73 units				Consumption per day			36			Cost per unit cost per month				7406.28 units							29,625/-						888,750/-	<ul style="list-style-type: none"> Calculations could not be located in the DPR. Details are not related to Chapter 12 (cost estimate). Please provide details for review.
Energy round trip (Byappanahalli and MEGR)	Consumption per trip between	Consumption per day	Cost per day @	Rs.4/- per unit cost per month	Cost per month																																		
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					29,625/-																																		
					888,750/-																																		



54	Chapter - 12	Energy consumption at Stations (assumed 18 hours working per day	Calculations could not be located in the DPR. Details are not related to Chapter 12 (cost estimate). Please provide details for review.
55	Chapter -13	BYPH SVRD HLRV IND TTY MAGR BYPT Total units Consumption per month Cost per month	7254 units 5184 units 4302 units 4950 units 4338 units 6210 units 65880 units 98118X30 2943540X4 Rs.11,774,160.00
56	Chapter – 13 fares Table 13.6 Page 5 of 18	Fixed Cost at 75% of the demand X 24,75,000-0.75 Fixed Charges = 1,856,250.00	Fixed Cost is the cost determined in Cost chapter and it is at the price level of July 2010. 75% does not have any significance. BMRCL proposed Fare Structure has not been received and hence the fare structure of DMRC duly escalated has been adopted.



Drawings and Land Acquisition

<p>The station layout box is considered same for all the Stations both On Road and Off Road. Kindly ensure that Site specific Station plan fits into this land and with provisions of TSS/ASS emergency staircases etc. Land for Parking / Property Development can be added in the following Stations:</p> <p>_____</p> <p>_____</p>	<p>Location specific station plans are now sent with this DPR. Soft copy of the same is also attached.</p>
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Rajarajeshwarinagar	To be provided as per availability
Anjanapura Township Vajarahalli	The area for the parking /traffic integration will be provided in the proposed Depot land at the end of this line. Not provided
Thalaghattapura	Not provided
Whitefield terminal	Provided
BMIC terminal	Provided for the BIEC Terminal station

The provisions of at least 100sqmt in all Stations may be made for providing Multi stacked car parking in the Land identified for Property Development and also in Stations where PD is not provided. It is already provided wherever available and feasible.

The provision of Land for Property Development may be enhanced by another 5 hectares at suitable stations where vacant land is available to enhance non-fare box revenue. PD land has been increased from 5 Ha to 15 Ha..



Annexure – I.

Comments / Reply on observation at SNo. 20

Zone No	Population			Employment		
	2011	2021	2031	2011	2021	2031
1	35400	39884	43192	74894	89097	98419
2	46265	52126	56450	26574	35191	38872
3	56920	62875	66751	21864	29937	33069
4	65408	70833	73718	15624	21864	22529
5	43394	46994	48908	32005	39254	40448
6	46306	50147	52189	6811	7231	7451
7	43842	46545	47960	29463	38414	42433
8	48637	52151	53737	3435	3832	4233
9	46524	50382	52434	4872	5435	6004
10	41500	44942	46772	45752	53849	54390
11	39908	42368	43656	109912	117201	117201
12	51950	56259	58551	11926	17937	18299
13	46330	50173	52216	8221	8728	8904
14	44149	47810	49758	5237	5559	5672
15	41712	45172	47012	5133	10726	10726
16	73309	79390	82623	6015	11663	11663
17	35013	37917	39461	2033	2158	2201
18	30790	33344	34702	9194	15037	15340
19	27785	30089	31315	3128	3321	3388
20	33634	36423	37869	2148	2280	2326
21	19385	20993	21826	11414	17394	17745
22	16123	17117	17637	12736	18611	18987
23	20525	22228	23133	12310	20054	22594
24	49591	53704	55891	9239	9808	10006
25	42412	45930	47800	1931	2050	2091
26	41372	44803	46628	2744	2913	2972
27	42347	45860	47727	8583	9112	9296
28	15250	16515	17187	6519	7566	8525
29	19287	20886	21521	8164	9475	10675
30	9346	9727	10023	9654	11204	12623
31	35549	36997	38122	39607	45477	45477
32	34511	35917	37009	40390	46275	46275
33	44099	45895	47290	17736	23165	23165
34	42817	44561	45916	22867	28399	28399
35	31644	33263	34274	1760	1795	1795



36	44256	46519	47933	1442	1471	1471
37	48869	52399	54534	8739	16387	19587
38	53054	56887	59203	11023	19116	22850
39	47989	51456	53552	9186	10147	10351
40	67364	72951	75922	8444	9327	9515
41	26193	28365	29520	13750	20678	21095
42	18664	20212	21035	10337	16909	17250
43	48530	52556	54696	18870	27667	30562
44	32816	36974	40041	3734	4552	5549
45	61873	65687	68362	23251	29665	30567
46	51685	55972	58251	1922	2297	2621
47	66222	71336	74242	4889	5012	5114
48	48503	52214	54341	7049	7228	7373
49	45111	47418	48859	1661	1703	1737
50	45005	47306	48745	16461	21973	21973
51	39391	41406	43092	12701	20508	23801
52	10464	10999	11447	2932	3271	3337
53	39365	41378	43063	8252	9206	9392
54	49117	51629	53732	7619	14494	16170
55	18308	19437	20229	9971	10585	10692
56	19834	21057	21914	5832	11468	11583
57	47216	49630	51652	17921	26566	29345
58	42645	44826	46189	5269	6115	6755
59	68685	72198	74393	7142	13512	13785
60	98788	103840	106998	17052	25557	29660
61	134381	142665	147003	61368	74743	75494
62	104379	113036	116473	5583	11203	11316
63	76407	80315	82757	56531	65292	65948
64	46940	49341	50841	31059	38250	38635
65	41393	43945	45281	8185	13966	14107
66	47005	49903	51421	5103	11540	13392
67	47241	50153	51678	950	1111	1266
68	14832	15591	16065	2530	2685	2712
69	19991	21224	22088	5131	5394	5448
70	29664	31493	32776	6787	7206	7278
71	33968	36062	37530	7766	13521	13657
72	24597	26114	27177	9222	9791	9889
73	75457	80109	83371	16866	25342	28979
74	26502	28417	29574	5093	5911	6759
75	37622	41558	43251	12992	21896	22338
76	32025	35376	36817	11942	21024	24399



77	16855	18619	19377	6065	7539	8750
78	33052	36510	37997	7692	13577	13851
79	21761	24518	26030	8395	10034	11474
80	16468	19609	21235	17441	25251	25761
81	20585	24606	26646	11325	18359	18730
82	49011	54139	56625	1088	1132	1167
83	62271	68785	71944	990	1030	1061
84	41476	44916	46745	14583	20349	20554
85	47581	51528	53627	2597	2703	2785
86	54092	59751	60623	10446	18427	20967
87	51570	58103	60470	43153	57522	62753
88	48561	54713	56942	3281	3922	4041
89	6464	7140	7431	3443	4116	4776
90	4845	5352	5570	3353	4007	4651
91	19865	21943	22837	731	807	937
92	16473	18197	18938	831	874	909
93	22240	24084	25065	23592	30023	30324
94	21367	22911	23844	24478	35200	40251
95	20181	21855	22745	12592	18645	19021
96	10243	10874	11317	5785	12118	13385
97	4756	5049	5254	3531	3979	4395
98	2329	2522	2624	1649	1751	1769
99	388	420	437	275	292	295
100	8856	9591	9981	6598	7005	7076
101	15649	17631	18350	9101	14938	15240
102	9742	10342	10657	7258	7706	7861
103	11070	11752	12110	6461	12136	12136
104	18560	19705	20304	5738	10979	10979
105	19712	20928	21564	15363	20847	20847
106	42670	46209	47614	6827	7248	7394
107	24193	26199	27266	927	985	1005
108	23244	25172	25937	914	1056	1214
109	39894	43203	44517	4874	5686	6483
110	64354	72507	76977	50238	64072	64393
111	40965	46155	48516	53738	68133	68474
112	44752	50422	53000	11734	18090	18455
113	23669	25632	26676	6480	12400	12650
114	24138	26140	27205	6301	12206	12452
115	72385	81556	85726	8973	15099	15404
116	10031	11302	11880	8764	9490	9682
117	7022	7911	8316	6771	7333	7481

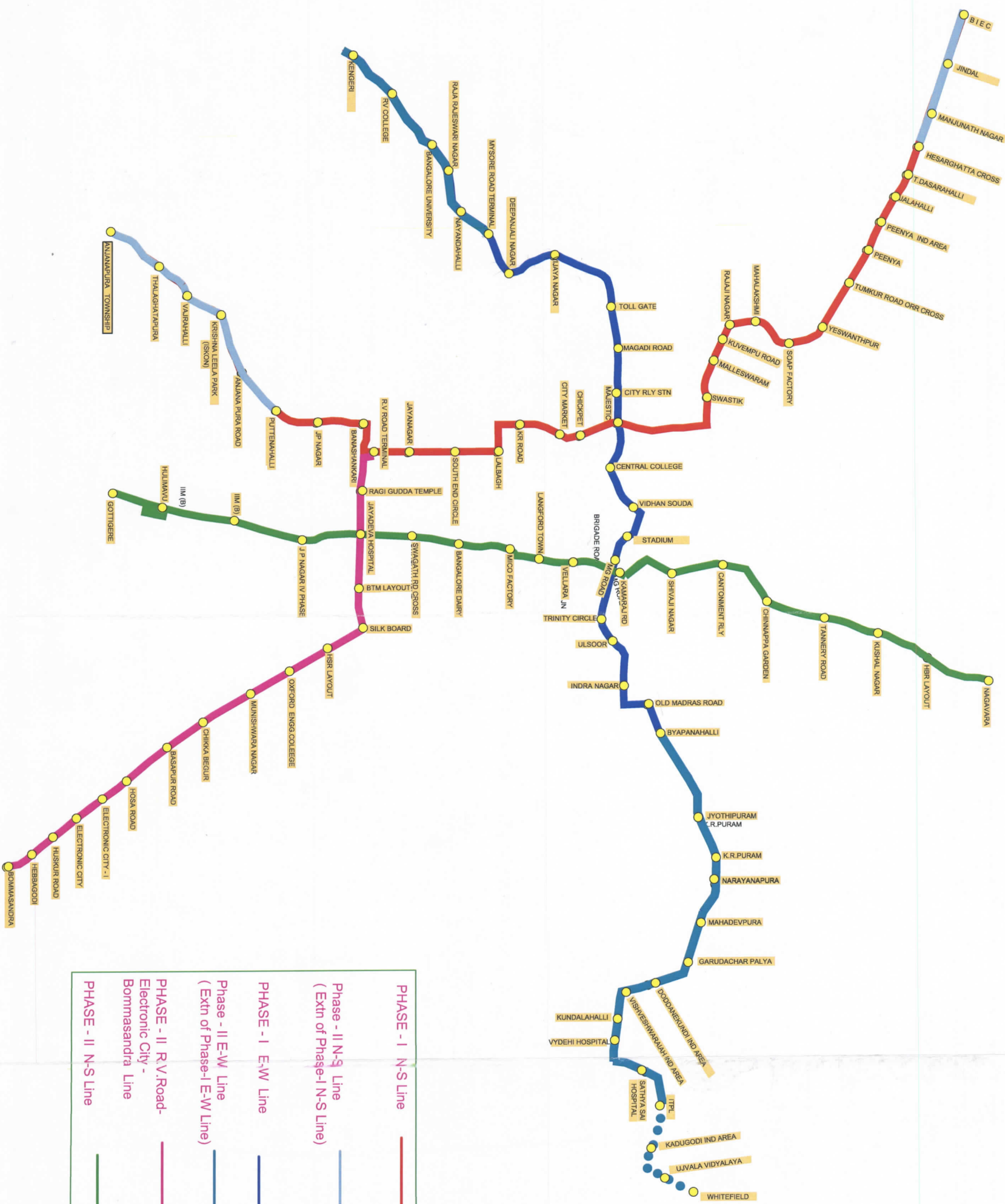


118	8359	9418	9900	6595	7142	7287
119	8025	9041	9504	5199	5575	5687
120	23167	26103	27437	5292	11335	11564
121	18955	20527	21363	7484	8267	8433
122	51935	56242	58533	2680	2960	3020
123	50316	54490	56709	5992	6619	6753
124	47430	51364	53456	9594	10598	10704
125	61672	66787	69507	9792	10817	10925
126	72810	78849	82060	14213	15240	15393
127	100977	109352	113806	11064	12078	12200
128	96873	107087	114349	12225	13672	13809
129	45492	49265	51272	1799	1987	2027
130	20733	22453	23368	946	1045	1066
131	17592	19051	19827	803	886	904
132	24503	26014	27073	1880	2016	2056
133	17133	18190	18930	2161	2387	2435
134	8567	9277	9655	602	665	679
135	6620	7169	7461	556	596	608
136	2726	2952	3103	7376	13638	13913
137	3894	4217	4433	14605	21623	22059
138	66923	72474	75425	18122	24761	25010
139	220051	325729	437753	107596	136643	206535
140	318570	416281	507444	40477	43301	72761
141	263755	398923	536119	32158	40534	76575
142	229520	356438	507669	68383	86638	133892
143	19511	30300	43156	65815	83949	124524
144	28985	45013	64112	1478	2295	3237
145	163268	266069	413197	47620	52788	78506
146	33450	51946	80671	245	363	487
147	51810	80459	115708	36375	35583	52709
148	33913	52666	77928	251	372	524
149	29241	45411	70521	6257	6002	10414
150	44138	68545	106448	9177	11689	21699
151	50157	77892	120963	10429	12177	19124
152	76238	118395	183864	15852	13685	25145
153	42629	66202	102916	88270	127402	164660
154	42853	69803	113701	10173	11799	18591
155	132844	216389	352474	31758	40506	67500
156	38568	62823	102331	9377	12014	22228
157	45777	71090	115798	25722	23638	48596
158	93012	151507	235286	71347	85351	159212



159	38755	63128	98036		29797	30276	52193
160	23253	37877	58821		18109	26237	26157
161	26226	42719	66342		50013	59409	84729
162	32054	52213	81085		64760	82310	115506
163	33128	53962	83801		253	375	504
164	35317	56711	88071		19853	30652	35587
165	46764	75092	116615		24949	24357	49767
166	58455	93865	145769		31186	35011	67121
167	51440	82601	128277		27444	28619	56709
168	42087	68556	106465		23595	20174	40036
169	78648	128109	200861		175864	289411	438336
170	68292	111240	172752		6884	8499	15609
171	360659	540899	839999		73701	91673	170482
172	18350	29890	51056		24548	36727	45482

Fig. 1.1
Bangalore Metro Phase-I & II



CHAPTER-2

TRAFFIC FORECAST



CHAPTER 2

TRAFFIC FORECAST

2.1 TRAVEL CHARACTERISTICS

2.1.1. General

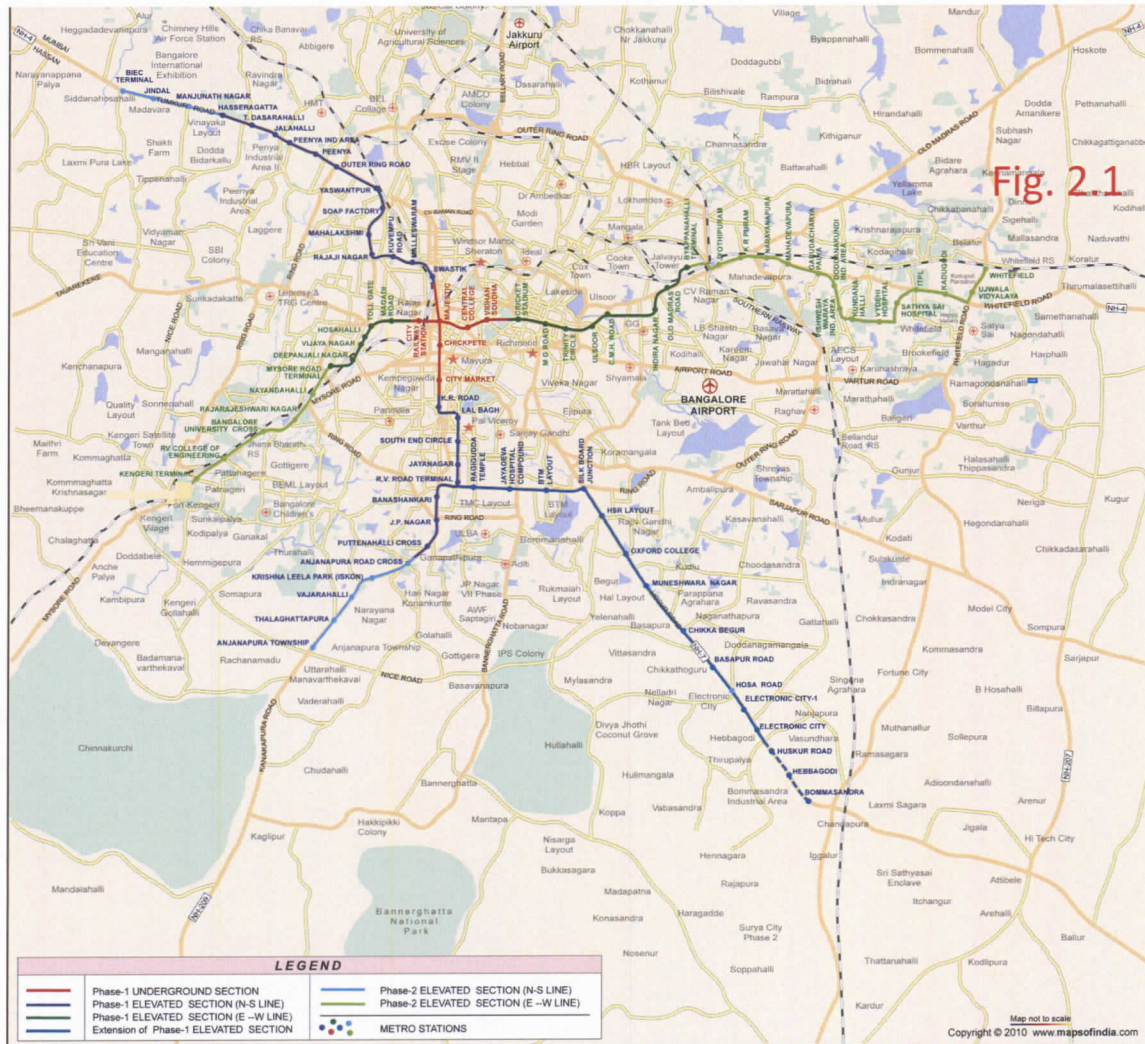
The Bengaluru Metro Phase-I presently under implementation comprises of two corridors covering 42.30 Km network as below.

- (i) East-West Corridor from Baiyapanhalli to Mysore Road – 18.10 km.
 - (ii) North-South Corridor from Hesaraghatta to Puttenahalli – 24.20 km.
- Total 42.30 Km

Now in the DPR for the Phase-II, the south end of N-S corridor is being proposed for extension from Puttenahalli Cross to Anjanapura Township (Nice Road x-ing) along the Kanakapura Road and north end from Hessarghatta cross to Bangalore International Exhibition Center (BIEC) on Tumkur Road (NH-4). The E-W corridor is being proposed for extension in the west direction from Mysore Road Terminal to Kengeri along the Mysore Road and in east direction from Baiyyappanahalli to Whitefield.

This Chapter covers the transport demand projections for extension of East –West Corridor and North – South Corridors on both sides as given below are and shown in Figure 2.1:

Extension of E-W and N-S Corridors of Phasse-I in both directions (four Extensions)		
Sl. No.	Metro Extension in Phase-II	Length (Km)
(i)	West side extension of E-W line from Mysore Road to Kengeri	6.465
(ii)	East side extension of E-W line from Baiyyappanahalli to Whitefield	15.50
(iii)	South side extension of N-S line from Puttenahalli to Anjanapura	6.29
(iv)	North side extension of N-S line from Hesaraghatta Cross to BIEC	3.77
	TOTAL	32.65





2.1.2. Transport Demand Modelling

Data Base

Detailed household surveys and various traffic surveys were carried out during the DPR study. A travel demand model was developed and the future OD- Matrices based on the projected population and employment were developed.

The network for the transport demand model including the metro alignments has been developed from the primary database.

The four stage Transport Demand Model involving Trip Generation, Trip distribution, Modal Split and Assignment has been adopted for this study.

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 **Figure2.3**.

2.1.3 Zoning

The entire study area has been delineated into 182 zones as shown in **Figure 2.1**. 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 1.1**.

Summary of population projection and employment projection is presented in the **Table2.1**.

Table2.1 Population and Employment projection

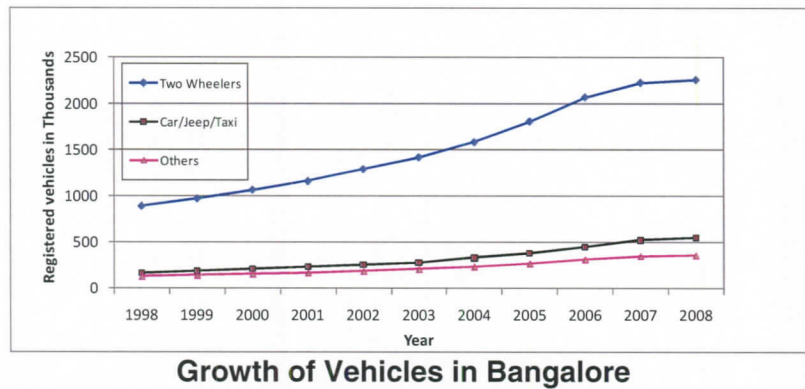
	2008	2011	2021	2031
Population(in lakhs)	73.99	80.15	99.68	123.11
Employment(in lakhs)	26.64	29.26	37.88	48.01

These figures are based on the Census (2001) and projected for future with reference to City development plan and revised structural plan 2031.



2.1.4 Vehicle Growth

About 11 Lakhs vehicles were plying on Bangalore roads in 1998 and it was 31 Lakhs in the year 2008. The annual rate of growth of motor vehicle population in Bangalore has been about 10% per year during the decade (1998-2008). The growth of two wheelers, cars/jeep/taxi and others are shown below. It is seen that two wheelers are growing faster than cars/jeep/taxi.



The number of Motor Vehicles registered in Bangalore is presented in Table2.2.

Table2.2 Vehicle Registration Data (1998-2008)

S. No.	Years	Two Wheelers	Three Wheelers	Cars	Jeeps	Taxies	Buses	Trucks	Tractors	Trailers	Maxi Cab	Others	Total
1	1998	892674	54689	160869	6676	5144	15832	34708	5357	4822	3195	12474	1196440
2	1999	971518	57304	178495	6800	5523	17701	36522	5713	5143	3698	17026	1305443
3	2000	1067430	61424	201052	6827	6299	20656	41887	6158	5544	4238	16542	1438057
4	2001	1162111	64001	221508	6934	7062	22841	47683	6743	6100	4723	16436	1566142
5	2002	1292228	67778	245893	7091	7974	24989	53424	7681	6873	5270	19728	1738929
6	2003	1419396	72107	269648	7434	9444	28262	59150	8723	7359	7219	23599	1912341
7	2004	1586397	74357	314931	7991	13132	34271	68186	10481	9456	10458	27820	2157480
8	2005	1811361	80432	359580	11012	16484	36888	84571	11994	11023	12659	31266	2467270
9	2006	2074306	90934	426394	7587	20025	39162	91699	18564	10699	16100	45682	2841152
10	2007	2232371	95029	490982	7609	28223	48159	109761	19646	11670	18017	45197	3106664
11	2008*	2263552	95859	515109	7272	30940	50096	109051	19151	11779	18653	52668	3174130

(Source: Regional Transport Office)

2.1.5 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 **Table2.3** and base year mode share is shown in **Figure. 2.3**.



Table 2.3 Distribution of Motorised Trips

Sl. No	Mode	Internal Trips	External Trips	Total Trips
1	Two-wheeler	1301232	59792	1361024
2	Car	588024	64256	652280
3	Auto rickshaw	659464	10496	669960
4	Public Transit	2502640	477952	2980592
	Total	5051360	612496	5663856

(Internal: - Zone to Zone movement inside the study area, External: - Zone to outside the study area and vice versa)

Mode wise distribution of registered vehicles is shown in Figure 2.2. The composition of two wheelers registered is more that is 71% followed by cars/jeeps with 16%.

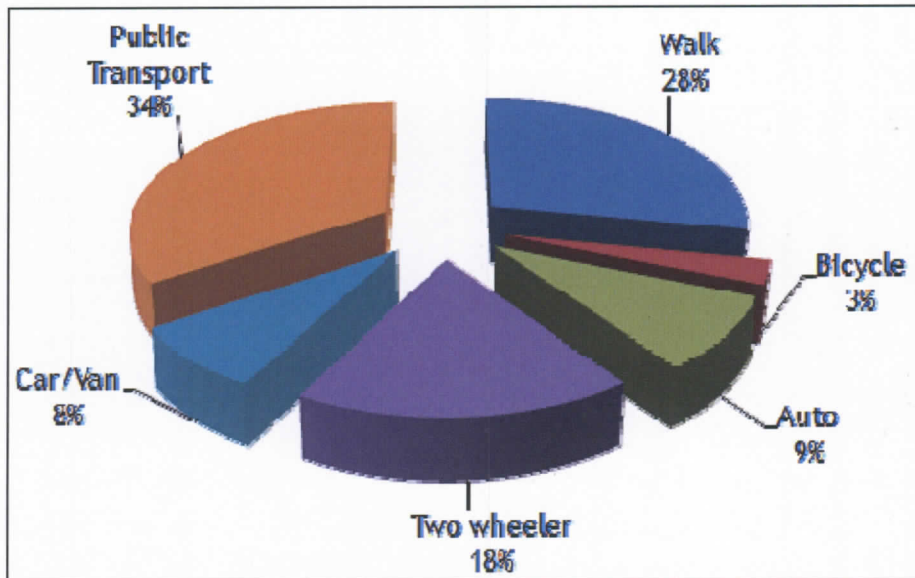


Figure 2.2. Mode Split

Bus trips constitute about 34% of the total trips while Two-wheeler trips are 18 %, Auto trips 9% and Car trips constitutes 8%.

2.2 TRANSPORT DEMAND MODEL AND PARAMETERS

2.2.1 Model Description

As stated earlier, the standard four stage model constituting Trip Generation, Trip Distribution, Modal Split and Assignment is used. Extensive household surveys and



traffic surveys were carried out to develop the four stage model. The horizon year Origin Destination (O – D) Matrices for private and public modes were developed using the Gravity Model. The parameters obtained from the model have been used for the transport demand projections for the proposed alignments.

2.2.2 Capacity of the Road System

The types of roads and their capacities are given in **Table 2.4**

Table 2.4 Types of Roads and their Capacities

Functional Characteristics	Directional capacity
1L-2W-UD	900
1.5L-2W-UD	1400
2L-1W-UD	6000
2L-2W-UD	1900
3L-2W-UD	2800
3L-2W-D	3400
4L-1W-UD	12000
4L-2W-UD	3800
4L-2W-D	4500
6L-1W-UD	18000
6L-2W-D	6700

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

2.2.3 Speed Flow Relationship

The speed flow curves were developed for different functional classes.

Speed flow curves have been adjusted to take into account delays at junctions. These speed flow curves were converted into BPR functions and fed into the model as input in the highway network. The form of the BPR function is

$$TC = T_0 * (1 + \alpha * (v/c)^\beta)$$

Where

Tc – Congested Link Travel time

T0 – Link Free flow time

V - Link Volumes

C – Link Capacity

α and β – Calibrated Parameters

The BPR functions developed for each category of road is given in **Table 2.5**.



Table 2.5: BPR Functions

Functional Characteristics	Free Flow Speed	ALPHA	BETA
1L-2W-UD	22	1.75	2.5
1.5L-2W-UD	27	1.70	2.5
2L-1W-UD	36	2.6	3.5
2L-2W-UD	36	4.1	3.5
3L-2W-UD	38	3.75	3.5
3L-2W-D	31	2.8	3.0
4L-1W-UD	45	3.5	4.0
4L-2W-UD	40	3.0	3.5
4L-2W-D	43	3.3	3.0
6L-1W-UD	58	4.0	4.5
6L-2W-D	49	5.0	3.75

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 ending 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, locational 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.
- A₀ = Constant term to be calibrated.
- a₀, a₁,.....a_k = Coefficients to be determined by the regression analysis
- X₁, X₂. = Zonal planning input factor (independent) variable)

The significance of the regression equation is tested on the basis of R² 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

The results of calibration of different models are given in **Table2.6**

**Table2.6 Generation for Total Trips**

	Co-off.
Intercept	1653
X Variable	0.037

By using the above table the value of R^2 was found to be 0.55, T-value – 14.5, F-value-212.8 (**Assuming Population in zones as the variable**).

Table2.7 Trip attraction for total trips

	Co-off.
Intercept	1312
X Variable	0.126

By using above expression the value of R^2 was found to be 0.81, T-value-26.1, F Value-684.5 (**Assuming Employment in zone as variable**).

The population and employment projection for the horizon years is presented in **Table2.8** below:

Table2.8 Population and employment projections

Year	Population(Lakhs)	Employment(Lakhs)
2008	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., 2008, 2016 and 2021 2031 are as given in the **Table2.9**.

Table2.9 Adopted PCTR (Motorised) Value

Year	PCTR Value
2008	0.96
2016	1.0
2021	1.1
2031	1.2



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)

F_{ijm}= Deterrence function for mode m

$$F_{ijm} = K_m e^{-\beta c_{ijm}} C_{ijm}^\alpha \quad \text{Eqn 1}$$

Where K= Constant Factor

C=Generalized Cost

β= Calibration Constant –Exponential function

α=Calibration Constant- Power function

Double Constraints are imposed by ensuring that

$$\sum_{j,m} T_{ij} = G_i \quad \text{and} \quad \sum_{i,m} T_{ij} = A_j$$

The calibration includes estimation of parameters of the deterrence function is 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 **Figure2.4**.

The cost of travel (C-generallised cost) between the zones has been estimated based on skims from the Highway and Public Transport assignment. The estimation of generallised 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	8.8
Auto Rickshaw	1.1	0.4	3.2
Public Transport	2.54	1.73E-13	22

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, rail, etc which are linked on to the zonal system via walk links. This methodology is presented in **Figure 2.6**.



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 Vehicle s & IPT	Modes	PCE Values
	Two wheeler	0.50
	Auto rickshaw	0.50
	Car	0.80
Commer cial 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 Metro Phase-1 N-S Line with Phase-2 extensions, Metro Phase-1 E-W Line with Phase-2 extensions, Metro Phase-2(N-S) and Metro Phase 1 EC Extension and distance between the stations is given in **Tables 2.12** to **Table 2.15**.

Table 2.12 – Inter station distances on the Metro Phase-1(N-S)

Station No	Station Name	Distance (in kms)
1	BIEC Terminal	-
2	Jindal	1.2
3	Manjunatha Nagar	1.2
4	Hesarghatta Cross	1.4
5	T. Dasarahalli	0.9
6	Jalahalli	0.8
7	Peenya Ind Area	0.7
8	Peenya	1.1
9	Outer Ring Road	0.8
10	Yeshwantapur	1.1



11	Soap Factory	1.1
12	Mahalakshmi	1.0
13	Rajaji Nagar	1.0
14	Kuvempu Road	0.9
15	Malleswaram	0.8
16	Swastik	1.1
17	Majestic	1.7
18	Chickpete	1.0
19	City Market	0.7
20	K R Road	1.2
21	Lal Bagh	1.0
22	South End Circle	1.0
23	Jayanagar	0.9
24	R V Road	0.9
25	Banashankari	1.4
26	J.P.Nagar	0.9
27	Puttenahalli Cross	1.4
28	Anjanapura Road Cross	1.1
29	Krishna Leela Park (ISKON)	1.2
30	Vajarahalli	1.3
31	Thalaghattapura	0.9
32	Anjanapura Township	1.9

**Table 2.13 – Inter station distances on the East-West Corridor
(Option-1 Extension upto ITPL)**

Station No	Station Name	Distance (in kms)
1.	Kengeri Terminal	-
2.	RV College of Engineering	1.8
3.	Bangalore University Cross	2.0
4.	Rajarajeshwari Nagar	0.8
5.	Nayandahalli	0.8
6.	Mysore Road Terminal	0.8
7.	Deepanjali Nagar	1.1
8.	Vijaya Nagar	1.2
9.	Hosahalli	1.1
10.	Toll Gate	1.0
11.	Magadi Road	1.2
12.	City Railway Station	1.2
13.	Majestic	0.7
14.	Central College	1.2
15.	Vidhan Soudha	0.6
16.	Cricket Stadium	1.3



17.	M G Road	0.7
18.	Trinity Circle	1.1
19.	Ulsoor	1.2
20.	CMH Road	0.9
21.	Old Madras Road	1.8
22.	Byappanahalli	1.0
23.	Jyothipuram	2.4
24.	K R Puram	0.8
25.	Narayanapura	0.9
26.	Mahadevapura	0.9
27.	Garudacharya Palya	1.2
28.	Doddanakundi Ind Area	1.0
29.	Vishweshwaraya Ind. Area	1.0
30.	Kundanahalli	0.9
31.	Vydehi Hospital	1.0
32.	Sathya Sai Hospital	0.8
33.	I T P L	1.5

(Option-2 further extension upto White Field)

34	Kadugodi	1.0
35	Ujwala Vidyalaya	1.0
36	Whitefield	1.0

The Metro Phase-1(N-S Corridor) including Phase –II extensions is 33.9 Km in length from BIEC to Anjanapura Township with 32 proposed stations. The Metro Phase-1(E-W Corridor) including Phase –II extensions from Kengeri Station to ITPL with 33 stations making total length of 36.275 Km in Option-1. If the Corridor is further extended upto White Field (option -2) the total length of Corridor will be 39.575 Km with 36 stations. It may be noted that station spacing along the alignment varies from 0.7 km to 2.4 km.

2.3.2 Section Loading

The traffic assignment was carried out with the four proposed alignments in place. The traffic figures have been worked out for all four extensions and new North South Corridor, R. V. Road to Bommasandra Corridor. However in this Chapter the traffic figures for extension of Phase-I corridors (four extensions) only and phpdt for the connected Corridors are given.

The Summary of the transport Demand for option-2(extension of East West Corridor upto Whitefield) on the proposed metro alignments is presented in Table 2.14

The Incremental Ridership for option-2(extension of East West Corridor upto Whitefield) on the proposed metro alignments is presented in Table 2.15



**Table 2.14 Summary of Transport demand (Option-2
Extn of E-W Corridor upto Whitefield)**

Option 2-2016					
Routes	Length in KM	Max. Sectional Load (PPHPD)	Daily Passenger-KM in Lakhs	Daily Ridership in Lakhs	Average Lead (KM)
Metro Phase-1(N-S) (including extensions)	33.9	21,803	60.9	6.03	10.1
Metro Phase-1(E-W) (including extensions)	40.2	19,675	56.6	4.80	11.8
Option 2-2021					
Metro Phase-1(N-S) (including extensions)	33.9	27,593	79.6	7.90	10.1
Metro Phase-1(E-W) (including extensions)	40.2	25,380	85.7	7.20	11.9
Option 2-2031					
Metro Phase-1(N-S) (including extensions)	33.9	36,557	106.8	10.36	10.3
Metro Phase-1(E-W) (including extensions)	40.2	34,263	115.6	9.67	12.0
Option 2-2041					
Metro Phase-1(N-S) (including extensions)	33.9	42,771	124.7	12.12	10.3
Metro Phase-1(E-W) (including extensions)	40.2	38,860	131.7	11.00	12.0

**Table 2.15 Incremental Ridership (Option-2 Extension of
E-W Corridor upto Whitefield)**

2016				
Extensions	Incremental Length in Km	Incremental Daily Ridership in lakhs	Incremental Daily Passenger KM in Lakhs	Incremental Average Lead in KM
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	2.05	31.07	15.2
From Mysore Road to Kengeri+Bypanahalli to Whitefield	22.7	2.03	38.05	18.7
Total	33.5	4.08	69.12	16.9
2021				
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	2.78	36.91	13.3



From Mysore Road to Kengeri+Bypanahalli to Whitefield	22.7	3.67	61.13	16.7
Total	33.5	6.45	98.04	15.2
2031				
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	3.48	49.52	14.2
From Mysore Road to Kengeri+Bypanahalli to Whitefield	22.7	4.96	80.94	16.3
Total	33.5	8.44	130.46	15.5
2041				
From Hesarghatta cross to BIEC + Puttenhalli to Nice Road	10.8	4.52	61.47	13.6
From Mysore Road to Kengeri+Bypanahalli to Whitefield	22.7	5.35	90.05	16.8
Total	33.5	9.87	151.52	15.4

The maximum range of PHPDT on the North-South Metro Corridor in 2016 will be 21,606 and by 2031 the maximum range of PHPDT is projected to be of the order of 36,545.

The maximum range of PHPDT on the East-West Metro Corridor –ph1 () in 2016 will be 18,835 and by 2031 the maximum range of PHPDT is projected to be of the order of 32,501.

The section wise loading and PHPDT only for option 2 i.e. the East –West corridor up to whitefield are presented in **Annexure 1.2**.

2.3.3 Station loading

The station loading (two way boarding's) for all the alignments are presented in **Table 2.16 and Table 2.17**.

Table 2.16 Daily Station Loading for Metro corridor (North-South Extn)

Option 2 (North-South Alignment)				
Station Name	2016	2021	2031	2041
BIEC Terminal	7504	9728	17896	20904
Jindal	18408	24072	33048	38608
Manjunatha Nagar	3408	4000	5496	6416



Hesarghatta Cross	8848	8984	11976	13984
T. Dasarahalli	26960	31880	43096	50344
Jalahalli	2936	3776	6816	7832
Peenya Ind Area	12504	15184	19664	23104
Peenya	2160	2760	3448	3888
Outer Ring Road	19480	29480	40520	48272
Yeshwantapur	13208	20312	27656	31512
Soap Factory	21232	21960	29584	34560
Mahalakshmi	5872	6208	7768	9072
Rajaji Nagar	20040	28832	38664	45168
Kuvempu Road	20416	23024	31216	36464
Malleswaram	29528	45336	61704	72072
Swastik	11808	14128	18976	22176
Majestic	104840	145088	192592	224984
Chickpete	5352	5736	7400	8640
City Market	28952	29360	37456	43760
K R Road	15800	21152	26928	31464
Lal Bagh	17712	24344	31104	36336
South End Circle	4344	4920	6080	7112
Jayanagar	6384	7320	9088	10616
R V Road	2960	3224	4048	4728
Banashankari	22248	32128	37224	43488
J.P.Nagar	25152	25424	29488	34456
Puttenahalli Cross	11680	16520	20248	23656
Anjanapura Road Cross	15864	18640	22784	26712
Krishna Leela Park (ISKON)	15416	18192	22320	26072
Vajarahalli	8656	12744	15616	18152
Thalaghattapura	15264	24792	30344	35448
Anjanapura Township	10736	16960	20808	24312

**Table 2.17 Daily Station Loading for Metro corridor
(East-West Extn)**

Option 2(East-West Alignment)				
Station Name	2016	2021	2031	2041
Kengeri Terminal	31328	52392	69248	78616
RV College of Engineering	8192	12832	16920	19400



Bangalore University Cross	1456	1352	2584	2848
Rajarajeshwari Nagar	3720	4448	5824	6672
Nayandahalli	3504	4416	5792	6520
Mysore Road Terminal	5248	6144	6704	7792
Deepanjali Nagar	18704	30296	40032	45912
Vijaya Nagar	2864	14792	19544	22408
Hosahalli	7728	13032	16880	19728
Toll Gate	15448	20296	26344	30760
Magadi Road	19336	25832	34120	39128
City Railway Station	11120	17168	22680	26008
Majestic	97400	116864	154400	177072
Central College	13560	17488	23816	26504
Vidhan Soudha	11976	12168	16520	18432
Cricket Stadium	3424	11848	16224	17944
M G Road	21328	37456	53056	56552
Trinity Circle	13360	14520	20224	21832
Ulsoor	6472	8616	12200	13056
CMH Road	13840	18256	25752	27664
Old Madras Road	7528	12040	17072	18256
Byappanahalli	8536	12312	16192	17544
Jyothipuram	20184	37376	51936	53976
K R Puram	8520	15456	21920	34712
Narayanapura	6968	9248	13736	13896
Mahadevapura	11984	19936	28360	29696
Garudacharya Palya	2520	2736	4112	4144
Doddanakundi Ind Area	5928	7904	11584	12784
Vishweshwaraya Ind. Area	2360	3424	4800	5184
Kundanahalli	1624	1520	2120	2304
Vydehi Hospital	8888	11768	16384	17528
Sathya Sai Hospital	5616	6872	10416	10968
I T P L	1888	2664	1488	1584
Kadugodi	4016	5088	7736	8240
Ujwala Vidyalaya	10176	13992	19072	20256
Whitefield	8184	10512	14928	15936

2.3.4 Mode Shift

The numbers of trips shifted to metro from personal modes; auto and public transport in the peak hour are given in **Table 2.18**. The private vehicles shift will be increased from 33% in 2016 to 40% in 2031. During peak hour 0.81 lakh trips will be shifted to metro in 2016 due to Extension and 1.69 lakh trips in 2031.



Table 2.18 Mode Shift

	Mode	TRIPS	%
2016	Two wheeler	17205	21%
	Car	9443	12%
	Auto	14290	17%
	Public Transport	40937	50%
	Total	81875	100%
2021	Two wheeler	28417	22%
	Car	16792	13%
	Auto	20667	16%
	Public Transport	63292	49%
	Total	129,167	100%
2031	Two wheeler	42448	25%
	Car	25469	15%
	Auto	22073	13%
	Public Transport	79802	47%
	Total	169,792	100%

2.3.5 Trip length frequency distribution

The trip length frequency distribution of the Metro trips is presented in **Annexure 1.3** it can be observed that the average trip length for the years 2016 and 2031 for North-south corridor is 10.1 and 10.3 km respectively and for East west corridor the trip length is 11.5 in 2016 and increasing to 11.7 in 2031.

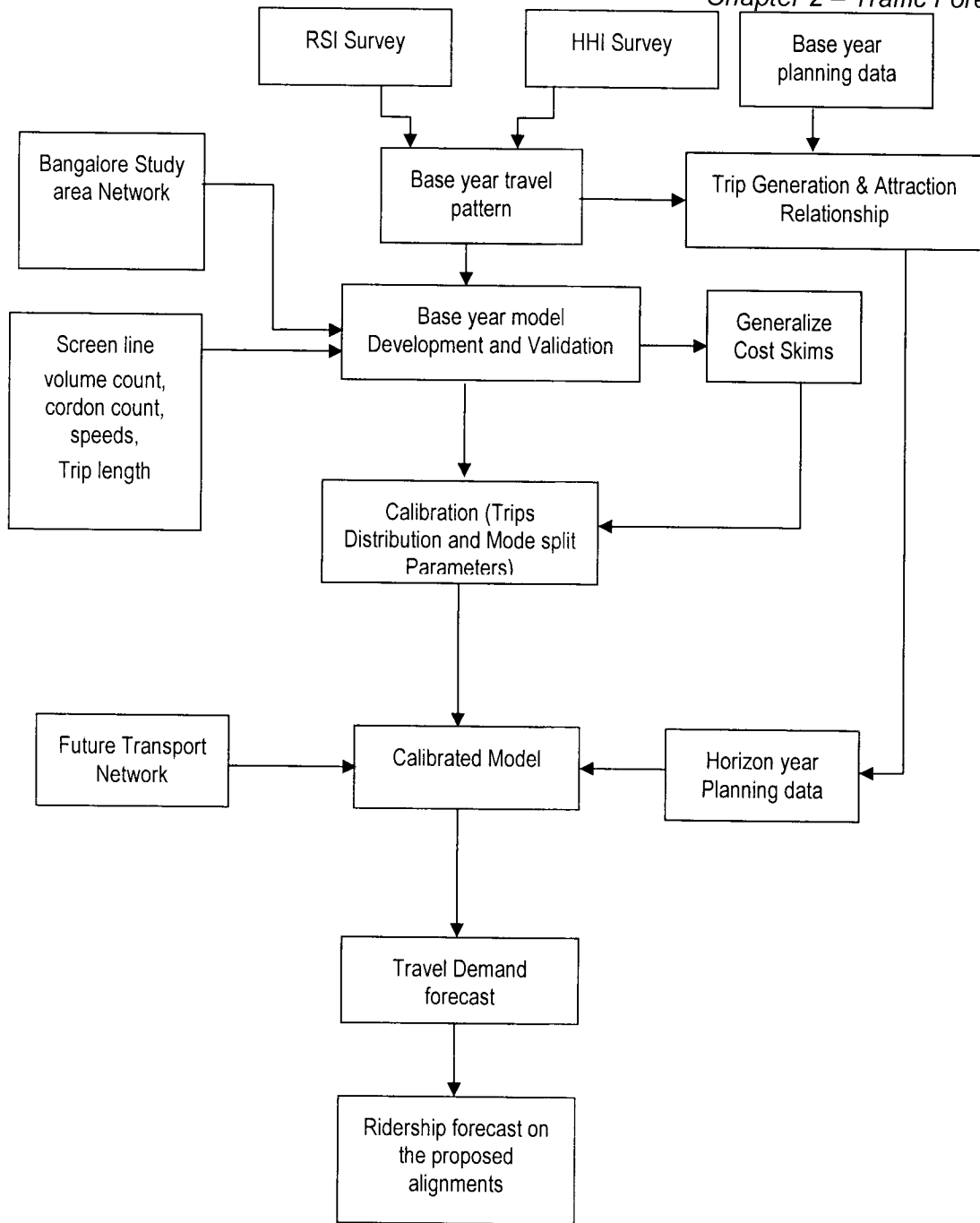


Figure 2.3: Modeling approach

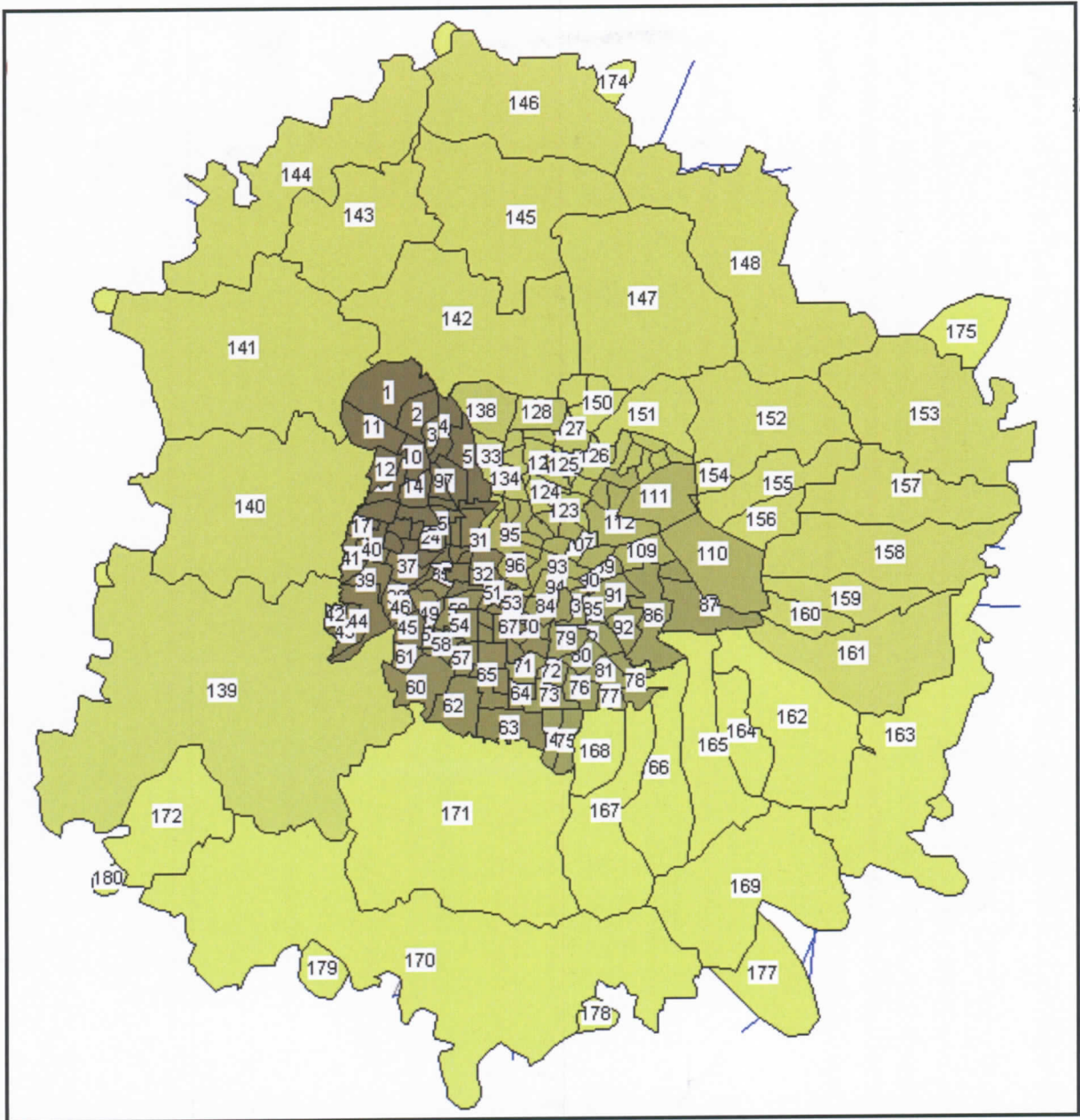


Figure 2.4 Zoning system

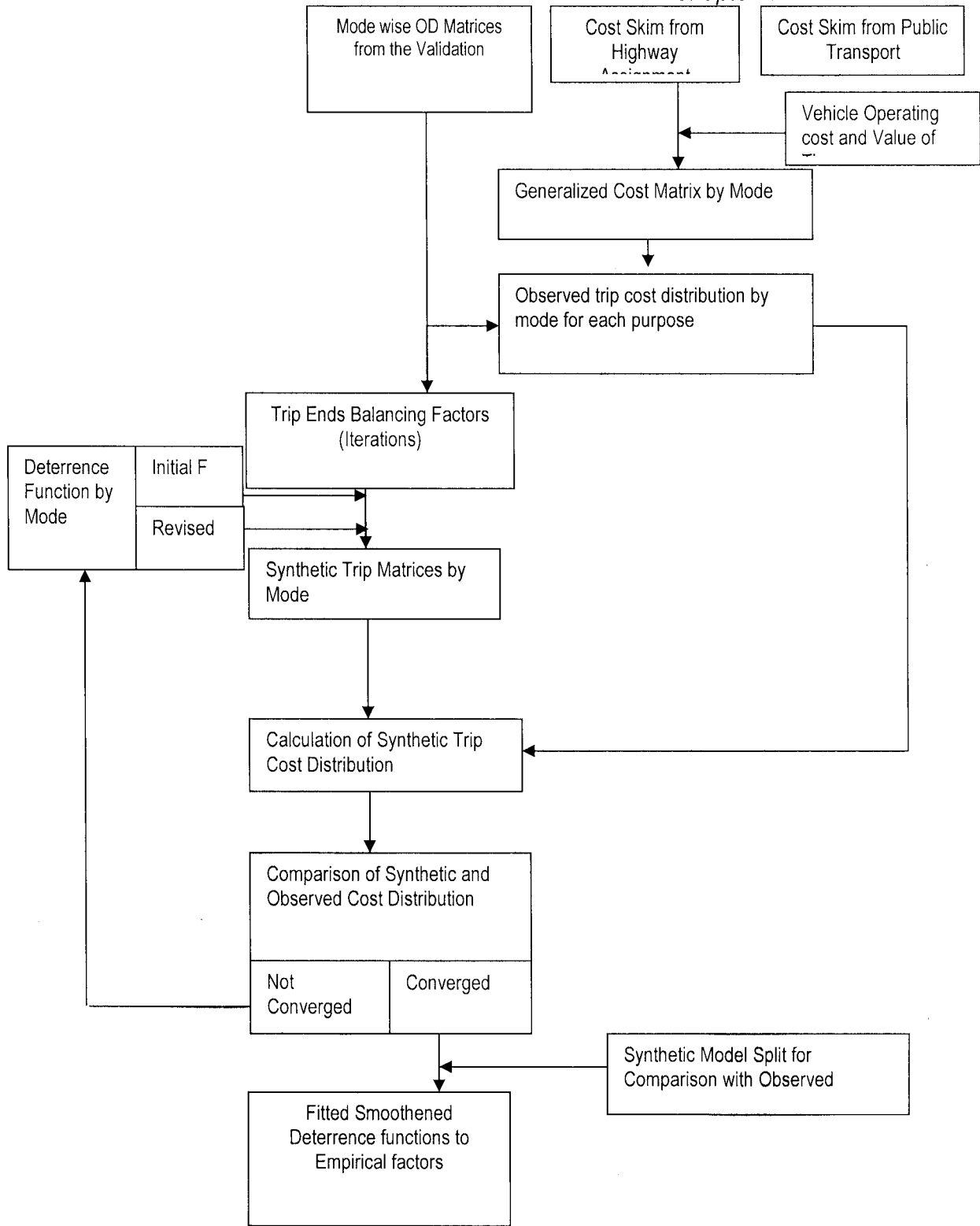


Figure2.5: Calibration process

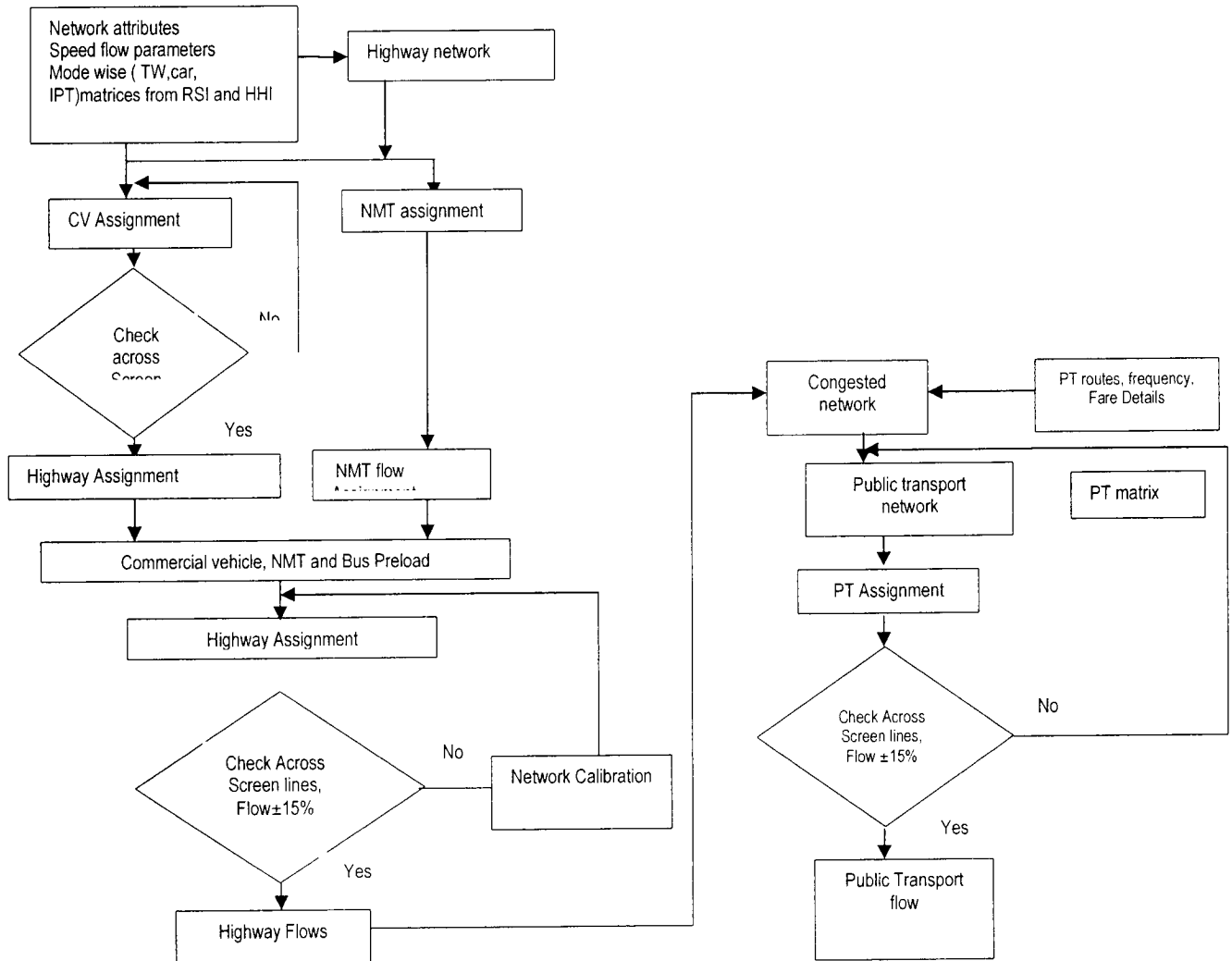


Figure 2.6. Trip Assignment



ZONE NUMBERS AND ZONE NAMES

Zone No	Zone name
1	HMT
2	Jalahalli
3	Yeshwanthapura
4	Mathikere
5	Kodandarampura
6	Dattatreya Temple
7	Malleswaram
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	Industrial Town
22	
23	
24	Sri Ram Mandir
25	Prakashnagar
26	Bashyamanagara
27	Ramachandrapuram
28	Sevashrama
29	
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
42	Mudala Palya
43	Chandra Layout



Zone No	Zone name
44	Attiguppe
45	Gali Anjaneya Temple
46	Bapuji Nagar
47	Padarayanapura
48	Jagajeevanaram Nagar
49	Azad Nagar
50	Chamrajpet
51	Dharmarayaswamy Temple
52	Sudhamanagara
53	
54	Kempegowdanagar
55	Vishweshwarapuram
56	
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	Hombegowdanagar
69	
70	
71	Lakkasandara
72	
73	Gurappanapalya
74	B.T.M. Layout
75	Madivala
76	
77	
78	
79	Koramangala
80	
81	
82	Ejipura
83	Neelasandra
84	Sahnthinagar
85	Austin Town
86	Domlur
87	Airport
88	Jeevanbhimanagar
89	Jougupalya
90	



Zone No	Zone name
91	
92	
93	Richmond Town
94	
95	Sampangiramanagara
96	
97	
98	
99	
100	Vasanthanagara
101	
102	
103	
104	Shivajinagar
105	
106	Bharathinagar
107	Ulsoor
108	
109	Hoysala Nagara
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	Jayamahal
125	Devarajeevanahalli
126	Kadugondanahalli
127	Kaval Byrasandra
128	Hebbal
129	J.C. Nagar
130	Ganga Nagar
131	
132	
133	Aramane Nagar
134	
135	
136	
137	
138	Sanjayanagar
139	Kengeri



Zone No	Zone name
140	Herohalli
141	Makali
142	Byatarayanapura
143	Bavalakere
144	Hesarghatta
145	Yelahanka
146	Bettaalasuru
147	Tanisandra
148	Bagaluru
149	Horamavu
150	
151	
152	
153	Avalahalli
154	K.R.Puram
155	
156	
157	Sadar Mangala
158	Whitefield
159	
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
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 1.2							
Option2 - BIEC Terminal - Anjanapura Township (North-South Corridor) -2016							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
BIEC Terminal	545	0	545	Anjanapura Township	1397	0	1397
Jindal	2376	0	2921	Thalaghattapura	1823	11	3209
Manjunatha Nagar	250	10	3161	Vajarahalli	1092	13	4288
Hesarghatta Cross	1146	12	4294	Krishna Leela Park (ISKON)	934	61	5161
T. Dasarahalli	3614	18	7890	Anjanapura Road Cross	1222	93	6290
Jalahalli	188	47	8031	Puttenahalli Cross	1014	193	7112
Peenya Ind Area	1529	551	9009	J.P.Nagar	1987	666	8433
Peenya	217	61	9164	Banashankari	3223	414	11241
Outer Ring Road	1936	201	10900	R V Road	7191	1103	17329
Yeshwantapur	1298	369	11829	Jayanagar	627	128	17828
Soap Factory	1672	581	12920	South End Circle	405	88	18144
Mahalakshmi	431	101	13250	Lal Bagh	1469	442	19172
Rajaji Nagar	1514	372	14392	K R Road	1237	226	20183
Kuvempu Road	1744	266	15869	City Market	1530	265	21449
Malleswaram	2796	276	18389	Chickpete	215	190	21474
Swastik	792	771	18410	Majestic	7880	10298	19056
Majestic	7987	4594	21803	Swastik	595	764	18886
Chickpete	355	697	21461	Malleswaram	882	1908	17860
City Market	1420	2059	20822	Kuvempu Road	611	1370	17101
K R Road	275	1367	19730	Rajaji Nagar	839	1187	16752
Lal Bagh	468	1890	18308	Mahalakshmi	209	786	16176
South End Circle	265	384	18189	Soap Factory	855	1779	15252



Jayanagar	185	567	17806	Yeshwantapur	323	3132	12444
R V Road	2612	11738	8680	Outer Ring Road	262	3908	8798
Banashankari	430	3058	6052	Peenya	109	245	8662
J.P.Nagar	334	1456	4931	Peenya Ind Area	349	3059	5951
Puttenahalli Cross	138	770	4299	Jalahalli	16	169	5798
Anjanapura Road Cross	67	782	3584	T. Dasarahalli	43	2155	3685
Krishna Leela Park (ISKON)	36	980	2639	Hesarghatta Cross	31	1056	2661
Vajarahalli	16	890	1766	Manjunatha Nagar	17	443	2234
Thalaghattapura	15	649	1131	Jindal	0	1649	585
Anjanapura Township	0	1131	0	BIEC Terminal	0	585	0

Option2 - BIEC Terminal - Anjanapura Township (North-South Corridor) -2021

Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
BIEC Terminal	698	0	698	Anjanapura Township	1788	0	1788
Jindal	3041	0	3740	Thalaghattapura	2333	14	4108
Manjunatha Nagar	319	13	4046	Vajarahalli	1398	17	5489
Hesarghatta Cross	1466	16	5497	Krishna Leela Park (ISKON)	1196	78	6607
T. Dasarahalli	4626	23	10099	Anjanapura Road Cross	1564	119	8052
Jalahalli	240	60	10279	Puttenahalli Cross	1298	247	9103
Peenya Ind Area	1957	705	11531	J.P.Nagar	2544	853	10794
Peenya	278	78	11731	Banashankari	4126	530	14389
Outer Ring Road	2478	257	13951	R V Road	9204	1412	22182
Yeshwantapur	1661	472	15141	Jayanagar	803	164	22820
Soap Factory	2140	744	16538	South End Circle	518	113	23225
Mahalakshmi	552	129	16960	Lal Bagh	1880	566	24540



Rajaji Nagar	1938	476	18422	K R Road	1583	289	25834
Kuvempu Road	2132	340	20213	City Market	1959	339	27454
Malleswaram	3279	353	23139	Chickpete	275	243	27486
Swastik	1013	987	23166	Majestic	10086	11181	26392
Majestic	9807	5380	27593	Swastik	761	978	26175
Chickpete	454	892	27155	Malleswaram	2129	2442	25861
City Market	1818	2636	26338	Kuvempu Road	783	1754	24890
K R Road	352	1750	24940	Rajaji Nagar	2073	1520	25444
Lal Bagh	599	2419	23120	Mahalakshmi	268	1006	24706
South End Circle	339	492	22966	Soap Factory	2094	2277	24523
Jayanagar	237	726	22477	Yeshwantapur	414	4008	20929
R V Road	3343	15025	10796	Outer Ring Road	335	5002	16262
Banashankari	550	3915	7431	Peenya	139	314	16087
J.P. Nagar	428	1863	5996	Peenya Ind Area	547	3916	12719
Puttenahalli Cross	177	985	5188	Jalahalli	120	217	12622
Anjanapura Road Cross	86	1001	4273	T. Dasarahalli	155	2759	10018
Krishna Leela Park (ISKON)	46	1255	3064	Hesarhatta Cross	140	1351	8807
Vajarahalli	20	1139	1945	Manjunatha Nagar	121	567	8361
Thalaghattapura	19	831	1133	Jindal	0	1811	6550
Anjanapura Township	0	1133	0	BIEC Terminal	0	6550	0
Option2 - BIEC Terminal - Anjanapura Township (North-South Corridor) -2031							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
BIEC Terminal	929	0	929	Anjanapura Township	2379	0	2379
Jindal	4045	0	4974	Thalaghattapura	3103	18	5464
Manjunatha Nagar	425	17	5381	Vajarahalli	1860	22	7301



Hesarghatta Cross	1950	21	7311	Krishna Leela Park (ISKON)	1590	104	8787
T. Dasarahalli	6152	31	13432	Anjanapura Road Cross	2080	158	10709
Jalahalli	320	80	13672	Puttenahalli Cross	1726	328	12107
Peenya Ind Area	2603	938	15336	J.P.Nagar	3383	1134	14356
Peenya	369	104	15602	Banashankari	5487	706	19137
Outer Ring Road	3295	341	18555	R V Road	12242	1878	29501
Yeshwantapur	2210	628	20138	Jayanagar	1068	219	30351
Soap Factory	2847	989	21995	South End Circle	689	151	30889
Mahalakshmi	734	172	22557	Lal Bagh	2501	752	32638
Rajaji Nagar	2577	633	24501	K R Road	2106	384	34359
Kuvempu Road	2836	453	26884	City Market	2605	451	36514
Malleswaram	4361	469	30775	Chickpete	365	323	36557
Swastik	1348	1312	30811	Majestic	13115	14871	34801
Majestic	12043	7155	35698	Swastik	1013	1301	34512
Chickpete	604	1186	35116	Malleswaram	2832	3248	34096
City Market	2418	3506	34029	Kuvempu Road	1041	2332	32804
K R Road	469	2328	32170	Rajaji Nagar	2257	2021	33040
Lal Bagh	796	3217	29749	Mahalakshmi	357	1338	32059
South End Circle	450	654	29545	Soap Factory	2785	3028	31816
Jayanagar	315	966	28894	Yeshwantapur	550	5331	27035
R V Road	4447	19983	13358	Outer Ring Road	446	6653	20828
Banashankari	732	5207	8883	Peenya	185	417	20596
J.P.Nagar	569	2478	6975	Peenya Ind Area	728	5208	16116
Puttenahalli Cross	236	1310	5900	Jalahalli	160	288	15987
Anjanapura Road Cross	114	1331	4682	T. Dasarahalli	206	3669	12524
Krishna Leela Park (ISKON)	61	1669	3074	Hesarghatta Cross	186	1797	10913



Vajarahalli	27	1515	1587	Manjunatha Nagar	161	754	10320
Thalaghattapura	25	1105	507	Jindal	0	2409	7911
Anjanapura Township	0	507	0	BIEC Terminal	0	7911	0
Option2 - BIEC Terminal - Anjanapura Township (North-South Corridor)-2041							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
BIEC Terminal	1087	0	1087	Anjanapura Township	2783	0	2783
Jindal	4733	0	5819	Thalaghattapura	3631	22	6392
Manjunatha Nagar	497	20	6296	Vajarahalli	2176	26	8542
Hesarghatta Cross	2282	24	8553	Krishna Leela Park (ISKON)	1861	122	10280
T. Dasarahalli	7198	36	15715	Anjanapura Road Cross	2434	185	12529
Jalahalli	374	94	15996	Puttenahalli Cross	2020	384	14165
Peenya Ind Area	3045	1098	17944	J.P.Nagar	3959	1327	16796
Peenya	432	122	18254	Banashankari	6420	825	22391
Outer Ring Road	3856	399	21710	R V Road	14323	2197	34517
Yeshwantapur	2585	734	23561	Jayanagar	1250	256	35511
Soap Factory	3331	1157	25734	South End Circle	806	176	36140
Mahalakshmi	858	201	26392	Lal Bagh	2926	880	38186
Rajaji Nagar	3015	741	28666	K R Road	2464	449	40201
Kuvempu Road	3318	530	31454	City Market	3048	527	42721
Malleswaram	5102	549	36007	Chickpete	428	378	42771
Swastik	1577	1536	36048	Majestic	15345	17399	40717
Majestic	14090	8372	41767	Swastik	1185	1522	40379
Chickpete	707	1387	41086	Malleswaram	3313	3800	39892
City Market	2829	4101	39814	Kuvempu Road	1218	2729	38381
K R Road	548	2723	37639	Rajaji Nagar	2641	2365	38657
Lal Bagh	931	3764	34806	Mahalakshmi	417	1565	37509
South End Circle	527	765	34568	Soap Factory	3258	3543	37225



Jayanagar	369	1130	33807	Yeshwantapur	644	6237	31631
R V Road	5203	23380	15629	Outer Ring Road	522	7784	24369
Banashankari	856	6092	10394	Peenya	217	488	24097
J.P.Nagar	666	2899	8160	Peenya Ind Area	851	6093	18856
Puttenahalli Cross	276	1533	6903	Jalahalli	187	337	18705
Anjanapura Road Cross	133	1558	5478	T. Dasarahalli	241	4293	14653
Krishna Leela Park (ISKON)	71	1953	3597	Hesarghatta Cross	218	2102	12769
Vajarahalli	32	1773	1856	Manjunatha Nagar	188	882	12075
Thalaghattapura	29	1293	593	Jindal	0	2818	9256
Anjanapura Township	0	593	0	BIEC Terminal	0	9256	0

Option2-East-West Corridor - Future Station to White Field -2016							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
Kengeri Terminal	4597	0	4597	Whitefield	1243	0	1243
RV College of Engineering	1488	854	5231	Ujwala Vidyalaya	1302	0	2545
Bangalore University Cross	1271	304	6198	Kadugodi	1275	17	3803
Rajarajeshwari Nagar	1608	168	7638	I T P L	582	62	4323
Nayandahalli	485	78	8045	Sathya Sai Hospital	626	151	4798
Mysore Road Terminal	751	140	8656	Vydehi Hospital	524	71	5251
				Kundanahalli	446	64	5633



Chapter 2 – Traffic Forecast

Deepanjali Nagar	2563	77	11142	Vishweshwaraya Ind. Area	1178	220	6592
Vijaya Nagar	484	39	11587	Doddanakundi Ind Area	566	289	6868
Hosahalli	2185	85	13686	Garudacharya Palya	873	353	7388
Toll Gate	2188	40	15834	Mahadevapura	1422	258	8552
Magadi Road	2252	762	17324	Narayanapura	1277	227	9602
City Railway Station	1577	114	18787	K R Puram	587	291	9899
Majestic	9310	11125	16972	Jyothispuram	439	691	9647
Central College	1890	612	18249	Byappanahalli	353	304	9696
Vidhan Soudha	775	721	18303	Old Madras Road	756	1083	9368
Cricket Stadium	499	190	18612	CMH Road	1300	460	10208
M G Road	212	567	18257	Ulsoor	288	415	10080
Trinity Circle	556	531	18281	Trinity Circle	511	977	9615
Ulsoor	424	184	18521	M G Road	640	144	10111
CMH Road	1188	341	19368	Cricket Stadium	1246	1236	10121
Old Madras Road	435	499	19304	Vidhan Soudha	313	771	9663
Byappanahalli	290	407	19188	Central College	129	1120	8672
Jyothispuram	778	292	19675	Majestic	1222	2468	7426
K R Puram	251	1612	18314	City Railway Station	286	1341	6370
Narayanapura	193	808	17698	Magadi Road	181	242	6309
Mahadevapura	447	930	17215	Toll Gate	195	1568	4936
Garudacharya Palya	74	1024	16265	Hosahalli	31	596	4371
Doddanakundi Ind Area	138	586	15817	Vijaya Nagar	124	486	4009



Vishweshwaraya Ind. Area	208	1139	14886	Deepanjali Nagar	26	481	3554
Kundanahalli	97	194	14789	Mysore Road Terminal	123	266	3411
Vydehi Hospital	203	1375	13617	Nayandahalli	36	450	2997
Sathya Sai Hospital	93	873	12837	Rajarajeshwari Nagar	69	316	2750
I T P L	63	829	12071	Bangalore University Cross	38	423	2365
Kadugodi	62	701	11432	RV College of Engineering	195	885	1547
Ujwala Vidyalaya	58	516	10974	Kengeri Terminal	0	1675	1675
Whitefield	0	10974	0				
Option2-East-West Corridor - Future Station to White Field -2021							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
Kengeri Terminal	7674	0	7674	Whitefield	2175	0	2175
RV College of Engineering	2232	1281	6846	Ujwala Vidyalaya	2279	0	4454
Bangalore University Cross	1907	456	8297	Kadugodi	2231	30	6656
Rajarajeshwari Nagar	2412	252	10457	I T P L	1019	108	7566
Nayandahalli	728	117	11068	Sathya Sai Hospital	1096	265	8397
Mysore Road Terminal	1126	210	11984	Vydehi Hospital	917	124	9190
Deepanjali Nagar	3245	116	15113	Kundanahalli	780	112	9858
Vijaya Nagar	726	58	15781	Vishweshwaraya Ind. Area	2062	384	11535
Hosahalli	3177	128	18830	Doddanakundi Ind Area	990	505	12020
Toll Gate	3382	60	22152	Garudacharya Palya	1527	618	12929
Magadi Road	2578	1143	23587	Mahadevapura	2489	451	14967
				Narayanapura	2235	398	16804



Chapter 2 – Traffic Forecast

City Railway Station	1965	172	25380	K R Puram	1027	508	17322
Majestic	11365	16688	20057	Jyothipuram	769	1209	16882
Central College	2835	918	21974	Byappanahalli	618	533	16968
Vidhan Soudha	1162	1082	22055	Old Madras Road	1323	1896	16394
Cricket Stadium	748	285	22517	CMH Road	2274	805	17863
M G Road	318	851	21985	Ulsoor	504	727	17640
Trinity Circle	834	797	22022	Trinity Circle	894	1709	16826
Ulsoor	636	276	22382	M G Road	1120	252	17694
CMH Road	1781	512	23652	Cricket Stadium	2181	2163	17711
Old Madras Road	653	749	23556	Vidhan Soudha	548	1350	16910
Byappanahalli	435	610	23382	Central College	226	1960	15175
Jyothipuram	1167	437	24112	Majestic	2139	4319	12995
K R Puram	377	2418	22071	City Railway Station	500	2347	11147
Narayanapura	289	1213	21147	Magadi Road	316	423	11040
Mahadevapura	670	1394	20423	Toll Gate	341	2743	8638
Garudacharya Palya	211	1536	19098	Hosahalli	54	1043	7650
Doddanakundi Ind Area	207	879	18426	Vijaya Nagar	217	851	7016
Vishweshwaraya Ind. Area	312	1708	17030	Deepanjali Nagar	46	842	6219
Kundanahalli	145	291	16884	Mysore Road Terminal	215	466	5969
Vydehi Hospital	305	2063	15126	Nayandahalli	63	788	5244
Sathya Sai Hospital	140	1310	13956	Rajarajeshwari Nagar	121	553	4812
I T P L	95	1244	12807	Bangalore University Cross	67	740	4138



Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
Kadugodi	93	1052	11849	RV College of Engineering	341	1549	2707
Ujwala Vidyalaya	87	774	11162	Kengeri Terminal	0	2930	2930
Whitefield	0	11162	0	Future Station	0		0
Option2-East-West Corridor - Future Station to White Field -2031							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
Kengeri Terminal	7959	0	7959	Whitefield	2937	0	2937
RV College of Engineering	3013	1730	9242	Ujwala Vidyalaya	3077	0	6013
Bangalore University Cross	2574	616	11201	Kadugodi	3012	41	8985
Rajarajeshwari Nagar	3257	340	14117	I T P L	1375	146	10214
Nayandahalli	983	158	14942	Sathya Sai Hospital	1479	358	11335
Mysore Road Terminal	1520	284	16178	Vydehi Hospital	1238	167	12406
Deepanjali Nagar	4381	156	20403	Kundanahalli	1053	151	13308
Vijaya Nagar	980	79	21304	Vishweshwaraya Ind. Area	2783	519	15573
Hosahalli	4289	172	25421	Doddanakundi Ind Area	1336	662	16227
Toll Gate	4566	82	29905	Garudacharya Palaya	2062	834	17455
Magadi Road	3480	1543	31842	Mahadevapura	3359	609	20205
City Railway Station	2653	232	34263	Narayanapura	3017	537	22685
Majestic	15343	22528	27078	K R Puram	1387	686	23385
Central College	3827	1240	29665	Jyothipuram	1038	1632	22791
				Byappanahalli	835	719	22906



Chapter 2 – Traffic Forecast

Vidhan Soudha	1369	1461	29573	Old Madras Road	1786	2560	22132
Cricknet Stadium	1010	385	30198	CMH Road	3070	1087	24115
M G Road	430	1148	29479	Ulsoor	680	981	23815
Trinity Circle	1125	1076	29529	Trinity Circle	1207	2307	22715
Ulsoor	859	372	30015	M G Road	1512	340	23887
CMH Road	2205	691	31530	Cricknet Stadium	2944	2920	23910
Old Madras Road	882	1011	31400	Vidhan Soudha	740	1822	22828
Byappanahalli	588	823	31165	Central College	305	2646	20487
Jyothispuram	1376	590	31951	Majestic	2887	4831	18543
K R Puram	509	3264	29195	City Railway Station	675	3169	16048
Narayanapura	390	1637	27948	Magadi Road	427	571	15904
Mahadevapura	905	1882	26971	Toll Gate	461	3703	12662
Garudacharya Palya	285	2074	25182	Hosahalli	73	1407	11327
Doddanakundi Ind Area	279	1186	24275	Vijaya Nagar	293	1149	10471
Vishweshwaraya Ind. Area	421	2306	22391	Deepanjali Nagar	62	1137	9396
Kundanahalli	196	393	22193	Mysore Road Terminal	291	629	9057
Vydehi Hospital	411	2784	19820	Nayandahalli	85	1063	8079
Sathya Sai Hospital	188	1768	18241	Rajarajeshwari Nagar	163	747	7496
I T P L	128	1679	16689	Bangalore University Cross	90	999	6586
Kadugodi	126	1420	15395	RV College of Engineering	460	2091	4653
Ujwala Vidyalaya	117	1045	14468	Kengeri Terminal	0	4956	4956
Whitefield	0	14468	0				



Option2-East-West Corridor - Future Station to White Field -2041							
Station Name	Boarding	Alighting	PPHPD	Station Name	Boarding	Alighting	PPHPD
Kengeri Terminal	9073	0	9073	Whitefield	3348	0	3348
RV College of Engineering	3435	1971	10536	Ujwala Vidyalaya	3508	0	6855
Bangalore University Cross	2935	702	12769	Kadugodi	3434	46	10243
Rajarajeshwari Nagar	3712	388	16094	I T P L	1568	167	11644
Nayandahalli	1120	180	17034	Sathya Sai Hospital	1686	408	12922
Mysore Road Terminal	1733	324	18443	Vydehi Hospital	1411	190	14143
Deepanjali Nagar	4994	178	23259	Kundanahalli	1200	172	15171
Vijaya Nagar	1117	90	24287	Vishweshwara Ind. Area	3173	591	17753
Hosahalli	4889	196	28980	Doddanakundi Ind Area	1523	777	18498
Toll Gate	5205	93	34091	Garudacharya Palya	2351	951	19898
Magadi Road	3768	1759	36100	Mahadevapura	3830	695	23034
City Railway Station	3024	264	38860	Narayanapura	3439	612	25861
Majestic	17491	25682	30669	K R Puram	1581	783	26659
Central College	4363	1413	33619	Jyothispuram	1183	1861	25982
Vidhan Soudha	1561	1665	33514	Byappanahalli	951	820	26113
Cricket Stadium	1151	439	34226	Old Madras Road	2036	2918	25231
				CMH Road	3500	1240	27491



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M G Road	490	1309	33407	Ulsoor	776	1119	27149
Trinity Circle	1283	1226	33464	Trinity Circle	1376	2630	25895
Ulsoor	979	424	34018	M G Road	1723	387	27231
CMH Road	2514	788	35744	Cricknet Stadium	3356	3329	27258
Old Madras Road	1005	1152	35597	Vidhan Soudha	844	2078	26024
Byappanahalli	670	938	35329	Central College	347	3016	23355
Jyothipuram	1569	673	36224	Majestic	3291	5507	21139
K R Puram	580	3721	33083	City Railway Station	769	3613	18295
Narayanapura	445	1866	31662	Magadi Road	487	651	18131
Mahadevapura	1031	2146	30547	Toll Gate	525	4222	14434
Garudacharya Palya	325	2364	28508	Hosahalli	83	1604	12913
Doddanakundi Ind Area	319	1352	27474	Vijaya Nagar	334	1310	11937
Vishweshwaraya Ind. Area	480	2628	25326	Deepanjali Nagar	71	1296	10711
Kundanahalli	223	448	25101	Mysore Road Terminal	331	717	10325
Vydehi Hospital	469	3174	22395	Nayandahalli	97	1212	9210
Sathya Sai Hospital	215	2015	20595	Rajarajeshwari Nagar	186	851	8545
I T P L	145	1914	18826	Bangalore University Cross	102	1139	7508
Kadugodi	143	1618	17351	RV College of Engineering	525	2384	5305
Ujwala Vidyalaya	134	1191	16294	Kengeri Terminal	0	5649	5649
Whitefield	0	16294	0				



Summary of Traffic Forecast Option 2-2016									
Routes	From	To	Length in KM	Max. Sectional Load (PPHPD)	Daily Passenger-KM in Lakhs	Daily Ridership in Lakhs	Average Lead (KM)		
Metro Phase-1(N-S)	BIEC Terminal	Anjanapura Township	33.9	21,803	60.9	6.0	10.1		
Metro Phase-1(E-W)	Future Station	White field	40.2	19,675	56.6	4.8	11.8		
Summary of Traffic Forecast Option 2-2021									
Metro Phase-1(N-S)	BIEC Terminal	Anjanapura Township	33.9	27,593	79.6	7.90	10.1		
Metro Phase-1(E-W)	Future Station	White field	40.2	25,380	85.7	7.20	11.9		
Summary of Traffic Forecast Option 2-2031									
Metro Phase-1(N-S)	BIEC Terminal	Anjanapura Township	33.9	36,557	106.8	10.36	10.3		
Metro Phase-1(E-W)	Future Station	White field	40.2	34,263	115.6	9.67	12.0		
Summary of Traffic Forecast Option 2-2041									
Metro Phase-1(N-S)	BIEC Terminal	Anjanapura Township	33.9	42,771	124.7	12.12	10.3		
Metro Phase-1(E-W)	Future Station	White field	40.2	38,860	131.7	11.00	12.0		



Annexure 1.3.
Trip length distribution for metro trips

Trip length distribution- Metro Phase 1(N-S) - 2016

Trip Length in KM	Trips
0 to 5	12611
5 to 10	28099
10 to 15	14804
15 to 20	8647
20 to 25	3061
25 to 30	967
30 to 35	663

Trip length distribution - Metro Phase 1(N-S) - 2021

Trip Length in KM	Trips
0 to 5	16770
5 to 10	34253
10 to 15	20265
15 to 20	12328
20 to 25	4069
25 to 30	1013
30 to 35	644

Trip length distribution - Metro Phase 1(N-S) - 2031

Trip Length in KM	Trips
0 to 5	21670
5 to 10	44914
10 to 15	26393
15 to 20	16137
20 to 25	5387
25 to 30	1374
30 to 35	1374



Trip length distribution - Metro Phase 1(N-S) - 2041

Trip Length in KM	Trips
0 to 5	25247
5 to 10	52329
10 to 15	30750
15 to 20	18800
20 to 25	6277
25 to 30	1601
30 to 35	1600

Trip length distribution – Metro Phase-1(E-W) – 2016

Trip Length in KM	Trips
0 to 5	13149
5 to 10	15506
10 to 15	7256
15 to 20	10078
20 to 25	2257
25 to 30	2624
30 to 35	1760
35 to 40	732

Trip length distribution – Metro Phase-1(E-W) – 2021

Trip Length in KM	Trips
0 to 5	17619
5 to 10	21177
10 to 15	17579
15 to 20	14998
20 to 25	4964
25 to 30	3228
30 to 35	2134
35 to 40	530



Trip length distribution – Metro Phase-1(E-W) – 2031

Trip Length in KM	Trips
0 to 5	23020
5 to 10	30173
10 to 15	24292
15 to 20	19061
20 to 25	5180
25 to 30	4474
30 to 35	2998
35 to 40	1393

Trip length distribution – Metro Phase-1(E-W) - 2041

Trip Length in KM	Trips
0 to 5	26211
5 to 10	34355
10 to 15	27659
15 to 20	21703
20 to 25	5898
25 to 30	5095
30 to 35	3414
35 to 40	1586

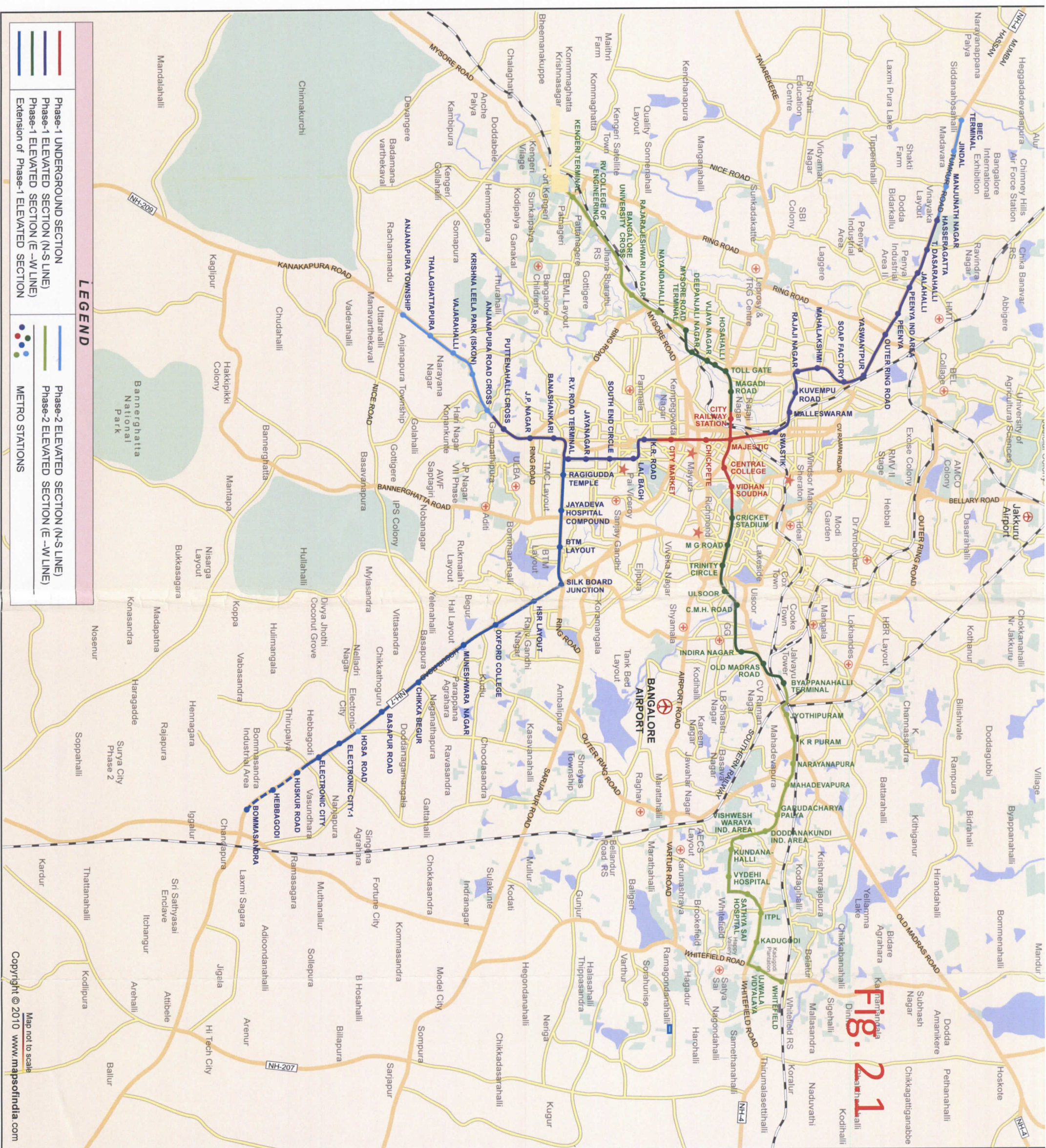


Fig. 21

CHAPTER-3

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.

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

Horizontal curves

Curve radius in mid section:		
Elevated Section	Minimum	200 m
	Absolute minimum	: 122.5 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



Chapter 3 – Planning and Design Parametres

- 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 'U' shaped structural design the rail level shall be at least 8.5 m above the road level. Similarly, the rail level for the stations on road locations (with concourse on sides on ground) shall be at least 10.5 m above the road level in the central portion and 9.5 m at ends. With elevated concourse the rail level at stations shall be 12.8 m. For the tracks carried on portals on roads, the minimum rail level shall be 9.5 m above the road level.

The track center to centre distance of 4.2 m will be provided on the elevated section keeping in view the minimum radius of 122.5 m.

3.2.2 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 %



3.2.3 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 : 1500 m
- And other Locations
- Minimum length of vertical curve : 25 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.



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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 Vossloh-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 65 cm. on viaducts. Most of the components of Vossloh-336 fastening system are now indigenously available. The toe load design for the clips is to be finalized at the detail design stage. The Fastening system will be finalized complying with the performance criteria laid down by Railway Board.

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.

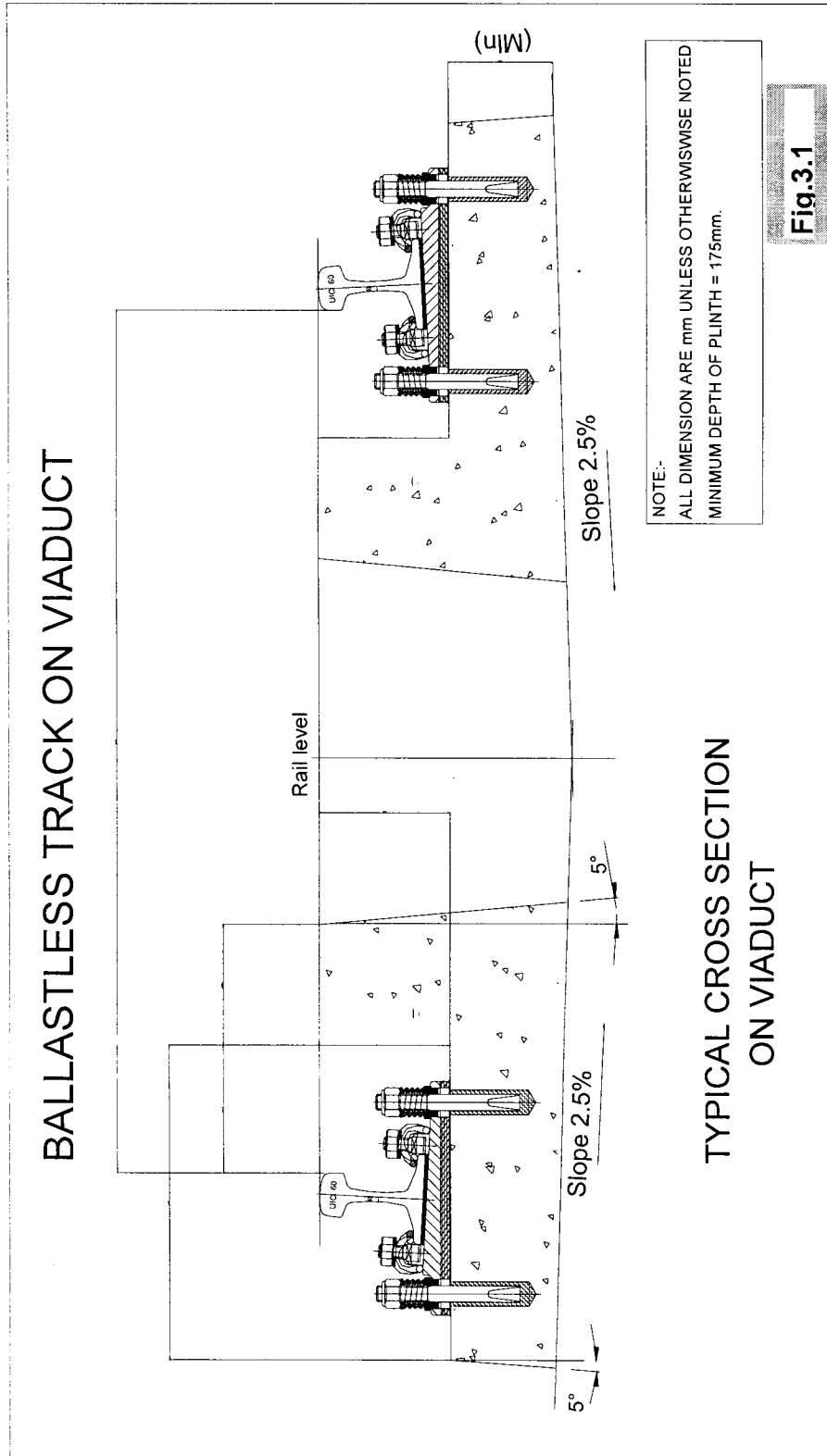


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- Normal Ballast less (as on viaduct) for Washing lines, Stabling and other running lines.

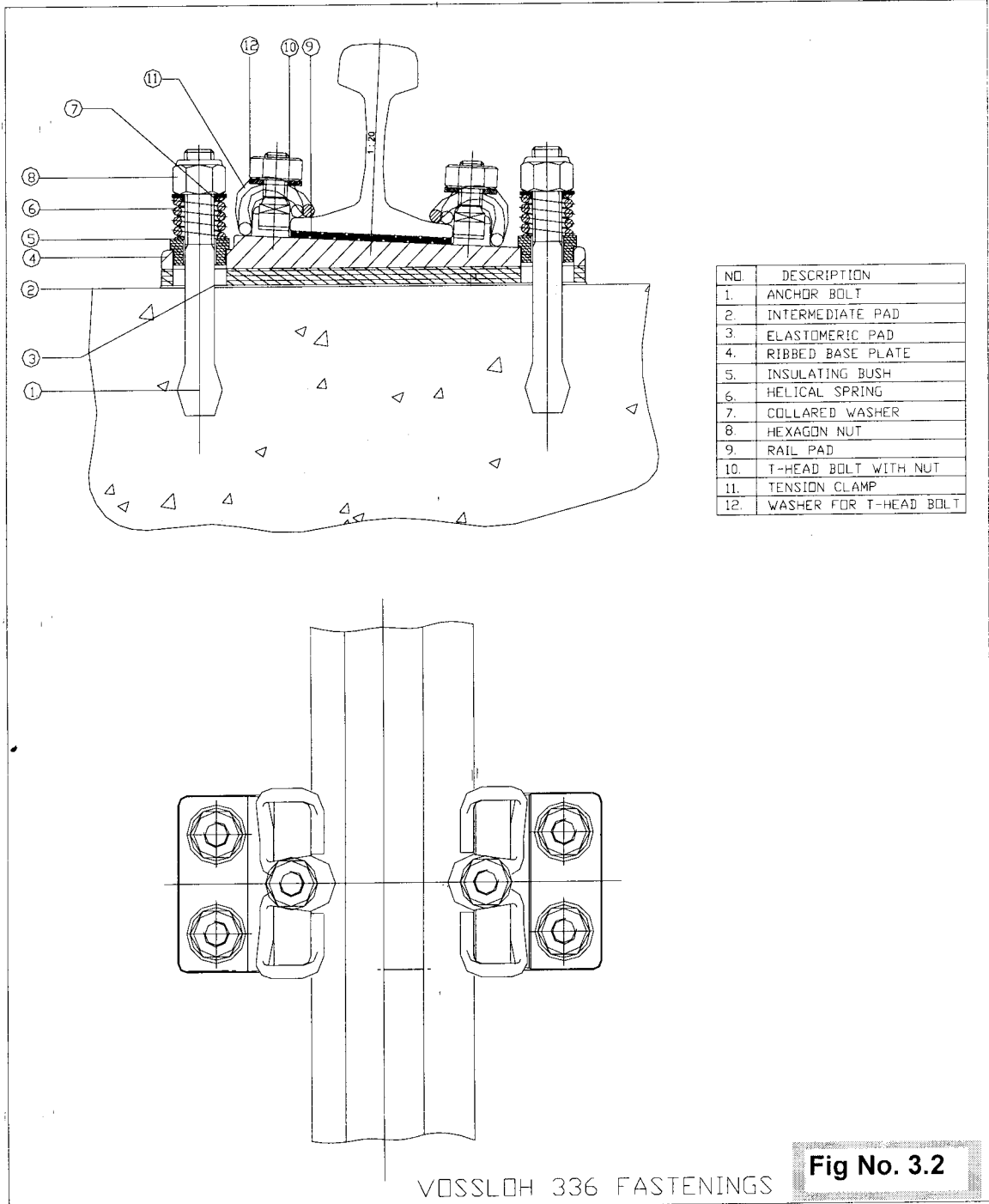
3.4.5 Turnouts

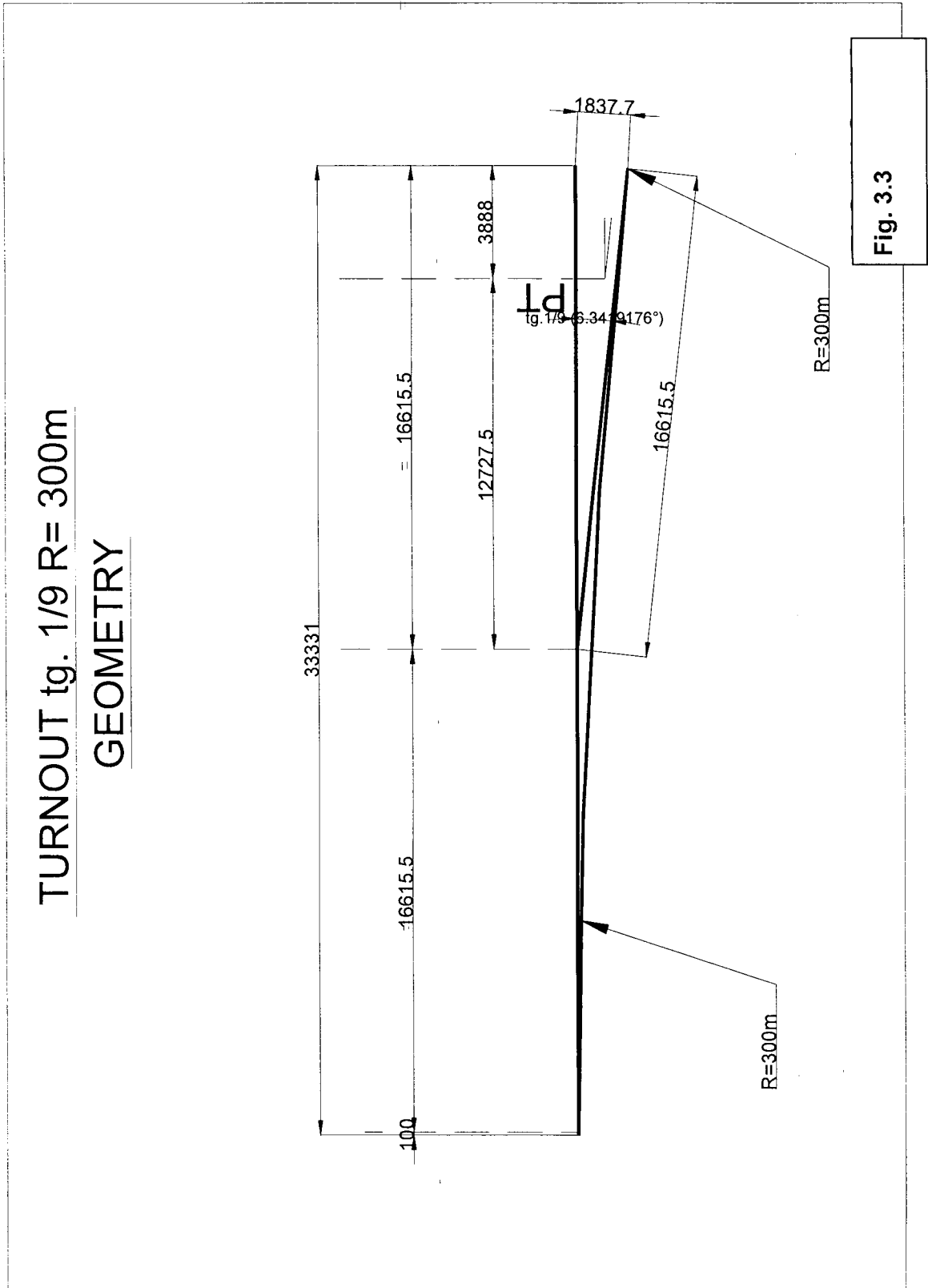
- From considerations of maintainability and riding comfort, it is proposed to lay the turnouts also with 1 in 20 cant. Further, it is proposed to adopt the following two types of turnouts:
 - i) On main lines, 1 in 9 type turnout with a lead radius of 300 metres and permissible speed on divergent track 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**).
- 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 minimising 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.

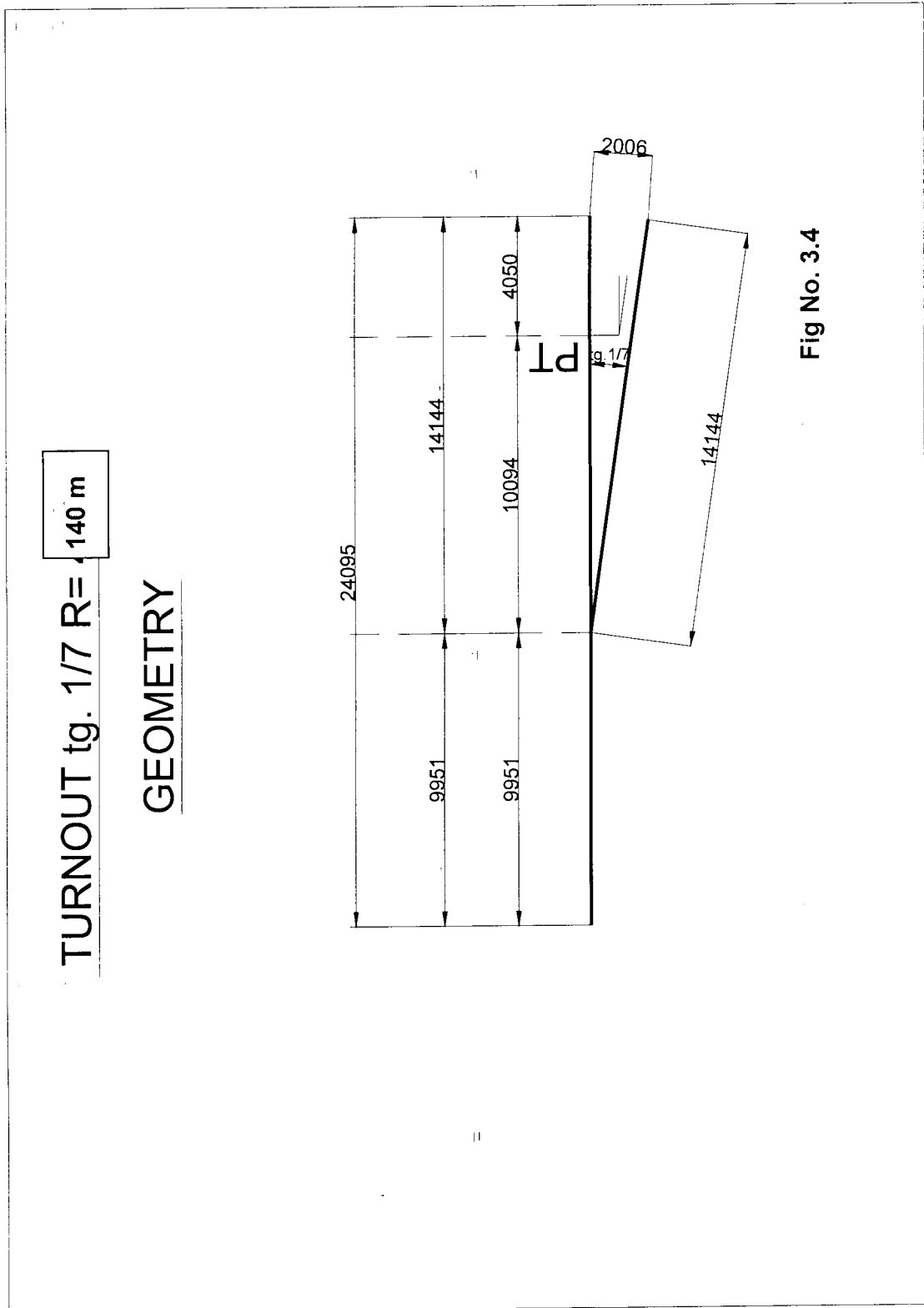




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DOUBLE CROSSOVER tg. 1/9 R= 300m C.L. 4500

AXLE SCHEME

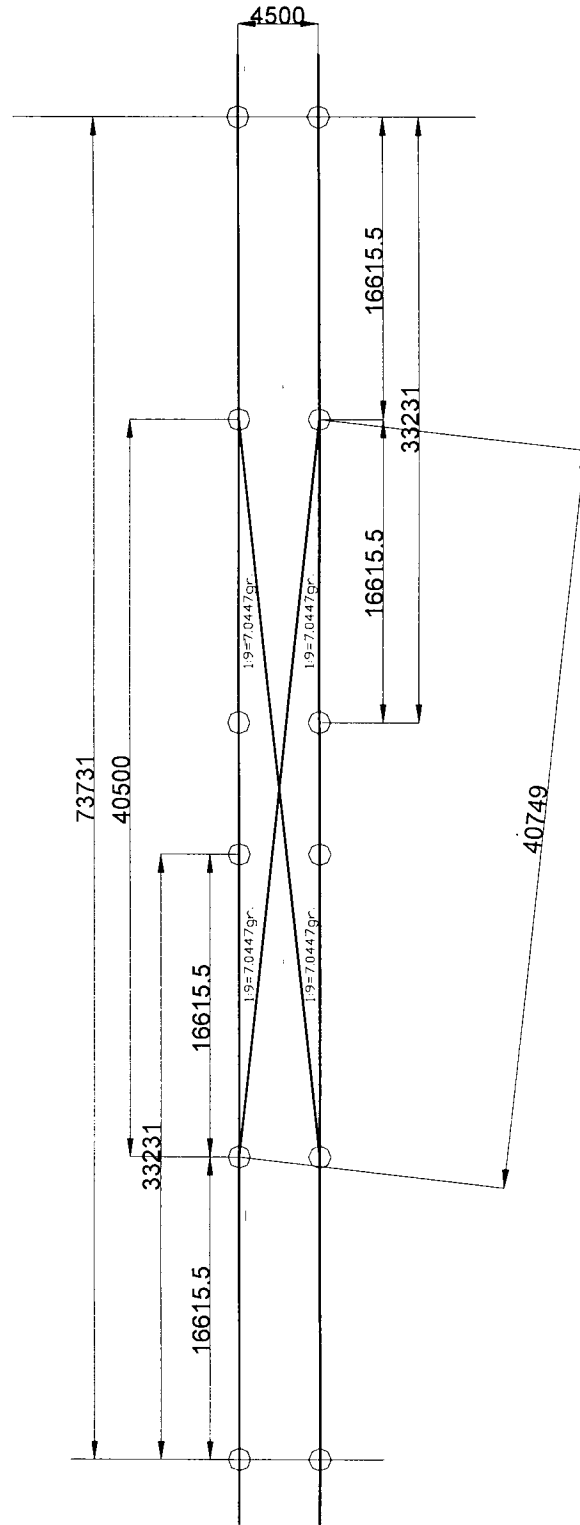


Fig No.3.5



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

CHAPTER-4

CIVIL ENGINEERING WORKS



CHAPTER 4

CIVIL ENGINEERING WORKS

4.1 EXTENSION OF EAST WEST LINE FROM MYSORE ROAD TERMINAL – KENGERI

4.1.1 DESCRIPTION OF ALIGNMENT

The line from Mysore road Terminal of Phase – I to Kengeri along Mysore road is an elevated standard gauge corridor with double line section having a route length of 6.465 km (up to dead end) and 5 stations (apart from Mysore road Terminal Station). Provision has been kept for extending the line beyond in future.

- Mysore Road Terminal station at the west end of E –W corridor of Ph-I is located on the Mysore road short of Outer Ring Road junction as elevated Terminal Station.
- This alignment is to be extended on the Mysore road upto Kengeri.
- The satellite town 'Kengeri' which has come up in the outskirts of southwestern part of Bengaluru has developed as a busy suburb and is further developing. The traffic on the Mysore road to Kengeri has also increased. Hence the necessity of extension of Mysore road Terminal to Kengeri.
- Provision has been kept for extending the line in future.

4.1.2 REFERENCE POINT

The centre line of Mysore Road Terminal Metro station has been taken as 0.00 km for reckoning of chainage on Mysore Road - Kengeri line. Chainage increases from Mysore Road Terminal Metro station towards Kengeri.

4.1.3 REFERENCE LINE

Line from Mysore Road Terminal station to Kengeri station has been named 'Up Line' and from Kengeri to Mysore Road Terminal has been named as 'Down Line'.

4.1.4 Index Plan of the alignment from the Centre line of Mysore Road Terminal Metro station to Dead end of Kengeri Terminal Metro station is given in **Figure 4.1**.



FIGURE 4.1 MYSORE ROAD TO KENGERI-FUTURE STATION



4.1.5 ALIGNMENT PLANNING AND DESIGN NORMS

The entire alignment of this extension line is **elevated**. As the work on the elevated stretches of Phase-I of the project have already been started, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc are finalized for phase-I and it is proposed to continue with the same for this line of Mysore Road – Kengeri Station extension.

4.1.6 TERMINAL STATION

It is proposed to plan elevated terminal station at Kengeri near the BMTCL Depot which will develop as the Kengeri passengers focal point as the last station on this corridor so as to facilitate extension of the Metro Rail towards Bidadi or towards Satellite town of Kengeri. At the end of this station, the train reversal facilities are being proposed towards extreme western end by providing cross-over and dead end. The C/L of the Kengeri station is at chainage (-) 6.306 km whereas the Dead End is at chainage (-) 6.725 km.

4.1.7 HORIZONTAL ALIGNMENT

The line extending from the existing dead end of Mysore Road Terminal Station will be generally on the median of the Mysore road and traverse up to Kengeri. There are five stations on this extension of Mysore Road – Kengeri line namely Nayandahalli



Chapter 4 – Civil Engineering Works
[Ch.(-)764.50], Rajarajeshwari Nagar [Ch.(-)1600], Bengaluru University Cross [Ch.(-)2400], R V College of ENGG [Ch.(-)4400], Kengeri Terminal [(-)6306] . Provision has been kept for extending the line beyond kengeri in future either towards Bidadi or towards the Satellite town of Kengeri.

4.1.8 CURVES

Total numbers of 27 horizontal curves have been provided up to Kengeri dead end. The radius of curves varies from 122m to 4500m. Hence, the sharpest curve is 122 m. A statement of curves is given at Table 4.1

TABLE 4.1 STATEMENTS OF CURVES

Curve No.	Direction of Curve	Radius (m)	Deflection Angle			Transition Length (m)		Circular Curve Length	Total Curve Length (m)	Straight between n
			D	M	S	L1	L2			
1	Right	250	26	45	52	55	55	61.78	171.78	38.930
2	Left	122.1	58	31	53	55	55	69.73	179.73	313.810
3	Right	450	9	59	51	55	55	23.52	133.52	25.589
4	Right	277.1	17	36	10	55	55	30.13	140.13	129.703
5	Left	352	32	12	55	55	55	142.97	252.97	112.654
6	Right	275	24	03	52	55	55	60.50	170.50	23.176
7	Left	270	17	16	21.4	55	55	26.4	136.4	25.328
8	Right	210	26	10	22.3	55	55	40.93	150.93	133.171
9	Right	600	8	3	39.3	40	40	44.41	124.41	30.555
10	Left	200	23	50	35.7	55	55	28.23	138.23	67.049
11	Right	3000	3	32	10	10	10	175.15	195.15	40.099
12	Right	1500	7	58	37.4	20	20	188.86	228.86	34.786
13	Left	500	15	26	2.9	40	40	94.69	174.69	52.92
14	Right	190	31	14	34.2	55	55	48.61	158.61	33.639
15	Left	190	43	14	27.6	55	55	88.39	198.39	26.779
16	Right	175	28	10	25.2	55	55	31.05	141.05	100.178
17	Left	600	11	36	51.3	40	40	81.62	161.62	46.797
18	Right	4500	0	24	23.4	10	10	21.93	41.93	52.347
19	Right	400	16	44	8.5	55	55	61.84	171.84	25.193
20	Right	1000	17	20	40.7	25	25	277.72	327.72	35.031



21	Right	2000	1	45	3.2	15	15	46.12	76.12	34.299
22	Right	2500	1	38	56.2	15	15	56.95	86.95	398.023
23	Left	123	44	43	7	20	20	76	116	30.736
24	Right	475	19	15	41.9	40	40	119.68	199.68	22.169
25	Left	300	17	32	31	55	55	36.85	146.85	87.57
26	Left	600	6	55	41.3	40	40	32.55	112.55	303.705
27	Right	1000	40	16	38.3	25	25	677.97	727.97	129.559

4.1.9 GRADIENTS

The detail statement of gradients is placed in tables 4.2:

Table 4.2
STATEMENT OF GRADIENTS
Mysore Road to Kengeri Station

S. No.	Chainage		Length (m)	Gradient	Remarks
	From	To			
1	-6725.000	-6468.352	256.648	1.26%	Rise
2	-6468.352	-6416.148	-52.204	-	-
3	-6416.148	-5980.714	435.434	0.000%	Fall
4	-5980.714	-5961.047	-19.667	-	-
5	-5961.047	-5696.856	264.191	-1.33%	Fall
6	-5696.856	-5675.903	-20.953	-	-
7	-5675.903	-5477.254	198.649	-1.55%	Fall
8	-5477.254	-5425.505	-51.749	-	-
9	-5425.505	-4998.859	426.646	1.90%	Rise
10	-4998.859	-4977.901	-20.958	-	-
11	-4977.901	-4739.270	238.631	2.85%	Rise
12	-4739.270	-4696.529	-42.741	-	-
13	-4696.529	-4296.620	399.909	0.00%	Level
14	-4296.620	-4276.141	-20.479	-	-
15	-4276.141	-3832.428	443.713	-1.28%	Fall
16	-3832.428	-3812.334	-20.094	-	-
17	-3812.334	-3400.695	411.639	-0.28%	Fall
18	-3400.695	-3372.066	-28.629	-	-



19	-3372.066	-2972.458	399.608	1.36%	Rise
20	-2972.458	-2950.304	-22.154	-	-
21	-2950.304	-2660.388	289.916	1.57%	Rise
22	-2660.388	-2632.549	-27.839	-	-
23	-2632.549	-2506.863	125.686	-0.29%	Fall
24	-2506.863	-2485.899	-20.964	-	-
25	-2485.899	-2271.628	214.271	0.00%	Level
26	-2271.628	-2251.131	-20.497	-	-
27	-2251.131	-1878.984	372.147	0.93%	Rise
28	-1878.984	-1858.953	-20.031	-	-
29	-1858.953	-1518.240	340.713	0.00%	Level
30	-1518.240	-1482.711	-35.529	-	-
31	-1482.711	-1144.916	337.795	2.37%	Rise
32	-1144.916	-1124.714	-20.202	-	-
33	-1124.714	-932.450	192.264	2.00%	Rise
34	-932.450	-901.724	-30.726	-	-
35	-901.724	-680.939	220.785	0.00%	Level
36	-680.939	-659.835	-21.104	-	-
37	-659.835	-513.347	146.488	1.06%	Rise
38	-513.347	-464.272	-49.075	-	-
39	-464.272	-342.841	121.431	-1.92%	Fall
40	-342.841	-277.935	-64.906	-	-
41	-277.935	-99.359	178.576	1.17%	Rise
42	-99.359	-75.924	-23.435	-	-
43	-75.924	124.484	200.408	0.41%	Rise
44	124.484	300.000	-175.516	-	-
45	300.000	300.000	0.000	0.00%	

4.1.10 Detailed Alignment Plans are given in Drawing No. Phase-I Extn/E-W (Mysore Road – Kengeri Station)/AL/GAD line/2010 (Sheet No. 1 to 14).

4.1.11 LAND

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. 1.12 Break-up of Land requirement

Out of the total land requirement of 19273.65 Sqm, the Private Land is 19273.65sq.m and the Government Land is nil. Section-wise land requirement for elevated section and ownership of the land is given at table 4.3.

Table 4.3
LAND REQUIREMENT & OWNERSHIP

Sl. No.	From chainage	To chainage	Pvt Land in sq.m	Govt Land in Sqm	Total Land area in Sqm
1.	(-) 554	(-) 694.50	877.12	-	877.12
2.	(-) 694.50	(-) 834.50	3041.37	-	3041.37
3.	(-) 834.50	(-) 1560	447.63	-	447.63
4.	(-) 1560	(-) 1700	2544.37	-	2544.37
5.	(-) 1700	(-) 2271	593.88	-	593.88
6.	(-) 2271	(-) 2411	1508.25	-	1508.25
7.	(-) 2411	(-) 4327.10	0	-	0
8.	(-) 4327.10	(-) 4467.10	2529.85	-	2529.85
9.	(-) 4467.10	(-) 6115	1016.39	-	1016.39
10.	(-) 6115	(-) 6255	2031.29	-	2031.29
11.	(-) 6255	(-) 6500	0	-	0
TOTAL LAND REQUIREMENT			14590.15		14590.15

- For Stations shown in blue

4.1.13 Land for Property Development

It is proposed that vacant plot of an area of approx 5375 Sq.m near Nayandanahalli Station on LHS [Chainage (-)764.50], approx 20000 Sqm in front of Bengaluru University Station [between Chainage (-)2500 to (-)2700], and approx 7667 Sqm by the side of BMTC Depot at Kengeri Station [Chainage (-) 6185] would be utilized for Property Development (Total of **33042**Sqm).

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



TABLE 4.4

S.N	Chainages		Important Locations / reference points	Locations w.r.t alignment
	From	To		
1.	(-) 554	(-)764.50	5 th Cross Street	RHS
			6 th Cross Street	LHS
			7 th Cross Street	LHS
			Ganapathi Temple Street	RHS
2	(-) 764.50	(-) 1630	2 nd Cross Street	RHS
			8 th Cross Street	LHS
			1 st Cross Street	RHS
			9 th Cross Street	LHS
			Lane	RHS
			Lane	LHS
			B T Road (Atmayothi Nagar)	LHS
			To Rajarajeshwari Nagar	LHS
3	(-) 1630	(-) 2341	ITL Road	RHS
			B T Road	RHS
			B T Road	RHS
			Road to Bengaluru University	RHS
			Mud Road	LHS
4	(-) 2341	(-) 4397.10	Way to Pattanigare	LHS
				LHS
5	(-) 4397.10	(-) 6185	B T Road	RHS
			Mud Road	RHS
			Valegarehalli KST	RHS



			Way to Mailasandra	LHS
6	(-) 6185	(-)6500	To Ambica Kalyana Mantapa To Kengeri Satellite Town	RHS RHS
			Way to Uttarahalli	LHS
7	(-) 6500	(-) 7231.97	B T Road	RHS
			B T Road	LHS
			Fort Street	LHS
			C C Road	LHS
			Kuvempu Road	RHS
			Vidyapeeta Road	LHS
			Kuvempu Street	RHS
			B T Road	RHS
			C C Road	RHS
			Mud Road	LHS
			Arch Bridge x-ing	Ahead

4.1.15 STATION PLANNING

Mysore Road to Kengeri alignment covers 6.465 km and consists of the following 5 stations:

1. Nayandahalli Station
2. Rajarajeshwari Nagar Station
3. Bengaluru University Cross Station
4. R V College of ENGG Station
5. Kengeri Terminal Station

4.1.16 Station Design

As per the configuration of alignment, all the stations would be elevated as follows.

1. on the middle of the road – Nayandahalli Station, Rajarajeshwari Nagar Station, Bengaluru University Cross Station, R V College of ENGG Station
2. partially on the service road –Kengeri Terminal Station



4.1.17 Station Locations

1. Nayandahalli Station

Nayandahalli Station will be the first station on Mysore Road Terminal – Kengeri line. The elevated station has been proposed on the middle of Mysore Road leading towards Kengeri/Mysore. The station is located on the centre of the Mysore road. The chainage of the station is (-) 764.50. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

2 Rajarajeshwari Nagar

This will be an elevated station, on the middle of the Mysore road leading towards Mysore. The station is located on the middle of Mysore road. The chainage of the station is (-)1600. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

3 Bengaluru University Cross

This will be the third station on Mysore Road Terminal – Kengeri line. The elevated station has been proposed on the middle of Mysore Road leading towards Mysore. The station is located on the middle of Mysore road. The chainage of the station is (-)2400. The accesses to the station are proposed across the road. Ancillary Structures required for operational activities have been housed in part of the area on RHS.

4. R V College of ENGG

This will be the 4th station on Mysore Road Terminal – Kengeri line. The elevated station has been proposed on the middle of Mysore Road leading towards Mysore. The station is located on the middle of the Mysore road. The chainage of the station is (-)4400. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on RHS.

5. Kengeri

This will be the 5th station on Mysore Road Terminal – Kengeri line. The elevated station has been proposed on the middle of left side service road of Mysore Road leading towards Mysore. The chainage of the station is (-)6185. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS. This Station is planned by the side of under construction BMTC Depot and hence traffic integration with the BMTC is to be planned in this Station area.



4.2 EXTENSION OF EAST WEST LINE FROM BAIYYAPPANAHALLI - ITPL - WHITEFIELD

4.2.1 Introduction

The extension of Baiyappanahalli Station of Phase – I to Whitefield is a double line elevated corridor of route length of 15.50 km (up to dead end)

Stations up to Whitefield:

- 1) Jyothipuram Station Ch.19800
- 2) K.R.Puram Station Ch.20625
- 3) Narayanapura Station Ch.21500
- 4) Mahadevapura Station Ch.22400
- 5) Garudacharpalya Station Ch.23600
- 6) Doddanekkundi Ind Area Station Ch.24635
- 7) Vishveshwaraiah Ind Area Station Ch.25635
- 8) Kundalahalli Station Ch.26500
- 9) Vydehi Hospital Station Ch.27500
- 10) Sathya Sai Hospital Station Ch.28300
- 11) ITPL Station Ch.29750
- 12) Kadugodi Station Ch.30800
- 13) Ujwala Vidyalaya/Whitefield Cross Station Ch.31800
- 14) Whitefield Station Ch.32800

- Baiyappanahalli station along with the depot at the east end of E – W corridor is located on the NGEF land by the side of Old Madras Road as elevated Terminal Station.
- This alignment is to be extended towards east on Old Madras Road – Whitefield Road up to ITPL in phase-II and beyond up to Whitefield Railway Station in future.
- The hub for the IT industry after Electronic City is the ITPL area. The Doddanekkundi Industrial Estate, Visveshwaraiah Industrial Estate, KIADB Export Promotional Industrial Area etc are also existing along this line which caters for a large number of clientele. There has been a lot of development around Whitefield. The Whitefield Railway Station is being planned to make it a transportation hub on the eastern side. Sri. Sathya Sai Baba Ashram is near Whitefield Railway Station. All these cater for large ridership. Also as per the traffic survey, the traffic on the Phase-I E-W line is almost doubled by the extension of this line up to Whitefield and hence the necessity of extension of Baiyappanahalli to Whitefield.

4.2.2 REFERENCE POINT

The centre line of Baiyappanahalli Terminal Metro station has been taken as 0.00 km for reckoning of chainage on Baiyappanahalli – ITPL/Whitefield line. Chainage

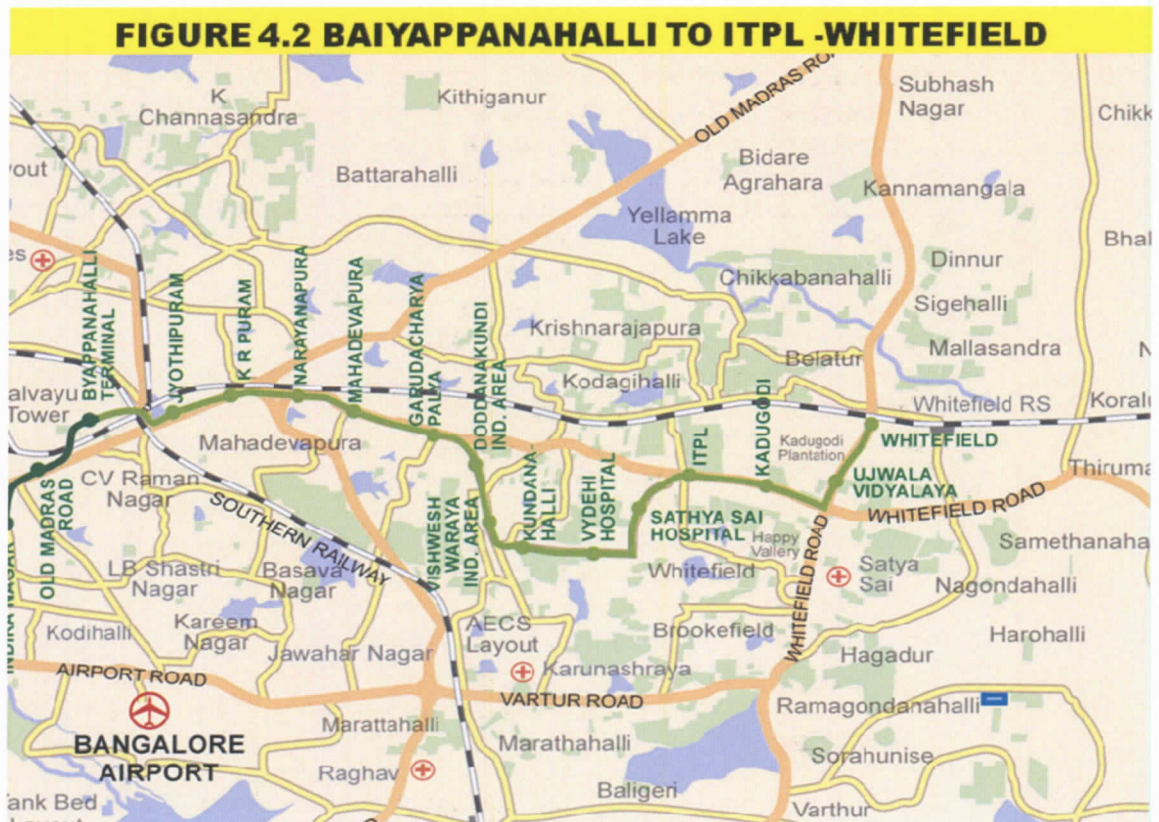


increases from Baiyyappanahalli Terminal Metro station to ITPL/Whitefield Terminal Metro station.

4.2.3 REFERENCE LINE

Line from Baiyyappanahalli Terminal station to Whitefield Terminal station is named 'Down Line' and from Whitefield Terminal to Baiyyappanahalli is named as 'Up Line'.

4.2.4 Index Plan of the alignment from the Centre line of Baiyyappanahalli Terminal Metro station to Dead end of Whitefield Terminal Metro station is given at **Figure 4.2**



4.2.5 ALIGNMENT PLANNING AND DESIGN NORMS

The entire alignment of this line is **elevated**. As the work on the Phase-I of the project on the elevated stretches have been already started and in progress, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc are finalized duly keeping the same norms.

For planning convenience and narrative purpose, the extreme end of the line i.e. about 300M beyond ITPL/Whitefield Station has been referred as ITPL/Whitefield Dead end.



4.2.6 TERMINAL STATION

It is proposed to plan elevated terminal station at ITPL Terminal near the ITPL, being the last station on this corridor for the present. At the end of this station, the train reversal facilities are being proposed towards extreme end by providing crossover and dead end. The C/L of the station is at chainage 29.75 km whereas the Dead End is at chainage 30.200km. In case Line is extended upto Whitefield, the Centre Line Chainage of Whitefield will be 32800 with deadend as Ch. 33250.

4.2.7 HORIZONTAL ALIGNMENT

The extension line starting from Baiyyappanahalli Depot main line dead end is continued on the south side of Bangalore - Chennai line (out side the railway boundary). Then the metro line crosses Bangalore -Salem line and the loop railway line to Baiyyappanahalli in one long span of about 40 mts and crosses the Kasturi Nagar road and then the outer ring road and reaches the median of the Old Madras road for a small length and then slightly shifted to the left side of the median to avoid the ramp of the Cable Stay Bridge and then the alignment crosses the approach of the Cable Stay Bridge and joins the Whitefield road. The metro alignment will also enter the Whitefield road at elevated level. The metro alignment continues between the Railway land and the outer ring road and reaches the median of Whitefield road. After crossing the flyover the alignment continues to be on the median of Whitefield road till the junction of Graphite India Road. Here the alignment turns to right and reaches the median of Graphite India Road. The alignment will be on the median of Graphite India Road till the junction of Road 2 (opp to Graphite India Research & Development Centre) where it takes a turn to the left and reaches the median of Road 2 and runs on the median of Road 2 till opposite to SAP Labs India Ltd. After this the alignment runs on the median till approx Ch.26800 (where it has two H T line crossings), at this location the overhead High Tension (HT) lines of 220 KV are running along the median of the road and hence the metro line is taken on the right side of the road till the crossing of Road 2 and Road 8 (Vydehi Hospital). Here the metro alignment takes a left turn after crossing H T lines twice and taken on the right side of Road 8/1st Main Road till short of Whitefield road. Here the metro alignment traverses on the existing vacant land (of DAN Hospitality India Pvt Ltd.) and turns right to reach Whitefield road. The alignment continues to be on the median up to the ITPL metro Station up to which the construction in first stage of extension is planned. The dead end of this station would be Ch.30100.

There are eleven stations on this extension of Baiyyappanahalli – ITPL line namely Jyothipuram (Ch19800), K.R. Puram (Ch.20625), Narayanapura (Ch.21500), Mahadevapura (Ch.22,400), Garudacharpalya (Ch.23,600), Doddanekkundi Ind Area (Ch.24,635), Visveshwaraiah Ind Area (Ch.25635), Kundalahalli (Ch.26,500), Vydehi Hospital (Ch.27,500), Satya Sai Hospital (Ch.28,300) and ITPL Terminal (Ch.29,750). This extension is fully elevated line from Baiyyappanahalli to ITPL Terminal. Provision has been kept for extending the line beyond ITPL Terminal in future in stage-II i.e upto Whitefield, wherein the the last station will be at Whitefield at Chainage 32800 with deadend at Ch. 33250.

The line may be continued later in stage II to Whitefield from the dead end of ITPL station along the median of Whitefield road till the junction of Whitefield Station road/Chennasandra Circle. Here the metro alignment turns to the left and reaches the



median of Whitefield Station road and continues along the median up to short of the Railway flyover. Here the alignment turns towards left of the flyover and terminates before the railway lines.

There are three stations on the stage II extension of ITPL – Whitefield line namely Kadugodi (Ch30800), Ujwala Vidyalaya/Whitefield Cross (Ch.31800) and Whitefield Terminal (Ch.32800).

4.2.8 CURVES

Total number of 58 horizontal curves has been provided up to Whitefield Terminal dead end (46 curves up to ITPL). The radius of curves varies from 122m to 10000m. Hence, the sharpest curve is 122 m. A statement of curves is given at Table 4.5:

TABLE 4.5 STATEMENTS OF CURVES

B.HALLI TO WHITEFIELD CURVE DETAILS AS ON 15.07.2010										
Curve No	Direction of Curve	Radius (m)	Deflection Angle			Transition Length (m)		Circular Curve Length	Total Curve Length (m)	(Horizontal)
			D	M	S	L1	L2			Staight between
			1	Right	800	7	22			57.6
2	Right	250	38	5	35.4	55	55	111.21	221.21	31.995
3	Left	900	4	55	6.4	40	40	37.26	117.26	81.387
4	Left	200	27	12	46.3	40	40	54.99	134.99	68.679
5	Left	1050	11	43	29.1	30	30	184.87	244.87	39.613
6	Right	1000	6	44	39.2	25	25	92.71	142.71	399.376
7	Left	2000	3	56	23.7	15	15	122.53	152.53	97.749
8	Right	125..20	51	11	9.9	55	55	56.88	166.88	0.019
9	Left	150	33	49	57.2	55	55	33.57	143.57	83.944
10	Right	300	19	9	33.2	55	55	45.32	155.32	15.101
11	Left	1200	3	20	54.7	20	20	50.13	90.13	4.302
12	Left	3500	0	40	21.4	10	10	31.09	51.09	266.477
13	Right	4000	0	33	33.6	10	10	29.05	49.05	52.182
14	Right	175.8	29	39	36.7	55	55	36.01	146.01	0.047
15	Right	375	15	54	13	55	55	49.09	159.09	27.632
16	Left	220	22	50	2.4	55	55	32.68	142.68	165.248



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17	Left	600	7	42	41	40	40	40.753	120.753	68.893
18	Right	9000	0	15	15.4	10	10	29.94	49.94	43.619
19	Right	700	6	2	4.3	30	30	43.73	103.73	72.015
20	Left	400	16	51	44.7	55	55	62.72	172.72	102.411
21	Right	400	11	43	44.6	55	55	26.88	136.88	81.318
22	Left	1000	5	54	56.8	25	25	78.25	128.25	42.293
23	Right	2500	0	59	11.1	15	15	28.04	58.04	79.203
24	Left	8000	0	34	21.9	10	10	69.97	89.97	34.734
25	Right	1250	2	7	39.7	20	20	26.42	66.42	0.349
26	Left	520	7	28	6.5	40	40	27.78	107.78	47.735
27	Right	122.1	71	52	22.6	55	55	98.16	208.16	36.713
28	Left	800	7	13	41.9	55	55	45.93	155.93	363.158
29	Left	6000	1	2	59.8	10	10	99.95	119.95	72.572
30	Right	350	17	1	59.1	55	55	49.05	159.05	26.053
31	Left	860	15	1	37.3	30	30	195.55	255.55	151.683
32	Left	2750	1	19	1.5	15	15	48.22	78.22	43.987
33	Left	123	72	25	28.9	55	55	100.44	210.44	0.004
34	Right	575	6	42	56.9	40	40	27.4	107.4	233.714
35	Right	1750	1	59	13.1	25	25	35.69	85.69	133.989
36	Left	1000	4	53	57	25	25	60.51	110.51	71.608
37	Right	675	6	2	36.2	40	40	31.2	111.2	30.247
38	Left	750	5	2	47.5	40	40	26.06	106.06	669.287
39	Left	122.1	93	46	15.8	55	55	144.83	254.83	149.036
40	Right	1004.8	30	13	36.8	25	25	505.09	555.09	0.019
41	Right	500	8	49	48.7	40	40	37.06	117.06	48.853
42	Right	250	22	26	0.6	55	55	42.88	152.88	71.004
43	Left	122.1	32	54	36.5	40	40	30.13	110.13	46.235
44	Right	122.1	68	29	50.4	40	40	105.97	185.97	106.8
45	Left	700	6	50	32.3	40	40	43.59	123.59	51.797
46	Left	1500	1	59	13.4	25	25	27.02	77.02	27.009
47	Left	10000	0	19	38.2	10	10	47.12	67.12	149.326



48	Right	407	17	34	38	55	55	69.86	179.86	0.028
49	Left	1100	2	42	10.9	25	25	26.89	76.89	42.144
50	Left	7000	0	19	32.6	10	10	29.79	49.79	214.767
51	Right	1500	7	19	3.9	25	25	166.58	216.58	109.054
52	Left	2500	1	34	41.6	25	25	43.86	93.86	92.476
53	Left	6000	0	20	54.1	10	10	26.48	46.48	211.528
54	Left	122.1	88	3	15.9	55	55	132.65	242.65	90.733
55	Right	3500	1	9	44.7	10	10	61.01	81.01	106.182
56	Left	3000	0	48	57.7	10	10	32.73	52.73	173.151
57	Right	500	15	17	38	40	40	93.46	173.46	187.071
58	Left	400	18	19	37	55	55	72.95	182.95	329.745

4.2.9 GRADIENTS

The detail statement of gradients is placed in tables 4.6:

S. No.	Chainage		Length (m)	Gradient	Remarks
	From	To			
1	18400.000	18834.325	434.325	0.00%	Level
2	18834.325	18865.675	31.350	-	-
3	18865.675	18926.907	61.232	-1.39%	Fall
4	18926.907	18953.093	26.186	-	-
5	18953.093	19097.254	144.161	0.35%	Rise
6	19097.254	19122.746	25.492	-	-
7	19122.746	19388.109	265.363	1.08%	Rise
8	19388.109	19411.891	23.782	-	-
9	19411.891	19598.643	186.752	-0.50%	Fall
10	19598.643	19621.357	22.714	-	-
11	19621.357	19973.736	352.379	0.00%	Level
12	19973.736	20026.264	52.528	-	-
13	20026.264	20398.736	372.472	3.50%	Rise
14	20398.736	20451.264	52.528	-	-
15	20451.264	20794.453	343.189	0.00%	Level



16	20794.453	20817.547	23.094	-	-
17	20817.547	21056.805	239.258	-0.92%	Fall
18	21056.805	21093.195	36.390	-	-
19	21093.195	21308.046	214.851	-3.35%	Fall
20	21308.046	21358.292	50.246	-	-
21	21358.292	21674.485	316.193	0.00%	Level
22	21674.485	21696.853	22.368	-	-
23	21696.853	21898.996	202.143	-0.89%	Fall
24	21898.996	21924.342	25.346	-	-
25	21924.342	22231.067	306.725	0.37%	Rise
26	22231.067	22251.933	20.866	-	-
27	22251.933	22518.972	267.039	0.00%	Level
28	22518.972	22558.028	39.056	-	-
29	22558.028	22723.483	165.455	-2.60%	Fall
30	22723.483	22757.855	34.372	-	-
31	22757.855	23029.759	271.904	-0.31%	Fall
32	23029.759	23051.578	21.819	-	-
33	23051.578	23165.394	113.816	-1.49%	Fall
34	23165.394	23205.944	40.550	-	-
35	23205.944	23494.764	288.820	1.21%	Rise
36	23494.764	23516.573	21.809	-	-
37	23516.573	23715.066	198.493	0.00%	Level
38	23715.066	23736.271	21.205	-	-
39	23736.271	23835.938	99.667	-0.62%	Fall
40	23835.938	23856.558	20.620	-	-
41	23856.558	23973.423	116.865	0.66%	Rise
42	23973.423	23995.125	21.702	-	-
43	23995.125	24157.892	162.767	-0.37%	Fall
44	24157.892	24193.446	35.554	-	-
45	24193.446	24525.654	332.208	2.00%	Rise
46	24525.654	24555.683	30.029	-	-
47	24555.683	24763.055	207.372	0.00%	Level
48	24763.055	24788.282	25.227	-	-
49	24788.282	24995.263	206.981	-1.68%	Fall



50	24995.263	25016.074	20.811	-	-
51	25016.074	25274.069	257.995	-0.46%	Fall
52	25274.069	25307.268	33.199	-	-
53	25307.268	25512.500	205.232	1.76%	Rise
54	25512.500	25538.837	26.337	-	-
55	25538.837	25828.360	289.523	0.00%	Level
56	25828.360	25862.977	34.617	-	-
57	25862.977	26105.317	242.340	-2.31%	Fall
58	26105.317	26126.020	20.703	-	-
59	26126.020	26222.197	96.177	-1.45%	Fall
60	26222.197	26279.141	56.944	-	-
61	26279.141	26394.536	115.395	2.35%	Rise
62	26394.536	26429.802	35.266	-	-
63	26429.802	26659.424	229.622	0.00%	Level
64	26659.424	26691.914	32.490	-	-
65	26691.914	26825.961	134.047	-1.72%	Fall
66	26825.961	26846.376	20.415	-	-
67	26846.376	26984.482	138.106	-1.67%	Fall
68	26984.482	27006.855	22.373	-	-
69	27006.855	27148.678	141.823	-0.18%	Fall
70	27148.678	27182.659	33.981	-	-
71	27182.659	27375.002	192.343	2.09%	Rise
72	27375.002	27406.335	31.333	-	-
73	27406.335	27714.069	307.734	0.00%	Level
74	27714.069	27757.269	43.200	-	-
75	27757.269	27950.836	193.567	-2.88%	Fall
76	27950.836	28030.501	79.665	-	-
77	28030.501	28172.436	141.935	2.43%	Rise
78	28172.436	28208.901	36.465	-	-
79	28208.901	28423.493	214.592	0.00%	Level
80	28423.493	28457.844	34.351	-	-
81	28457.844	28710.257	252.413	-1.72%	Fall
82	28710.257	28743.743	33.486	-	-
83	28743.743	28929.507	185.764	0.52%	Rise



84	28929.507	28951.830	22.323	-	-
85	28951.830	29097.879	146.049	0.33%	Rise
86	29097.879	29119.458	21.579	-	-
87	29119.458	29345.163	225.705	0.39%	Rise
88	29345.163	29366.174	21.011	-	-
89	29366.174	29627.811	261.637	0.94%	Rise
90	29627.811	29648.526	20.715	-	-
91	29648.526	29851.133	202.607	0.00%	Level
92	29851.133	29900.204	49.071	-	-
93	29900.204	29991.955	91.751	-3.27%	Fall
94	29991.955	30039.382	47.427	-	-
95	30039.382	30187.632	148.250	-0.11%	Fall
96	30187.632	30208.705	21.073	-	-
97	30208.705	30285.635	76.930	0.59%	Rise
98	30285.635	30305.702	20.067	-	-
99	30305.702	30430.529	124.827	0.48%	Rise
100	30430.529	30460.809	30.280	-	-
101	30460.809	30626.919	166.110	2.50%	Rise
102	30626.919	30664.419	37.500	-	-
103	30664.419	30904.725	240.306	0.00%	Level
104	30904.725	30948.613	43.888	-	-
105	30948.613	31063.289	114.676	-2.93%	Fall
106	31063.289	31088.048	24.759	-	-
107	31088.048	31311.311	223.263	-1.80%	Fall
108	31311.311	31333.387	22.076	-	-
109	31333.387	31500.540	167.153	-1.82%	Fall
110	31500.540	31540.158	39.618	-	-
111	31540.158	31628.149	87.991	0.82%	Rise
112	31628.149	31650.549	22.400	-	-
113	31650.549	31875.854	225.305	0.00%	Level
114	31875.854	31912.844	36.990	-	-
115	31912.844	32229.737	316.893	-2.47%	Fall
116	32229.737	32258.960	29.223	-	-
117	32258.960	32648.345	389.385	-0.52%	Fall



118	32648.345	32670.353	22.008	-	-
119	32670.353	32873.991	203.638	0.00%	Level

4.2.10 Detailed Alignment Plans are given in Drawing No. Phase-I Extn/E-W (Baiyyappanahalli – ITPL/Whitefield)/AL/GAD line/2010 (Sheet No1 to 23/29).

4.2.11 LAND

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 and costly 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.

4.2.12 Break-up of Land requirement

Out of the total land requirement of 62742.94Sqm, the Private Land is 62682.94sq.m and the Government Land is 60.00 Sqm. Section-wise land requirement for elevated section and ownership of the land is given at table 4.4. In addition, the Land requirement for stage II extension including Stations (3 Nos) & depot has been worked out separately and is 80229.42 Sqm (Pvt land).

Table 4.7
LAND REQUIREMENT & OWNERSHIP

Sl. No.	From chainage	To chainage	Pvt Land in sq.m	Govt Land in Sqm	Total Land area in Sqm
1.	18595	18750	1723.10	-	1723.10
2.	18920	18990	951.95	-	951.95
3.	19200	19245	520.48	-	520.48
4.	19300	19400	2127.33	-	2127.33
5.	19730	19870	0	-	0
6.	19870	20555	5968.52	-	5968.52
7.	20555	20695	3525.56	-	3525.56
8.	20695	21430	3839.85	60.00	3899.85
9.	21430	21570	1034.37	-	1034.37
10.	21570	22330	87.80	-	87.80
11.	22330	22470	3362.65	-	3362.65
12.	22470	23530	0	-	0
13.	23530	23670	3443.45	-	3443.45
14.	23670	24565	3866.54	-	3866.54
15.	24565	24705	3957.54	-	3957.54
16.	24705	25565	382.15	-	382.15
17.	25565	25705	3906.22	-	3906.22



18.	25705	26430	1752.40	-	1752.40
19.	26430	26570	3603.91	-	3603.91
20.	26570	27430	1547.64	-	1547.64
21.	27430	27570	2560.60	-	2560.60
22.	27570	28230	1990.73	-	1990.73
23.	28230	28370	3330.99	-	3330.99
24.	28370	29680	5681.87	-	5681.87
25.	29680	29820	3517.09	-	3517.09
26.	29820	30100	0	-	0
TOTAL			62682.94	60.00	62742.94
ITPL - WHITEFIELD					
27.	30100	30730	0	-	0
28.	30730	30870	3389.71	-	3389.71
29.	30870	31730	2188.54	-	2188.54
30.	31730	31870	3506.95	-	3506.95
31.	31870	32730	1705.58	-	1705.58
32.	32730	32870	4438.64	-	4438.64
33.	31900	32300	65000.00	-	65000.00*
TOTAL			80229.42	-	80229.42

- For Stations shown in blue
- * For Car maintenance Depot

4.2.13 Land for Property Development

It is proposed that vacant plot of an area of approx 3000 sq.m near Narayanapura Station (Chainage 21500), and approx 5800 Sqm near Garudacharpalya Station (Chainage 23600) would be utilized for Property Development (Total of 8800Sqm).

4.2.14 The important locations and reference points along the corridor is presented in table 4.8 as under :

TABLE 4.8

S.N	Chainages		Important Locations / reference points	Locations w.r.t alignment
	From	To		
1.	18595	19800	Benniganahalli B T Road	Right
			SWR line x-ing (Salem line)	Across
			B T Road	Across
			Loop from Bangalore end of Old Madras Road to ORR	Across
			Loop from Chennai end of Old Madras Road to ORR	Across
			Loop from ORR TO Old Madras Road	Across
			BT Road	Right
2	19800	20625	BT Road	RHS
			BT Road	LHS



			BT Road	LHS
			BT Road	LHS
			BT Road	LHS
			BT Road	LHS
3	20625	21500	Cable Stay Bridge x-ing	Across
			ORR	RHS
4	21500	22400	BT Road	RHS
			BT Road	RHS
			Mud Road	RHS
			BT Road	RHS
			BT Road	RHS
			BT Road	RHS
			BT Road	RHS
			BT Road	RHS
			BT Road	RHS
			BT Road	RHS
			BT Road	LHS
5	22400	22600	BT Road	RHS
			BT Road	RHS
			Mud Road	RHS
			BT Road	LHS
			Mud Road	RHS
			Mud Road	RHS
			Mud Road	RHS
			BT Road	RHS
			BT Road	LHS
			Mud Road	LHS
			Mud Road	RHS
			BT Road	LHS
			BT Road	RHS
			Mud Road	RHS
			BT Road	RHS
			Mud Road	RHS
			Mud Road	RHS
			Mud Road	RHS
			Mud Road	RHS
			Mud Road	RHS
			Mud Road	RHS
			Road	LHS
			Mud Road	RHS
			Mud Road	RHS
6	23600	24635	B T Road	LHS
			B T Road	RHS
			B T Road	LHS
			B T Road	LHS
			Whitefield Road	LHS
			Graphite India Road	Along
			B T Road	LHS
7	24635	25635	B T Road	RHS
			Hudi Main Road	LHS
			Akshaya Layout Road	RHS
			B T Road	LHS
			Road	LHS
8	25635	26500	Whitefield Road	RHS
			SeethaRama Palya Road	LHS



9	26500	27500	U India Road	RHS
			B T Road	RHS
			Way to KTPO Exhibition Complex	LHS
			Way to Genisys Software	LHS
10	27500	28300	Way to Vydehi Hospital (Road 2B)	RHS
			B T Road (Road No.7)	LHS
			B T Road	RHS
11	28300	29750	B T Road (Road No.10)	LHS
			B T Road	LHS
			Way to Mahadevapura (Whitefield Main Road)	LHS
			B T Road	RHS
			B T Road	LHS
			B T Road (Pattandur Agrahara Road)	RHS
12.	29750	30800	B T Road (Way to Central wayside Company Ltd)	LHS
			B T Road	RHS
			B T Road	RHS
			Mud Road	RHS
			Mud Road	RHS
13	30800	31800	B T Road	LHS
			B T Road	RHS
			Whitefield Road	RHS
			Chennasandra Main Road	RHS
			Whitefield Station Road	Along

4.2.15 STATION PLANNING

Baiyyappanahalli – ITPL- Whitefield alignment covers 14.22 kms of which 11.50 kms is the length from Baiyyappanahalli to ITPL and consists of the following 11 stations up to ITPL:

- 1) Jyothipuram Station Ch.19800
- 2) K.R.Puram Station Ch.20625
- 3) Narayanapura Station Ch.21500
- 4) Mahadevapura Station Ch.22400
- 5) Garudacharpalya Station Ch.23600
- 6) Doddanekkundi Ind Area Station Ch.24635
- 7) Vishveshwaraiah Ind Area Station Ch.25635
- 8) Kundalahalli Station Ch.26500
- 9) Vydehi Hospital Station Ch.27500
- 10) Sathya Sai Hospital Station Ch.28300
- 11) ITPL Station Ch.29750

ITPL to Whitefield alignment consisting of the following 3 Stations:

- 12) Kadugodi Station Ch.30800
- 13) Ujwala Vidyalaya/Whitefield Cross Station Ch.31800



14) Whitefield Station Ch.32800

4.2.16 Station Design

All the stations would be elevated with the following configuration;

- 1 on the middle of the road – Jyothipuram Station, Narayanapura Station, Mahadevapura Station, Garudacharpalya Station, Doddanekkundi Ind Area Station, Vishveshwaraiah Ind Area Station, Kundalahalli Station, ITPL Station, Kadugodi Station and Ujwala Vidyalaya/Whitefield Cross.
- 2 partially on the road – K.R. Puram Station, Vydehi Hospital Station, Satya Sai Hospital Station and Whitefield Station.

4.2.17 Station Locations

1. Jyothipuram Station

Jyothipuram Station is the first station on Baiyyappanhalli – ITPL Terminal line. The elevated station has been proposed on the middle of Old Madras Road. The chainage of the station is 19800. The main access to the station is proposed across the road.

2 K R Puram Station

This is an elevated station, on the left side of the Old Madras road. The chainage of the station is 20625. The main access to the station is proposed by the side of road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

3 Narayanapura Station

This is the third station on Baiyyappanhalli – ITPL Terminal line. The elevated station has been proposed on the middle of Whitefield Road leading towards Whitefield. The chainage of the station is 21500. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed on RHS.

4. Mahadevapura Station

This is the 4th station on Baiyyappanhalli – ITPL Terminal line. The elevated station has been proposed on the middle of Whitefield Road leading towards Whitefield. The chainage of the station is 22400. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on RHS.

5. Garudacharpalya Station



This is the 5th station on Baiyyappanahalli – ITPL Terminal line. The elevated station has been proposed on the middle of Whitfield Road leading towards Whitefield. The chainage of the station is 23600. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

6. Doddanekkundi Industrial Area Station

This is the 6th station on Baiyyappanahalli – ITPL Terminal line. The elevated station has been proposed on the middle of Graphite India Road. The chainage of the station is 24635. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on RHS.

7 Visveshwaraiah Ind Area Station

This is the 7th station on Baiyyappanahalli – ITPL Terminal line. The elevated station has been proposed on the middle of Graphite India Road. The chainage of the station is 25635. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on RHS.

8 Kundalahalli Station

This is the 8th station on Baiyyappanahalli – ITPL Terminal line. The elevated station has been proposed on the middle of Road 2. The chainage of the station is 26500. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

9 Vydehi Hospital Station

This is the 9th station on Baiyyappanahalli – ITPL Terminal line. The elevated station has been proposed on the RHS of Road 8. The chainage of the station is 27500. Ancillary Structures required for operational activities have been housed in open area on RHS.

10 Satya Sai Hospital Station

This is the 10th station on Baiyyappanahalli – ITPL Terminal line. The elevated station has been proposed on the RHS of 1 Main Road. The chainage of the station is 28300. Ancillary Structures required for operational activities have been housed in open area on RHS.

11 ITPL

This is the 11th and last station on Baiyyappanahalli – ITPL Terminal line of Stage-I. The elevated station has been proposed on the middle of Whitefield Road. The chainage of the station is 29750. The access to the station is



proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

12 Kadugodi Station

This is the 1st station on ITPL - Whitefield Terminal stage II extension (the 12th Station on Baiyyappananahalli – ITPL – Whitefield extension) line. The elevated station has been proposed on the middle of Whitefield Road. The chainage of the station is 30800. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

13 Ujwala Vidyalaya/Whitefield Cross Station

This is the 2nd station on ITPL - Whitefield Terminal Stage II extension (the 13th Station on Baiyyappananahalli – ITPL – Whitefield extension) line. The elevated station has been proposed on the middle of Whitefield Station Road. The chainage of the station is 31800. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

14 Whitefield Terminal Station

This is the 3rd and Terminal station on ITPL - Whitefield Terminal Stage-II extension line (the last Terminal Station on Baiyyappananahalli – ITPL – Whitefield extension). The elevated station has been proposed on the LHS of Whitefield Station Road by the side of flyover. The chainage of the station is 32800. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

Conceptual Plans of the above-proposed Metro Stations are given in set of Drawings

4.3 EXTENSION OF NORTH – SOUTH LINE FROM PUTTENAHALLI CROSS TO ANJANAPURA TOWNSHIP (Up to NICE Road Crossing)

4.3.1 DESCRIPTION OF ALIGNMENT

The line from Puttenahalli Cross of Phase – I to Anjanapura Township (up to NICE Road Crossing) along Kanakapura Road is an elevated standard gauge corridor with double line section having a route length of 6.29 km (up to dead end) and 5 stations (apart from Puttenahalli Cross Station).

- Puttenahalli Cross station at the south end of N – S Phase-I corridor is located on the Kanakapura road after the Outer Ring Road junction as elevated Terminal Station.



- This alignment can be extended on the Kanakapura road up to Anjanapura Township (NICE Road Crossing).
- The Phase-I N-S line is already under construction up to Puttenahalli cross on Kanakapura road. In phase-II the same line is proposed for extension up to Anjanapura Township (NICE road x-ing) along Kanakapura road. There is good ridership from this part of the city who travel to & fro City Center. Therefore the necessity of extension of Phase-I N-S line on the southern side to Anjanapura Township (NICE road x-ing) is felt.

4.3.2 REFERENCE POINT

The centre line of Puttenahalli Cross Metro station has been taken as 0.00 km for reckoning of chainage on Puttenahalli – Anjanapura Township line. Chainage increases from Puttenahalli Cross Metro station to Anjanapura Township Terminal Metro station.

4.3.3 REFERENCE LINE

Line from Puttenahalli Cross station to Anjanapura Township Terminal station has been named 'Up Line' and from Anjanapura Township Terminal to Puttenahalli Cross has been named as 'Down Line'.

4.3.4 Index Plan of the alignment from the Centre line of Puttenahalli Cross Metro station to Dead end of Anjanapura Township Terminal Metro station is given at **Figure 4.3**

4.3.5 ALIGNMENT PLANNING AND DESIGN NORMS

The entire alignment of this line is ELEVATED. As the work on the Phase-I of the project viz., all the elevated stretches 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 line of Puttenahalli Cross – Anjanapura Township Terminal line.

For planning convenience and narrative purpose, the extreme end of the line i.e. about 300M beyond Anjanapura Township Terminal Station has been referred as Anjanapura Township Dead end.



FIGURE 4.3
PUTTENANAHALLI CROSS TO ANJANAPURA TOWNSHIP

4.3.6 TERMINAL STATION

It is proposed to plan elevated terminal station at Anjanapura Township near the NICE road crossing, being last station on this corridor. At the end of this station, the train reversal facilities are being proposed towards extreme southern end by providing cross-over and dead end. The C/L of the station is at chainage 24.182 km whereas the Dead End is at chainage 24.632km.

4.3.7 HORIZONTAL ALIGNMENT

The line starting from the existing dead end of Puttenahalli Cross Station continues to be on the median of the Kanakapura road and traverse along the median up to Anjanapura Township (NICE road x-ing). There are five stations on this extension of Puttenahalli Cross – Anjanapura Township line namely Anjanapura Road Cross (Ch18900), Krishna Leela Park (ISKON) (Ch.20083), Vajara Halli (Ch.21400), Talaghattapura (Ch.22285) and Anjanapura Township Terminal (24182). This extension is fully elevated line from Puttenahalli Cross to Anjanapura Township (NICE road x-ing).



4.3.8 CURVES

Total number of 20 horizontal curves has been provided up to Anjanapura Township dead end. The radius of curves varies from 122m to 9000m. Hence, the sharpest curve is 122 m. A statement of curves is given at Table 4.9

TABLE 4.9 STATEMENT OF CURVES

PUTTENAHALLI TO NICE ROAD CURVE DETAILS										
Curve No.	Direction of Curve	Radius (m)	Deflection Angle			Transition Length (m)		Circular Curve Length	Total Curve Length (m)	Straight between
			D	M	S	L1	L2			
1	Right	3000	5	52	16.4	10	10	297.42	317.42	199.569
2	Right	5000	0	50	9.1	10	10	62.94	82.94	177.053
3	Right	9000	0	20	3.9	10	10	42.53	62.53	237.846
4	Right	2500	1	14	53	10	10	44.46	64.46	26.674
5	Right	1000	4	27	55.2	15	15	62.93	92.93	29.047
6	Right	500	18	17	3.2	40	40	119.56	199.56	783.471
7	Right	3000	30	1	10.6	10	10	148.11	168.11	348.48
8	Left	122.5	52	34	10.4	55	55	57.4	167.4	29.548
9	Left	6000	1	8	47.8	10	10	110.07	130.07	131.723
10	Right	1750	1	46	24.3	20	20	34.17	74.17	3593.025
11	Right	150	38	55	9.5	55	55	46.89	156.89	63.16
12	Right	2000	2	16	1.3	10	10	69.13	89.13	74.05
13	Left	300	18	19	36.5	55	55	40.96	150.96	25.583
14	Left	800	8	7	12.7	25	25	88.38	138.38	271.253
15	Left	4500	0	36	34.1	10	10	37.87	57.87	399.751
16	Left	6000	0	36	54.10	10	10	54.41	74.41	124.556
17	Right	2000	2	26	8.2	15	15	70.02	100.02	48.703
18	Right	605	8	45	45.8	40	40	52.53	132.53	0.198
19	Right	500	10	46	15.3	40	40	53.99	133.99	1.502
20	Left	300	27	20	3.7	55	55	88.12	198.12	438.346

**4.3.9 GRADIENTS**

The detail statement of gradients is placed in tables 4.10:

Table 4.10 STATEMENT OF GRADIENTS

Puttenahalli Cross to Anjanapura Township					
S. No.	Chainage		Length (m)	Gradient	Remarks
	From	To			
1	18400.000	18834.325	434.325	0.00%	Level
2	18834.325	18865.675	31.350	-	-
3	18865.675	18926.907	61.232	-1.39%	Fall
4	18926.907	18953.093	26.186	-	-
5	18953.093	19097.254	144.161	0.35%	Rise
6	19097.254	19122.746	25.492	-	-
7	19122.746	19388.109	265.363	1.08%	Rise
8	19388.109	19411.891	23.782	-	-
9	19411.891	19598.643	186.752	-0.50%	Fall
10	19598.643	19621.357	22.714	-	-
11	19621.357	19973.736	352.379	0.00%	Level
12	19973.736	20026.264	52.528	-	-
13	20026.264	20398.736	372.472	3.50%	Rise
14	20398.736	20451.264	52.528	-	-
15	20451.264	20794.453	343.189	0.00%	Level
16	20794.453	20817.547	23.094	-	-
17	20817.547	21056.805	239.258	-0.92%	Fall
18	21056.805	21093.195	36.390	-	-
19	21093.195	21308.046	214.851	-3.35%	Fall
20	21308.046	21358.292	50.246	-	-
21	21358.292	21674.485	316.193	0.00%	Level
22	21674.485	21696.853	22.368	-	-
23	21696.853	21898.996	202.143	-0.89%	Fall
24	21898.996	21924.342	25.346	-	-
25	21924.342	22231.067	306.725	0.37%	Rise
26	22231.067	22251.933	20.866	-	-
27	22251.933	22518.972	267.039	0.00%	Level
28	22518.972	22558.028	39.056	-	-



29	22558.028	22723.483	165.455	-2.60%	Fall
30	22723.483	22757.855	34.372	-	-
31	22757.855	23029.759	271.904	-0.31%	Fall
32	23029.759	23051.578	21.819	-	-
33	23051.578	23165.394	113.816	-1.49%	Fall
34	23165.394	23205.944	40.550	-	-
35	23205.944	23494.764	288.820	1.21%	Rise
36	23494.764	23516.573	21.809	-	-
37	23516.573	23715.066	198.493	0.00%	Level
38	23715.066	23736.271	21.205	-	-
39	23736.271	23835.938	99.667	-0.62%	Fall
40	23835.938	23856.558	20.620	-	-
41	23856.558	23973.423	116.865	0.66%	Rise
42	23973.423	23995.125	21.702	-	-
43	23995.125	24157.892	162.767	-0.37%	Fall
44	24157.892	24193.446	35.554	-	-
45	24193.446	24525.654	332.208	2.00%	Rise
46	24525.654	24555.683	30.029	-	-
47	24555.683	24763.055	207.372	0.00%	Level
48	24763.055	24788.282	25.227	-	-
49	24788.282	24995.263	206.981	-1.68%	Fall
50	24995.263	25016.074	20.811	-	-
51	25016.074	25274.069	257.995	-0.46%	Fall
52	25274.069	25307.268	33.199	-	-
53	25307.268	25512.500	205.232	1.76%	Rise
54	25512.500	25538.837	26.337	-	-
55	25538.837	25828.360	289.523	0.00%	Level
56	25828.360	25862.977	34.617	-	-
57	25862.977	26105.317	242.340	-2.31%	Fall
58	26105.317	26126.020	20.703	-	-
59	26126.020	26222.197	96.177	-1.45%	Fall
60	26222.197	26279.141	56.944	-	-
61	26279.141	26394.536	115.395	2.35%	Rise
62	26394.536	26429.802	35.266	-	-
63	26429.802	26659.424	229.622	0.00%	Level



64	26659.424	26691.914	32.490	-	-
65	26691.914	26825.961	134.047	-1.72%	Fall
66	26825.961	26846.376	20.415	-	-
67	26846.376	26984.482	138.106	-1.67%	Fall
68	26984.482	27006.855	22.373	-	-
69	27006.855	27148.678	141.823	-0.18%	Fall
70	27148.678	27182.659	33.981	-	-
71	27182.659	27375.002	192.343	2.09%	Rise
72	27375.002	27406.335	31.333	-	-
73	27406.335	27714.069	307.734	0.00%	Level
74	27714.069	27757.269	43.200	-	-
75	27757.269	27950.836	193.567	-2.88%	Fall
76	27950.836	28030.501	79.665	-	-
77	28030.501	28172.436	141.935	2.43%	Rise
78	28172.436	28208.901	36.465	-	-
79	28208.901	28423.493	214.592	0.00%	Level
80	28423.493	28457.844	34.351	-	-
81	28457.844	28710.257	252.413	-1.72%	Fall
82	28710.257	28743.743	33.486	-	-
83	28743.743	28929.507	185.764	0.52%	Rise
84	28929.507	28951.830	22.323	-	-
85	28951.830	29097.879	146.049	0.33%	Rise
86	29097.879	29119.458	21.579	-	-
87	29119.458	29345.163	225.705	0.39%	Rise
88	29345.163	29366.174	21.011	-	-
89	29366.174	29627.811	261.637	0.94%	Rise
90	29627.811	29648.526	20.715	-	-
91	29648.526	29851.133	202.607	0.00%	Level
92	29851.133	29900.204	49.071	-	-
93	29900.204	29991.955	91.751	-3.27%	Fall
94	29991.955	30039.382	47.427	-	-
95	30039.382	30187.632	148.250	-0.11%	Fall
96	30187.632	30208.705	21.073	-	-
97	30208.705	30285.635	76.930	0.59%	Rise



98	30285.635	30305.702	20.067	-	-
99	30305.702	30430.529	124.827	0.48%	Rise
100	30430.529	30460.809	30.280	-	-
101	30460.809	30626.919	166.110	2.50%	Rise
102	30626.919	30664.419	37.500	-	-
103	30664.419	30904.725	240.306	0.00%	Level
104	30904.725	30948.613	43.888	-	-
105	30948.613	31063.289	114.676	-2.93%	Fall
106	31063.289	31088.048	24.759	-	-
107	31088.048	31311.311	223.263	-1.80%	Fall
108	31311.311	31333.387	22.076	-	-
109	31333.387	31500.540	167.153	-1.82%	Fall
110	31500.540	31540.158	39.618	-	-
111	31540.158	31628.149	87.991	0.82%	Rise
112	31628.149	31650.549	22.400	-	-
113	31650.549	31875.854	225.305	0.00%	Level
114	31875.854	31912.844	36.990	-	-
115	31912.844	32229.737	316.893	-2.47%	Fall
116	32229.737	32258.960	29.223	-	-
117	32258.960	32648.345	389.385	-0.52%	Fall
118	32648.345	32670.353	22.008	-	-
119	32670.353	32873.991	203.638	0.00%	Level

4.3.10 Detailed Alignment Plans are given in Drawing No. Phase-I Extn/N-S (Puttenahalli Cross – Anjanapura Township)/AL/GAD line/2010 (Sheet No.1 - 13).

4.3.11 LAND

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. 3.12 Break-up of Land requirement

Out of the total land requirement of 22340.45 Sqm, the Private Land is 22340.45 Sq.m and the Government Land is nil. Section-wise land requirement for elevated section and ownership of the land is given at table 4.11.

**Table 4.11
LAND REQUIREMENT & OWNERSHIP**

Sl. No.	From chainage	To chainage	Pvt Land in sq.m	Govt Land in Sqm	Total Land area in Sqm
1.	18289.969	18820	18.88	-	18.88
2.	18820	18960	3782.93	-	3782.93
3.	18960	20030	419.82	-	419.82
4.	20030	20170	403.93	-	403.93
5.	20170	21351	325.35	-	325.35
6.	21351	21491	4015.89	-	4015.89
7.	21491	22330	677.67	-	677.67
8.	22330	22470	4267.66	-	4267.66
9.	22470	23805	2884.81	-	2884.81
10.	23805	23945	4270.73	-	4270.73
11.	23945	24290	1272.78	-	1272.78
TOTAL LAND REQUIREMENT			22340.45	-	22340.45

■ For Stations shown in blue.

4.3.13 Land for Property Development

It is proposed that vacant plot of an area of approx 20000 sq.m on LHS near Anjanapura Road Cross Station (Chainage 18890), approx 15000Sqm on LHS near Krishna Leela Park (ISKON) Station (Chainage 20100), would be utilized for Property Development (Total of 35000Sqm).

4.3.14 The important locations and reference points along the corridor is presented in table 4.12 as under :

TABLE 4.12

S.N	Chainages		Important Locations / reference points	Locations w.r.t alignment
	From	To		
1.	18289.969	18890	Way to Vasanthapura Main Road	RHS
			Amrutha Nagara Main Road (Road to Anjanapura Layout)	LHS
			Canara Bank Road	RHS
2	18890	20100	Way to Raja Farm	LHS
			A R Bridge Road	RHS
			Mud Road	RHS
			Mud Road	LHS
			Mud Road	RHS
			Mud Road	LHS
			Way to Vasanthapuram	RHS
		C C Road	LHS	



			B T Road	LHS
			B T Road	LHS
			B T Road	LHS
3	20100	21421	Way to Gokulam Complex (Krishna Leela Park)	RHS
			Way to Navarathna Gardens	LHS
			Way to Gubbala	RHS
			Mud Road	LHS
			24 th Main Road	LHS
			11 th Main Road	LHS
			Mud Road	LHS
			Mud Road	LHS
			Manjunatha Nagar 1 Cross	RHS
			Manjunatha Nagar 2 Cross	RHS
			Manjunatha Nagar 3 Cross	RHS
			Manjunatha Nagar 4 Cross	RHS
			Manjunatha Nagar 5 Cross	RHS
			B T Road	RHS
			B T Road	LHS
			Mud Road	LHS
			Mud Road	RHS
			B T Road	LHS
			WBM Road	LHS
			5 th Main Road	LHS
4	21421	22400	B T Road	RHS
			Road to Kumaran College	LHS
			4 th Cross Road	RHS
			Road	LHS
			C C Road	LHS
			Mud Road	RHS
			Road	LHS
			Mud Road	LHS
			Way to Hollow block Factory	LHS
5	22400	23875	Way to Library	RHS
			C C road	RHS
			Metal Road	LHS
			B T Road	RHS
			B T Road	RHS
			Way to Judicial Layout	LHS
			Way to Yokile Garden	LHS
			C C Road	RHS
			Way to Suvridha Retirement Village	LHS
6	23875	24290	Way to Lake View	RHS
			Nice Road loop to Electronic City	LHS
			NICE Road x-ing	Ahead



4.3.15 STATION PLANNING

Puttenahalli Cross to Anjanapura Township alignment covers 6.00 km and consists of the following 5 stations:

1. Anjanapura Road Cross Station Ch.18900
2. Krishna Leela Park (ISKON) Station Ch.20083
3. Vajarahalli Station Ch.21400
4. Thalaghattapura Station Ch.22285
5. Anjanapura Township Terminal Station Ch.24182

4.3.16 Station Design

As per the configuration of alignment, all the stations would be elevated and on the middle of the road.

4.3.17 Station Locations

1. Anjanapura Road Cross Station

Anjanapura Road Cross Station is the first station on Puttenahalli – Anjanapura Township line. The elevated station has been proposed on the middle of Kanakapura Road. The chainage of the station is 18900. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

2. Krishna Leela Park (ISKON) Station

This is an elevated station, on the middle of the Kanakapura road. The station is located on the middle of Kanakapura road. The chainage of the station is 20083. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

3. Vajarahalli Station

This is the third station on Puttenahalli Cross – Anjanapura Township line. The elevated station has been proposed on the middle of Kanakapura Road. The chainage of the station is 21400. The accesses to the station are proposed across the road. Ancillary Structures required for operational activities have been housed in part of the park area on LHS.

4. Thalaghattapura Station

This is the 4th station on Puttenahalli Cross – Anjanapura Township line. The elevated station has been proposed on the middle of Kanakapura Road. The chainage of the station is 22285. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.



5. Anjanapura Township Station

This is the 5th and final station on Puttenahalli Cross – Anjanapura Township line. The elevated station has been proposed on the middle of Kanakapura Road. The chainage of the station is 24182. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS. This Station is planned by the side of NICE road and hence traffic integration facilities are to be planned in this Station area.

Conceptual Plans of the above-proposed Metro Stations are given in set of Drawings

4.4 EXTENSION OF NORTH – SOUTH LINE FROM HESARAGHATTA CROSS – BENGALURU INTERNATIONAL EXHIBITION CENTRE (BIEC) [beyond NICE Road]

4.4.1 Description of Alignment

The line from Hesaraghatta Cross of Phase – I (N-S Metro Rail) to BIEC (beyond NICE Road) along RHS of Tumkur Road is an elevated standard gauge corridor with double line section having a route length of 3.77 km (up to dead end) and 3 stations (apart from Hesaraghatta Cross Station). Provision has been kept for extending the line beyond in the future.

- Hesaraghatta Cross station at the north end of N – S Phase-I Metro Rail corridor is located on the RHS of Tumkur road as elevated Terminal Station.
- This alignment can be extended on the RHS of Tumkur road up to BIEC now and even beyond in future. The Metro alignment will have to be continued on the RHS of Tumkur road as the tolled elevated/at grade High way is under construction on the existing median of the Tumkur road.
- The Phase-I N-S line is already under construction up to Hesaraghatta cross on RHS of Tumkur road. In phase-II the same line is proposed for extension up to BIEC (beyond NICE road x-ing) along the RHS of Tumkur road. Even though from the traffic point, this extension may not be wholly justified, but a lot of visitors who intend to go to the Exhibition Center from various parts of the city and outskirts are not going to BIEC as the travel time required by road as of now is too much and the travel time will be reduced if the existing N-S line from Hesaraghatta Cross is extended up to BIEC. Therefore the necessity of extension of Phase-I N-S line on the Northern side to BIEC is felt. Provision has been kept for extending the line in future.

4.4.2 REFERENCE POINT

The centre line of Hesaraghatta Cross Metro station has been taken as 0.00 km for reckoning of chainage on Hesaraghatta Cross – BIEC line. Chainage increases from Hesaraghatta Cross Metro station to BIEC Terminal Metro station.



4.4.3 REFERENCE LINE

Line from Hesaraghatta Cross station to BIEC Terminal station has been named 'Down Line' and from BIEC Terminal to Hesaraghatta Cross has been named as 'Up Line'.

4.4.4 Index Plan of the alignment from the Centre line of Hesaraghatta Cross Metro station to Dead end of BIEC Terminal Metro station is given at **Figure 4.4**.



4.4.5 ALIGNMENT PLANNING AND DESIGN NORMS

The entire alignment of this line is **elevated**. As the work on the Phase-I of the project viz., all the elevated stretches have been already started, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed, track centre etc are finalized, it is proposed to continue with the same for this line of Hesaraghatta Cross – BIEC Terminal line.

For planning convenience and narrative purpose, the extreme end of the line i.e. about 300M beyond BIEC Terminal Station has been referred as BIEC Dead end.



4.4.6 TERMINAL STATION

It is proposed to plan elevated terminal station at BIEC beyond the NICE road crossing, being the last station on this corridor. At the end of this station, the train reversal facilities are being proposed towards extreme northern end by providing cross-over and dead end. The C/L of the station is at chainage (-) 9.224 km whereas the Dead End is at chainage (-) 9.674km.

4.4.7 HORIZONTAL ALIGNMENT

The line starting from the existing dead end of Hesaraghatta Cross Station continues to be on the RHS of the Tumkur road and traverse along the RHS of Tumkur road up to BIEC (beyond NICE road x-ing). This extension is fully elevated line from Hesaraghatta Cross to BIEC (beyond NICE road x-ing) and there are three stations namely Manjunatha Nagar [Ch.(-)6825], Jindal Metro Station [Ch.(-)8074] and BIEC Terminal [Ch.(-)9224]. Provision has been kept for extending the line beyond BIEC in future.

4.4.8 CURVES

Total number of 10 horizontal curves has been provided up to BIEC dead end. The radius of curves varies from 500m to 25000m. Hence, the sharpest curve is 500 m. A statement of curves is given at Table 4.13

**TABLE 4.13 STATEMENT OF CURVES
HESARAGHATTA TO B.I.E.C CURVE DETAILS**

Curve No.	Direction of Curve	Radius (m)	Deflection Angle			Transition Length (m)		Circular Curve Length	Total Curve Length (m)	Staight between
			D	M	S	L1	L2			
1	Right	9000	0	23	33.2	10	10	51.66	71.66	519.864
2	Left	1300	2	19	10.3	25	25	27.63	77.63	28.774
3	Right	500	9	43	39.7	40	40	44.89	124.89	27.413
4	Left	850	3	45	24.1	25	25	30.73	80.73	221.684
5	Right	8000	0	33	20.1	10	10	67.57	87.57	529.643
6	Right	25000	0	9	1.7	10	10	55.66	75.66	306.882
7	Left	15000	0	15	3.2	10	10	55.68	75.68	416.315
8	Left	2000	1	42	7.2	15	15	44.41	74.41	73.526
9	Right	700	4	31	21.2	30	30	25.25	85.25	32.96
10	Left	2000	2	3	13.7	15	15	56.69	86.69	363.468

**4.4.9 GRADIENTS**

The detail statement of gradients is placed in tables 4.14:

Table 4.14 STATEMENT OF GRADIENTS
Hesaraghatta Cross to BIEC

S. No.	Chainage		Length (m)	Gradient	Remarks
	From	To			
1	-9450.000	-9100.950	349.050	0.00%	Level
2	-9100.950	-9049.050	51.900	-	-
3	-9049.050	-8924.065	124.985	3.46%	Rise
4	-8924.065	-8875.935	48.130	-	-
5	-8875.935	-8711.112	164.823	0.25%	Rise
6	-8711.112	-8691.070	20.042	-	-
7	-8691.070	-8236.619	454.451	1.05%	Rise
8	-8236.619	-8215.559	21.060	-	-
9	-8215.559	-7886.902	328.657	0.00%	Level
10	-7886.902	-7863.098	23.804	-	-
11	-7863.098	-7472.386	390.712	0.30%	Rise
12	-7472.386	-7428.702	43.684	-	-
13	-7428.702	-7210.810	217.892	3.21%	Rise
14	-7210.810	-7189.190	21.620	-	-
15	-7189.190	-7001.964	187.226	3.45%	Rise
16	-7001.964	-6950.214	51.750	-	-
17	-6950.214	-6714.465	235.749	0.00%	Level
18	-6714.465	-6687.713	26.752	-	-
19	-6687.713	-6236.035	451.678	1.34%	Rise
20	-6236.035	-6213.965	22.070	-	-
21	-6213.965	-5900.000	313.965	0.00%	Level

4.4.10 Detailed Alignment Plans are given in Drawing No. Phase-I Extn/N-S (Hesaraghatta Cross – BIEC)/AL/GAD line/2010 (Sheet No. 1 - 7).

4.4.11 LAND

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



Chapter 4 – Civil Engineering Works 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. 4.12 Break-up of Land requirement

Out of the total land requirement of 45802.46 Sqm, the Private Land is 40916.62sq.m and the Government Land is 4885.84 Sqm. Section-wise land requirement for elevated section and ownership of the land is given at table 4.15.

Table 4.15 LAND REQUIREMENT & OWNERSHIP

Sl. No.	Location	From chainage	To chainage	Pvt Land in sq.m	Govt Land in Sqm	Total Land area in Sqm
1.	Alignment	(-) 6400	(-) 6755	3427.64	-	3427.64
2.	Manjunatha Nagar Station	(-) 6755	(-) 6895	4083.04	-	4083.04
3.	Alignment	(-) 6895	(-) 8005	10598.78	-	10598.78
4.	Jindal Station	(-) 8005	(-) 8145	4376.49	-	4376.49
5.	Alignment	(-) 8145	(-) 9130	16036.60	-	16036.60
6.	BIEC Station	(-) 9130	(-) 9270	-	4242.14	4242.14
7.	Alignment	(-) 9270	(-) 9451.64	2394.07	643.70	3037.77
TOTAL LAND REQUIREMENT				40916.62	4885.84	45802.46

4. 4.13 Land for Property Development

It is proposed that vacant plot of an area of, approx 21,463 Sqm after dead end would be utilized for Property Development (Total of approx **21463**Sqm).

4.4.14 The important locations and reference points along the corridor is presented in table 4.16 as under :

TABLE 4.16

S.No	Chainages		Important Locations / reference points	Locations w.r.t alignment
	From	To		
1.	(-) 6400	(-) 6825	Tumkur Road (NH-4) Asphalt road	Along right



			Way to Vijaya Sree Hospital, Manjunatha Nagar	right
			Asphalt road	right
				-
2	(-) 6825	(-) 8075	Tumkur Road (NH-4)	Along
			B.T. Road	right
			B.T. Road	right
			B.T. Road	right
			Mud Road	right
			Mud Road	right
			Way to Kirloskar Layout	right
3	(-) 8075	(-) 9451.61	Tumkur Road (NH-4)	Along
			Mud Road	right
			Mud Road	right
			B.T. Road	right
			NICE roads x-ing	X-ing

4.4.15 STATION PLANNING

Hesaraghatta Cross to BIEC alignment covers 3.04 km and consists of the following 3 stations:

1. Manjunatha Nagar Station Ch.(-) 6825
2. Jindal Metro Station Ch. (-) 8074
3. BIEC Terminal Station Ch. (-) 9224

4.4.16 Station Design

As per the configuration of alignment, all the stations would be elevated and on the middle of the road.

4.4.17 Station Locations

1. Manjunatha Nagar Station

Manjunatha Nagar Station is the first station on Hesaraghatta Cross – BIEC line. The elevated station has been proposed on the RHS of Tumkur Road. The chainage of the station is (-)6825. 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. Jindal Metro Station

This is an elevated station, on the RHS of the Tumkur road. The station is located on the RHS of Tumkur road. The chainage of the station is (-)8074. 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. BIEC Terminal Station

This is the third and final station on Hesaraghatta Cross – BIEC line. The elevated station has been proposed on the RHS of Tumkur Road. The station is located on the RHS of Tumkur road. The chainage of the station is (-)9224. The accesses to the station are proposed across the road. Ancillary Structures required for operational activities have been housed in part of the area on RHS.

Conceptual Plans of the above-proposed Metro Stations are given in set of Drawings

4.5 UTILITIES AND SERVICES

The proposed alignments of (i) Mysore Road Terminal to Kengeri- Future Station, (ii) Baiyyappanahalli to ITPL/Whitefield Terminal, (iii) Puttenahalli Cross to Anjanapura Township and (iv) Hesaraghatta Cross to BIEC extensions are traversing along the busy City Roads. Number of sub-surface, surface and overhead 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 alignments. 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 4.17.

Table 4.17
ORGANISATION RESPONSIBLE FOR UTILITIES AND SERVICES

S.No	Organisation / Department	Utility services
1	Bengaluru 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 Bengaluru Mahanagara Palike (BBMP)	Roads, surface water drains, nallahs etc.
3	Karnataka Power Transmission Corporation Limited (KPTCL)	H.T. Lines with Pylons, Power cables and their appurtenances
4	Bengaluru 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	Bengaluru 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 H. T. Line across alignment

The list of major electrical wires (H.T Line) crossings are given below at Table Nos. 4.18 to 4.20 . These H.T. lines are to be replaced by underground cabling.

Table No.4.18

H T lines crossings the alignment of Mysore Road Terminal - Kengeri- Future Station

S. No.	Chainage	Voltage	Remark
1	(-) 789	H T line (66/11KV)	Electrolux Area Office
2	(-) 1700	H T line (66/11 KV)	Near Rajarajeshwari Nagar Arch/ 66/11 KV Sub-station

Table No.4.19

H T lines crossings the alignment of Baiyyappanahalli to ITPL/Whitefield Terminal

S. No.	Chainage	Voltage	Remark
1	21934	H T line (66/11 KV)	Near IOCL
2	24419	H T line (22 KV)	Near Karnataka State Small Industries Development Corporation Ltd
3	24432	H T line (66 KV)	
4	26579	H T line (220 KV)	Near SAP Labs India Ltd
5	26730	H T line (66/11 KV)	Near KPTCL
6	27700	H T line (220 KV)	Near BMTC building
7	27776	H T line (220 KV)	
8	29005	H T line (220 KV)	Near Oracle India Pvt. Ltd.
9	32750	H T line (66/11 KV)	Near Kadugodi Police Station

Table No.4.20

H T lines crossings the alignment of Puttenahalli Cross to Anjanapura Township

S. No.	Chainage	Voltage	Remark
1	20586	H T line (220 KV)	Near Singanth Paint Company

There is no major electrical wires (H.T. Line) crossing is encountered in the alignment of Hesaraghatta Cross to BIEC extension.



4.7 Environmental Impact Assessment/Environmental Management Planning (EIA/EMP)

The EIA and EMP studies were entrusted to M/s SECON Pvt Ltd, Bangalore and their report is enclosed as separate volume. However, the numbers of trees affected due are given in Table No.4.21.

Table No.4.21.
Number of Trees affected due to proposed Metro Corridor/extension

Sl. No.	Metro Corridor/Extension	No. of trees affected in 10m strip of alignment and within the station area.
1.	Mysore Road - Kengeri –Future Station	50
2.	Baiyyappanahalli to ITPL/Whitefield Terminal	385
3.	Puttenahalli – Anjanapura Township (NICE Road x-ing)	253
4.	Hesaraghatta Cross - BIEC	26

4.8 Station Facilities

The elevated alignment of (1) above, generally 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 also proposed in the paid concourse.

- The ground level has been proposed for parking/ ancillary structures and space for movement of commuters.
- Ticket / token counters and information have been proposed in the unpaid area of concourse.
- Automatic Fare Collection machines have been proposed between paid & unpaid concourse. The commuter after purchasing ticket / token enters into the paid concourse.
- A conflict free circulation system is proposed for commuters and operational staff.
- The proposed stations will have two side platforms and the access to the platforms is through staircases and escalators, housed in the paid area of concourse.
- 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.

4.9 Architectural Finishes

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.

4.10 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.

4.11 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.

4.12 GEOTECHNICAL INVESTIGATIONS

The main purpose of the Geotechnical Investigations undertaken is to have an in-sight into the geological conditions along the proposed corridors of extension of Bengaluru Metro



Phase I (Phase II Bengaluru Metro), so as to arrive at the type of foundations to be adopted for elevated corridors.

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

The detailed investigations report submitted by M/s SECON Pvt Ltd is enclosed as separate volume.

4.12.1 General Description of the Area and Geology

Bengaluru, the Capital City of Karnataka State the Principal Financial and Administrative Center of the state. The City is situated on a latitude of 12° 58' N and longitude of 77° 36' E. Bengaluru is popularly called as "Garden City / Pensioner's Paradise / Silicon Valley" of India and is India's fifth largest City. Bengaluru 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.

Bengaluru 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.

Bengaluru is situated at an elevation of 900 m above Mean Sea Level on a gently sloping rolling topography, sloping gently from North to South. Terrain wise, 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 having undulating topography.

Geology wise, Bengaluru district shows dominant presence of 'Archean' crystalline formation comprising Peninsular Gneissic complex with small patch of hornblende schist in the northern part and intrusive closepet granites all along the western part of the district. These Gneissic complexes are in the age of 2.6 to 3.0 billion Years. They are essentially Granodioritic and Granitic formed due to several thermal-tectonic movements with large influx of Sialic materials representing remobilized parts of an older crust with abundant additions of granitic materials. These Gneissic complexes act as basement for belt of Schists, largely basaltic and characterized by Gold mineralization which is noticed in nearby Kolar. Small stretch comprising unconsolidated sediments are also noticed in Channapatna and Devanahalli. The soil overburden generally is dominated by Silty sand /residual silt and shows presence of clay as a nominal interstitial binder. Overburden in upper layers is generally in loose /medium compact condition especially in areas with high water table. The overburden thickness is variable and is reflective of typical differential weathering that has occurred over a prolonged period. This is followed by completely weathered and highly weathered rock.

Bangalore falls under Zone II of Seismic Zoning Map as per IS: 1893 (Part I) – 2002.

4.12.2 FIELD INVESTIGATION

Field investigation has been carried out along all the four extensions at 54 locations 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 along the alignment.

Borehole exploration was carried out by rotary drilling method using heavy duty rotary drilling rigs. Drilling in soil was carried out by MS soil cutters having suitable cutting edges. In soft/weathered rock, where strata are very dense, advancement of borehole was done by Tungsten Carbide (TC) bits of Nx size. In moderately weathered and hard rock, core drilling was progressed using Nx size Diamond bits with double tube core barrel.

Standard Penetration Tests (SPT) were carried out in the boreholes as per IS 2131 at regular intervals of generally at 1.5 m depth. Undisturbed soil samples were collected by using thin walled steel tubes of 100 mm diameter, 450 mm long as per IS 2132, in cohesive soil strata. Both SPT and UDS samples were sealed and labeled 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 stabilised.

The details of stratification, SPT values, Ground Water Table etc., are indicated in the Sub-Soil Profiles given at Fig 4.5(a),(b), (c) and (d).

4.12.3 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

4.12.4 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.

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

4.12.5 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 0.26 kg/cm² and angle of internal friction is ranging from 12 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 mylonite 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 76%. In the hard rock, the percentage core recovery is ranging from 62 to 100% and RQD is varying from 50 to 100%.

It is seen from the index properties that specific gravity of rock varies from 2.55 to 2.94, water absorption ranges from 0.15 to 2.04%.

Uniaxial compressive strength results indicate that strength of hard rock varies from 17.3 MPa to 100.48 MPa. Point load strength index values in the range of 0.35 to 11.76 MPa. Modulus of Elasticity (E) values of rock varies from 0.039×10^5 MPa to 0.78×10^5 MPa.

4.12.6 RECOMMENDATIONS

The type of foundation depends on stratification, type of structure, loading, allowable settlement, etc. In the present case, the structure is elevated Metro railway system. The various structures envisaged in the system include Elevated tracks supported on piers, Elevated Stations. 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.

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. 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

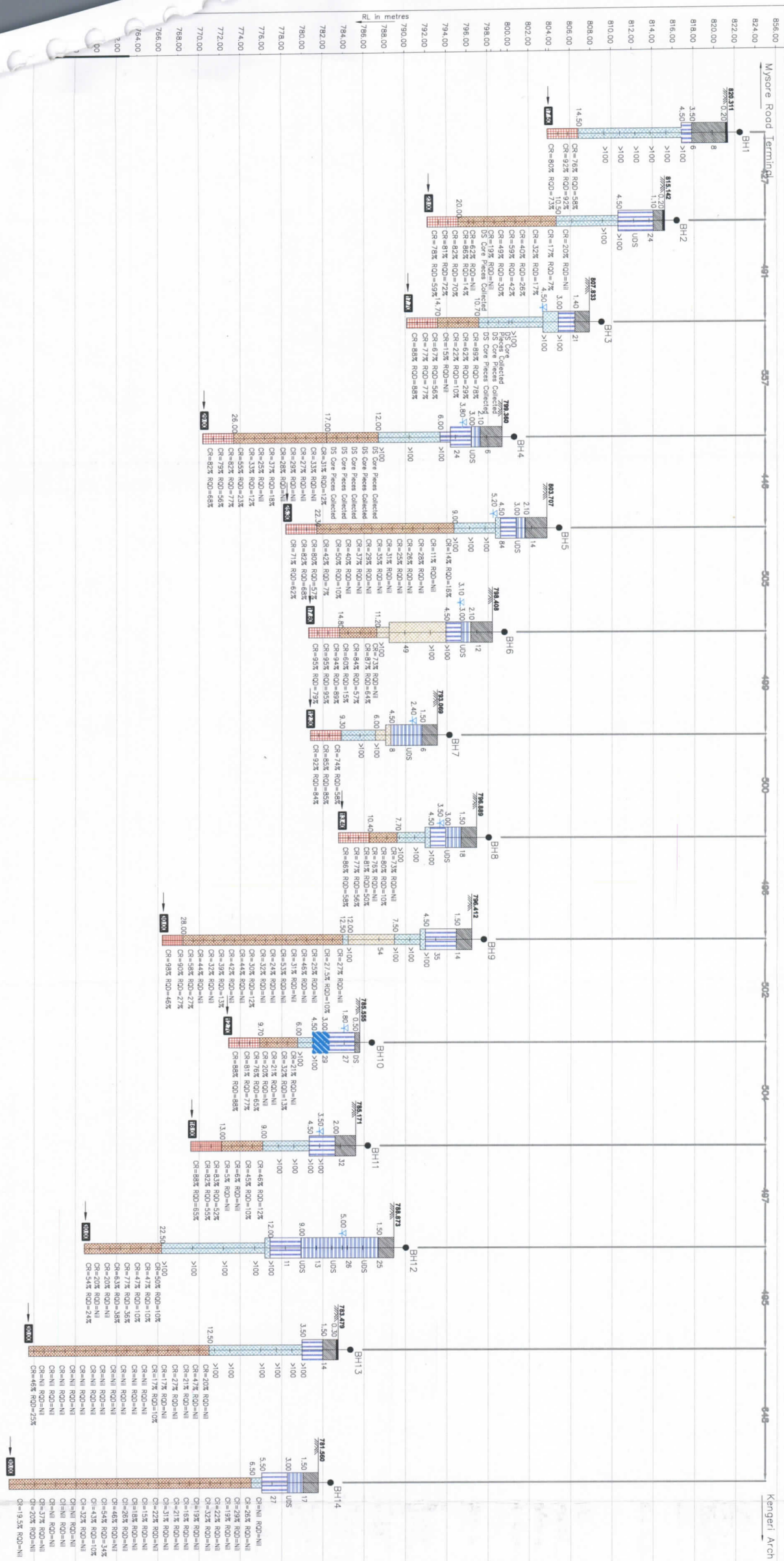
The increase in grade of concrete increases the structural capacity. However it is recommended to limit the safe loads as above, in view of the uncertainties involved in quality of in-situ concrete in the pile bore. Further, in highly weathered rock, the capacities are also governed by the properties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

FIGURE 4.5(a)



LEGEND		ABBREVIATIONS	
[Black Box]	FILLED UP SOIL	UDS	UNDISTURBED SAMPLE
[Blue Box]	SILTY SAND / SANDY SILT WITH CLAY BINDER	CR	CORE RECOVERY (%)
[Green Box]	CLAYEY SILT	RQD	ROCK QUALITY DESIGNATION (%)
[Red Box]	GROUND WATER TABLE DEPTH	SPT	SPT N VALUE
[Orange Box]	ROAD MATERIAL	GWT	STANDARD PENETRATION TEST
[Yellow Box]	CLAYEY SAND	RL	REDUCED LEVEL
[Light Blue Box]	COMPLETELY WEATHERED ROCK		
[Medium Blue Box]	HIGHLY WEATHERED ROCK		
[Dark Blue Box]	MODERATELY WEATHERED ROCK		
[Grey Box]	HARD ROCK		
[Light Grey Box]	JOINTED HARD ROCK		
[Dashed Line]	BORERHOLE TERMINATION DEPTH		
[Circle]	BORERHOLE		

Note :

- The drawing illustrates soil and rock profiles observed in boreholes up to drilled depth.
- This drawing shall be read in conjunction with location plans, Refer Annexure I
- GWT shown is as observed during the time of soil investigations.
- All Dimensions are in meters unless specified otherwise.
- For Borehole location coordinates, Refer Para 3.1 of Draft Factbook Report.

No.	Particulars	Date	Name	Date	Name	Date	Name
02	Issued for Final Report	07.07.10	YSB	07.07.10	KRL	07.07.10	KRL
01	Issued for Final Report	28.01.10	YSB	28.01.10	TSR	28.01.10	KRL
00	Issued for Draft Factbook Report	17.08.09	YSB	17.08.09	TSR	17.08.09	KRL

CLIENT	DELHI METRO RAIL CORPORATION LIMITED KINGDOM SHAWA, 13, FINE SPINNE LANE, GANDHIANAGAR ROAD
PROJECT	GEOTECHNICAL INVESTIGATIONS FOR DPR OF PROPOSED PHASE II BANGALORE METRO RAIL PROJECT
TITLE	SOIL PROFILE IN BORERHOLES SHEET NO 1 OF 1
STRETCH	MYSORE ROAD TERMINAL TO KENGERI
SEASON	July 2010
SCALE	VER: 1cm=3m, HOR: 1cm=150m
GEOTECH INVESTIGATIONS	SECON PRIVATE LIMITED

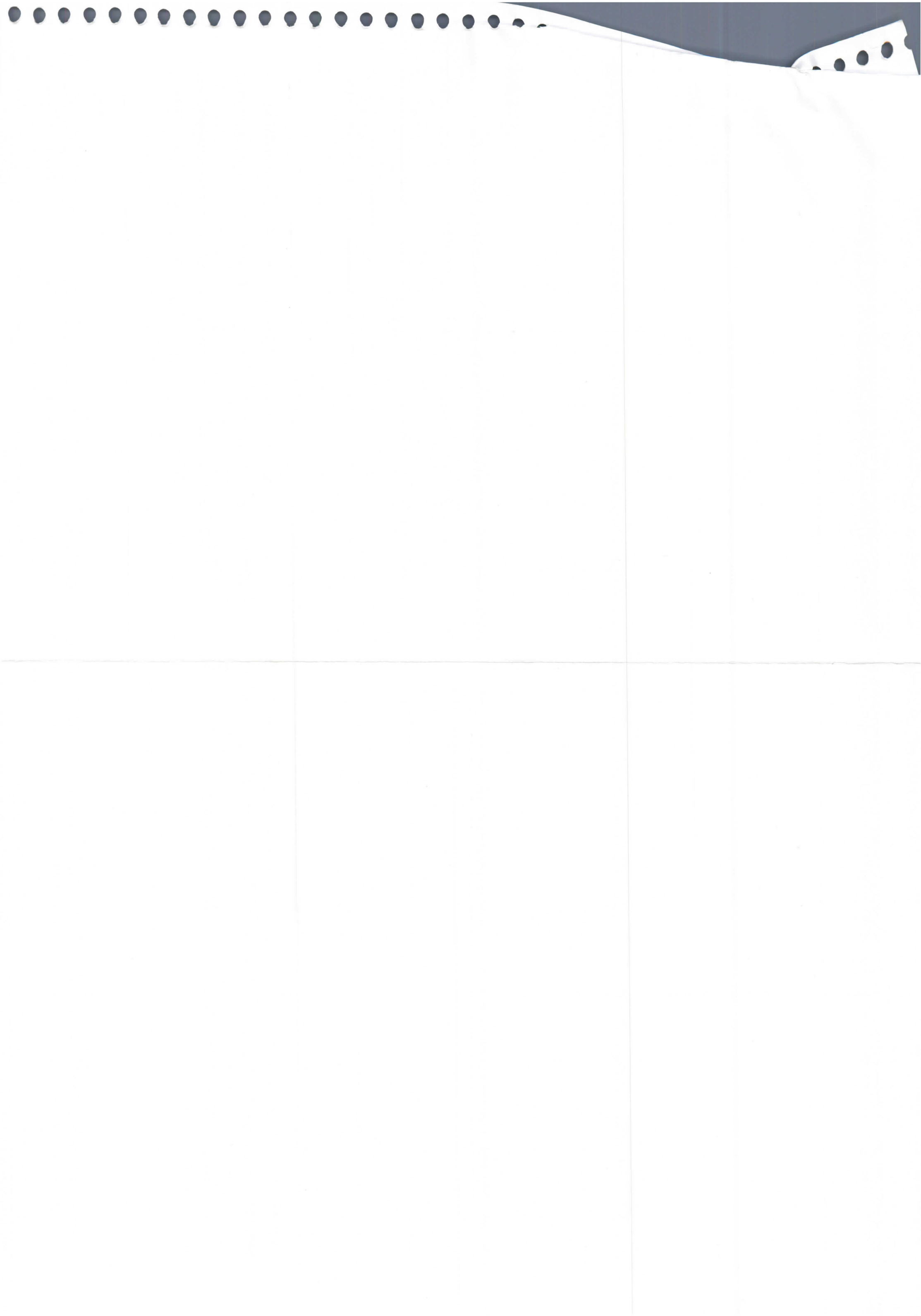
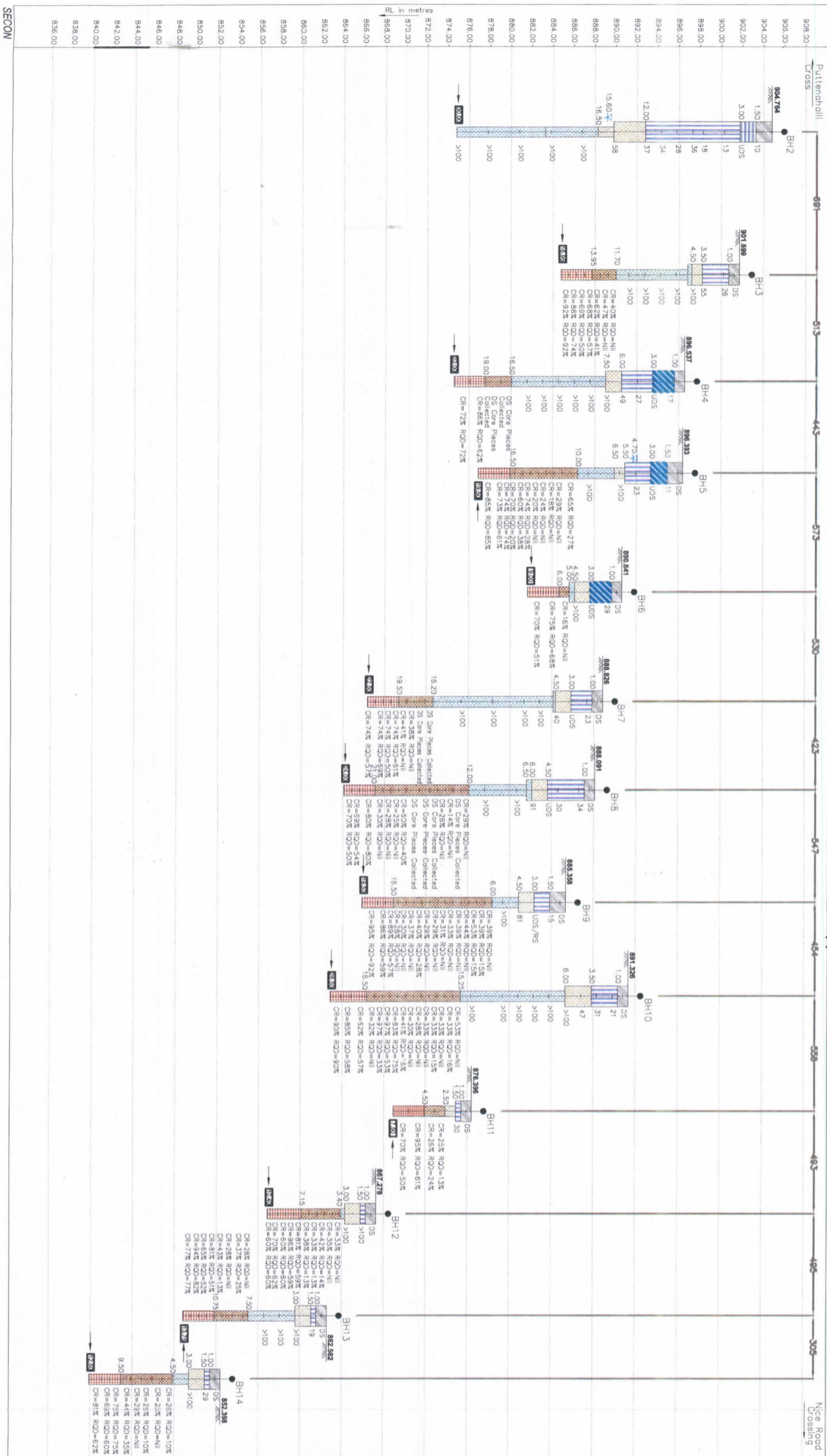


FIGURE 4.5(C)



LEGEND

- FILLED UP SOIL
- ▨ SILTY SAND / SANDY SILT WITH CLAY BANDER
- ▨ CLAYEY SILT
- ▨ GROUND WATER TABLE DEPTH
- ▨ CLAYEY SAND
- ▨ COMPLETELY WEATHERED ROCK
- ▨ HIGHLY WEATHERED ROCK
- ▨ MODERATELY WEATHERED ROCK
- ▨ HARD ROCK
- ▨ JOINTED HARD ROCK
- ▨ BOREHOLE TERMINATION DEPTH
- BH BOREHOLE

ABBREVIATIONS

- US : UNDISTURBED SAMPLE
- US/RS : REPRESENATIVE SAMPLE
- CR : CORE RECOVERY (%)
- RQD : ROCK QUALITY DESIGNATION (%)
- SPT : SPT N VALUE
- GWT : STANDARD PENETRATION TEST
- RL : GROUND WATER TABLE
- RL : REDUCED LEVEL

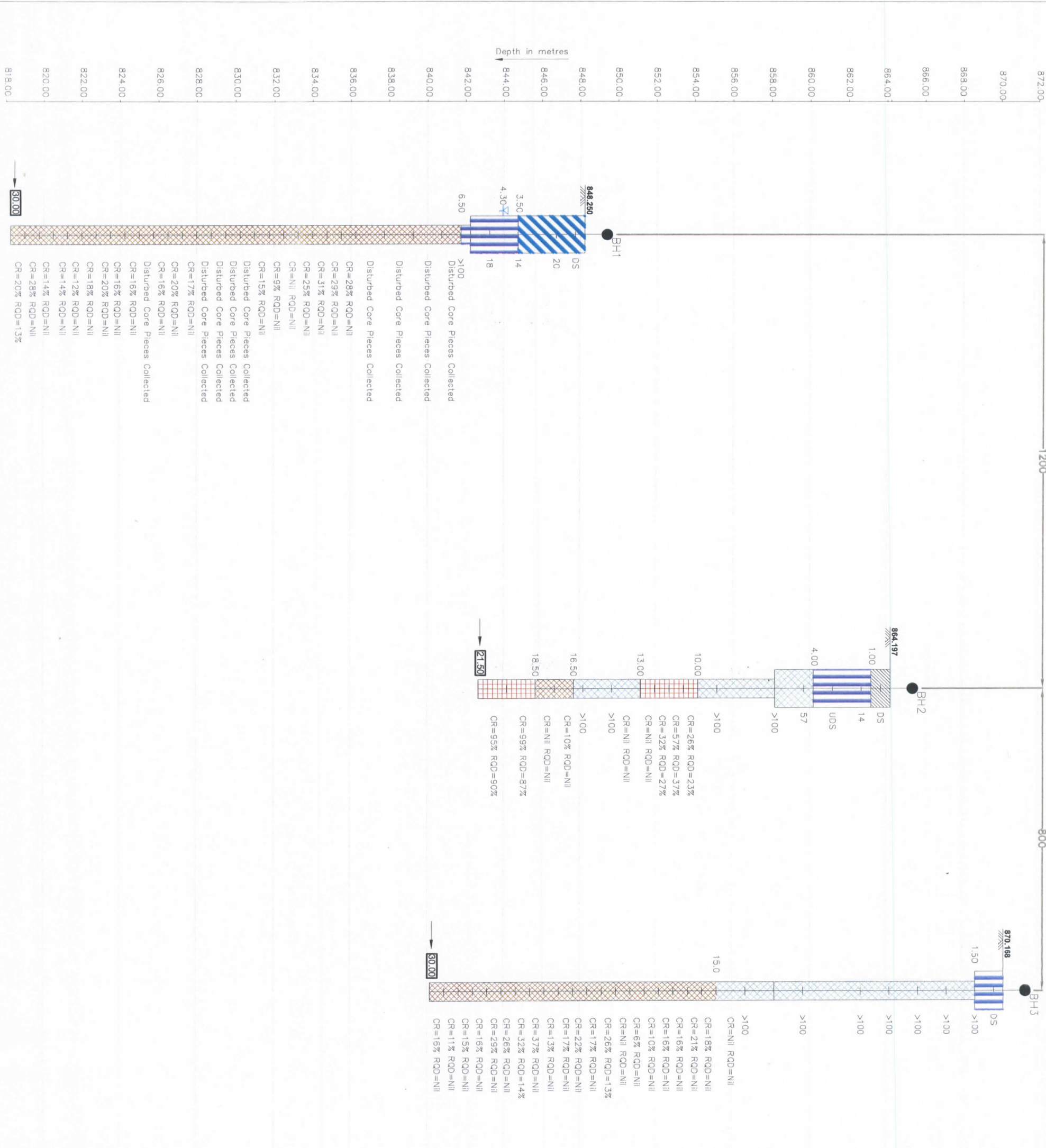
Note :

- The drawing illustrates sub soil/rock profiles observed in boreholes up to drilled depth.
- This drawing shall be read in conjunction with location plans, Refer Annexure I
- GWT Shown is as observed during the time of soil investigations.
- All Dimensions are in meters unless specified otherwise.
- For Borehole location coordinates, Refer Para 3.1 of Draft Feasibility Report.

No.	Particulars	Date	Name	Checked	Approved
03	Issued for Final Report	12.07.10	YSB	12.07.10	KRL
02	Issued for Final Report	29.01.10	YSB	29.01.10	KRL
01	Rel. of Bangalore Location Review & Submitted	19.11.09	YSB	19.11.09	KRL
00	Issued for Draft Feasibility Report	17.08.09	YSB	17.08.09	KRL

CLIENT	DELHI METRO RAIL CORPORATION LIMITED METRO STATION, 13, FINE BROADWAY LANE, BANAGLORE ROAD
PROJECT	GEOTECHNICAL INVESTIGATIONS FOR DPR OF PROPOSED PHASE II BANGALORE METRO RAIL PROJECT
TITLE	SOIL PROFILE ALONG THE STRETCH SHEET NO 1 OF 1
STRETCH	PUTTENAHALLI CROSS TO NICE ROAD CROSSING
SEASON	JULY 2010
SCALE	VERT: 1cm=3m, HOR: 1cm=150m
GEOTECH INVESTIGATIONS	SECON PRIVATE LIMITED

FIGURE 4.5(D)



LEGEND

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

ABBREVIATIONS

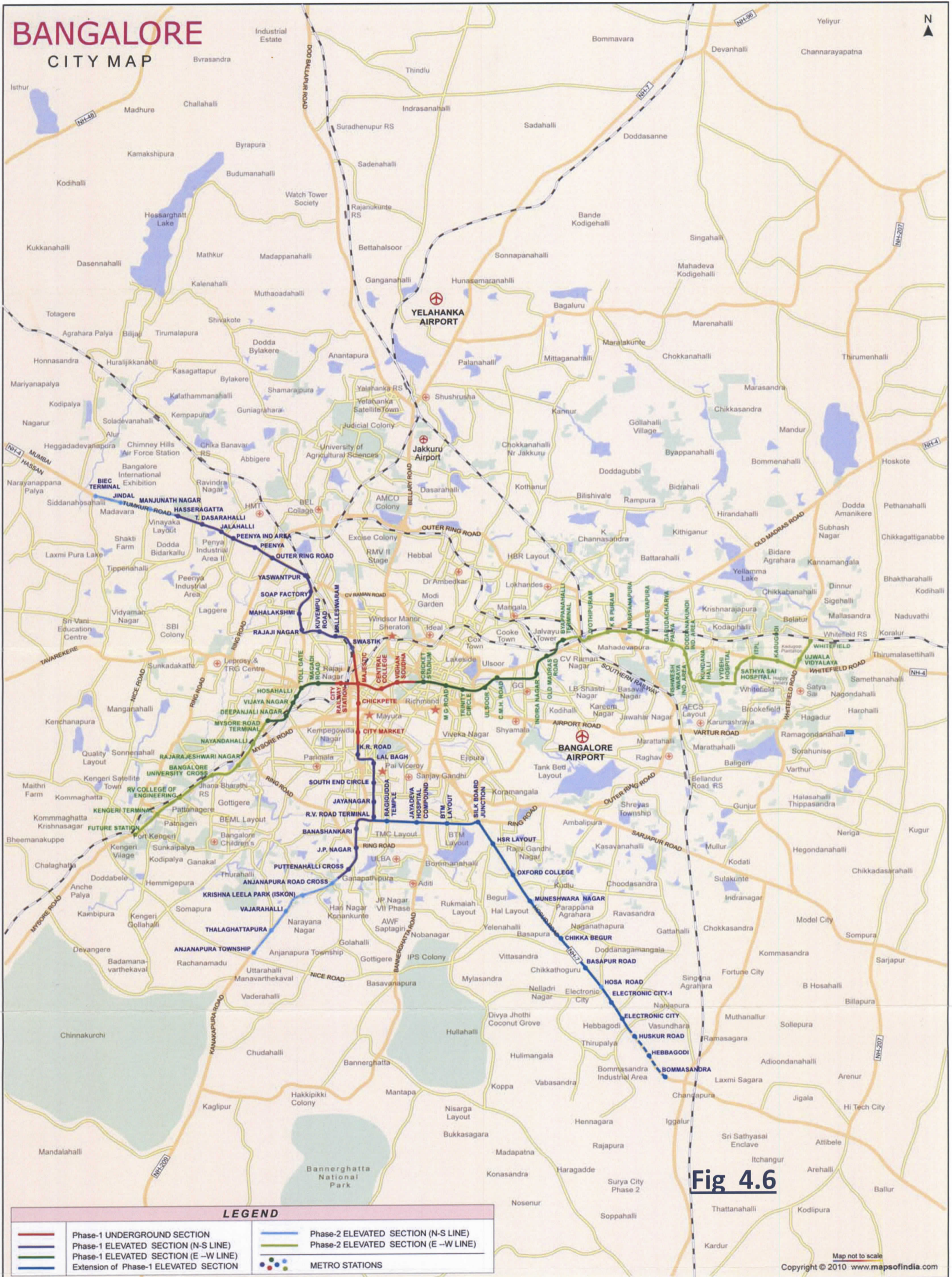
UDS : UNDISTURBED SAMPLE
 CR : CORE RECOVERY (%)
 ROD : ROCK QUALITY DESIGNATION(%)
 EGL : EXISTING GROUND LEVEL
 DS : DISTURBED SAMPLE

Note :

- The drawing illustrates sub soil / rock profile observed in boreholes up to drilled depth.
- All Dimensions are in meters unless specified otherwise.

01	04.08.10	ISSUED FOR FINAL REPORT	YSB	BSP	KRL
00	04.05.10	ISSUED FOR DRAFT REPORT	YSB	TSR	KRL
No.	DATE	REVISIONS	BY	CHKD	APPD
CLIENT					
<p>DELHI METRO RAIL CORPORATION LIMITED METRO BHAVAN, 13, FIRE BRIDGE LANE, BANSHALIA ROAD, NEW DELHI-110001 Ph: 23417910 / 12, FAX: 91-11-23417921</p>					
PROJECT					
GEOTECHNICAL INVESTIGATIONS FOR DPR OF PROPOSED PHASE II BANGALORE METRO RAIL PROJECT					
TITLE					
SOIL PROFILE IN BOREHOLE				SHEET NO 1 OF 1	
LOCATION					
HESARUGHATTA CROSS TO BIEC					
SEASON					
AUGUST 2010					
SCALE					
SPL /SSP2/BBS			REV		
VER:1cm=2m			HOR:1cm=150m		
GEOTECH INVESTIGATIONS					
SECON PRIVATE LIMITED			REV 01		
PLOT NO:17, 7-B ROAD, EXPORT PRODUCTION INDUSTRIAL PARK (EPZ) WHITEFIELD, BANGALORE-560 086, Ph:41197776, FAX:91-080-41194277					

BANGALORE CITY MAP

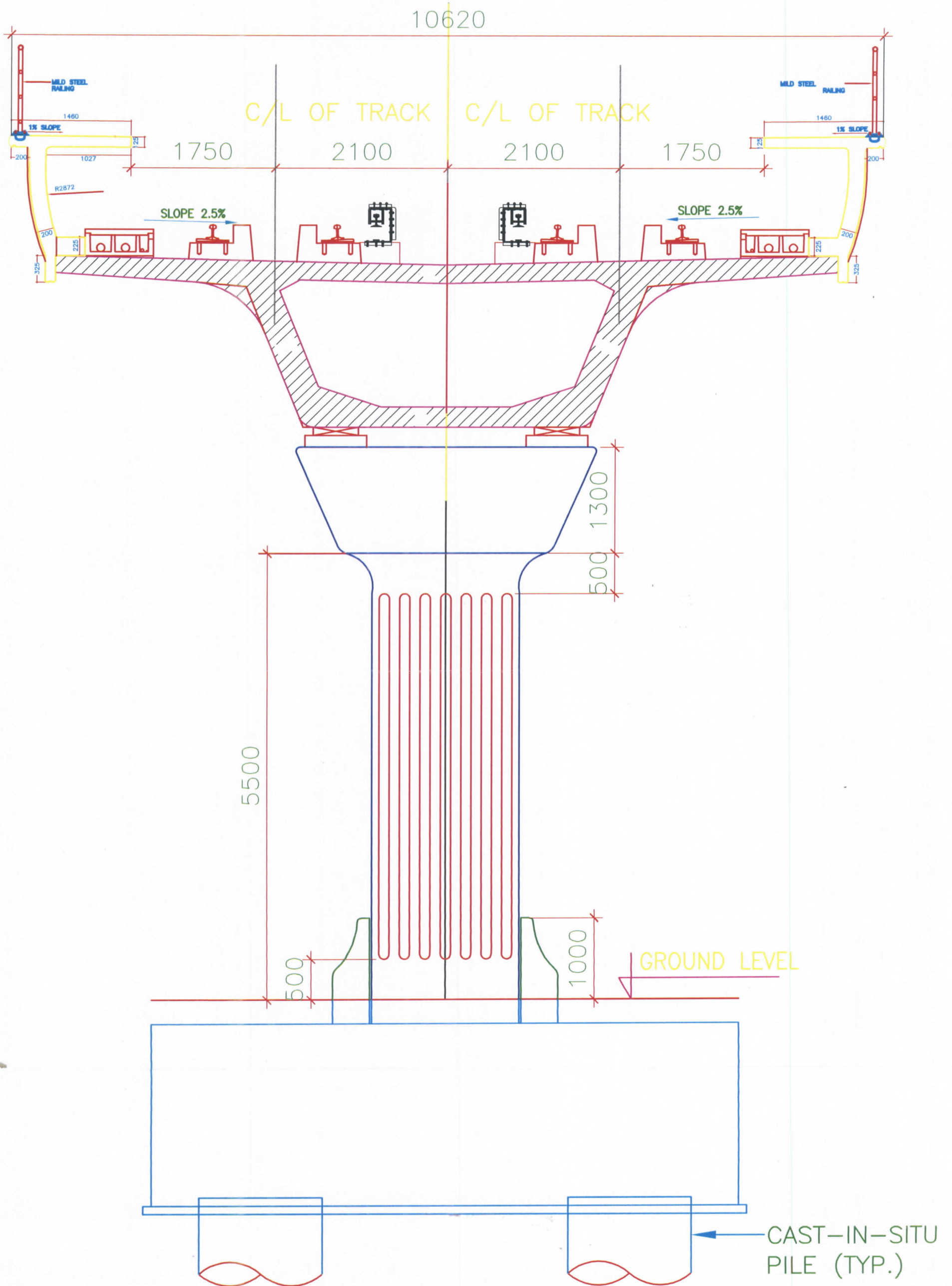


LEGEND

- | | | | |
|--|---------------------------------------|--|-------------------------------------|
| | 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) | | METRO STATIONS |
| | Extension of Phase-1 ELEVATED SECTION | | |

Fig 4.6

C/L OF DECK/PIER/PIER CAP



TYPICAL CROSS SECTION OF VIADUCT

Fig. 4.7

CHAPTER-5

TRAIN OPERATION PLAN

CHAPTER 5

TRAIN OPERATION PLAN

North-South Corridor: BIEC Terminal-Anjanapura Township and East-West Corridor: Kengeri-Whitefield

5.1 Operation Philosophy

The underlying operation philosophy is to make the MRT System more attractive and economical, the main features being:

- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections.
- Economical & optimum train service frequency not only during peak period, but also during off-peak period.
- Multi-tasking of train operation and maintenance staff.

5.2 Stations

List of stations for the two Corridors of Bangalore Metro are given below:

NORTH-SOUTH CORRIDOR (BIEC Terminal- Anjanapura Township)				
S. No	Name of Stations	Change (in m)	Inter – Station Distance (in m)	Remarks
	Dead End	(-) 9674.00		
1	BIEC Terminal	(-) 9224	450	Elevated
2	Jindal	(-) 8074	1150	Elevated
3	Manjunatha Nagar	(-) 6825	1249	Elevated
4	Hasseragatta	-5400	1425	Elevated
5	T. Dasarahalli	-4497	903	Elevated
6	Jalahalli	-3747	750	Elevated
7	Peenya Ind Area	-3021	726	Elevated
8	Peenya	-1950	1071	Elevated
9	Outer Ring Road	-1138	812	Elevated
10	Yeshwantapur	0	1138	Elevated
11	Soap Factory	1103	1103	Elevated
12	Mahalakshmi	2102	999	Elevated
13	Rajaji Nagar	3069	967	Elevated
14	Kuvempu Road	3975	906	Elevated
15	Malleswaram	4728	753	Elevated
16	Swastik	5864	1136	Elevated
17	Majestic	7540	1676	Elevated
18	Chickpete	8559	1019	Elevated
19	City Market	9235	676	Elevated

NORTH-SOUTH CORRIDOR (BIEC Terminal- Anjanapura Township)				
S. No	Name of Stations	Change (in m)	Inter – Station Distance (in m)	Remarks
20	K R Road	10427	1192	Elevated
21	Lal Bagh	11431	1004	Elevated
22	South End Circle	12386	955	Elevated
23	Jayanagar	13288	902	Elevated
24	R V Road	14180	892	Elevated
25	Banashankari	15540	1360	Elevated
26	J.P.Nagar	16413	873	Elevated
27	Puttenahalli Cross	17798	1385	Elevated
28	Anjanapura Road Cross	18900	1102	Elevated
28	Krishna Leela Park (ISKON)	20083	1183	Elevated
30	Vajarahalli	21400	1317	Elevated
31	Thalaghattapura	22285	885	Elevated
32	Anjanapura Township	24182	1897	Elevated
	Dead End	24632	450	Elevated

EAST-WEST CORRIDOR with Whitefield (Kengeri Terminal-Whitefield)				
S. No	Name of Stations	Change (in m)	Inter - Station Distance (in m)	Remarks
1	Dead End			
2	Kengeri Terminal	(-) 6306.3		Elevated
3	RV College of Engineering	(-) 4400	1906	Elevated
4	Bangalore University Cross	(-) 2400	2000	Elevated
5	Rajarajeshwari Nagar	(-) 1600	800	Elevated
6	Nayandahalli	(-) 765	835	Elevated
7	Mysore Road Terminal	0	765	Elevated
8	Deepanjali Nagar	1117	1117	Elevated
9	Vijaya Nagar	2345	1228	Elevated
10	Hosahalli	3446	1101	Elevated
11	Toll Gate	4448	1002	Elevated
12	Magadi Road	5600	1152	Elevated
13	City Railway Station	6755	1155	Elevated
14	Majestic	7503	748	Elevated
15	Central College	8697	1194	Elevated
16	Vidhan Soudha	9318	621	Elevated
17	Cricket Stadium	10643	1325	Elevated
18	M G Road	11380	737	Elevated
19	Trinity Circle	12522	1142	Elevated
20	Ulsoor	13725	1203	Elevated
21	CMH Road	14610	885	Elevated

EAST-WEST CORRIDOR with Whitefield (Kengeri Terminal-Whitefield)				
S. No	Name of Stations	Change (in m)	Inter - Station Distance (in m)	Remarks
22	Old Madras Road	16419	1809	Elevated
23	Byappanahalli	17374	955	Elevated
24	Jyothipuram	19800	2426	Elevated
25	K R Puram	20625	825	Elevated
26	Narayanapura	21500	875	Elevated
27	Mahadevapura	22400	900	Elevated
28	Garudacharya Palya	23600	1200	Elevated
29	Doddanakundi Ind Area	24635	1035	Elevated
30	Vishweshwaraya Ind. Area	25635	1000	Elevated
31	Kundanahalli	26500	865	Elevated
32	Vydehi Hospital	27500	1000	Elevated
33	Sathya Sai Hospital	28300	800	Elevated
34	I T P L	29750	1450	Elevated
35	Kadugodi	30800	1050	Elevated
36	Ujwala Vidyalaya	31800	1000	Elevated
37	Whitefield	32800	1000	Elevated
38	Total	39106.3		

5.3 Train Operation Plan

5.3.1 Salient Features

- Running of services for 19 hours of the day (5 AM to Midnight) with a station dwell time of 30 seconds,
- Make up time of 5-10% with 8-12% coasting.
- Scheduled speed for these corridors has been assumed as:
 - North- South Corridor ('BIEC Terminal-Anjanapura Township' loop) : 34 kmph
 - North- South Corridor ('Hessarghatta Cross-RV Road' loop) : 33 kmph
 - East-West Corridor ('Kengeri Terminal-Whitefield' loop) : 34 kmph

5.3.2 Traffic Demand

Peak hour peak direction traffic (PHPDT) demands for the Bangalore Metro 'North-South Corridor' & 'East-West Corridor' for the year 2016, 2021, 2031 and 2041 for the purpose of planning are indicated in Attachment I/A1, B1, C1 & D1 and Attachment I/A2, B2, C2 & D2 respectively.

5.3.3 Train formation

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

Composition

DMC : Driving Motor Car
 MC : Motor Car
 TC : Trailer Car

3 Car Train Compositions: DMC + TC + DMC

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

Capacity (with standees @6 passengers per sqm of standee area)

DMC : 253 Passengers (Sitting-43, Crush Standing-210)
 TC/MC : 280 Passengers (Sitting-50, Crush Standing-230)
 3 Car Train: 786 Passengers (Sitting-136, Crush Standing-650)
 6 Car Train: 1626 Passengers (Sitting-286, Crush Standing-1340)

Note by BMRCL

DMRCL has considered the above proposal of 6 persons per Sq meter of standee area However BMRCL has calculated train carrying capacity at 8 persons per Sq meter of standee area. Accordingly the train carrying capacity will be as shown below.

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

	Driving Motor car		Trailer Car / Motor car		3 Car Train		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	136	136	286	286
Standing	105	279	115	306	325	864	670	1782
Total	148	322	165	356	461	1000	956	2068

NORMAL-3 Person/sqm of standee area

CRUSH -8 Person/sqm of standee area

5.3.4 Train Operation Plan

Based on the projected PHPDT demand, train operation has been planned for Bangalore Metro for the year 2016, 2021, 2031 and 2041 as detailed below:

North-South Corridor:

Train Operation Plan for North-South Corridor has been planned in such a way that there are two loops of train operation. In one loop, trains run from 'Hasseragatta to RV Road' at a given headway and in other loop trains run from 'BIEC Terminal to Anjanapura Township' at the same headway, thus resulting in half the headway in 'Hasseragatta to R V Road' Section as compared to 'BIEC Terminal-Hasseragatta' & 'RV Road-Anjanapura Township' Section.

Train operation plan with train carrying **capacity @ 6 persons per square meter of standee area** on North-South Corridor are given below:

i) Year 2016

Train operation in 'BIEC Terminal to Anjanapura Township' Loop at 7 min headway with 3-Car train & in 'Hasseragatta to RV Road' Loop at 7 min headway with 6-Car train. This results in following train operation in different sections:

(a) North-South Corridor: BIEC Terminal to Hasseragatta Section and RV Road to Anjanapura Township Section (Refer Attachment I/A1)

- 7 min Headway with 3-car train.

- Available Peak Hour Peak Direction Capacity of 6737 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 8571 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 11241 is in the Section between RV Road & Banashankari and demand in the remaining sections is in the range of 8433 to 585 only. The planned capacity of 6737 (8571 under dense loading) is less than the PHPDT demand in three (one, with dense loading capacity) sections out of eight sections of 'RV Road to Anjanapura Township' section. The planned capacity of 6737 (8571 under dense loading) is more than the PHPDT demand in 'BIEC Terminal to Hasseragatta' section.

(b) North-South Corridor: 'Hasseragatta to RV Road Section' (Refer Attachment I/A1)

- 3.5 min Headway with alternate 3-car/6-car train.
- Available Peak Hour Peak Direction Capacity of 20674 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 26297 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 21803 is in the Section between Majestic and Chickpete and demand in the remaining sections is in the range of 21461 to 4294 only. The planned capacity of 20674 (26297 under dense loading) is less than the PHPDT demand in three (zero, with dense loading capacity) sections out of twenty sections.

With the above Train operation plan & 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/A1.

Note by BMRCL

In the DPR of Phase-1 of BMRCL it was envisaged to convert 3 car trains in to 6 car train by the year 2011. During the discussion with the DMRCL it was suggested to them that it would not be prudent to run 3 car trains in the year 2016. However DMRCL has not considered this proposal and have unfortunately suggested the train operation plan of 3 car train followed by 6 car train. This appears to be a retrograde step as they are contradicting their own proposal of converting a 3 car train in to a 6 car train by the year 2011. Since the phase –II works are expected to be completed in the year 2016 it makes sense to run a 6 car train in the entire North – South Corridor. Hence BMRCL is suggesting the following train operation plan.

YEAR 2016: North – South Corridor

Train Composition - 6 cars –Capacity of train – 2004

Schedule Speed – 34 Kmph

Sl. No	Section	R Km	Peak Traffic Demand as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement

1	BICE terminal to Hesaraghatta cross	3.77	3147	8016	15 mt	28 Trains (168 coaches)
2	Hesaraghatta to Puttenahalli	24.2	21606	24048	5 mt	
3	Puttenahalli to Anjanapura township	6.29	8447	8016	15 mt	

**Train acquired in Phase-1 – 29 Trains (87 coaches)
Additional Requirement – 168-87= 81 coaches**

The PHPDT is 21803 between Majestic and Chikkpete section. If the train carrying capacity at 6 persons /Sqm of standee area, the capacity provided will be 20674 which will be slightly less than PHPDT of 21803. If the train carrying capacity is considered at 8 persons /Sqm of standee area, the capacity provided will be 24048.

In view of above explanation it is considered prudent to run 6 car trains at varying headway as suggested in above table.

ii) Year 2021

Train operation in 'BIEC Terminal to Anjanapur Township' Loop at 7 min headway with 6-Car train & in 'Hesaraghatta to RV Road' Loop at 7 min headway with 6-Car train. This results in following train operation in different section:

(a) North-South Corridor: BIEC Terminal to Hesaraghatta Section and RV Road to Anjanapur Township Section (Refer Attachment I/B1)

- 7 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 13937 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 17726 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 14389 is in the Section between RV Road & Banashankari and demand in the remaining sections is in the range of 10794 to 1788 only. The planned capacity of 13937 (17726 under dense loading) is less than the PHPDT demand in one (zero, with dense loading capacity) sections out of eight sections of 'RV Road to Anjanapura Township' section. The planned capacity of 13937 (17726 under dense loading) is more than the PHPDT demand in 'BIEC Terminal to Hasseragatta' section.

(b) North-South Corridor: Hesaraghatta to RV Road Section (Refer Attachment I/B1)

- 3.5 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 27874 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 35451 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 27593 is in the Section between Majestic and Chickpete and demand in the remaining sections is in the range of 27454 to 10018 only. The planned capacity of 27874 (35451 under dense loading) is more than the PHPDT demand in all twenty sections.

With the above Train operation plan & 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/B1.

iii) **Year 2031**

Train operation in 'BIEC Terminal to Anjanapur Township' Loop at 6 min headway with 6-Car train & in 'Hesaraghatta to RV Road' Loop at 6 min headway with 6-Car train. This results in following train operation in different section:

(a) North-South Corridor: BIEC Terminal to Hesaraghatta Section and RV Road to Anjanapur Township Section (Refer Attachment I/C1)

- 6 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 16260 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 20680 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 19137 is in the Section between RV Road & Banashankari and demand in the remaining sections is in the range of 14356 to 2379 only. The planned capacity of 16260 (20680 under dense loading) is less than the PHPDT demand in one (zero, with dense loading capacity) section out of eight sections of 'RV Road to Anjanapur Township' section. The planned capacity of 16260 (20680 under dense loading) is more than the PHPDT demand in 'BIEC Terminal to Hesaraghatta' section.

(b) North-South Corridor: Hesaraghatta to RV Road Section (Refer Attachment I/C1)

- 3 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 32520 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 41360 @ 8 persons per square meter of standee area under dense loading conditions.

The maximum PHPDT demand of 36557 in the Section between Majestic and Chickpete and demand in the remaining sections is in the range of 36514 to 12524 only. The planned capacity of 32520 (41360 under dense loading) is less than the PHPDT demand in nine (zero, with dense loading capacity) section out of twenty sections.

With the above Train operation plan & 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 2031 is tabulated and represented on a chart enclosed as Attachment I/C1.

iv) **Year 2041**

Train operation in 'BIEC Terminal to Anjanapura Township' Loop at 5 min headway with 6-Car train & in 'Hasseragatta to RV Road' Loop at 5 min headway with 6-Car train. This results in following train operation in different section:

(a) North-South Corridor: BIEC Terminal to Hasseragatta Section and RV Road to Anjanapura Township Section (Refer Attachment I/D1)

- 5 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 19512 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 24816 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 22391 is in the Section between RV Road & Banashankari and demand in the remaining sections is in the range of 16796 to 2783 only. The planned capacity of 19512 (24816 under dense loading) is less than the PHPDT demand in one (zero, with dense loading capacity) sections out of eight sections of 'RV Road to Anjanapura Township' section. The planned capacity of 19512 (24816 under dense loading) is more than the PHPDT demand in 'BIEC Terminal to Hasseragatta' section.

(b) North-South Corridor: Hasseragatta to RV Road Section (Refer Attachment I/D1)

- 2.5 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 39024 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 49632 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 42771 is in the Section between Majestic and Chickpete and demand in the remaining sections is in the range of 42721 to 14653 only. The planned capacity of 39024 (49632 under dense loading) is less than the PHPDT demand in three (zero, with dense loading capacity) sections out of twenty sections.

With the above Train operation plan & 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/D1.

East-West Corridor:

Train operation plan with train carrying **capacity @ 6 persons per square meter of standee area** on East- West Corridor is given below:

i) **Year 2016**

East-West Corridor: Kengeri Terminal to Mysore Road Terminal Section and Byappanahalli to Whitefield Section (Refer Attachment I/A2)

- 5.5 min Headway with 6- car train.

- Available Peak Hour Peak Direction Capacity of 17738 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 22560 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 19675 is in the Section between Jyothipuram & K R puram and demand in the remaining sections is in the range of 19368 to 4049 only. The planned capacity of 17738 (22560 under dense loading) is less than the PHPDT demand in thirteen (zero, with dense loading capacity) sections out of thirty five sections.

With the above Train operation Plan & 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/A2.

Note by BMRCL

BMRCL agrees with the train operation plan of 6 car train between Kengeri Terminal to Whitefield. The proposed train operation plan in this corridor will be as shown below:

YEAR 2016: East – West Corridor

**Train Composition - 6 car; Capacity of train – 2004
Schedule Speed – 34 Kmph**

Sl. No	Section	R Km	Peak Traffic Demand as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
1	Kengeri to Mysore Road	6.18	5106	12024	11 mt	28 Trains (168 coaches)
2	Mysore Road to Baiyappanahalli	18.1	18820	22044	5.5 mt	
3	Baiyappanahalli to White field	15.42	13056	12024	11 mt	

Trains acquired in Phase-1 – 21Trains (63 coaches)

Additional Coaches Required – 105 coaches

**** 11 Trains / hour in peak direction**

*** 6 Trains / hour in peak direction**

ii) Year 2021

East-West Corridor: Kengeri Terminal to Mysore Road Terminal Section and Baiyappanahalli to Whitefield Section (Refer Attachment I/B2)

- 4 min Headway with 6- car train.

- Available Peak Hour Peak Direction Capacity of 24390 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 31020 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 25380 is in the Section between City Railway station & Majestic and demand in the remaining sections is in the range of 24112 to 5073 only. The planned capacity of 24390 (31020 under dense loading) is less than the PHPDT demand in (zero, with dense loading capacity) sections out of thirty five sections.

With the above Train operation Plan & 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/B2.

iii) Year 2031

East-West Corridor: Kengeri Terminal to Mysore Road Terminal Section and Byappanahalli to Whitefield Section (Refer Attachment I/C2)

- 3 min Headway with 6- car train.
- Available Peak Hour Peak Direction Capacity of 32520 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 41360 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 34263 is in the Section between City Railway station & Majestic and demand in the remaining sections is in the range of 31842 to 6849 only. The planned capacity of 32520 (41360 under dense loading) is less than the PHPDT demand in (zero, with dense loading capacity) sections out of thirty five sections.

With the above train operation plan and 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 2031 is tabulated and represented on a chart enclosed as Attachment I/C2.

iv) Year 2041

(a) East-West Corridor: Kengeri Terminal to WHITEFIELD Section (Refer Attachment I/D2)

- 3 min Headway with 6- car train.
- Available Peak Hour Peak Direction Capacity of 32520 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 41360 @ 8 persons per square meter of standee area under dense loading conditions.

- The maximum PHPDT demand of 38860 is in the Section between City Railway station & Majestic and demand in the remaining sections is in the range of 36100 to 7808 only. The planned capacity of 32520 (41360 under dense loading) is less than the PHPDT demand in (zero, with dense loading capacity) sections out of thirty five sections.

With the above train operation plan and 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 2031 is tabulated and represented on a chart enclosed as Attachment I/D2.

The above Train Operation Plan is based on calculations on the basis of available traffic data. In case of any mismatch in the capacity provided and the actual traffic, the capacity can be moderated suitably by adjusting the Headway.

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

Capacity Provided for North-South Corridor:

North - South Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
BIEC Terminal to Hasseragatta Section	2016	7	21 Rakes of 3-car and 14 Rakes of 6-car	3-car	147	3161	6737 (8571*)
Hasseragatta to RV Road Section		3.5		Alternate 3-cars/ 6-car		21803	20674 (26297*)
RV Road to Anjanapura Township Section		7		3-car		11241	6737 (8571*)
BIEC Terminal to Hasseragatta Section	2021	7	35 Rakes of 6-car	6-car	210	8807	13937 (17726*)
Hasseragatta to RV Road Section		3.5		6-car		27593	27874 (35451*)
RV Road to Anjanapura Township Section		7		6-car		14389	13937 (17726*)
BIEC Terminal to Hasseragatta Section	2031	6	39 Rakes of 6-car	6-car	234	10913	16260 (20680*)
Hasseragatta to RV Road Section		3		6-car		36557	32520 (41360*)
RV Road to Anjanapura Township Section		6		6-car		19137	16260 (20680*)
BIEC Terminal to Hasseragatta Section	2041	5	47 Rakes of 6-car	6-car	282	12769	19512 (24816*)
Hasseragatta to RV Road Section		2.5		6-car		42771	39024 (49632*)
RV Road to Anjanapura Township Section		5		6-car		22391	19512 (24816*)

* @ 8 persons per square meter of standee area

Capacity Provided for East-West corridor

East - West Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches	Max. PHPDT Demand	PHPDT Capacity Available
Kengeri Terminal to Whitefield Section Kengeri Terminal to Whitefield Section	2016	5.5	32	6-car	192	19675	17738 (22560*)
	2021	4	43	6-car	258	25380	24390 (31020*)
	2031	3	56	6-car	336	34263	32520 (41360*)
	2041	3	56	6-car	336	38860	32520 (41360*)

* @ 8 persons per square meter of standee area

5.3.5 Train frequency

North - South Corridor

The train operation North-South Corridors provides for the following train frequency:

North - South 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
BIEC Terminal to Hasseragatta Section	7 min	12 to 24 min	7 min	12 to 24 min	6 min	10 to 24 min	5 min	10 to 24 min
Hasseragatta to RV Road Section	3.5 min	6 to 12 min	3.5 min	6 to 12 min	3 min	5 to 12 min	2.5 min	5 to 12 min
RV Road to Anjanapura Township Section	7 min	12 to 24 min	7 min	12 to 24 min	6 min	10 to 24 min	5 min	10 to 24 min

East - West Corridor

The train operation East West Corridors provides for the following train frequency:

East - West 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
Kengeri Terminal to Whitefield Section	5.5 min	8 to 15 min	4 min	6 to 15 min	3 min	5 to 15 min	3 min	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.

5.3.6 Hourly Train Operation plan

The hourly distribution of daily transport capacity is presented in **Table 1.1A, 1.1B, 1.1C, 1.2A, 1.2B, 1.2C, 1.3A, 1.3B, 1.3C, 1.4A, 1.4B, 1.4C, 1.5A, 1.6A, 1.7A & 1.8A** for years 2016, 2021, 2031 & 2041 for North-south Corridor: 'BIEC Terminal to Hasseragatta, Hasseragatta to RV Road, RV Road to Anjanapura Township Section' and 'East-West Corridor: Kengeri Terminal to Whitefield Section' respectively and enclosed as Attachment II. Number of train trips per

direction per day for above corridors are worked out as 97, 194 & 97 in the year 2016, 97, 194 & 97 in the year 2021, 109, 218, & 109 in the year 2031 and 121, 242 & 121 in the year 2041 respectively in North-south Corridor. Number of train trips per direction per day for above corridors are worked out as 141 in the year 2016, 178 in the year 2021, 216 in the year 2031 and 216 in the year 2041 respectively in East-West Corridor. The directional splits for North-South Corridor and East- West Corridor are presented in **Table 2.1 & 2.2** enclosed as Attachment III.

5.3.7 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometers for North-South corridor and East-West Corridor is given in **Table 3.1 & 3.2** enclosed as Attachment IV.

5.4 Year wise rake Requirement

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

North - South Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches
BIEC Terminal to Hasseragatta	2016	7	21 Rakes of 3-car and 14 Rakes of 6-car	3-car	147
Hasseragatta to RV Road		3.5		Alternate 3-cars/ 6-car	
RV Road to Anjanapura Township Section		7		3-car	
BIEC Terminal to Hasseragatta	2021	7	35 Rakes of 6-car	6-car	210
Hasseragatta to RV Road		3.5		6-car	
RV Road to Anjanapura Township Section		7		6-car	
BIEC Terminal to Hasseragatta	2031	6	39 Rakes of 6-car	6-car	234
Hasseragatta to RV Road		3		6-car	
RV Road to Anjanapura Township Section		6		6-car	
BIEC Terminal to Hasseragatta	2041	5	47 Rakes of 6-car	6-car	282
Hasseragatta to RV Road		2.5		6 car	
RV Road to Anjanapura Township Section		5		6 car	

East - West Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches
Kengeri Terminal to Mysore Road Terminal Section	2016	5.5	32	6-car	192
	2021	4	43	6-car	258
	2031	3	56	6-car	336
	2041	3	56	6-car	336

Requirements of coaches is calculated based on following assumptions-

Assumptions –

- (i) Train Composition planned as under
 - 3 car Train Composition : DMC + TC + DMC
 - 6 car Train Composition : DMC + TC + MC + MC + TC+ DMC
 - Train carrying Capacity of 3 Car Train : 786 passengers
 - Train Carrying Capacity of 6 Car Train : 1626 passengers
- (ii) Coach requirement has been calculated based on headway during peak hours.

- (iii) Traffic reserve is taken as one/two train per train operation loop 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:
 - North-South Corridor:
Loop 1: BIEC Terminal to Anjanapura Township Section: 34 kmph;
Loop 2: Hasseragatta to RV Road: 33 kmph.
 - East-West corridor: Kengeri Terminal to WHITEFIELD Section: 34 kmph;
- (vii) Total Turn round time is taken as 6 min at terminal stations.

5.5 Cost Estimate

The estimated cost per coach at May 2011 Price level exclusive of taxes and duties may be assumed as INR 10 Crores per Coach. Total $147+192 = 339$ coaches are required in year 2016 for the two Corridors. Procurement of 150 coaches is being made by Bangalore Metro Rail Corporation Ltd. in Phase I. Hence for additional 189 coaches, budget provision of INR 1890 Crores is to be kept in the Estimate for Rolling Stock.

PHPDT Demand and Capacity Chart

North- South Corridor: BIEC- Hesaraghatta- Puttenahalli- Anjanapura Township

Year: **2016**

No. of Cars per Train: **3** *(in BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township)*

No. of Cars per Train: **6** *(in Hasseragatta to R V Road)*

Passenger Capacity @ 6 persons/sqm of a 3-Car Train: **786**

Passenger Capacity @ 8 persons/sqm of a 3-Car Train: **1000**

Passenger Capacity @ 6 persons/sqm of a 6-Car Train: **1626**

Passenger Capacity @ 8 persons/sqm of a 6-Car Train: **2068**

Headway (min) **7** *(in BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township)*

Headway (min) **3.5** *(in Hasseragatta to R V Road)*

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	BIEC Terminal	Jindal	585	6737	8571
2	Jindal	Manjunatha Nagar	2921	6737	8571
3	Manjunatha Nagar	Hasseragatta	3161	6737	8571
4	Hasseragatta	T. Dasarahalli	4294	20674	26297
5	T. Dasarahalli	Jalahalli	7890	20674	26297
6	Jalahalli	Peenya Ind Area	8031	20674	26297
7	Peenya Ind Area	Peenya	9009	20674	26297
8	Peenya	Outer Ring Road	9164	20674	26297
9	Outer Ring Road	Yeshwantapur	12444	20674	26297
10	Yeshwantapur	Soap Factory	15252	20674	26297
11	Soap Factory	Mahalakshmi	16176	20674	26297
12	Mahalakshmi	Rajaji Nagar	16752	20674	26297
13	Rajaji Nagar	Kuvempu Road	17101	20674	26297
14	Kuvempu Road	Malleswaram	17860	20674	26297
15	Malleswaram	Swastik	18886	20674	26297
16	Swastik	Majestic	19056	20674	26297
17	Majestic	Chickpete	21803	20674	26297
18	Chickpete	City Market	21461	20674	26297
19	City Market	K R Road	20822	20674	26297
20	K R Road	Lal Bagh	19730	20674	26297
21	Lal Bagh	South End Circle	18308	20674	26297
22	South End Circle	Jayanagar	18189	20674	26297
23	Jayanagar	R V Road	17806	20674	26297
24	R V Road	Banashankari	11241	6737	8571
25	Banashankari	J.P.Nagar	8433	6737	8571
26	J.P.Nagar	Puttenahalli Cross	7112	6737	8571
27	Puttenahalli Cross	Anjanapura Road Cross	6290	6737	8571
28	Anjanapura Road Cross	Krishna Leela Park (ISKON)	5161	6737	8571
29	Krishna Leela Park (ISKON)	Vajarahalli	4288	6737	8571
30	Vajarahalli	Thalaghattapura	3209	6737	8571
31	Thalaghattapura	Anjanapura Township	1397	6737	8571

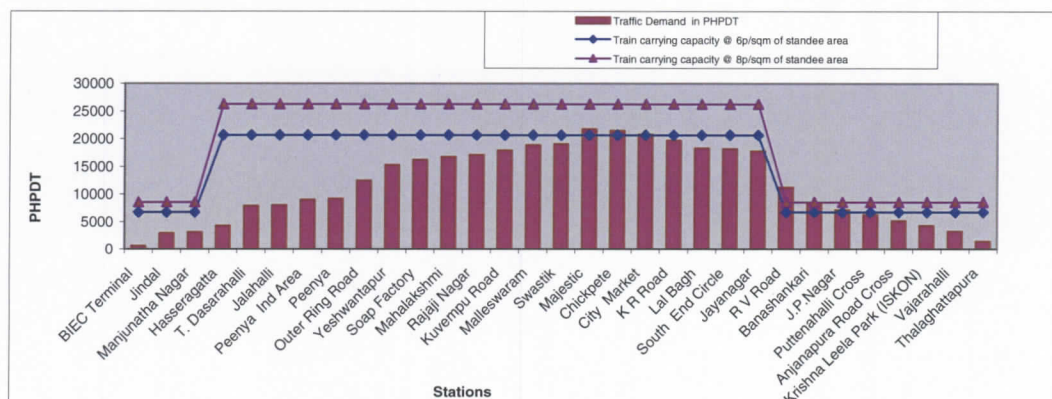


Fig 1.1

PHPDT Demand and Capacity Chart

North- South Corridor: BIEC- Hesaraghatta- Puttenahalli- Anjanapura Township

Year: 2021
 No. of Cars per Train: 6
 Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626
 Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068

Headway (min) 7

(in BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township)

Headway (min) 3.5

(in Hasseragatta to R V Road)

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	BIEC Terminal	Jindal	6550	13937	17726
2	Jindal	Manjunatha Nagar	8361	13937	17726
3	Manjunatha Nagar	Hasseragatta	8807	13937	17726
4	Hasseragatta	T. Dasarahalli	10018	27874	35451
5	T. Dasarahalli	Jalahalli	12622	27874	35451
6	Jalahalli	Peenya Ind Area	12719	27874	35451
7	Peenya Ind Area	Peenya	16087	27874	35451
8	Peenya	Outer Ring Road	16262	27874	35451
9	Outer Ring Road	Yeshwantapur	20929	27874	35451
10	Yeshwantapur	Soap Factory	24523	27874	35451
11	Soap Factory	Mahalakshmi	24706	27874	35451
12	Mahalakshmi	Rajaji Nagar	25444	27874	35451
13	Rajaji Nagar	Kuvempu Road	24890	27874	35451
14	Kuvempu Road	Malleswaram	25861	27874	35451
15	Malleswaram	Swastik	26175	27874	35451
16	Swastik	Majestic	26392	27874	35451
17	Majestic	Chickpete	27593	27874	35451
18	Chickpete	City Market	27454	27874	35451
19	City Market	K R Road	26338	27874	35451
20	K R Road	Lal Bagh	24940	27874	35451
21	Lal Bagh	South End Circle	23225	27874	35451
22	South End Circle	Jayanagar	22966	27874	35451
23	Jayanagar	R V Road	22477	27874	35451
24	R V Road	Banashankari	14389	13937	17726
25	Banashankari	J.P.Nagar	10794	13937	17726
26	J.P.Nagar	Puttenahalli Cross	9103	13937	17726
27	Puttenahalli Cross	Anjanapura Road Cross	8052	13937	17726
28	Anjanapura Road Cross	Krishna Leela Park (ISKON)	6607	13937	17726
29	Krishna Leela Park (ISKON)	Vajarahalli	5489	13937	17726
30	Vajarahalli	Thalaghattapura	4108	13937	17726
31	Thalaghattapura	Anjanapura Township	1788	13937	17726

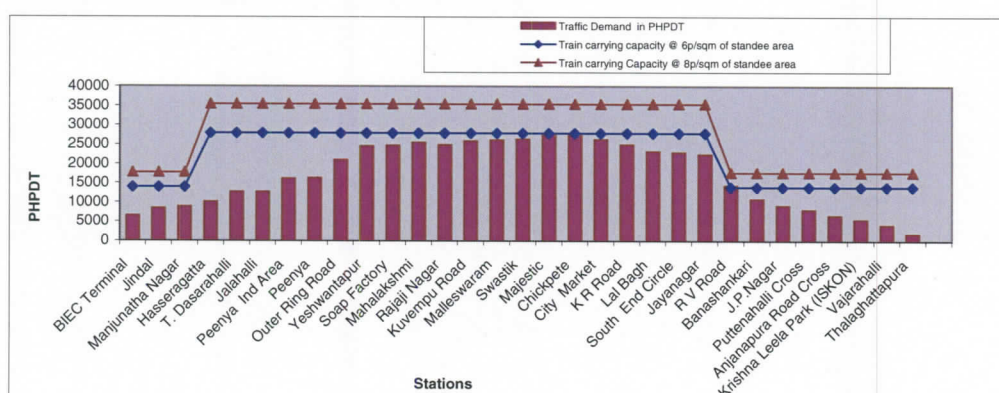


Fig 2.1

PHPDT Demand and Capacity Chart

North- South Corridor: BIEC- Hesaraghatta- Puttenahalli- Anjanapura Township

Year: 2031
 No. of Cars per Train: 6
 Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626
 Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068
 Headway (min) 6

(in BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township)

Headway (min) 3

(in Hasseragatta to R V Road)

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	BIEC Terminal	Jindal	7911	16260	20680
2	Jindal	Manjunatha Nagar	10320	16260	20680
3	Manjunatha Nagar	Hasseragatta	10913	16260	20680
4	Hasseragatta	T. Dasarahalli	12524	32520	41360
5	T. Dasarahalli	Jalahalli	15987	32520	41360
6	Jalahalli	Peenya Ind Area	16116	32520	41360
7	Peenya Ind Area	Peenya	20596	32520	41360
8	Peenya	Outer Ring Road	20828	32520	41360
9	Outer Ring Road	Yeshwantapur	27035	32520	41360
10	Yeshwantapur	Soap Factory	31816	32520	41360
11	Soap Factory	Mahalakshmi	32059	32520	41360
12	Mahalakshmi	Rajaji Nagar	33040	32520	41360
13	Rajaji Nagar	Kuvempu Road	32804	32520	41360
14	Kuvempu Road	Malleswaram	34096	32520	41360
15	Malleswaram	Swastik	34512	32520	41360
16	Swastik	Majestic	34801	32520	41360
17	Majestic	Chickpete	36557	32520	41360
18	Chickpete	City Market	36514	32520	41360
19	City Market	K R Road	34359	32520	41360
20	K R Road	Lal Bagh	32638	32520	41360
21	Lal Bagh	South End Circle	30889	32520	41360
22	South End Circle	Jayanagar	30351	32520	41360
23	Jayanagar	R V Road	29501	32520	41360
24	R V Road	Banashankari	19137	16260	20680
25	Banashankari	J.P.Nagar	14356	16260	20680
26	J.P.Nagar	Puttenahalli Cross	12107	16260	20680
27	Puttenahalli Cross	Anjanapura Road Cross	10709	16260	20680
28	Anjanapura Road Cross	Krishna Leela Park (ISKON)	8787	16260	20680
29	Krishna Leela Park (ISKON)	Vajarahalli	7301	16260	20680
30	Vajarahalli	Thalaghattapura	5464	16260	20680
31	Thalaghattapura	Anjanapura Township	2379	16260	20680

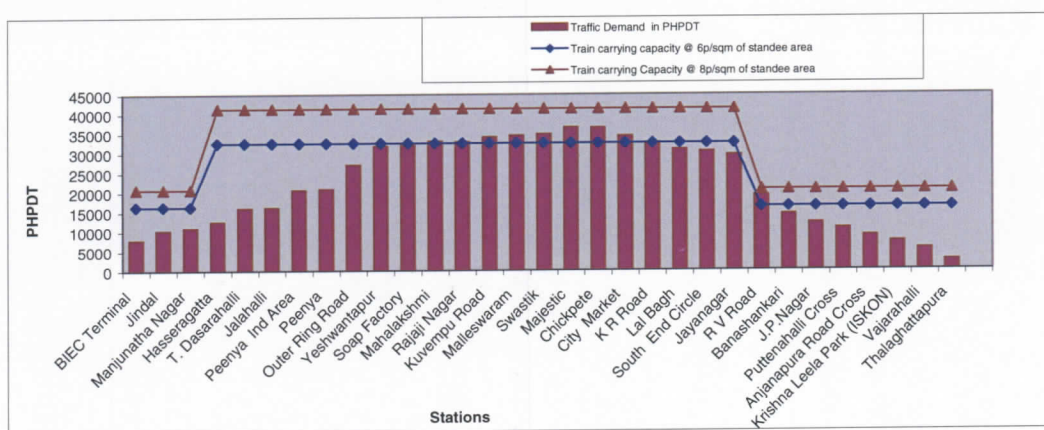


Fig 3.1

PHPDT Demand and Capacity Chart

North- South Corridor: BIEC- Hesarhatta- Puttenahalli- Anjanapura Township

Year: 2041
 No. of Cars per Train: 6
 Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626
 Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068
 Headway (min): 5

(in BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township)

Headway (min) 2.5

(in Hasseragatta to R V Road)

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	BIEC Terminal	Jindal	9256	19512	24816
2	Jindal	Manjunatha Nagar	12075	19512	24816
3	Manjunatha Nagar	Hasseragatta	12769	19512	24816
4	Hasseragatta	T. Dasarahalli	14653	39024	49632
5	T. Dasarahalli	Jalahalli	18705	39024	49632
6	Jalahalli	Peenya Ind Area	18856	39024	49632
7	Peenya Ind Area	Peenya	24097	39024	49632
8	Peenya	Outer Ring Road	24369	39024	49632
9	Outer Ring Road	Yeshwantapur	31631	39024	49632
10	Yeshwantapur	Soap Factory	37225	39024	49632
11	Soap Factory	Mahalakshmi	37509	39024	49632
12	Mahalakshmi	Rajaji Nagar	38657	39024	49632
13	Rajaji Nagar	Kuvempu Road	38381	39024	49632
14	Kuvempu Road	Malleswaram	39892	39024	49632
15	Malleswaram	Swastik	40379	39024	49632
16	Swastik	Majestic	40717	39024	49632
17	Majestic	Chickpete	42771	39024	49632
18	Chickpete	City Market	42721	39024	49632
19	City Market	K R Road	40201	39024	49632
20	K R Road	Lal Bagh	38186	39024	49632
21	Lal Bagh	South End Circle	36140	39024	49632
22	South End Circle	Jayanagar	35511	39024	49632
23	Jayanagar	R V Road	34517	39024	49632
24	R V Road	Banashankari	22391	19512	24816
25	Banashankari	J.P.Nagar	16796	19512	24816
26	J.P.Nagar	Puttenahalli Cross	14165	19512	24816
27	Puttenahalli Cross	Anjanapura Road Cross	12529	19512	24816
28	Anjanapura Road Cross	Krishna Leela Park (ISKON)	10280	19512	24816
29	Krishna Leela Park (ISKON)	Vajarahalli	8542	19512	24816
30	Vajarahalli	Thalaghattapura	6392	19512	24816
31	Thalaghattapura	Anjanapura Township	2783	19512	24816

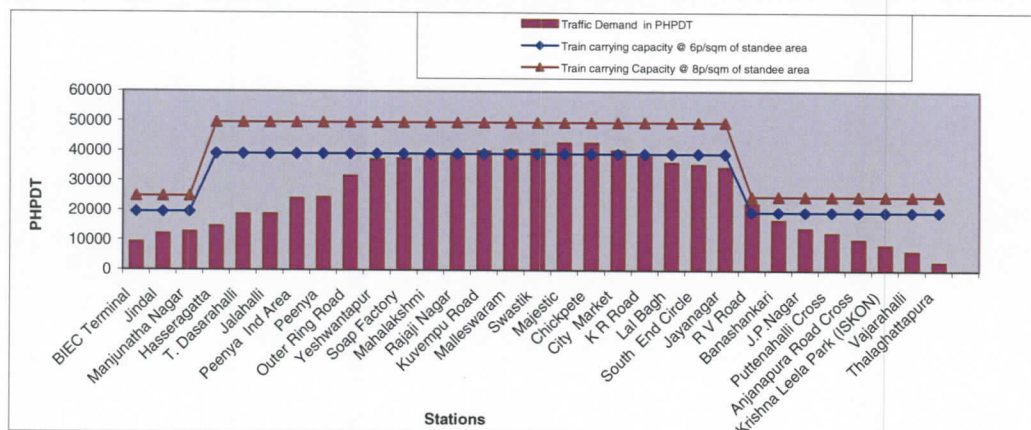


Fig 4.1

TABLE 1.1 A

Hourly Train Operation Plan for BIEC Terminal to Hasseragatta

Year: 2016

Configuration: 3 Car

Headway(min): 7

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	3
6 to 7	20	3	3
7 to 8	12	5	5
8 to 9	7	8	9
9 to 10	7	9	8
10 to 11	7	8	9
11 to 12	12	5	5
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	12	5	5
17 to 18	7	9	8
18 to 19	7	8	9
19 to 20	7	9	8
20 to 21	12	5	5
21 to 22	20	3	3
22 to 23	24	3	3
23 to 24	24	3	3
Total No. of train trips per direction per day		97	97

TABLE 1.1 B
Hourly Train Operation Plan for Hasseragatta to R V Road
Year: 2016
Configuration: Alternate 3 Car/6 Car Trainset
Headway(min): 3.5

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	3.5	17	18
9 to 10	3.5	18	17
10 to 11	3.5	17	18
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	3.5	18	17
18 to 19	3.5	17	18
19 to 20	3.5	18	17
20 to 21	6	10	10
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	12	5	5
Total No. of train trips per direction per day		194	194

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 194 trips, about 97 trips will be of 3-car trains and 97 trips will be of 6-car trains.

TABLE 1.1 C**Hourly Train Operation Plan for R V Road to Anjanapura Township****Year: 2016****Configuration: 3 Car****Headway(min): 7**

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	3
6 to 7	20	3	3
7 to 8	12	5	5
8 to 9	7	8	9
9 to 10	7	9	8
10 to 11	7	8	9
11 to 12	12	5	5
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	12	5	5
17 to 18	7	9	8
18 to 19	7	8	9
19 to 20	7	9	8
20 to 21	12	5	5
21 to 22	20	3	3
22 to 23	24	3	3
23 to 24	24	3	3
Total No. of train trips per direction per day		97	97

TABLE 1.2 A

Hourly Train Operation Plan for BIEC Terminal to Hasseragatta

Year: 2021

Configuration: 6 Car

Headway(min): 7

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	3
6 to 7	20	3	3
7 to 8	12	5	5
8 to 9	7	8	9
9 to 10	7	9	8
10 to 11	7	8	9
11 to 12	12	5	5
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	12	5	5
17 to 18	7	9	8
18 to 19	7	8	9
19 to 20	7	9	8
20 to 21	12	5	5
21 to 22	20	3	3
22 to 23	24	3	3
23 to 24	24	3	3
Total No. of train trips per direction per day		97	97

TABLE 1.3 A

Hourly Train Operation Plan for BIEC Terminal to Hasseragatta

Year: 2031

Configuration: 6 Car

Headway(min): 6

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	2
6 to 7	20	3	3
7 to 8	10	6	6
8 to 9	6	10	10
9 to 10	6	10	10
10 to 11	6	10	10
11 to 12	10	6	6
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	10	6	6
17 to 18	6	10	10
18 to 19	6	10	10
19 to 20	6	10	10
20 to 21	10	6	6
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	24	3	3
Total No. of train trips per direction per day		109	109

TABLE 1.3 B**Hourly Train Operation Plan for Hasseragatta to R V Road****Year: 2031****Configuration: 6 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	6	5
14 to 15	12	5	6
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	12	5	5
Total No. of train trips per direction per day		218	218

TABLE 1.3 C

Hourly Train Operation Plan for R V Road to Anjanapura Township

Year: 2031

Configuration: 6 Car

Headway(min): 6

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	2
6 to 7	20	3	3
7 to 8	10	6	6
8 to 9	6	10	10
9 to 10	6	10	10
10 to 11	6	10	10
11 to 12	10	6	6
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	10	6	6
17 to 18	6	10	10
18 to 19	6	10	10
19 to 20	6	10	10
20 to 21	10	6	6
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	24	3	3
Total No. of train trips per direction per day		109	109

TABLE 1.4 A**Hourly Train Operation Plan for BIEC Terminal to Hasseragatta****Year: 2041****Configuration: 6 Car****Headway(min): 5**

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	2
6 to 7	20	3	3
7 to 8	10	6	6
8 to 9	5	12	12
9 to 10	5	12	12
10 to 11	5	12	12
11 to 12	10	6	6
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	10	6	6
17 to 18	5	12	12
18 to 19	5	12	12
19 to 20	5	12	12
20 to 21	10	6	6
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	24	3	3
Total No. of train trips per direction per day		121	121

TABLE 1.4 B**Hourly Train Operation Plan for Hasseragatta to R V Road****Year: 2041****Configuration: 6 Car****Headway(min): 2.5**

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	2.5	24	24
9 to 10	2.5	24	24
10 to 11	2.5	24	24
11 to 12	5	12	12
12 to 13	10	6	6
13 to 14	12	6	5
14 to 15	12	5	6
15 to 16	10	6	6
16 to 17	5	12	12
17 to 18	2.5	24	24
18 to 19	2.5	24	24
19 to 20	2.5	24	24
20 to 21	5	12	12
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	12	5	5
Total No. of train trips per direction per day		242	242

TABLE 1.4 C
Hourly Train Operation Plan for R V Road to Anjanapura Township
Year: 2041
Configuration: 6 Car
Headway(min): 5

Time of Day	Headway in Minutes	No. of Trains per day	
		UP	DN
5 to 6	24	3	2
6 to 7	20	3	3
7 to 8	10	6	6
8 to 9	5	12	12
9 to 10	5	12	12
10 to 11	5	12	12
11 to 12	10	6	6
12 to 13	20	3	3
13 to 14	24	3	2
14 to 15	24	2	3
15 to 16	20	3	3
16 to 17	10	6	6
17 to 18	5	12	12
18 to 19	5	12	12
19 to 20	5	12	12
20 to 21	10	6	6
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	24	3	3
Total No. of train trips per direction per day		121	121

TABLE 2.1
North- South Corridor: BIEC- Hesarghatta- Puttenahalli- Anjanapura Township
PHPDT for the Year 2016

S.No	From Station	To Station	Maximum PHPDT	Directional Split to Anjanapura Township	Directional Split to BIEC Terminal
1	BIEC Terminal	Jindal	585	50%	50%
2	Jindal	Manjunatha Nagar	2921	50%	50%
3	Manjunatha Nagar	Hasseragatta	3161	50%	50%
4	Hasseragatta	T. Dasarahalli	4294	50%	50%
5	T. Dasarahalli	Jalahalli	7890	50%	50%
6	Jalahalli	Peenya Ind Area	8031	50%	50%
7	Peenya Ind Area	Peenya	9009	50%	50%
8	Peenya	Outer Ring Road	9164	50%	50%
9	Outer Ring Road	Yeshwantapur	12444	50%	50%
10	Yeshwantapur	Soap Factory	15252	50%	50%
11	Soap Factory	Mahalakshmi	16176	50%	50%
12	Mahalakshmi	Rajaji Nagar	16752	50%	50%
13	Rajaji Nagar	Kuvempu Road	17101	50%	50%
14	Kuvempu Road	Malleswaram	17860	50%	50%
15	Malleswaram	Swastik	18886	50%	50%
16	Swastik	Majestic	19056	50%	50%
17	Majestic	Chickpete	21803	50%	50%
18	Chickpete	City Market	21461	50%	50%
19	City Market	K R Road	20822	50%	50%
20	K R Road	Lal Bagh	19730	50%	50%
21	Lal Bagh	South End Circle	18308	50%	50%
22	South End Circle	Jayanagar	18189	50%	50%
23	Jayanagar	R V Road	17806	50%	50%
24	R V Road	Banashankari	11241	50%	50%
25	Banashankari	J.P.Nagar	8433	50%	50%
26	J.P.Nagar	Puttenahalli Cross	7112	50%	50%
27	Puttenahalli Cross	Anjanapura Road Cross	6290	50%	50%
28	Anjanapura Road Cross	Krishna Leela Park (ISKON)	5161	50%	50%
29	Krishna Leela Park (ISKON)	Vajarahalli	4288	50%	50%
30	Vajarahalli	Thalaghattapura	3209	50%	50%
31	Thalaghattapura	Anjanapura Township	1397	50%	50%

TABLE 3.1
Vehicle Kilometer

North-South Corridor: BIEC- Hesarghatta- Puttenahalli- Anjanapura Township

Year	2016			2021			2031			2041		
	BIEC Terminal to Hasseragatta	Hasseragatta to R V Road	R V Road to Anjanapura	BIEC Terminal to Hasseragatta	Hasseragatta to R V Road	R V Road to Anjanapura	BIEC Terminal to Hasseragatta	Hasseragatta to R V Road	R V Road to Anjanapura	BIEC Terminal to Hasseragatta	Hasseragatta to R V Road	R V Road to Anjanapura
Section Length	3.82	19.58	10.00	3.82	19.58	10.00	3.82	19.58	10.00	3.82	19.58	10.00
No of cars per Train	3	3	3	6	6	6	6	6	6	6	6	6
No of working Days in a year	340	340	340	340	340	340	340	340	340	340	340	340
Number of Trains per day each Way	97	97	97	97	194	97	109	218	109	121	242	121
Daily Train -KM	742	3799	1940	742	7597	1940	834	8537	2180	925	9477	2420
Annual Train - KM (10 ⁵)	2.52	12.91	6.60	2.52	25.83	6.60	2.83	29.03	7.41	3.15	32.22	8.23
Annual Vehicle - KM (10 ⁵)	7.57	38.74	19.79	15.13	154.98	39.58	17.01	174.15	44.48	18.88	193.33	49.38

Rate Requirement**North-South Corridor: BIEC- Hesaraghatta- Puttenahalli- Anjanapura Township, Year : 2016**

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			No. of Cars per rake	No. of Cars
				Bare	Traffic Reserve	R&M		
BIEC Terminal - Anjanapura Township	33.406	34	7	18	1	2	21	#REF!
Hassaraghatta - R V Road	19.580	33	7	12	1	1	14	#REF!
				30	2	3	35	#REF!

Above train Operation resulting in:

Section	Effective headway (min)	No. of Cars per Rake	No. of Rakes	No. of Car
BIEC Terminal to Hassaraghatta and R V Road to Anjanapura Township	7	#REF!	#REF!	#REF!
Hassaraghatta - R V Road	3.5	#REF!		
Total Turn Round Time(min)	6			

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement				Total No. of Cars
		3-Car	No. of cars	6-Car	No. of cars	
BIEC Terminal to Hassaraghatta	3.824	3	9	-	-	9
Hassaraghatta to R V Road	19.580	12	36	14	84	120
R V Road to Puttenahalli	3.618	2	6	-	-	6
Puttenahalli Cross to Anjanapura Township	6.384	4	12	-	-	12
		21	63	14	84	147

North-South Corridor: BIEC- Hesaraghatta- Puttenahalli- Anjanapura Township, Year : 2021

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			No. of Cars per rake	No. of Cars
				Bare	Traffic Reserve	R&M		
BIEC Terminal - Anjanapura Township	33.41	34	7	18	1	2	21	126
Hassaraghatta - R V Road	19.58	33	7	12	1	1	14	#REF!
				30	2	3	35	#REF!

Above train Operation resulting in:

Section	Effective headway (min)	No. of Cars per Rake	No. of Rakes	No. of Car
BIEC Terminal to Hassaraghatta and R V Road to Anjanapura Township	7	#REF!	35 Rakes of 6 Cars	#REF!
Hassaraghatta - R V Road	3.5	6		
Total Turn Round Time(min)	6			

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement				Total No. of Cars
		3-Car	No. of cars	6-Car	No. of cars	
BIEC Terminal to Hassaraghatta	3.824	-	-	3	18	18
Hassaraghatta to R V Road	19.580	-	-	26	156	156
R V Road to Puttenahalli	3.618	-	-	2	12	12
Puttenahalli Cross to Anjanapura Township	6.384	-	-	4	24	24
		-	-		210	210

North- South Corridor: BIEC- Hesarghatta- Puttenahalli- Anjanapura Township, Year : 2031

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	No. of Cars per Rake			No. of Rakes			No. of Cars		
				Effective headway (min)	No. of Cars per Rake	No. of Rakes	3-Car	6-Car	6-Cars	Bare	Traffic Reserve	R&M
BIEC Terminal - Anjanapura Township	33.41	34	7	7	6	39	6	21	2	24	6	144
Hasseragatta - R V Road	19.58	33	7	7	6	39	6	13	1	15	6	90
Total Turn Round Time(min)				6				34	2	39		234

Above train Operation resulting in:

Section	Effective headway (min)	No. of Cars per Rake	No. of Rakes	No. of Car
BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township	7	6	39	234
Hasseragatta - R V Road	3.5	6		
Total Turn Round Time(min)				6

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement			Total No. of Cars
		3-Car	6-Car	6-Cars	
No. of rake	No. of cars	No. of rake	No. of cars	No. of rake	No. of cars
BIEC Terminal to Hasseragatta	3.824	-	2	12	12
Hasseragatta to R V Road	19.580	-	29	174	174
R V Road to Puttenahalli	3.618	-	3	18	18
Puttenahalli Cross to Anjanapura Township	6.384	-	5	30	30
Total					234

North- South Corridor: BIEC- Hesarghatta- Puttenahalli- Anjanapura Township, Year : 2041

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	No. of Cars per Rake			No. of Rakes			No. of Cars		
				Effective headway (min)	No. of Cars per Rake	No. of Rakes	3-Car	6-Car	6-Cars	Bare	Traffic Reserve	R&M
BIEC Terminal - Anjanapura Township	33.41	34	5	5	6	47	6	25	3	29	6	174
Hasseragatta - R V Road	19.58	33	5	5	6	47	6	16	1	18	6	108
Total Turn Round Time(min)				6				41	2	47		282

Above train Operation resulting in:

Section	Effective headway (min)	No. of Cars per Rake	No. of Rakes	No. of Car
BIEC Terminal to Hasseragatta and R V Road to Anjanapura Township	5	6	47	282
Hasseragatta - R V Road	2.5	6		
Total Turn Round Time(min)				6

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement			Total No. of Cars
		3-Car	6-Car	6-Cars	
No. of rake	No. of cars	No. of rake	No. of cars	No. of rake	No. of cars
BIEC Terminal to Hasseragatta	3.824	-	3	18	18
Hasseragatta to R V Road	19.580	-	35	210	210
R V Road to Puttenahalli	3.618	-	3	18	18
Puttenahalli Cross to Anjanapura Township	6.384	-	6	36	36
Total					282

PHPDT Demand and Capacity Chart

East- West Corridor - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield

Year: 2016

No. of Cars per Train: 6

Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626

Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068

Headway (min) 5.5

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	Kengeri Terminal	RV College of Engineering	4049	17738	22560
2	RV College of Engineering	Bangalore University Cross	5231	17738	22560
3	Bangalore University Cross	Rajarajeshwari Nagar	6198	17738	22560
4	Rajarajeshwari Nagar	Nayandahalli	7638	17738	22560
5	Nayandahalli	Mysore Road Terminal	8045	17738	22560
6	Mysore Road Terminal	Deepanjali Nagar	8656	17738	22560
7	Deepanjali Nagar	Vijaya Nagar	11142	17738	22560
8	Vijaya Nagar	Hosahalli	11587	17738	22560
9	Hosahalli	Toll Gate	13686	17738	22560
10	Toll Gate	Magadi Road	15834	17738	22560
11	Magadi Road	City Railway Station	17324	17738	22560
12	City Railway Station	Majestic	18787	17738	22560
13	Majestic	Central College	16972	17738	22560
14	Central College	Vidhan Soudha	18249	17738	22560
15	Vidhan Soudha	Cricket Stadium	18303	17738	22560
16	Cricket Stadium	M G Road	18612	17738	22560
17	M G Road	Trinity Circle	18257	17738	22560
18	Trinity Circle	Ulsoor	18281	17738	22560
19	Ulsoor	Indira Nagar	18521	17738	22560
20	Indira Nagar	Old Madras Road	19368	17738	22560
21	Old Madras Road	Byappanahalli	19304	17738	22560
22	Byappanahalli	Jyothipuram	19188	17738	22560
23	Jyothipuram	K R Puram	19675	17738	22560
24	K R Puram	Narayanapura	18314	17738	22560
25	Narayanapura	Mahadevapura	17698	17738	22560
26	Mahadevapura	Garudacharya Palya	17215	17738	22560
27	Garudacharya Palya	Doddanakundi Ind Area	16265	17738	22560
28	Doddanakundi Ind Area	Vishweshwaraya Ind. Area	15817	17738	22560
29	Vishweshwaraya Ind. Area	Kundanahalli	14886	17738	22560
30	Kundanahalli	Vydehi Hospital	14789	17738	22560
31	Vydehi Hospital	Sathya Sai Hospital	13617	17738	22560
32	Sathya Sai Hospital	I T P L	12837	17738	22560
33	I T P L	Kadugodi	12071	17738	22560
34	Kadugodi	Ujwala Vidyalaya	11432	17738	22560
35	Ujwala Vidyalaya	Whitefield	10974	17738	22560

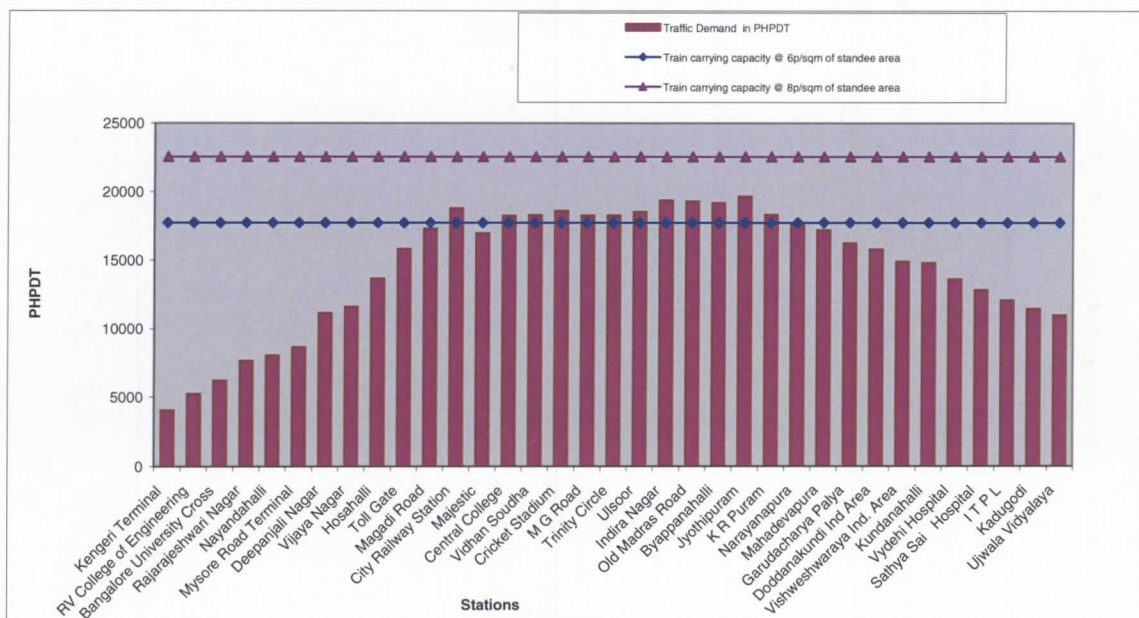


Fig 1.1

PHPDT Demand and Capacity Chart

East- West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield

Year: 2021

No. of Cars per Train: 6

Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626

Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068

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	Kengeri Terminal	RV College of Engineering	5073	24390	31020
2	RV College of Engineering	Bangalore University Cross	6846	24390	31020
3	Bangalore University Cross	Rajarajeshwari Nagar	8297	24390	31020
4	Rajarajeshwari Nagar	Nayandahalli	10457	24390	31020
5	Nayandahalli	Mysore Road Terminal	11068	24390	31020
6	Mysore Road Terminal	Deepanjali Nagar	11984	24390	31020
7	Deepanjali Nagar	Vijaya Nagar	15113	24390	31020
8	Vijaya Nagar	Hosahalli	15781	24390	31020
9	Hosahalli	Toll Gate	18830	24390	31020
10	Toll Gate	Magadi Road	22152	24390	31020
11	Magadi Road	City Railway Station	23587	24390	31020
12	City Railway Station	Majestic	25380	24390	31020
13	Majestic	Central College	20057	24390	31020
14	Central College	Vidhan Soudha	21974	24390	31020
15	Vidhan Soudha	Cricket Stadium	22055	24390	31020
16	Cricket Stadium	M G Road	22517	24390	31020
17	M G Road	Trinity Circle	21985	24390	31020
18	Trinity Circle	Ulsoor	22022	24390	31020
19	Ulsoor	Indira Nagar	22382	24390	31020
20	Indira Nagar	Old Madras Road	23652	24390	31020
21	Old Madras Road	Byappanahalli	23556	24390	31020
22	Byappanahalli	Jyothipuram	23382	24390	31020
23	Jyothipuram	K R Puram	24112	24390	31020
24	K R Puram	Narayanapura	22071	24390	31020
25	Narayanapura	Mahadevapura	21147	24390	31020
26	Mahadevapura	Garudacharya Palya	20423	24390	31020
27	Garudacharya Palya	Doddanakundi Ind Area	19098	24390	31020
28	Doddanakundi Ind Area	Vishweshwaraya Ind. Area	18426	24390	31020
29	Vishweshwaraya Ind. Area	Kundanahalli	17030	24390	31020
30	Kundanahalli	Vydehi Hospital	16884	24390	31020
31	Vydehi Hospital	Sathya Sai Hospital	15126	24390	31020
32	Sathya Sai Hospital	I T P L	13956	24390	31020
33	I T P L	Kadugodi	12807	24390	31020
34	Kadugodi	Ujwala Vidyalaya	11849	24390	31020
35	Ujwala Vidyalaya	Whitefield	11162	24390	31020

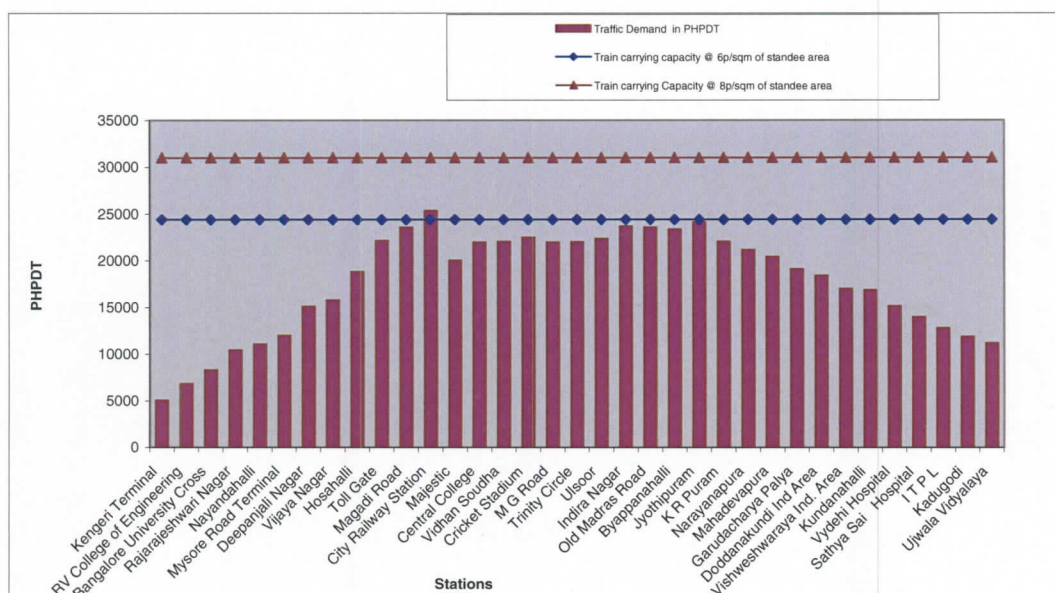


Fig 1.2

PHPDT Demand and Capacity Chart

East- West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield

Year: 2031

No. of Cars per Train: 6

Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626

Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068

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	Kengeri Terminal	RV College of Engineering	6849	32520	41360
2	RV College of Engineering	Bangalore University Cross	9242	32520	41360
3	Bangalore University Cross	Rajarajeshwari Nagar	11201	32520	41360
4	Rajarajeshwari Nagar	Nayandahalli	14117	32520	41360
5	Nayandahalli	Mysore Road Terminal	14942	32520	41360
6	Mysore Road Terminal	Deepanjali Nagar	16178	32520	41360
7	Deepanjali Nagar	Vijaya Nagar	20403	32520	41360
8	Vijaya Nagar	Hosahalli	21304	32520	41360
9	Hosahalli	Toll Gate	25421	32520	41360
10	Toll Gate	Magadi Road	29905	32520	41360
11	Magadi Road	City Railway Station	31842	32520	41360
12	City Railway Station	Majestic	34263	32520	41360
13	Majestic	Central College	27078	32520	41360
14	Central College	Vidhan Soudha	29665	32520	41360
15	Vidhan Soudha	Cricket Stadium	29573	32520	41360
16	Cricket Stadium	M G Road	30198	32520	41360
17	M G Road	Trinity Circle	29479	32520	41360
18	Trinity Circle	Ulsoor	29529	32520	41360
19	Ulsoor	Indira Nagar	30015	32520	41360
20	Indira Nagar	Old Madras Road	31530	32520	41360
21	Old Madras Road	Byappanahalli	31400	32520	41360
22	Byappanahalli	Jyothipuram	31165	32520	41360
23	Jyothipuram	K R Puram	31951	32520	41360
24	K R Puram	Narayanapura	29195	32520	41360
25	Narayanapura	Mahadevapura	27948	32520	41360
26	Mahadevapura	Garudacharya Palya	26971	32520	41360
27	Garudacharya Palya	Doddanakundi Ind Area	25182	32520	41360
28	Doddanakundi Ind Area	Vishweshwaraya Ind. Area	24275	32520	41360
29	Vishweshwaraya Ind. Area	Kundanahalli	22391	32520	41360
30	Kundanahalli	Vydehi Hospital	22193	32520	41360
31	Vydehi Hospital	Sathya Sai Hospital	19820	32520	41360
32	Sathya Sai Hospital	I T P L	18241	32520	41360
33	I T P L	Kadugodi	16689	32520	41360
34	Kadugodi	Ujwala Vidyalaya	15395	32520	41360
35	Ujwala Vidyalaya	Whitefield	14468	32520	41360

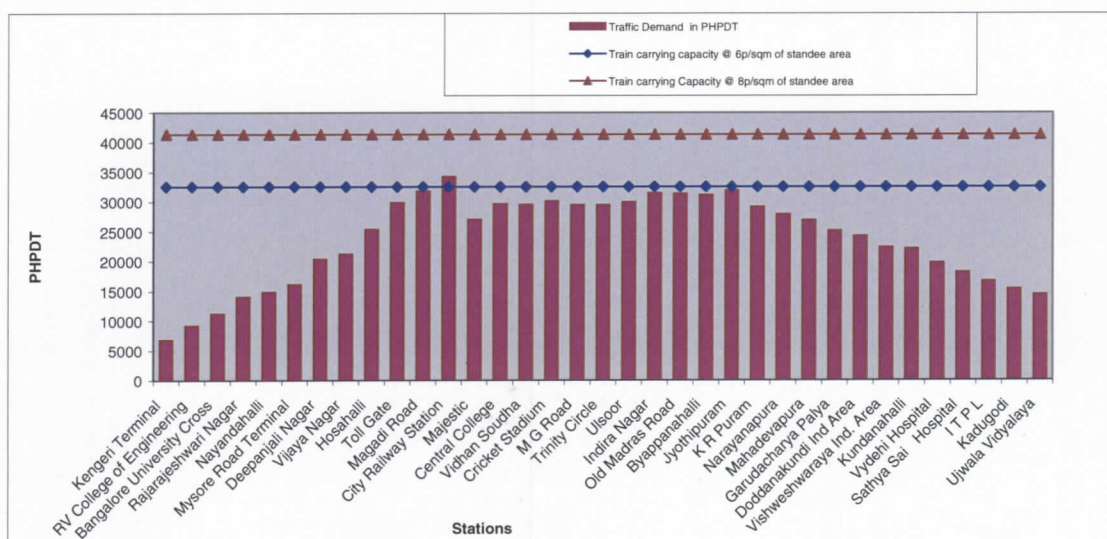


Fig 1.3

PHPDT Demand and Capacity Chart

East- West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield

Year: 2041
 No. of Cars per Train: 6
 Passenger Capacity @ 6 persons/sqm of a 6-Car Train: 1626
 Passenger Capacity @ 8 persons/sqm of a 6-Car Train: 2068
 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	Kengeri Terminal	RV College of Engineering	7808	32520	41360
2	RV College of Engineering	Bangalore University Cross	10536	32520	41360
3	Bangalore University Cross	Rajarajeshwari Nagar	12769	32520	41360
4	Rajarajeshwari Nagar	Nayandahalli	16094	32520	41360
5	Nayandahalli	Mysore Road Terminal	17034	32520	41360
6	Mysore Road Terminal	Deepanjali Nagar	18443	32520	41360
7	Deepanjali Nagar	Vijaya Nagar	23259	32520	41360
8	Vijaya Nagar	Hosahalli	24287	32520	41360
9	Hosahalli	Toll Gate	28980	32520	41360
10	Toll Gate	Magadi Road	34091	32520	41360
11	Magadi Road	City Railway Station	36100	32520	41360
12	City Railway Station	Majestic	38860	32520	41360
13	Majestic	Central College	30669	32520	41360
14	Central College	Vidhan Soudha	33619	32520	41360
15	Vidhan Soudha	Cricket Stadium	33514	32520	41360
16	Cricket Stadium	M G Road	34226	32520	41360
17	M G Road	Trinity Circle	33407	32520	41360
18	Trinity Circle	Ulsoor	33464	32520	41360
19	Ulsoor	Indira Nagar	34018	32520	41360
20	Indira Nagar	Old Madras Road	35744	32520	41360
21	Old Madras Road	Byappanahalli	35597	32520	41360
22	Byappanahalli	Jyothipuram	35329	32520	41360
23	Jyothipuram	K R Puram	36224	32520	41360
24	K R Puram	Narayanapura	33083	32520	41360
25	Narayanapura	Mahadevapura	31662	32520	41360
26	Mahadevapura	Garudacharya Palya	30547	32520	41360
27	Garudacharya Palya	Doddanakundi Ind Area	28508	32520	41360
28	Doddanakundi Ind Area	Vishweshwaraya Ind. Area	27474	32520	41360
29	Vishweshwaraya Ind. Area	Kundanahalli	25326	32520	41360
30	Kundanahalli	Vydehi Hospital	25101	32520	41360
31	Vydehi Hospital	Sathya Sai Hospital	22395	32520	41360
32	Sathya Sai Hospital	I T P L	20595	32520	41360
33	I T P L	Kadugodi	18826	32520	41360
34	Kadugodi	Ujwala Vidyalaya	17351	32520	41360
35	Ujwala Vidyalaya	Whitefield	16294	32520	41360

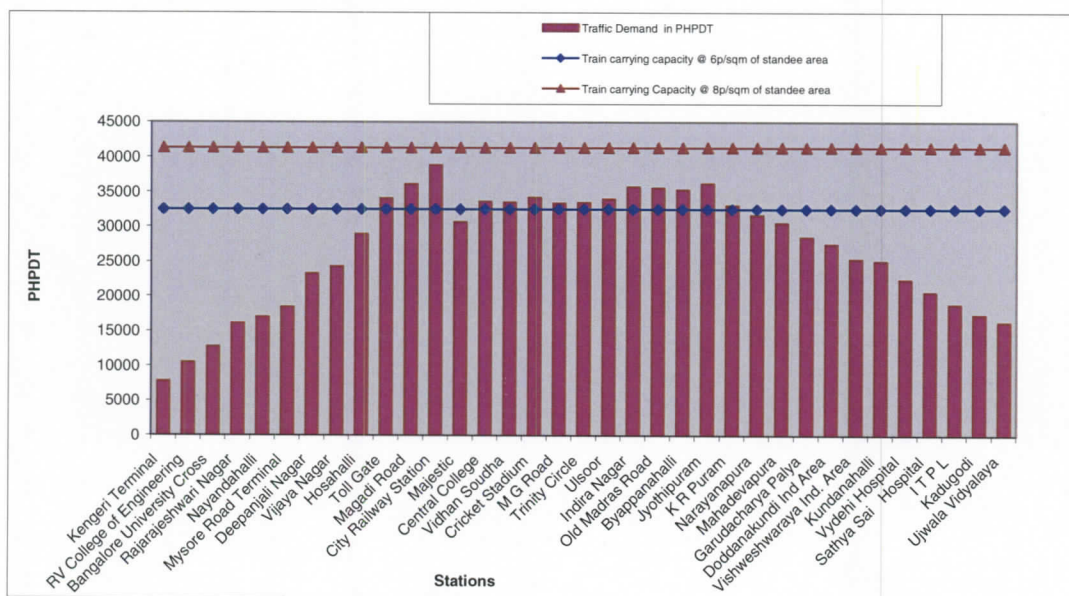


Fig 1.4

TABLE 1.5 A

Hourly Train Operation Plan for Kengeri Terminal to Whitefield

Year: 2016

Configuration: 6 Car

Headway(min): 5.5

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	8	8	7
8 to 9	5.5	10	11
9 to 10	5.5	11	10
10 to 11	5.5	10	11
11 to 12	8	8	7
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	8	7	8
17 to 18	5.5	11	10
18 to 19	5.5	10	11
19 to 20	5.5	11	10
20 to 21	8	7	8
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
Total No. of train trips per direction per day		141	141

TABLE 1.6 A

Hourly Train Operation Plan for Kengeri Terminal to Whitefield

Year: 2021

Configuration: 6 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
Total No. of train trips per direction per day		178	178

TABLE 1.7 A

Hourly Train Operation Plan for Kengeri Terminal to Whitefield

Year: 2031

Configuration: 6 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
Total No. of train trips per direction per day		216	216

TABLE 1.8 A

Hourly Train Operation Plan for Kengeri Terminal to Whitefield

Year: 2041

Configuration: 6 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
Total No. of train trips per direction per day		216	216

TABLE 2.2

East- West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield
 PHPDT for the Year 2016

S.No	From Station	To Station	Maximum PHPDT	Directional Split to Whitefield	Directional Split to Kengeri Terminal
1	Kengeri Terminal	RV College of Engineering	4049	50%	50%
2	RV College of Engineering	Bangalore University Cross	5231	50%	50%
3	Bangalore University Cross	Rajarajeshwari Nagar	6198	50%	50%
4	Rajarajeshwari Nagar	Nayandahalli	7638	50%	50%
5	Nayandahalli	Mysore Road Terminal	8045	50%	50%
6	Mysore Road Terminal	Deepanjali Nagar	8656	50%	50%
7	Deepanjali Nagar	Vijaya Nagar	11142	50%	50%
8	Vijaya Nagar	Hosahalli	11587	50%	50%
9	Hosahalli	Toll Gate	13686	50%	50%
10	Toll Gate	Magadi Road	15834	50%	50%
11	Magadi Road	City Railway Station	17324	50%	50%
12	City Railway Station	Majestic	18787	50%	50%
13	Majestic	Central College	16972	50%	50%
14	Central College	Vidhan Soudha	18249	50%	50%
15	Vidhan Soudha	Cricket Stadium	18303	50%	50%
16	Cricket Stadium	M G Road	18612	50%	50%
17	M G Road	Trinity Circle	18257	50%	50%
18	Trinity Circle	Ulsoor	18281	50%	50%
19	Ulsoor	Indira Nagar	18521	50%	50%
20	Indira Nagar	Old Madras Road	19368	50%	50%
21	Old Madras Road	Byappanahalli	19304	50%	50%
22	Byappanahalli	Jyothipuram	19188	50%	50%
23	Jyothipuram	K R Puram	19675	50%	50%
24	K R Puram	Narayanapura	18314	50%	50%
25	Narayanapura	Mahadevapura	17698	50%	50%
26	Mahadevapura	Garudacharya Palya	17215	50%	50%
27	Garudacharya Palya	Doddanakundi Ind Area	16265	50%	50%
28	Doddanakundi Ind Area	Vishweshwaraya Ind. Area	15817	50%	50%
29	Vishweshwaraya Ind. Area	Kundanahalli	14886	50%	50%
30	Kundanahalli	Vydehi Hospital	14789	50%	50%
31	Vydehi Hospital	Sathya Sai Hospital	13617	50%	50%
32	Sathya Sai Hospital	I T P L	12837	50%	50%
33	I T P L	Kadugodi	12071	50%	50%
34	Kadugodi	Ujwala Vidyalaya	11432	50%	50%
35	Ujwala Vidyalaya	Whitefield	10974	50%	50%

TABLE 3.2
Vehicle Kilometer

East-West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield

Year	2016	2021	2031	2041
Section	<i>Kengeri Terminal to Whitefield</i>	<i>Kengeri Terminal to Whitefield</i>	<i>Kengeri Terminal to Whitefield</i>	<i>Kengeri Terminal to Whitefield</i>
Section Length	39.11	39.11	39.11	39.11
No of cars per Train	6	6	6	6
No of working Days in a year	340	340	340	340
Number of Trains per day each Way	141	178	216	216
Daily Train -KM	11028	13922	16894	16894
Annual Train - KM (10⁵)	37.50	47.33	57.44	57.44
Annual Vehicle - KM (10⁵)	224.97	284.01	344.64	344.64

Rake Requirement**East- West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield, Year : 2016**

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
				Bare	Traffic Reserve	R&M			
Kengeri Terminal to Whitefield	39.106	34	5.5	27	2	3	32	6	192
Total Turn Round Time(min)	6								

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement	
		6-Car	No. of cars
Kengeri Terminal to Mysore Road Terminal(Phase II)	6.306	5	30
Mysore Road Terminal to Byappanahalli (Phase I)	17.374	14	84
Byappanahalli to Whitefield (Phase II)	15.426	13	78
		32	192

East- West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield, Year : 2021

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
				Bare	Traffic Reserve	R&M			
Kengeri Terminal to Whitefield	39.106	34	4	37	2	4	43	6	258
Total Turn Round Time(min)	6								

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement	
		6- Car	No. of cars
Kengeri Terminal to Mysore Road Terminal(Phase II)	6.306	7	42
Mysore Road Terminal to Byappanahalli (Phase I)	17.374	19	114
Byappanahalli to Whitefield (Phase II)	15.426	17	102
		43	258

East-West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield, Year : 2031

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
				Bare	Traffic Reserve	R&M			
Kengeri Terminal to Whitefield	39.11	34	3	49	2	5	56	6	336
Total Turn Round Time(min)		6							

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement 6- Car	
		No. of rake	No. of cars
Kengeri Terminal to Mysore Road Terminal(Phase II)	6.3063	9	54
Mysore Road Terminal to Byappanahalli (Phase I)	17.374	25	150
Byappanahalli to Whitefield (Phase II)	15.426	22	132
		56	336

East-West Corridor: - Kengeri Terminal- Mysore Road- Toll Gate- Byappanahalli- Narayanapura-ITPL- Whitefield, Year : 2041

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
				Bare	Traffic Reserve	R&M			
Kengeri Terminal to Whitefield	39.106	34	3	49	2	5	56	6	336
Total Turn Round Time(min)		6							

Allocation of Rake requirement to different sections of corridor pro-rata based on the respective kilometers of the sections and planned train operation as noted above:

Sections:	KM	Rake Requirement 6- Car	
		No. of rake	No. of cars
Kengeri Terminal to Mysore Road Terminal(Phase II)	6.306	9	54
Mysore Road Terminal to Byappanahalli (Phase I)	17.374	25	150
Byappanahalli to Whitefield (Phase II)	15.426	22	132
		56	336



CHAPTER 6

ROLLING STOCK

6.1 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.

6.2 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 1.

Table 1
Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC)	20.9 m	2.88 m	3.8 m
Trailer car (TC)/Motor Car (MC)	20.9 m	2.88 m	3.8 m

6.3 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, 210 standing thus a total of 253 passengers for a Driving Motor Car, and 50 seated, 230 standing thus a total of 280 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

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.

Table 2.1 and 2.2 shows the carrying capacity of Mass Rail Vehicles with standing passenger @ 6 passenger per sqm of standee area and @ 8 passenger per sqm of standee area respectively.



Table 2.1
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
Seated	43	43	50	50	136	136	286	286
Standing	105	210	115	230	325	650	670	1340
Total	148	253	165	280	461	786	956	1626

NORMAL-3 Person/sqm of standee area
CRUSH -6 Person/sqm of standee area

Table 2.2
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
Seated	43	43	50	50	136	136	286	286
Standing	105	279	115	306	325	864	670	1782
Total	148	322	165	356	461	1000	956	2068

NORMAL-3 Person/sqm of standee area
CRUSH -8 Person/sqm of standee area

Note by BMRCL

The Train Carrying Capacity of 3 Car & 6 Car train will be 975 and 2004 respectively. A 3 car train will have 2 DMCs and 1 MC/TC and similarly 6 car trains will have 2 DMCs and 4 MC/TC. Accordingly, the carrying capacity of these trains is shown below:

	Driving Motor car		Trailer car / Motor car		3 Car Train		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	136	136	286	286
Standing	105	279	115	306	325	839	670	1718
Total	148	322	165	356	461	975	956	2004



6.4 WEIGHT

The weights of motorcar and trailer cars have been estimated as in Table 3, referring to the experiences in Delhi Metro. The average passenger weight has been taken as 65 kg.

Table 3 : Weight of Mass Rail Vehicles (TONNES)

	DMC	TC	MC	3 Car train	6 Car train
TARE (maximum)	36	32	34	104	240
Passenger					
(Normal)	9.62	10.73	10.73	40.69	62.14
(Crush @6p/sqm)	16.44	18.20	18.20	51.09	105.69
(Crush @8p/sqm)	20.93	23.14	23.14	65.17	134.72
Gross					
(Normal)	45.62	42.73	44.73	144.69	266.14
(Crush @6p/sqm)	52.44	50.20	52.20	155.09	309.69
(Crush @8p/sqm)	56.93	55.14	57.14	169.17	338.72
Axle Load @6 person/sqm	13.111	12.550	13.05		
Axle Load @8 person/sqm	14.233	13.785	14.285		

The axle load @ 6persons/sqm of standing area works out in the range of 13.111T to 13.05T. 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 **15 T axle** load.

6.5 Performance Parameters

The recommended performance parameters are:

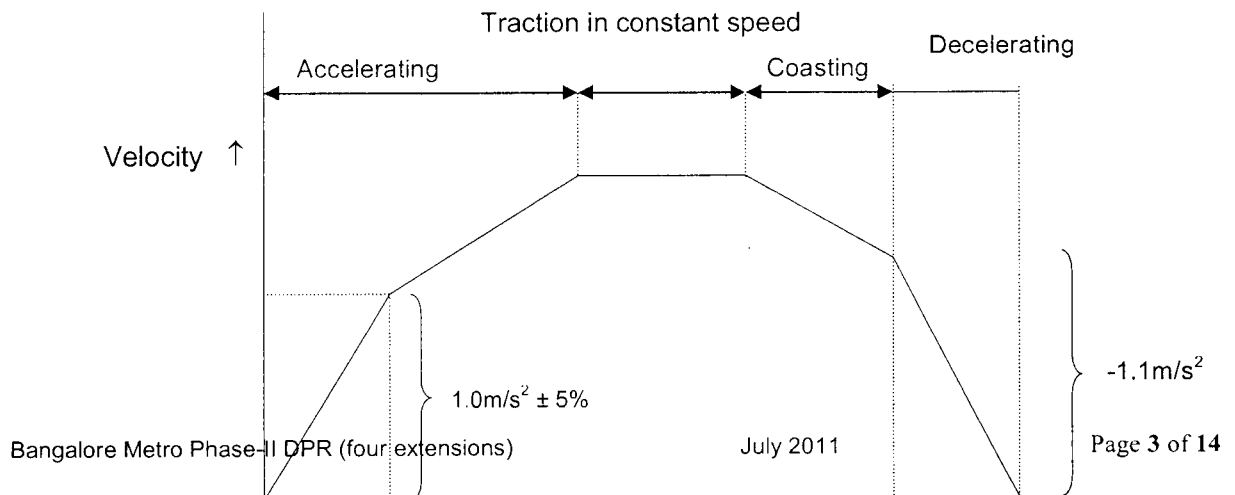
Maximum Design Speed: 90 kmph

Maximum Operating Speed: 80 kmph

Max. Acceleration: $1.0 \text{ m/s}^2 \pm 5\%$

Max. Deceleration 1.1 m/s^2 (Normal brake)

More than 1.3 m/s^2 (Emergency brake)





0

Time →

6.6 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.

6.7 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-

6.7.1 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.

6.7.2 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.

6.7.3 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.

6.7.4 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



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 DC voltage from the 3rd Rail is stepped up through a 'STEP up Chopper' to DC link voltage, which feeds Inverter operated with Pulse Width Modulation (PWM) control technology and using insulated Gate Bipolar Transistors (IGBT). Thus three-phase variable voltage variable frequency output drives the traction motors for propulsion.

Recently advanced IGBT has been developed for inverter units. The advanced IGBT incorporates its own over current protection, short circuit protection; over temperature protection and low power supply detection. The inverter unit uses optical fiber cable to connect the control unit to the gate interface. This optical fiber cable transmits the gate signals to drive the advanced IGBT via the gate interface. The optical fiber cable provides electrical isolation between the advanced IGBT and the control unit and is impervious to electrical interference. These are recommended for adoption in trains of this corridor.

6.7.5 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



6.7.6 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



6.7.7 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.

6.7.8 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



An emergency door for easy detrainment of the passenger on the track has been provided at the center of the front side of the each cabin which has an easy operation with one handle type master controller.

6.7.9 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.

6.7.10 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.

6.7.11 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 smoke zero halogen type which ensures passenger safety in case of fire.

(iii) **Emergency door**

The rolling stock is provided with emergency doors at both ends of the cab 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



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	750 V dc
2.2	Method of current collection	Third Rail Bottom 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.
6	Designed - Passenger Loading	
6.1	Design of Propulsion equipment	8 Passenger/ m ²
6.2	Design of Mechanical systems	10 Passenger/ m ²
7	Carrying capacity- @ 8 standees/sqm	
7.1	Coach carrying capacity	
	DMC	316 (seating - 43 ; standing - 273)
	TC	343 (seating - 50 ; standing - 293)
	MC	343 (seating - 50 ; standing - 293)
7.2	Train Carrying capacity	
	3 car train	975 (seating - 136 ; standing - 839)
	6 car train	2004 (seating - 286 ; standing - 1718)



8	Weight (Tonnes)	
8.1	Tare weight (maximum)	
	DMC	38
	TC	37
	MC	37
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	58.54
	TC	59.295
	MC	59.295
9	Axle load(T)(@ 8 persons per sqm of standee area)	Not more than 15T
		System should be designed for 15T axleload
10	Speed	
10.1	Maximum Design Speed	90 Kmph
10.2	Maximum Operating Speed	80 Kmph
11	Wheel Profile	UIC 510-2, Appendix B
12	Traction Motors Ventilation	Self
13	Acceleration on level tangent track	0.95 m/sec ² ± 5%
14	Deacceleration on level tangent track	1.1 m/sec ² (>1.3 m/sec ² during emergency)
15	Type of Bogie	Fabricated
16	Secondary Suspension springs	Air



17	Brakes	<ul style="list-style-type: none">- An electro-pneumatic (EP) service friction brake- An electric regenerative service brake- Provision of smooth and continuous blending of EP and regenerative braking- A fail safe, pneumatic friction emergency brake- A spring applied air-release parking brake- The brake actuator shall operate a Wheel Disc Brake- Brake Control Electronics (BCE) and Brake Control Unit (BCU) for each individual bogie
18	Coupler	Auto
	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
19	Detrainment Door	Side doors
20	Type of Doors	External sliding
21	Passenger Seats	Stainless Steel
22	Cooling	
22.1	VVVF & APS	Self/Forced
22.2	TM	Self ventilated
23	Control System	Train line control by 110V dc signals for vital safety equipments/items and Train Management System for other control equipment monitoring
24	Traction Motors	3 phase VVVF controlled
25	Temperature Rise Limits	
25.1	Traction Motor	Temperature Index minus 70 deg C
25.2	VVVF & APS	10 deg C temperature margin for Junction temperature
26	HVAC	<ul style="list-style-type: none">- 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.
27	PA/PIS including PSSS (CCTV)	Required



28	Passenger Surviellance	Required
29	Battery	Nickle Cadmium
30	Headlight type	LED
31	Coasting	Minimum 8% coasting to achieve specified commercial speed.
32	Average Cost per car exclusive of taxes and duties at May 2010 Price level in Rs. Crores	10.3



CHAPTER 7

POWER SUPPLY

7.0 POWER SUPPLY, SYSTEM OF TRACTION AND POWER TARIFF DETAILS

7.1 Power Supply Arrangements

Electricity is the only source of energy for operation of Metro system. The electric power supply is required by Metro system for the following purposes:-

- For running trains
- For station services e.g. lighting, ventilation and air-conditioning (only in underground stations), lifts, escalators, signaling & telecom, fire fighting and pumping etc.
- For workshops, depots and other maintenance infrastructure within premises of metro system.

The major component of power supply is traction requirements for elevated section and auxiliary requirements for underground section.

7.1.1 Power Demand Estimation

The power requirement of a metro system is determined by peak-hour demands of power for traction and auxiliary applications. Broad estimation of auxiliary and traction power demand is made based on the following requirements:-

- (i) Specific energy consumption of rolling stock – 75KWh/1000 GTKM
- (ii) Regeneration by rolling stock – 20%
- (iii) Elevated/at –grade station load – initially 200KW, which will increase to 500 KW in the year 2041
- (iv) Depot auxiliary load - initially 2250 KW in the year 2016, which will increase to 2750 KW in the year 2041.

Keeping in view of the train operation plan and demand of auxiliary and traction power, power requirement have been worked out for the year 2016, 2021, 2031 and 2041 which is briefly summarized in table 7.1 below:-

Table 7.1:- Power Demand Estimation (MVA)

Corridor		Year			
		2016	2021	2031	2041
Extension of N – S corridor BIEC to Hesarghatta	Traction	0.7	1.4	1.7	2.0
	Auxiliary	0.7	0.90	1.1	1.9
	Sub Total (A)	1.4	2.3	2.8	3.9
Extension of N – S corridor Puttenahalli to Anjanapur Township	Traction	0.7	1.4	1.6	1.9
	Auxiliary	1.2	1.5	1.9	3.1
	Sub Total (B)	1.9	2.9	3.5	5.0
Total (A+B)		3.3	5.2	6.3	8.9



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Extension of E – W corridor Kengeri Station to Mysore Road Terminal	Traction	2.9	4.0	5.4	5.4
	Auxiliary	1.2	1.5	1.9	3.1
	Sub Total (C)	4.1	5.5	7.3	8.5
Extension of E – W corridor Byappanahalli to White field (OPTION – II)	Traction	7.3	10.1	13.4	13.4
	Auxiliary	3.5	4.3	5.2	8.6
	Sub Total (D)	10.8	14.4	18.6	22.0
	Total (C+D)	14.9	19.9	25.9	30.5

Detailed calculations of power demand estimation are attached at Annexure 7.1 & 7.2.

Note by BMRCL:

The power tariff for Bangalore Metro has been fixed by KERC at Rs.4.07 per unit plus Rs.180 per KVA per month as fixed charges and hence, the cost of power will be calculated at the above rates for determining the O & M cost.

7.1.2 Need for High Reliability of Power Supply

The proposed Bangalore metro system is being designed to handle 43,000 passengers per direction during peak hours when trains are expected to run at about 2.5 minute's intervals. The tolerance level of any power interruption during this period is extremely low, as such incidences, apart from affecting train running, will cause congestion at stations. In underground stations, the ventilation and air-conditioning as well as lighting will also be affected. Interruption of power at night or at any time in underground stations 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 signaling and communication may affect train operation and passenger safety as well.

Accordingly, Metro system requires a very high level of reliable and quality of power supply. To ensure reliability of power supply, it is essential that both the sources of Supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. Therefore, it is desirable to obtain power supply at high grid voltage of 220kV or 66kV from stable grid sub-stations and further transmission & distribution to the stations along the corridor is done by the Metro Authority itself.

7.1.3 Selection of Inputs Supply Voltage and the Locations of Receiving Sub-Stations (RSS)

The high voltage power supply network of Bangalore city was studied in brief. The city has got 220kV, 66kV and 11kV network to cater to the various types of demand. 220kV sub-stations are generally located at outskirts of the city.



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66kV sub-stations are located near to the alignment of E-W and N-S corridor. Keeping in view of the reliability requirements, 2 input sources of 66kV voltage level have already been considered for each corridor and accordingly, 2 receiving sub-stations (66/33kV) are proposed to be set up each for existing E-W and N-S corridors. The existing E-W corridor from Mysore Terminal to Byappanahalli is 17.37 km, whereas N-S Corridor from Hesarghatta to Puttenahalli is 23.19 km section having four RSS's .

The 4 RSS's of phase – I corridors are being provided with 2 transformers each having capacity of 20 / 25 MVA based on the simulation studies carried out for BMRCL in phase - I. The 66 KV will be stepped down to 33 KV level at the above RSS's of metro authority.

In case of failure of one RSS, the other RSS of the same line will feed entire corridor. If both the RSS's of any corridor fail, then the power can be supplied through RSS's of other corridor through 33 KV link provided at Majestic station.

Since the proposed corridors in Phase – 2, are extension of the existing corridors of E-W and N-S, the efforts have been made to minimize the need of additional RSS. In Phase – 2 following extensions have been proposed:-

- (a) **E – W corridor:-**
 - East side extension:-
East side extension of 15.5 Km up to Whitefield
 - West side extension:-
West Side extension of 6.465 Km up to Kengeri.
- (b) **N – S corridor:-**
 - South side extension:- 6.29 km extension up to Anjanapur Township,
 - North side extension:- 3.77 km extension up to BIEC Terminal.

The East – West corridor is likely to be extended beyond Kengeri up to Future city / Satellite town, therefore it is essential to have one more RSS towards East (up to ITPL) & one RSS towards West if the extension is also considered.

Similarly 6.29 km extension towards south also requires one RSS to improve reliability of the North – South corridor. 3.77 km extension towards North can be fed from the existing RSS at Peenya existing RSS and no new RSS will be required.

Keeping in view the above, the discussions were held with Director/ KPTCL and following sources have been identified:-



Sl. No	Corridor	Grid sub – station (Input Source)	Location of RSS of Metro Authority	Approx. length of 66kV cables
1.	E-W corridor	EPIP Park 220 kV GSS (2 no. 66 kV bays)	Near ITPL station	2km. (Double circuit)
		Vrishabhavathi 220kV GSS (2 no. 66kV bays)	Kengeri Depot	4km. (Double circuit)
3.	N-S Corridor	Khodays factory 220kV GSS (2 no. 66kV bays)	Anjanapur Depot	5km. (Double circuit)

The detailed calculation and power required etc can be finalized through simulation studies during detailed design stage.

Note by BMRCL:

BMRCL agrees with the proposal of 3 RSS and their location as shown above. However, the final number of RSS would be decided based on the AC power flow study. The exact locations of the RSS are to be firmed up at the detailed design stage.

M/s KPTCL in the minutes of meeting issued vide memo no:- KPTCL/CEE/P&C/KCO – 88/25958, dated:- 28.10.2010 (Annexure – 7.3) have indicated that metro authorities (BMRCL) may confirm the requirement of power requirements at 66kV level from already planned EPIP Park 220/66 KV GIS Grid sub-station, 220 / 66 kV Khoday factory GSS and existing 220/66kV Vrishabhavathi GSS.

If additional power requirement is a certainty, BMRCL may indicate and deposit money so that the GSSs can be designed and equipment procured now itself.

Note by BMRCL:

The requirement of the power can be confirmed based on the power flow study during detailed design stage.

M/s BMRCL may like to address this issue.

The 66kV cables will be single core XLPE insulated with 630 sq.mm Al conductor. The cables shall be laid through public pathways to RSSs of Metro Authority. New RSS's of each corridor shall be provided with 2nos. (1 as standby) 66/33kV 3 phase main receiving transformers for feeding to traction as well as auxiliary loads, capacity of these transformers may be kept same as being used for Phase-1 RSS for ease or replacement and to minimize inventory requirement. However, this standardization may be verified through simulation at the time of detailed design. The location of two RSS of each



corridor on either end has been so selected that these will be able to cater the additional power supply requirements in case of likely extensions of the corridors.

Since all these sections are located on outer periphery, conventional outdoor type 66kV switchgear is proposed for each RSS to be located in approx. 60m x 60m (3600 sqm) land plot. The typical RSS layout as being used in Phase – 1 may be followed.

7.1.4 Utility diversion:-

The extension of East corridor is having around 3 Km 220 KV double circuit transmission line physically infringing the alignment. The transmission line needs to be shifted or replaced through equivalent cable network. The estimated cost of this work will be around Rs 80 Cr. The fund provision has been to be kept separately.

7.2 Selection of Traction System:-

Existing system of electric traction on all the corridors of Bangalore Metro constructed in Phase – 1 is at 750 V DC. This is based on techno economic studies for Bangalore.

The same traction system for the proposed extension of the existing corridors and new corridors has been considered, viz 750 V DC third rail bottom current collections.

7.2.1 Design Criteria for Power Supply and Traction System:

Power requirement has been evaluated considering Train operation plan, which envisages running of trains as summarized below:-

Corridor	Year	
	2016	2041
E – W Corridor		
- Train composition	6 car	6 car
- Headway	5.5 minutes	3 minutes
N-S Corridor		
- Train composition	3 car	6 car
- Headway	7 minutes	5 minutes

In train bunching situation, headway may get reduced to 150 seconds for short durations. Accordingly, traction power supply system has been planned to cater for 6-car train operation at 150 seconds headway in year 2041 under bunching conditions in part of the corridor. However, initially equipment will be installed to cater the expected power requirement during initial years of operations. As and when the traffic builds up in year 2031 & 2041, the power supply system may need slight augmentation by way of adding main power transformers & traction transformer-rectifier sets.



7.2.2 Traction Sub-stations (33kV/750V dc)

Traction sub-stations (33kV/750V dc) are required to be set up for feeding 750V dc power supply to the third rail. In order to cater to traction load as per design criteria, it is envisaged to provide traction sub-stations (TSS) at alternate stations. The TSS along with Auxiliary Sub-Stations (ASS) will be located at station building itself at mezzanine or platform level inside a room. An additional traction sub-station will be located in each maintenance depot. The total requirement of TSS works out to be 10 and 4 for the E-W and N-S corridor respectively.

Self-cooled, cast resin dry type rectifier-transformer is proposed, which is suitable for indoor application. Initially, 1 x 2 .5 MW transformer-rectifier set shall be provided in each TSS with space provisions for an additional set to be accommodated in future as and when trains composition is increased to 6 coaches at 3 minutes headway. From the traction sub-stations, 750V dc cables will be laid up to third rail and return current cables will be connected to running rails.

Note by BMRCL:

The proposal is generally correct as in the case of Phase – I. The capacity of transformer used in Phase-I is in KVA i.e. 2850 KVA and not in MW. This needs standardization. However, the exact location of TSS can only be decided on the DC power flow study to be done at detailed design stage.

7.3 Rating of major equipment

Based on emergency demand expected at each RSS and simulation study, 2 nos. 66 / 33kV main receiving transformers of 20/25 MVA capacities are being provided, at all the 4 RSS's of Phase – I.

From reliability, uniformity of spares, standardization considerations it is proposed to have similar transformers of 20/25 MVA at all the new RSS's.

The 66kV cable shall be 3-phase single core XLPE insulated with 630mm² Al conductors to meet the normal & emergency loading requirements and fault level of the 66kV supply.

Traction transformer-rectifier set (33kV/750V dc) shall be of 2.5MW rated capacity with overload requirement of 150% for 2 hours with four intermittent equally spaced overloads of 300% for 1 minute, and with one 450% full load peak of 15 seconds duration at the end of 2 hour period. The traction transformer - rectifier set shall produce 750V dc nominal output voltage with 12-pulse rectification so as to minimize the ripple content in the output dc voltage. The IEC 850 international standard envisages the minimum and maximum voltages of 500V and 900V respectively for 750V dc traction system



and therefore, the dc equipment shall be capable of giving desired performance in this voltage range.

33kV cable network shall be adequately rated to transfer requisite power during normal as well as emergency situations and to meet the fault current requirement of the system. Accordingly, proposed 33kV cables sizes are as under:-

- 3 core x 400 mm² copper from RSS to 33kV cable network
- 3 core x 300 mm² copper for 33kV ring main cable network.

Entire 33kV cables shall be 3 phase, XLPE insulated with copper conductors.

Note by BMRCL:

The size of 33 KV cables used in Phase - I is 240 mm sq copper XLPE cables. The same will be adopted for Phase – II also.

Adequate no. of cables is required for transfer of power from TSS to third rail. Single phase XLPE insulated cables with 400mm² copper conductors are proposed for 750V dc as well as return current circuit. Based on current requirements, 3 cables are required for each of the four circuit to feed power to third rail.

The above capacities of transformers, cables etc. have been worked out based on the conceptual design and therefore, these capacities may be required to be fine tuned during design stage of project implementation.

7.4 AUXILIARY SUPPLY ARRANGEMENTS FOR STATIONS & DEPOT

Auxiliary sub-stations (ASS) are envisaged to be provided at each station. A separate ASS is required at each depot. The ASS will be located at mezzanine or platform level inside a room. Wherever TSS is required, ASS & TSS will be housed together inside a room. The auxiliary load requirements have been assessed to be about 500 kW for elevated/at-grade stations and accordingly two dry type cast resin transformers (33/0.415kV) of 630 kVA for elevated / at grade stations (with one transformer as standby) are proposed to be installed. Both the Depot ASSs will also be provided with 2 x 3000 kVA auxiliary transformers.

Note by BMRCL:

The capacity of transformers provided at depot at Phase-I are of 2 x 2000 KVA. So the capacity of the transformer at the depots in Phase-II will be finalized during the detailed design.



7.5 STANDBY DIESEL GENERATOR (DG) SETS

In the unlikely event of simultaneous tripping of all the four RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby DG set of 100 / 150 KVA capacity at elevated/at-grade stations to cater the following essential services:

- (i) Lift operation
- (ii) Essential lighting
- (iii) Signaling & telecommunications
- (iv) Fire fighting system.

Capacity may be fine tuned depending on S&T requirement for Interlock stations.

Silent types of DG sets are proposed which have low noise levels and do not require separate room for installation.

Note by BMRCL:

The capacity of DG set provided in Phase-I is of 180/200 KVA for elevated stations and the same could be retained in the Phase-II also.

7.6 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

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

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

7.7 EMERGENCY TRIP SYSTEM (ETS)

In underground portion of each corridor, Emergency Trip System (ETS) shall be provided at platform ends and cross-passages in accordance with the requirements of NFPA-130. ETS can be operated by passengers and metro staff in case of emergency situations to stop the train(s). Operation of ETS push button will result in tripping of relevant section of third rail in order to stop the trains in that section. ETS cable shall be fire rated for one hour at 500⁰ C.



7.8 STRAY CURRENT CORROSION PROTECTION MEASURES

7.8.1 Concept of dc Stray Current Corrosion

In dc traction systems, bulk of return current finds its path back to the traction sub-station via the return circuit i.e. running rails. The running rails are normally insulated to minimize leakage of currents to the track bed. However, due to leaky conditions, some current leakage takes place, which is known as 'stray current'. The current follows the path of least resistance. Return current deviates from its intended path if the resistance of the unintended path is lower than that of intended path. The stray current may flow through the unintended path of metallic reinforcements of the structure back to the sub-station. It is also possible that part of the stray current may also flow into soil, where it may be picked up by metallic utilities and discharged back to soil and then to near the sub-station.

The dc stray currents cause metal detraction in watery electrolytes as per the following chemical reactions:-

- Stray current enters in the metal
 $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$ (development of Hydrogen gas)
- Stray current exits from metal
 $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$ (Fe^{2+} ions migrate away from the metal)

7.8.2 That is how, dc stray currents cause corrosion of metallic structure where it leaves the metal. Pitting and general form of corrosion are most often encountered on dc electrified railways.

7.8.3 Effect of Corrosion

Detraction rate of metals can be calculated by Faraday's First Law:

m	=	c.i.t
Where m	=	mass (kg)
c	=	Coefficient of detraction (kg/Amp.year)
i	=	Current (Amp)
t	=	time (year)
c	=	2.90 for Aluminium
	=	33.80 for Lead
	=	9.13 for Iron
	=	10.4 for Copper

That means dc stray current of 1 – ampere flowing continuously can eat away approx. 9 kg of steel in a year. If 5000 amperes of current flows for one year to power the trains on a transit system, and that 2 percent of this current (100 amperes) leaks as stray current, the amount of steel metal loss is 0.9 ton per year. Therefore, the safety implications are considerable for structural reinforcements. In addition, corrosion may also affect neighboring infrastructure components such as buried pipelines and cables.



7.8.4 Measures for Protection against Stray Current Corrosion

Earthing & bonding and protection against stray current corrosion are inter-related and conflicting issues. Therefore, suitable measures are required to suppress the stray currents as well as the presence of high touch potentials. Safety of personnel is given preference even at a cost of slightly increased stray currents.

Following measures are required to restrict the stray current:-

- (i) Decreasing the resistance of rail-return circuit
- (ii) Increasing the resistance of rail to ground insulation

Whenever buried pipes and cables are in the vicinity of dc systems, efforts shall be made to ensure that metal parts are kept away as far as practicable to restrict stray current. A minimum distance of 1 meter has been found to be adequate for this purpose.

Generally, 3 types of earthing arrangements (viz. Earthed System, Floating System & Hybrid Earthing System) are prevalent on metros worldwide for protection against stray current corrosion. Traditionally, Earthed system was used by old metros. Hybrid earthing system is being tried on experimental basis on few new metros. Floating system has been extensively used by recent metros. As per the trends worldwide, floating system (i.e. traction system with floating negative) is proposed which reduces the dc stray current to considerable level. The arrangement shall comply with following latest CENELEC standards:-

- EN 50122-1:- Railway Applications (fixed installations) protective provisions relating to electrical safety & earthing
- EN 50122-2:- Railway Applications (fixed installations) protective provisions against the effects of stray currents caused by dc traction system

The conceptual scheme of proposed floating system is described below :-

- i) The running rails shall be adequately insulated as per EN50122-2. The recommended conductance per unit length for single track sections is 0.5 Siemens / Km for elevated section.
- ii) Stray Current Collector Cables {commonly known as structural earth (SE) cable} (2x200 mm² copper) shall be provided along the viaduct/tunnel and all the metallic parts of equipment, cable sheath, tunnel/viaduct reinforcement, signal post etc. shall be connected to SE cable.
- iii) The continuity of the reinforcement bars of the viaduct/tunnels as well as track slabs has to be ensured along with a tapping point for connection with SE cable in order to drain back the stray current.



- iv) A provision shall be made to earth the running rail (i.e. negative bus) in case of rail potential being higher than limits prescribed (120V) in relevant standard (EN 50122-1) in order to ensure safety of personnel. This will be achieved by providing track earthing panel (TEP) at stations close to platform and at traction sub-stations.
- v) In addition, provisions shall be made for connection of SE cable to negative return path through diode only for the purpose of periodical monitoring of stray currents. Under normal operations, switch provided for this connection will be in normally open (NO) position and switch will be closed for monitoring of stray current once or twice in a year as required.

7.8.5 Special Arrangements in Depot

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

The prescribed limit of highest touch potential in depot is 60V as per EN50122-1 and therefore Track Earthing Panels (TEP) shall be provided at suitable locations to earth the rail in case the rail potential exceeds this limit. In areas, where leaky conditions exist (e.g. washing lines, pit wheel lathe etc.), insulated rail joints (IRJ) shall be provided with power diodes to bridge the IRJ to facilitate passage of return current.

A detailed scheme may be developed during the detailed design stage keeping in view the experiences of Phase – 1.

Note by BMRCL:

The negative in depot DSS in Reach-1 is solidly earthed and there is no TEP and running rail is designed to be at earth potential always.

7.9 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

AC traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. However, dc traction currents do not cause electromagnetic induction effect resulting induced voltages and magnetic fields.



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The rectifier-transformer used in dc traction system produces harmonic voltages, which may cause interference to telecommunications and train control/protection systems. The rectifier-transformer shall be designed with the recommended limits of harmonic voltages, particularly the third and fifth harmonics. The proposed 12-pulse rectifier-transformer reduces the harmonics level considerably. Detailed specification of equipment e.g. power cables, rectifiers, transformer, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signaling & telecom, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMC plan will require to be developed during project implementation stage.

7.10 ENERGY SAVING MEASURES

Energy charges of any metro system constitute a substantial portion of operation & maintenance (O & M) costs. Therefore, it becomes imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement. The proposed system of Bangalore Metro includes the following energy saving features:

- (i) Modern rolling stock with 3-phase VVVF drive and light-weight stainless steel coaches has been proposed, which has the benefits of low specific energy consumption and almost unity power factor.
- (ii) Rolling stock has regeneration features and it is expected that 20% of total traction energy will be regenerated and fed back to 750V dc third rail 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 service escalators will be provided with 3-phase VVVF drive which gives energy efficiency & improved power factor. Further, the escalators will be provided with infra-red 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.

7.11 ELECTRIC POWER TARIFF

The electricity is the only source of energy for operation of the Metro system. The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of a metro system and it is expected to constitute about 25-35% of total annual working cost. Therefore, it is the key element for the financial viability of the Project. The annual energy consumption for **Option- 2** extension of N – S corridor is assessed to be about 12 million units in initial years (2016), which will 30 million units by horizon year 2041 and for extension of E – W corridor is assessed to be about 55.4 million units in initial years (2016), which will 96.1 million units by horizon year 2041. In addition to keep the energy consumption to optimum, it is also necessary that the electric power tariff be kept at minimum in order to contain the O& M costs. Therefore, the power tariff for Bangalore Metro should be at effective rate of purchase price (at 66kV voltage level) plus nominal administrative charges i.e. no profit no loss basis. This is expected to be in the range of Rs. 2.50-2.75 per unit. It is proposed that Government of Karnataka take necessary steps to fix power tariff for Bangalore 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.



Corridor - 1

Annexure-7.1

POWER REQUIREMENTS	BIEC to Hessarghatta					Puttenahalli Cross to Anjanapura Township				
	Year 2016	Year 2021	Year 2031	Year 2041	Year 2041	Year 2016	Year 2021	Year 2031	Year 2041	Year 2041
Traction power requirements										
No of cars	3 (2DTIC+1TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	3 (2DTIC+1TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)
Tare weight of train	104 T	204.0 T	204.0 T	204.0 T	204.0 T	104 T	204.0 T	204.0 T	204.0 T	204.0 T
Passenger weight	60 T	124.1 T	124.1 T	124.1 T	124.1 T	60 T	124.1 T	124.1 T	124.1 T	124.1 T
Total Train weight	164 T	328.1 T	328.1 T	328.1 T	328.1 T	164 T	328.1 T	328.1 T	328.1 T	328.1 T
Section length	3.82 KM	3.82 KM	3.82 KM	3.82 KM	3.82 KM	3.82 KM	3.82 KM	3.82 KM	3.82 KM	3.82 KM
Headway	7 mts	7 mts	6 mts	5 mts	5 mts	7 mts	7 mts	5 mts	5 mts	5 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
No. of trains/hr in both directions	17	17	20	24	24	17	17	20	24	24
Peak traction power requirement	0.8 MW	1.6 MW	1.9 MW	2.3 MW	2.3 MW	0.8 MW	1.5 MW	1.8 MW	2.1 MW	2.1 MW
Less Regeneration @20%	0.2 MW	0.3 MW	0.4 MW	0.5 MW	0.5 MW	0.2 MW	0.3 MW	0.4 MW	0.4 MW	0.4 MW
Depot Power requirement	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW
Net traction power requirement	0.6 MW	1.3 MW	1.5 MW	1.8 MW	1.8 MW	0.6 MW	1.2 MW	1.4 MW	1.7 MW	1.7 MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	0.7 MVA	1.4 MVA	1.7 MVA	2.0 MVA	2.0 MVA	0.7 MVA	1.4 MVA	1.6 MVA	1.9 MVA	1.9 MVA
Station aux power requirement										
Elevated/at-grade station	0.20 MW	0.25 MW	0.30 MW	0.50 MW	0.50 MW	0.20 MW	0.25 MW	0.30 MW	0.50 MW	0.50 MW
no. of elevated/at-grade stations	3	3	3	3	3	3	3	3	3	3
Total Station Aux Power requirement	0.6 MW	0.8 MW	0.9 MW	1.5 MW	1.5 MW	0.6 MW	1.3 MW	1.5 MW	2.5 MW	2.5 MW
Depot Aux power requirement	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW
Total Aux Power requirement	0.6 MW	0.8 MW	0.9 MW	1.5 MW	1.5 MW	0.6 MW	1.3 MW	1.5 MW	2.5 MW	2.5 MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	0.7 MVA	0.9 MVA	1.1 MVA	1.9 MVA	1.9 MVA	0.7 MVA	1.5 MVA	1.9 MVA	3.1 MVA	3.1 MVA
Total traction & aux power requirement (MW)	1.24 MW	2.04 MW	2.40 MW	3.30 MW	3.30 MW	1.61 MW	2.47 MW	2.93 MW	4.21 MW	4.21 MW
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	1.5 MVA	2.4 MVA	2.8 MVA	3.8 MVA	3.8 MVA	1.9 MVA	2.9 MVA	3.4 MVA	5.0 MVA	5.0 MVA

Note:- The requirement of PD load is not considering in estimation of power calculation.



Annexure-7.2

POWER REQUIREMENTS	Kengeri to Mysore Road Terminal					Byappanahalli to Whitefield						
	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	6 (2DMC+2M C+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2M C+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2 MC+2TC)	6 (2DMC+2M C+2TC)
Tare weight of train	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T	204.0 T
Passenger weight	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T	124.1 T
Total Train weight	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T	328.1 T
Section length	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM	6.18 KM
Headway	5.5 mts	4 mts	3 mts	3 mts	3 mts	3 mts	3 mts	3 mts	3 mts	3 mts	3 mts	3 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	22	30	40	40	40	40	40	40	40	40	40	40
Peak traction power requirement	3.3 MW	4.6 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW	6.1 MW
Less Regeneration @20%	0.7 MW	0.9 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW	1.2 MW
Depot Power requirement	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW
Net traction power requirement	2.7 MW	3.7 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW	4.9 MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	2.9 MVA	4.0 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA	5.4 MVA
Station aux power requirement												
Elevated/at-grade station	0.20 MW	0.25 MW	0.30 MW	0.50 MW	0.20 MW	0.20 MW	0.25 MW	0.20 MW	0.25 MW	0.30 MW	0.30 MW	0.50 MW
no. of elevated/at-grade stations	5	5	5	5	5	5	5	5	5	5	5	5
Total Station Aux Power requirement	1.0 MW	1.3 MW	1.5 MW	2.5 MW	1.0 MW	1.0 MW	1.3 MW	1.0 MW	1.3 MW	1.5 MW	1.5 MW	2.5 MW
Depot Aux power requirement	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW	0.0 MW
Total Aux Power requirement	1.0 MW	1.3 MW	1.5 MW	2.5 MW	1.0 MW	1.0 MW	1.3 MW	1.0 MW	1.3 MW	1.5 MW	1.5 MW	2.5 MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	1.2 MVA	1.5 MVA	1.9 MVA	3.1 MVA	1.2 MVA	1.2 MVA	1.5 MVA	1.2 MVA	1.5 MVA	1.9 MVA	1.9 MVA	3.1 MVA
Total traction & aux power requirement (MW)	3.65 MW	4.90 MW	6.37 MW	7.37 MW	3.65 MW	3.65 MW	4.90 MW	3.65 MW	4.90 MW	6.37 MW	6.37 MW	7.37 MW
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	4.2 MVA	5.6 MVA	7.2 MVA	8.5 MVA	4.2 MVA	4.2 MVA	5.6 MVA	4.2 MVA	5.6 MVA	7.2 MVA	7.2 MVA	8.5 MVA

Note:-

The requirement of PD load is not considering in estimation of power calculation.



Annexure - 7.3

KARNATAKA POWER TRANSMISSION CORPORATION LTD

MINUTES OF MEETING DT: 10-10-2010.

The Bangalore Metro Rail Corporation Ltd(BMRCL) is constructing North-South corridor between Hesarghatta to Puttenahalli station(23.19kms) and EAST - West corridor from Byappanahalli station to Mysore Road Terminal(17.37 kms).

BMRCCL is planning to extend the existing corridors and has commissioned Delhi Metro Rail Corporation (DMRCCL) for preparing DPF of metro links/extension to the existing corridors.

DMRCCL had requested for additional power requirements for the extensions. Hence the meeting between KPTCL, BMRCL and DMRCCL was convened at 3.30 P.M on 20-10-2010 in the Conference Hall-2, 2nd floor, KPTCL, Kaveri Bhavan to discuss and examine the issue of providing additional power supply to BMRCL.

Due to the above, the revised power requirements are as under:

Sl. No	Name of the Corridor	Power requirement of the existing corridor (MVA)		Revised Power requirement with extensions (MVA)	
		2014-15	2041	2014-15	2041
1	North-South corridor with extension on both sides	30.7	44.1	35.8	54.3
2	East-West corridor with extension on both sides	22.8	33.7	34.6	56.7

The Director (Transmission) KPTCL welcomed the Officers from BMRCL, DMRCCL and KPTCL to the meeting.

The following issues were discussed.

1.0 Baiyappanahalli-ITPL-Whitefield/Kadgudi Alignment.

It is agreed to cater power supply from the proposed EPIP park 220KV GIS station by providing two numbers of 66KV terminal bays at the proposed 220KV station which is already in the pipeline.

(a) **Action Required by Metro Authorities for Power supply requirement:**

- (1) To confirm the requirement of two numbers of 66KV terminal bays from the already planned (Design Under review) EPIP 220KV station for modification of GIS design.
- (2) To make payments to add two more 66KV terminal bays for which KPTCL would furnish the amount to be deposited.

(b) **Action Required by Metro Authorities for shifting of 220KV D/C ITPL Transmission line running on the proposed phase-2 Metro alignment:**



- (1) To confirm the requirement of conversion of 220KV D.C ITFL Transmission line running parallel to the proposed phase-2 Metro alignment to underground cable for making suitable changes in design in the planned (Design Under review) EPIP GIS 220KV station to accommodate two numbers of 220KV terminal bays.
- (2) To make payments to add two more 220KV terminal bays for which KPTCL would furnish the amount to be deposited.
- (3) Acquire additional land required for additional Bays.

2.0 Puttenhalli-Anjanapura layout Alignment.

It is agreed to make power supply available from the existing 66KV Khoday's factory substation where a 220/66kV sub station is planned to be constructed by KPTCL and providing two numbers of 66KV terminal bays.

(a) Action Required by Metro Authorities for Power supply requirement:

- (1) To confirm the requirement of two numbers of 66KV terminal bays from Khoday's 66KV substation by converting the existing 66KV station to 220KV station.
- (2) To pay for the construction of 66KV bays in the station.

3.0 Mysore Road Terminal - Kengeri / Kengeri satellite town Alignment.

It is agreed to make power supply available from the existing Vrishabhavathi 220KV substation by providing two numbers of 66KV terminal bays

(a) Action Required by Metro Authorities for Power supply requirement:

- 1) To confirm the requirement of two numbers of 66KV terminal bays from existing Vrishabhavathi 220KV substation by providing two numbers of 66KV terminal bays.
- 2) Initiate proposal to acquire additional land for locating the 66KV terminal bays.

4.0 IIM (Meenakshi Temple) - Nagvara Alignment.

It is agreed to make power supply available from the following stations:

- (i) Providing two numbers of 66KV terminal bays from the existing Nimhans 220KV sub station or Audugodi 66KV station.
- (ii) Providing two numbers of GIS 66KV terminal bays from the existing East Division compound 220KV GIS substation.
OR
- (iii) Providing two numbers 66KV terminal bays from the proposed Manyatha 220KV substation.

(a) Action Required by Metro Authorities for Power supply requirement:

- 1) To confirm the requirement of two numbers of 66KV terminal bays from the above stations
- 2) Agree to acquire additional land at Nimhans for locating the 66KV terminal bays.
- 3) Agree to provide the additional 66KV GIS modules at East division compound
- 4) To share the apportioned cost of installing 220/66KV station at Manyatha.

Follow up action may please be initiated immediately for effective planning and firming up of the power supply proposals made during the meeting by KPTCL.



Chapter 7 - Power Supply

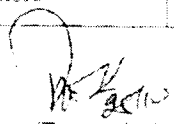
The action initiated may please be intimated for inclusion of proposals by KPTCL in its plan of actions, budget proposals and re-designing the projects which are already in the pipeline.

Advance measures by KPTCL to provide power supply to the Metro Project as requested at this stage are essential to avoid constraints at the time of actual power availability.

The meeting concluded with the Director(Transmission) thanking all the officers and requested DMRC/DMRCL/BMRCL to confirm the decisions taken in the meeting immediately to facilitate further action to provide additional power supply to BMRCL.

The following officers were present.

Sl.No	Name of the Officer Sriyuths.	Designation	Organization
1	S.Pratap Kumar	Director(Transmission)	KPTCL
2	M.Muniraju	Chief Engineer,Electy P&C	KPTCL
3	I. Sri Rama	Chief Electrical Engineer	DMRCL
4	Hanumantharayappa	Superintending Engineer(EI) Plg	KPTCL
5	Prasanna Kumar	Superintending Engineer(EI) Tech	KPTCL
6	Sharad Sharma	Executive Director EI	DMRCL
7	Syed Zubair Anamdar	Dy Chief Electrical Engineer (Trac)	BMRCL
8	Syed Nates Husseni	Dy Chief Electrical Engineer	BMRCL
9	Shivanna	EE(EI)-office, Transmission Zone, Bangalore	KPTCL
10	Gopala Krishna	EE(EI) MWND, TZ, Bangalore	KPTCL
11	Prahlad	EE(EI) MWSD, TZ, Bangalore	KPTCL


Director (Transmission)KPTCL

Memo No. KPTCL/CBE/P&C/KCO-88/25958 Dt. 28-10-2010.

Copies:-

- 1) The Chief Engineer Electy, Transmission Zone, Bangalore, KPTCL.
- 2) To all the officers concerned.

CHAPTER-8

SIGNALLING SYSTEM



CHAPTER 8

SIGNALLING SYSTEM

8.0 SIGNALLING

8.1 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.

8.2 Signalling and Train Control

8.2.1 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.



8.2.2 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.

(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.

(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.

8.2.3 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 Descriptor System	Automatic Train Supervision system. Movement of all trains to be logged on to a central computer and displayed on workstations in the Operational Control Centre and at the SCR. Remote control of stations from the OCC.



▪ 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.

8.3 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.

8.4 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 /

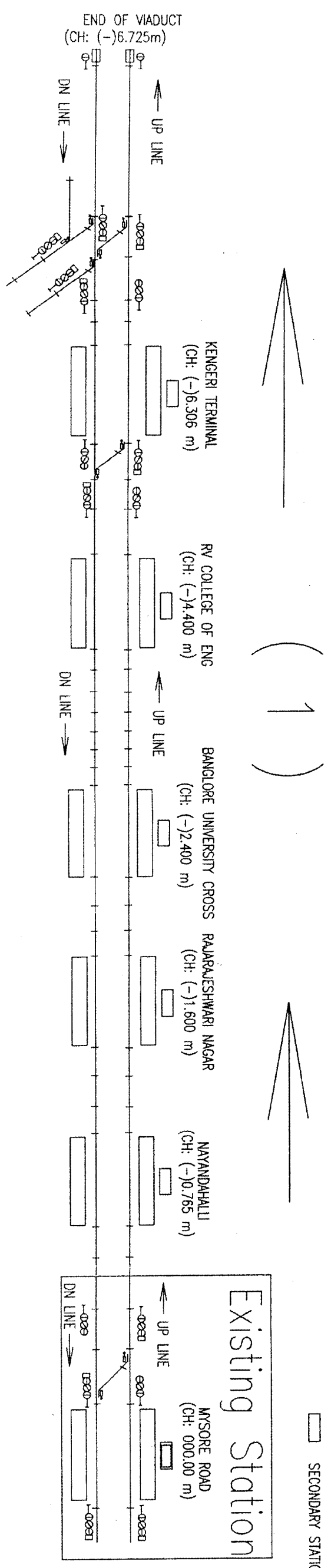


Chapter 8 – Signalling System

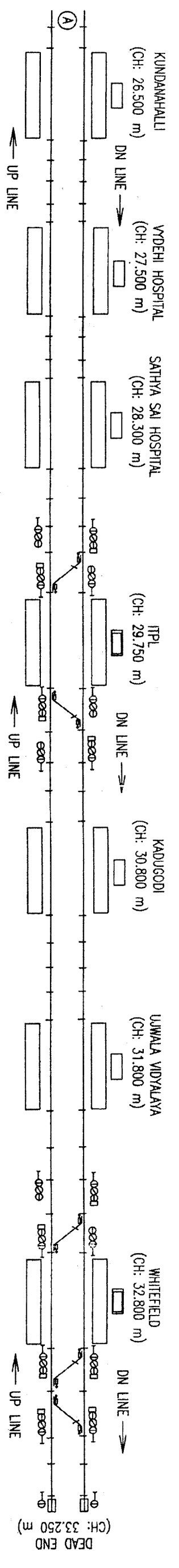
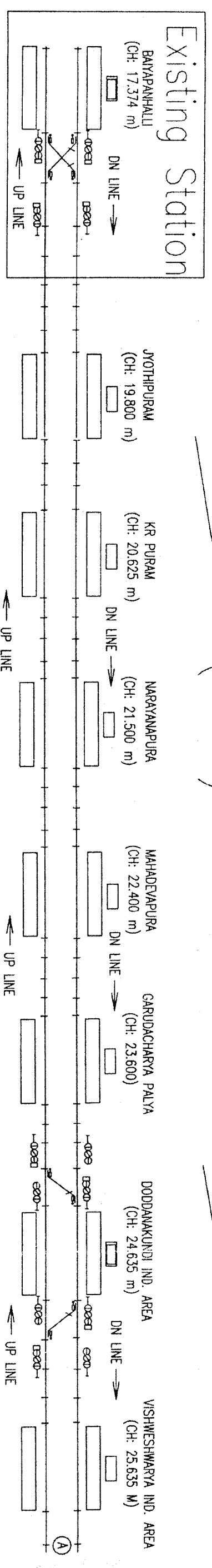
equipments requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

Signalling Scheme Plan of Bangalore Metro Rail Project

INTERLOCKED STATION
 SECONDARY STATION



(2)

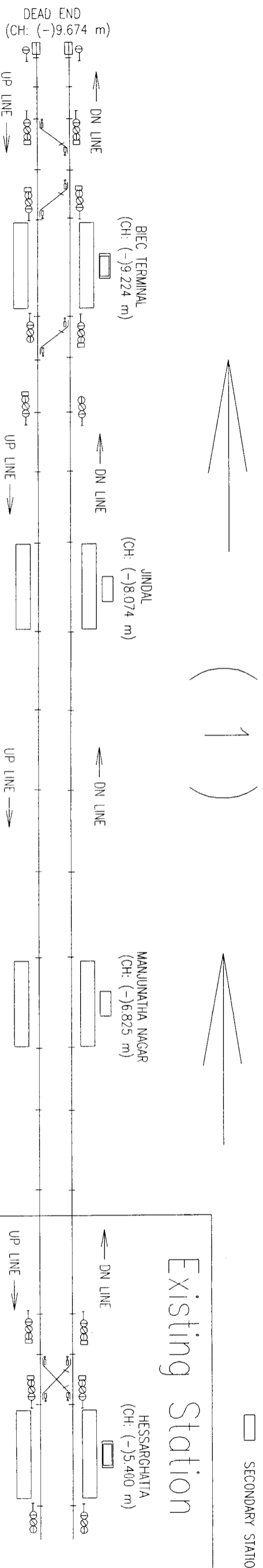


DELHI METRO RAIL CORPORATION LTD.
 CONCEPTUAL SIGNALLING SCHEME PLAN
 BANGALORE METRO PHASE -II, E-W CORRIDOR
 MYSORE ROAD - KENGERI TERMINAL
 (EXISTING STN) & TPL - WHITEFIELD CORRIDOR
 (EXISTING STN) BAYAPANAHALLI
 Drawn By Satish Kumar JE/Sig | Date 24th Sep 2010

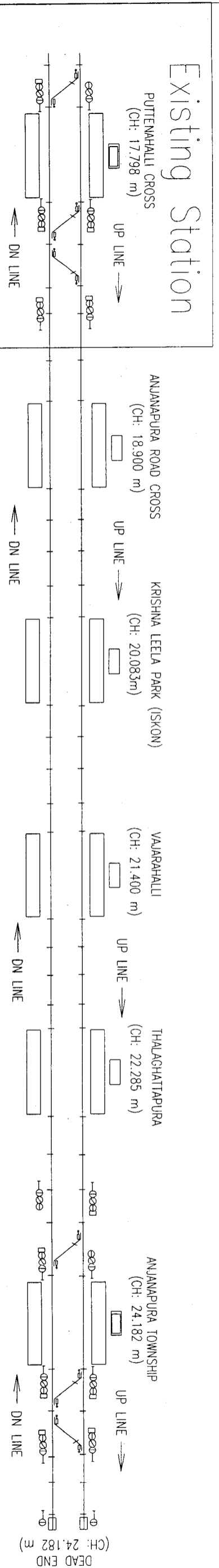


Signalling Scheme Plan of Bangalore Metro Rail Project

 INTERLOCKED STATION
 SECONDARY STATION



(2)



DELHI METRO RAIL CORPORATION LTD.
CONCEPTUAL SIGNALLING SCHEME PLAN
BANGALORE METRO PHASE -II, N-S CORRIDOR
HESSARGHATTA - MANJUNATHA NAGAR - BEC TERMINAL
(ORIGINAL)
PUTTENAHALLI CROSS-ANJANAPURA ROAD CROSS-ANJANAPURA TOWNSHIP
(ISSUE NO)
Drawn By Satish Kumar JE/Sig Date 24th Sep 2010

CHAPTER-9

**TELECOMMUNICATION &
AUTOMTIC FARE COLLECTION SYSTEM**



CHAPTER 9

TELECOMMUNICATIONS AND AUTOMATIC FARE COLLECTION SYSTEM

9.1 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.

9.2 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
- Integrated Passenger Announcement System and Passenger Information and Display System within the station and from Central Control to each station.
- Centralised 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.

9.3 TELECOMMUNICATION SYSTEM AND TRANSMISSION MEDIA

i) Fibre Optic System (FOTS) - Main Telecommunication Bearer

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a minimum 48 Fibre optical fiber cable is proposed to be laid in ring configuration with path diversity.



Minimum SDH STM-4 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. Further small routers and switches shall be provided for LAN network at stations. Alternatively a totally IP Based High Capacity, highly reliable and fault tolerant, MPLS Ethernet Network can be provided in lieu of SDH/MUX.

ii) Telephone Exchange

For an optimized cost effective solution Small exchanges of 30 port each shall be planned at each station and a 60 Port Exchange at the Terminal Stations shall be provided. The exchanges at OCC/Depot shall be of larger sizes as per the actual number of users. 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 minimum 8 logical 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. To provide adequate coverage, based on the RF site survey to be carried out, base stations for the system will be located at sites conveniently selected after detailed survey.

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 Roaming. The system shall provide instant mobile radio communication between the Train Operator of the moving cars from any place and the Central Control .The Train Operator can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

To provide adequate coverage, based on the RF site survey to be carried out during detailed Design stage, base stations for the system will be located at sites conveniently selected after detailed survey. As per initial survey for North-South Corridor including extension on both ends (BIEC- Hessarghatta- Puttenahalli- Anjanapura Township) 7 Base Station with a 40 m tower, for East-West Corridor upto ITPL (Kengeri- Mysore Road- Byappanahalli- ITPL) 8 Base Station with a 40 m tower including East –West Corridor upto Whitefield shall be required. During design stage, further Radio survey will need to be carried out, in case coverage is to be further improved



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 case of emergency announcements. The System shall be linked to Signalling System for automatic train actuated announcements.

v) 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 same MMI.

vi) Centralised Clock System

This will ensure an accurate display of time through a synchronization system of slave clocks driven from a Master Clock at the Operation Control Center. The Master Clock signal shall also be required for synchronization of 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.

vii) 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.

viii) 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.

ix) Standards

The standards proposed to be adopted for telecommunication systems are shown in **Table 9.1**:



TABLE 9.1

System	Standards
• Transmission System	SDH based for the entire telecom network.
• Transmission Media	Optical Fibre system as the main bearer for bulk of the telecommunication network,
• Telephone Exchange	EPABX of minimum 30 ports is to be provided at all Stations, an Exchange of 60 Ports to be provided at Terminal Station
• Train Radio System	Digital Train Radio (TETRA) communication between Train Operator of moving cars, stations, maintenance personnel and central control.
• 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's in the Base Stations, Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
• Environmental Conditions	All equipment rooms to be air-conditioned.
• Maintenance Philosophy	System to have, as far as possible, automatic switching facility to alternate routes/circuits in the event of failure. Philosophy of preventive checks of maintenance to be followed. System networked with NMS for diagnosing faults and co-ordination. Card/module level replacement shall be done in the field and repairs undertaken in the central laboratory/manufacture's premises.



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 Signal & Telecom equipment shall be generally 30 sq.m each for Telecom Room and 50 sq.m. for UPS Room (common for signal, telecom and AFC). 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 equipment 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 / equipment requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

9.4 AUTOMATIC FARE COLLECTION

9.4.1 INTRODUCTION

Metro Rail Systems handle large number of passengers. Ticket issue and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. In view of above, computer based automatic fare collection system is proposed.

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 chances of confrontation.
5. Almost 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 due to automatic ticket check by control gates.
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, including in other lines of the Metro.
8. AFC systems are the worldwide accepted systems for LRT/Metro environment.

The proposed ticketing system shall be of Contactless Smart Token/Card type. The equipment for the same shall be provided at each station Counter/Booking office and at convenient locations and will be connected to a local area network with a computer in the Station Master's room.

C) Choice of Control Gates

Retractable Flap Type/Paddle Type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern metros internationally. Tripod turnstile type gates offer less throughput 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.

9.4.2 Standards

The standard proposed for AFC systems are given in Table 9.2:

TABLE 9.2

Standards	Description
<ul style="list-style-type: none"> • Fare media 	<ol style="list-style-type: none"> a) Contactless smart token – For single journey. They shall have stored value amount for a particular journey. Tokens are captured at the exit gate. b) Contactless smart card – For multiple journeys.
<ul style="list-style-type: none"> • Gates 	<p>Computer controlled retractable flap type automatic gates at entry and exit. There will be following types of gates:</p> <ul style="list-style-type: none"> • Entry • Exit • Reversible (if required as per final station layout) – can be set to entry or exit • Reversible Handicapped Gate -gate for disabled people.



Standards	Description
<ul style="list-style-type: none">Station computer, Central computer and AFC Network	All the fare collection equipment shall be connected in a local area network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control 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">Ticket Office Machine (TOM/EFO)	Manned Ticket office machine shall be installed in the stations for selling tickets to the passengers.
<ul style="list-style-type: none">Ticket Reader (TR) and portable ticket decoder.	Ticket reader shall be installed near EFO for passengers to check information stored in the ticket.
<ul style="list-style-type: none">UPS (uninterrupted power at stations as well as for OCC).	Common UPS of S&T system will be utilized.
<ul style="list-style-type: none">Maintenance philosophy	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.

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



Chapter 9- Telecommunications and Automatic Fare Collection System

AFC Equipments Estimate for North South Corridor with Extension on both sides (projection for 2016 OPTION-I)												
S.No.	Station	Hourly Boarding	Hourly Alighting	Peak Min Boarding	Peak Min alighting	Gate		Disabled Gate	TOM	EFO	TR	TVM
						Entry	Exit					
BIEC to Anjanapura Township Option II												
1	BIEC Terminal	938	1006	19	20	2	2	1	2	2	4	2
2	Jindal	2301	1975	46	40	2	2	1	2	2	4	2
3	Manjunath Nagar	414	369	8	7	2	2	1	2	2	4	2
4	Hesarghatta Cross	1073	1107	21	22	2	2	1	2	2	4	2
5	T. Dasarahalli	3331	1847	67	37	2	2	1	3	2	4	2
6	Jalahalli	342	273	7	5	2	2	1	2	2	4	2
7	Peenya Ind Area	1301	3394	26	68	2	2	1	2	2	4	2
8	Peenya	226	264	5	5	2	2	1	2	2	4	2
9	Outer Ring Road	2088	2673	42	53	2	2	1	2	2	4	2
10	Yeshwantpur	1424	1848	28	37	2	2	1	2	2	4	2
11	Soap Factory	1968	1368	39	27	2	2	1	2	2	4	2
12	Mahalakshmi	561	690	11	14	2	2	1	2	2	4	2
13	Rajaji Nagar	1752	935	35	19	2	2	1	2	2	4	2
14	Kuvempu Road	2029	1093	41	22	2	2	1	2	2	4	2
15	Malleswaram	2904	1255	58	25	2	2	1	3	2	4	2
16	Swastik	989	967	20	19	2	2	1	2	2	4	2
17	Majestic	7441	8766	149	175	5	6	1	7	2	4	2
18	Chickpete	442	516	9	10	2	2	1	2	2	4	2
19	City Market	3039	1407	61	28	2	2	1	2	2	4	2
20	K R Road	1760	1300	35	26	2	2	1	2	2	4	2
21	Lal Bagh	1674	1940	33	39	2	2	1	2	2	4	2
22	South End Circle	433	550	9	11	2	2	1	2	2	4	2
23	Jayanagar	626	643	13	13	2	2	1	2	2	4	2
24	R V Road	263	1472	5	29	2	2	1	2	2	4	2
25	Banashankari	2326	3743	47	75	2	2	1	2	2	4	2
26	J P Nagar	2594	2436	52	49	2	2	1	3	2	4	2
27	Puttenahalli Cross	1272	911	25	18	2	2	1	2	2	4	2
28	Anjanapura Road Cross	1908	1286	38	26	2	2	1	2	2	4	2
29	Krishna Leela Park(ISKON)	1880	924	38	18	2	2	1	2	2	4	2
30	Vajarahalli	1067	804	21	16	2	2	1	2	2	4	2
31	Thalaghattapura	1897	2685	38	54	2	2	1	2	2	4	2
32	Anjanapura Township	1342	686	27	14	2	2	1	2	2	4	2
Total						67	68	32	72	64	128	64
Assumptions:												
1. 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.												
2. One Disabled gate at each station.												
3. Throughput of gate 30 passengers per minute, TOM 10 transactions per minutes.												
4. Peak hour traffic = 12% of day traffic. Peak Minute traffic = 2% of peak hour traffic.												
5. For Calculation purpose, It is assumed that 50 % passenger will use Smart Card.												



AFC Equipments Estimate for Bangalore Metro E-W Corr upto Whitefield (projection for 2016 opt II)											
S.No.	Station	Hourly Boarding	Hourly Alighting	Peak Min Boarding	Peak Min alighting	Gate		Dis abled Gate	TOM	EF O	TR
						Entry	Exit				
1	kengri teminal	3788	3371	76	67	4	4	2	4	4	8
2	RV College of engg	957	885	19	18	2	2	1	2	2	4
3	Banglore university cross	144	423	3	8	2	2	1	2	2	4
4	Rajarajeshwari Nagar	396	316	8	6	2	2	1	2	2	4
5	Nayanadahalli	402	450	8	9	2	2	1	2	2	4
6	Mysore Road Terminal	458	219	9	4	2	2	1	2	2	4
7	Deepanjali Nagar	2215	1291	44	26	2	2	1	2	2	4
8	Vijaya Nagar	186	484	4	10	2	2	1	2	2	4
9	Hosahalli	786	1011	16	20	2	2	1	2	2	4
10	Toll Gate	1725	1335	35	27	2	2	1	2	2	4
11	Magadi Road	1455	1011	29	20	2	2	1	2	2	4
12	City Railway Station	1010	603	20	12	2	2	1	2	2	4
13	Majestic	10581	8541	212	171	7	6	1	11	2	4
14	Central College	1109	965	22	19	2	2	1	2	2	4
15	Vidhan Soudha	823	1014	16	20	2	2	1	2	2	4
16	Cricket Stadium	286	1100	6	22	2	2	1	2	2	4
17	M G Road	2101	1621	42	32	2	2	1	2	2	4
18	Trinity Circle	1138	1229	23	25	2	2	1	2	2	4
19	Ulsoor	646	483	13	10	2	2	1	2	2	4
20	Indira Nagar	1490	1210	30	24	2	2	1	2	2	4
21	Old Madras Road	768	706	15	14	2	2	1	2	2	4
22	Byappanahalli	590	1130	12	23	2	2	1	2	2	4
23	Jyothipuram	1731	2557	35	51	2	2	1	2	2	4



24	K R Puram	838	2445	17	49	2	2	1	2	2	4
25	Narayanapura	773	912	15	18	2	2	1	2	2	4
26	Mahadevpura	1316	1151	26	23	2	2	1	2	2	4
27	Garudacharya Palya	219	234	4	5	2	2	1	2	2	4
28	Doddanakundi Ind Area	679	641	14	13	2	2	1	2	2	4
29	Vishweshwara Ind Area	191	672	4	13	2	2	1	2	2	4
30	Kundanahalli	155	123	3	2	2	2	1	2	2	4
31	Vydehi Hospital	908	1375	18	28	2	2	1	2	2	4
32	Sathya Sai Hospital	609	873	12	17	2	2	1	2	2	4
33	ITL	173	129	3	3	2	2	1	2	2	4
34	Kadugodi	440	701	9	14	2	2	1	2	2	4
35	Ujwala Vidyalaya	1169	1516	23	30	2	2	1	2	2	4
36	Whitefield	1023	1858	20	37	2	2	1	2	2	4
	Total					79	77	37	83	74	148

CHAPTER-10

TRAIN MAINTENANCE DEPOT



CHAPTER 10

TRAIN MAINTENANCE DEPOT

10.1 FOR ROLLING STOCK MAINTENANCE NEEDS

10.1.1 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

**10.1.2 Washing Needs of Rolling Stock**

Same as discussed vide Depot Chapters submitted earlier as referred in Para-1. The requirement of lines given in earlier Depot Chapters, are all inclusive.

10.2 (i) Year-wise planning of maintenance facility setup at depot-cum- workshop at Peenya and Byappanahalli is tabulated below as per TOP (option-2):

Year	North – South Corridor			East- West Corridor		
	Head way in minutes	No. of trains	No. of Coaches	Head way in minutes	No. of trains	No. of Coaches
2016	7.0	21 (3-Car) and 14 (6-Car)	147	5.5	32 (6-Car)	192
2021	7.0	35 (6-Car)	210	4.0	43 (6-Car)	258
2031	7.0	39 (6-Car)	234	3.0	56 (6-Car)	336
2041	5.0	47 (6-Car)	282	3.0	56 (6-Car)	336

However, as at Baiyappanahalli, the expansion of Depot to accommodate 50 rakes may not be possible, is planned to have satellite Depot at Kengeri. For North – South Corridor Peenya Depot has to be expanded for accommodating 47 rakes required in 2041

(ii) Average Earning/Day/Rake (19 hrs working)

Year	North – South Corridor		East- West Corridor		Remarks
	Earning/day/train (Kms)	Total trains	Earning/day/train (Kms)	Total trains	
2016	560	21 (3-Car) and 14 (6-Car)	Above 530	32 (6-Car)	i) 'A' inspection frequency after every 10 days
2021	Above 550	35 (6-Car)	520	43 (6-Car)	
2031	-do-	39 (6-Car)	-do-	56(6-Car)	ii) 'B' inspection frequency after every 30 days
2041	-do-	47 (6-Car)	-do-	56 (6-Car)	



(ii) Bare Requirement of Stabling and inspection lines:

North – South Corridor Requirement			East- West Corridor Requirement		
Year	SBL	IBL	Year	SBL	IBL
2016	(i) 21 lines X 3 Car or 11 lines X 6-Car and (ii) 11 lines X 6-Car	6 lines X 6- Car	2016	26 lines X 6-Car	6 lines X 6- Car
2021	29 lines X 6-Car	6 lines X 6- Car	2021	37 lines X 6-Car	6 lines X 6- Car
2031	33 lines X 6-Car	6 lines X 6- Car	2031	50 lines X 6-Car	-do-
2041	41 lines X 6-Car	-do-	2041	50 lines X 6-Car	-do-

10.3 Distribution of stabling lines at terminals:

Year	North – South Corridor Requirement				East- West Corridor Requirement			
	BIEC	Hesarg h-atta	Putte nhalli	Anjana- pura**	Byappan -ahalli	Mysore Road	Kenger i**	White Field
2016	2 lines X 3 Cars or 1 line x 6-Car	1 line X 6- Cars	1 line X 6- Cars	2 lines X 3 Cars or 1 line X 6-Car	1 line X 6- Cars	1 line X 6- Cars	2 lines X 6-Car	2 lines X 6-Car
2021	2 lines X 6-Car	-do-	-do-	2 lines X 6-Car	-do-	-do-	3 lines X 6- Cars	3 lines X 6- Cars
2031	-do-	-do-	-do-	-do-	2 lines X 6- Cars	2 lines X 6- Cars	3 lines X 6- Cars	3 lines X 6- Cars
2041	-do-	2 lines X 6-Car	2 lines X 6- Car	-do-	-do-	-do-	-do-	-do-

** The Stabling lines at Anjanapura and Kengeri should be increased from 2 lines X 6-Cars and 3 lines X 6-Cars to 6 lines X 6-Cars. Increased number of stabling lines at these terminals will ease morning train operation from these terminals. Present land availability will have to be reviewed for more rake stabilization at these terminals.

**10.4 Distribution of SBLs, IBLs and WSLs in Depot-cum-Workshops:**

Year	North – South Corridor (Peenya)			East- West Corridor (Byappanahalli)		
	Depot-cum-Workshop / Peenya			Depot-cum-Workshop / Byappanahalli		
	SBLs	IBLs	WSLs	SBLs	IBLs	WSLs
2016	18 lines X 6-Car + 1 line for Exigency	6 lines X 6- Cars	4 lines X 6- Cars	18 lines X 6-Car + 1 line for Exigency	6 lines X 6- Cars	4 lines X 6- Cars
2021	30 lines X 6-Car + 1 line for Exigency	6 lines X 6- Cars	-do-	23 lines X 6-Car + 1 line for Exigency	6 lines X 6- Cars	6 lines X 6- Cars
2031	34 lines X 6-Car + 1 line for Exigency	-do-	6 lines X 6- Cars	29 lines X 6-Car + 1 line for Exigency	-do-	6 lines X 6- Cars
2041	36 lines X 6-Car + 1 line for Exigency	-do-	-do-	36 lines X 6-Car + 1 line for Exigency	-do-	-do-

Note by BMRCL:

Depot capacity created at the end of Phase-I for East-West and North-South Corridor is as under.

(1) East – West Corridor – Baiyappanahalli Depot

Stabling lines – 6 each of 6 cars

Inspection bay - 3 each of 6 cars

Balance capacity for stabling and inspection has to be created at Kengeri.

Full fledged layout for Kengeri depot need to be developed during detailed design stage from the interim consultants to meet the operational requirements.

(2) North – South Corridor – Peenya Depot

Capacity created at Peenya Depot is

Stabling lines - 24 each of 6 car

**Inspection bay - 3 each of 6 car**

A satellite terminal depot needs to be developed at Anjanapur. According to the availability of land layout has to be developed for adequate stabling lines and inspection bay to meet the operational requirement.

Workshop facility shall be met from the existing workshop at Baiyappanahalli and Peenya.

10.5 (i) Requirement of Inspection lines at Peenya Depot-cum-Workshop:

Schedule	Maintenance Requirement (No. of Cars)	Lines Needed
i) Year 2016 - Maximum no. of rake holding is (21X3 +14X6) = 147 Cars		
'A' Checks (5000 km) 10 days	(21X3+14X6) =147 Cars	2 line x 6-Cars or (2 rakes of 3-Cars on each line)
'B' Checks (15000 km) 30 days	(21X3+14X6) =147 Cars	2 line x 6 Cars
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 line x 6 Cars
Requirement: Same as above		2 Bays of 3 lines each (one line for future use)
ii) Year 2021 - Maximum no. of rake holding is (35 X 6) Cars = 210 Cars		
'A' Checks (5000 km) 10 days	(35 X 6) Cars = 210 Cars	3 lines X 6 Cars (Sunken)
'B' Checks (15000 km) 30 days	(35 X 6) Cars = 210 Cars	2 lines X 6 Cars (Sunken)
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 lines X 6 Cars (Sunken)
Requirement: Same as above		2 Bays of 3 lines each
iii) Year 2031 (Maximum no. of rake holding is (39X6) Cars = 234 Cars		
'A' Checks (5000 km) 10 days	(39X6) Cars = 234 Cars	3 Line X 6 Cars
'B' Checks (15000 km) 30 days	(39X6) Cars = 234 Cars	2 Line X 6 Cars
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6 Cars (Sunken floor)
Requirement: Same as above		2 Bays of 3 lines each
iv) Year 2041 (Maximum no. of rake holding is (47X6) Cars = 282 Cars		
'A' Checks (5000 km)	(47X6) Cars = 282 Cars	3 Line X 6 Cars (Sunken



10 days		floor)
'B' Checks (15000 km) 30 days	(47X6) Cars = 282 Cars	2 Line X 6 Cars (Sunken floor)
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6 Cars (Sunken floor)
Requirement: Same as above		2 Bays of 3 lines each

(ii) Requirement of inspection lines at Byappanahalli Depot-cum-Workshop:

Schedule	Maintenance Requirement (No. of Cars)	Lines Needed
i) Year 2016 - Maximum no. of rake holding is (32X6) = 192 Cars		
'A' Checks (5000 km) 10 days	(33 X 6) Cars = 198 Cars	3 Line X 6 Cars (Sunken floor)
'B' Checks (15000 km) 30 days	(33 X 6) Cars = 198 Cars	2 Line X 6 Cars (Sunken floor)
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6 Cars (Sunken floor)
Requirement: Same as above		2 Bay of 3 lines each
ii) Year 2021 - Maximum no. of rake holding is (43 X 6) Cars = 258 Cars		
'A' Checks (5000 km) 10 days	(43X6) Cars = 258 Cars	3 Line X 6 Cars
'B' Checks (15000 km) 30 days	(43X6) Cars = 258 Cars	2 Line X 6 Cars
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6 Cars
Requirement: Same as above		2 Bays of 3 lines each
iii) Year 2031 (Maximum no. of rake holding is (56X6) Cars = 336 Cars		
'A' Checks (5000 km) 10 days	(56X6) Cars = 336 Cars	3 Line X 6 Cars
'B' Checks (15000 km) 30 days	(56X6) Cars = 336 Cars	2 Line X 6 Cars
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6 Cars
Requirement: Same as above		2 Bays of 3 lines each



iv) Year 2041 (Maximum no. of rake holding is (56X6) Cars = 336Cars		
'A' Checks (5000 km) 10 days	(56X6) Cars = 336 Cars	Same as above
'B' Checks (15000 km) 30 days	(56X6) Cars = 336 Cars	
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	
Requirement: Same as above		2 Bays of 3 lines each

(iii) Requirement of Additional Workshop lines visa-vis the provision made in Depot chapters already included in DPR:

Year	Depot-cum-Workshop / Peenya		Depot-cum-Workshop / Byappanahalli	
	Already Provided	Additional requirement	Already Provided	Additional requirement
2016	4 lines (2 Bays)	Nil	4 lines (2 Bays)	Nil
2021	6 lines (3 Bays)	Nil	4 lines (2 Bays)	Nil
2031	Not mentioned	2* lines (1 Bay)	Not mentioned	2 lines (1 Bay)
2041	Not mentioned	-do-	Not mentioned	-do-

(iv) Summary sheet of year wise requirement :

a) Provision of SBLs / IBLs / WSLs as per depot Chapters submitted earlier for North – South Corridor.:

Year	No. of rakes	At terminals		Depot –cum-Workshop / Peenya		
		Hassergata-Cross	R.V.Road	SBLs	IBLs	WSLs
Upto 2021	29 (3-Car)	2 Lines x 3-Car at each terminal	2 Lines x 3-Car at each terminal	11 Lines x 6-Car + 1 line for exigency	3 lines x 6-Car	4 lines X 6-Car
After 2021	29 (6-Car)	-do-	-do-	22 Lines x 6-Car + 1 line for exigency	-do-	4 lines X 6-Car with provision of expansion by 2 lines



b). *Year wise Additional lines required (over and above provisions of earlier DPR as tabulated at A above).

Year	Total no. of rakes	Terminals (SBL)				Depot-cum-Workshop / Peenya		
		BIEC	Hesar ghatta	Puttenh alli	Anjanapura	SBLs	IBLs	WSLs
2016	21X3-Car and 14X6-Car	1 line* x 6-Car	Nil (already provided)	1 line* X 6- Cars	1 line* X 6-Car	7 lines* X 6-Cars (11 lines already provided)	3 lines* X 6-Cars + (3 lines already provided)	-Nil- (4 lines already provided)
2021	35 X6-Car	1 line* X 6-Car	Nil	Nil	1 line* X 6-Car	1 line* X 6-Car (22 lines already provided)	Nil	-Nil-
2031	39 X6-Car	Nil	Nil	Nil	Nil	4 line* X 6-Car	Nil	2 lines* X 6- Cars
2041	47 X6-Car	Nil	1 line* X 6-Cars	1 line* X 6- Cars	Nil	2 lines* X 6-Cars	Nil	Nil
Total Additional Requirement		2 lines* X 6-Cars	1 line* X 6-Cars	2 lines* X 6-Cars	2 lines* X 6- Cars	14 lines* X 6- Cars	3 lines* X 6-Cars	2 lines* X 6- Cars

c). Provision of SBLs / IBLs / WSLs as per depot Chapters submitted earlier for East- West Corridor:

Year	No. of rakes	Terminals at		Depot-cum-Workshop / Byappanahalli		
		Mysore -Road	Byappanahalli	SBLs	IBLs	WSLs
Upto 2021	18 (3-Car)	2 lines X 3-Car at each	2 lines X 3-Car at each	16 lines x 6-Car	3 lines X 6-Car	4 lines X 6-Car
After 2021	27 (3-Car)	-do-	-do-	-do-	-do-	-do-

d) *Year wise Additional lines requirement of lines (over and above the provisions of earlier DPR as tabulated at C above).



Year	No. of Rakes	Terminals (SBLs)				Depot-cum-Workshop / Byappanahalli		
		Byappanahalli	Mysore Road	Kengri	White Field	SBLs	IBLs	WSLs
2016	22X3-Car + 11X6-Car	Nil (already provided)	Nil (already provided)	1 line* X 6- Cars	1 line* X 6- Car	2 lines* X 6- Cars (16 lines already provided)	3 lines* X 6- Cars + (3 lines already provided)	Nil (4 lines already provided)
2021	33 X6 -Car	Nil	Nil	1 line* X 6- Cars	1 line* X 6- Cars	5 lines* X 6- Cars	Nil	Nil
2031	43 X6 -Car	1 line* X 6- Cars	1 line* X 6- Cars	1 line* X 6- Cars	1 line* X 6- Cars	6 lines* X 6- Cars	Nil	2 lines* X 6- Cars
2041	50 X6 -Car	Nil	Nil	Nil	Nil	7 lines* X 6- Cars	Nil	Nil
Total Additional Requirement		1 line* X 6- Cars	1 line* X 6- Cars	3 lines* X 6- Cars	3 lines* X 6- Cars	20 lines* X 6- Cars	3 lines* X 6- Cars	2 lines* X 6- Cars

Note: For exercising the requirements of TOP (option-2), there shall be no change in line requirement for N-S corridor while for East-West corridor year-wise additional requirement of SBLs in Byappanahalli Depot shall be as indicated below:

Year	Additional requirement of SBLs
2016	Nil
2021	4 lines X 6-Car
2031	5 lines X 6-Car
2041	5 lines X 6-Car



10.6 Provision of Infrastructure Facilities both at Peenya and Byappanahalli Depot-cum-Workshops:

I. Inspection Sheds

- (a) As indicated in Paras 11.2 (ii), 11.4 and 11.5.
- (b) The length of Inspection lines, Workshop lines shall be 159 mtrs. (Say 160m) and Inspection / Maintenance / Overhaul / Repair scheduled shall be done as indicated in earlier DPR. The A & B inspections shall be carried out at a frequency of 10 days and 30 days respectively keeping in view the average Km Earning /Train.

II. Stabling Lines in Depots

- a) The length of stabling lines shall be of the order of 160 mtrs.
- b) The requirement of lines shall be in accordance with the table indicated at Paras 11.2(ii), 11.3 and 11.4. 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.
- c) 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. Workshop lines

As per Tables given in Para 11.5(iii).

IV. 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 throughput 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.

V. 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.



VI. Test Track

A test track of 1000m in length covered & fenced is provided beside workshop in the depot. It shall be equipped with signaling equipments (ATP/ATO). It shall be used for the commissioning of the new trains, their trials and testing of the trains after the IOH and POH. Entry into the test track shall be planned for a 6 Car train. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized tress passing across or along the track.

VII. 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.

VIII. 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.

IX. 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.

X. 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.

XI. 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.

XII. Watch Towers

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

XIII. 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.

XIV. Parking Facilities

- a) 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.
 - iii. Close to repair bay.
- b) Space for parking of road vehicles and re-railing equipments.

Since IOH/POH of equipments of Extension line has to be done at Peenya Village and Byappanahalli Depot –cum-Workshop, a lot of road transport will have to be utilized. Both the depots need to have enough space for parking of Road vehicles. Enough space will also have to be earmarked adjacent to workshop and repair bay. Similarly provision of space for parking of re-railing equipments will have to be made close to the main exit gate of the Depots.



XV. 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.

XVI. 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.

10.7 Requirement of buildings and major plants and machinery, is given at Annexure I and II for Peenya and Byappanahalli Depots (Independently for each Depot) respectively:

Following Safety features should be incorporated in the design of all the Maintenance Depots

- a) Access to the under-carriages should be interlocked with 3rd rail supply system so that inspection of under carriage is possible. Only when Supply is isolated and grounded.
- b) Red flashers lights should be installed along the inspection lines at conspicuous location to indicate the 3rd rail supply is 'Live'.
- c) Multi level wheel and TM stacking arrangement should be a inbuilt feature at the end of Heavy repair bay.
- 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 inspection platform only after the traction supply is isolated.
- 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.

Both the depot and depot-cum-workshop will have all the facilities shown above.

Annexure-I

List of Buildings at Depot at Peenya and Byappanahalli (independently for each depot)

S.No.	Name of Building	Size	Brief Function
1.	Inspection Shed	160 x 40 m	Servicing of Cars for 10 days & 30 days inspection.
	Workshop* at Peenya	160 x 84 m	i) Lifting of cars for unit replacement of repaired bogies, wheels, under hung electric and mechanical equipments. ii) IOH/POH
	Workshop at Byappanahalli	160 X 63 m	
	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	i. Stocking of spares for regular & emergency requirement including consumable items. ii. This store caters for the requirement of depot for rolling stock & other disciplines. iii. To be provided with computerized inventory control. iv. Loading/unloading of material received by road.
3.	Elect. Sub-station DG set room	25 x 22 m	To cater for normal and emergency power supply for depot, workshop, service and all other ancillary buildings, essential power supply essential loads and security light.



4.	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	60 x 6 m 40 x 6 m 40 x 10 m	i. Close to the depot entry. ii. Close to the stabling lines. iii. Close to the repair bay.
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	130 x 6.5m	Heavy wet washing of rakes from inside, under frame, roof at 30 days interval.
8.	P.way office, store & Workshop including Welding plant	80 x 20m	i. For track maintenance of section and depot. ii. To weld rails for construction period only. iii. To stable track Tamping machine.
9.	Security office & time office garages (4 Nos.)	15 x 8m	i. For security personnel. ii. For time punching. iii. For parking vehicle jeep, truck etc.
10.	Check post (2 Nos.)	5 x 3m	For security check of incoming/outgoing staff, material and coaches.
11.	Watch tower (3 Nos.)	3.5 x 2.5m	For security of the depot especially during night time.
12.	Depot control 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)	10 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.
		10 x 7m	

*Workshop Shed at Peenya shall be of the size 160m X 84m because IOH/POH of trains for extension lines of Noth-South corridor (R.V.Road – Electronic City).

Annexure-II

List of Plants & Equipments at Peenya and Byappanahalli (independently for each depot)

S.No.	Equipment
1	Under floor Pit wheel lathe suitable for inside face to face turning, Chip crusher and conveyor for lathe on pit, Electric tractor for movement over under floor wheel lathe
2	Mobile jacks 15T for lifting cars
3	Pit jacks (complete set on one line)
4	Re-railing equipment consisting of rail cum road vehicle and associated jack system etc.
5	Run through type Automatic Washing plant for Metro cars.
6	Work lift platform
7	Electric bogie tractor for pulling cars and bogies inside workshop
8	Chemical cleaning tanks, ultrasonic cleaning tanks, etc
9	Compressor for Inspection shed & shop air supply
10	Travelling O/H crane repair-shop 15 T:- 2 Nos; 3 T :- 2 Nos



11	Mobile jib crane
12	Mobile lifting table
13	Car body stands
14	Bogie turn tables
15	Under frame & Bogie blowing plant
16	AC filter cleaning machine
17	Portable cleaning plant for rolling stock
18	High-pressure washing pump for front and rear end cleaning of car
19	Shot blast cleaner
20	Axle shaft inspection station
21	Industrial furniture
22	Minor equipment and collective tools
23	Induction heater
24	Oven for the motors
25	EMU battery charger
26	Welding equipments (Mobile welding, oxyacetylene, fixed arc welding)
27	Electric and pneumatic tools
28	Measuring and testing equipment
29	Tool kits
30	Mobile safety steps
31	Fork lift tractor
32	Pallet trucks
33	Diesel/battery Shunting Locomotive
34	Road vehicles (pickup van/ truck)



Chapter 10 - Train Maintenance Depot

35	Miscellaneous office equipments
36	Special jigs and fixtures and test benches for Rolling Stock
37	Battery operated rail-cum-road shunter with suitable coupler

The requirement of SBLs, IBLs and WSLs at Kengeri is given in annexure to this chapter .The depot plan of Kengeri with 21 stabling lines, 4 IBLs and 2 WSLs has been done and put up in the end of this chapter.



DMRC/134/11/RS2/1520/3009

23rd July 2011

Note

Sub. : Revised line requirement for Bangalore Metro Phase-II (East- West corridor).

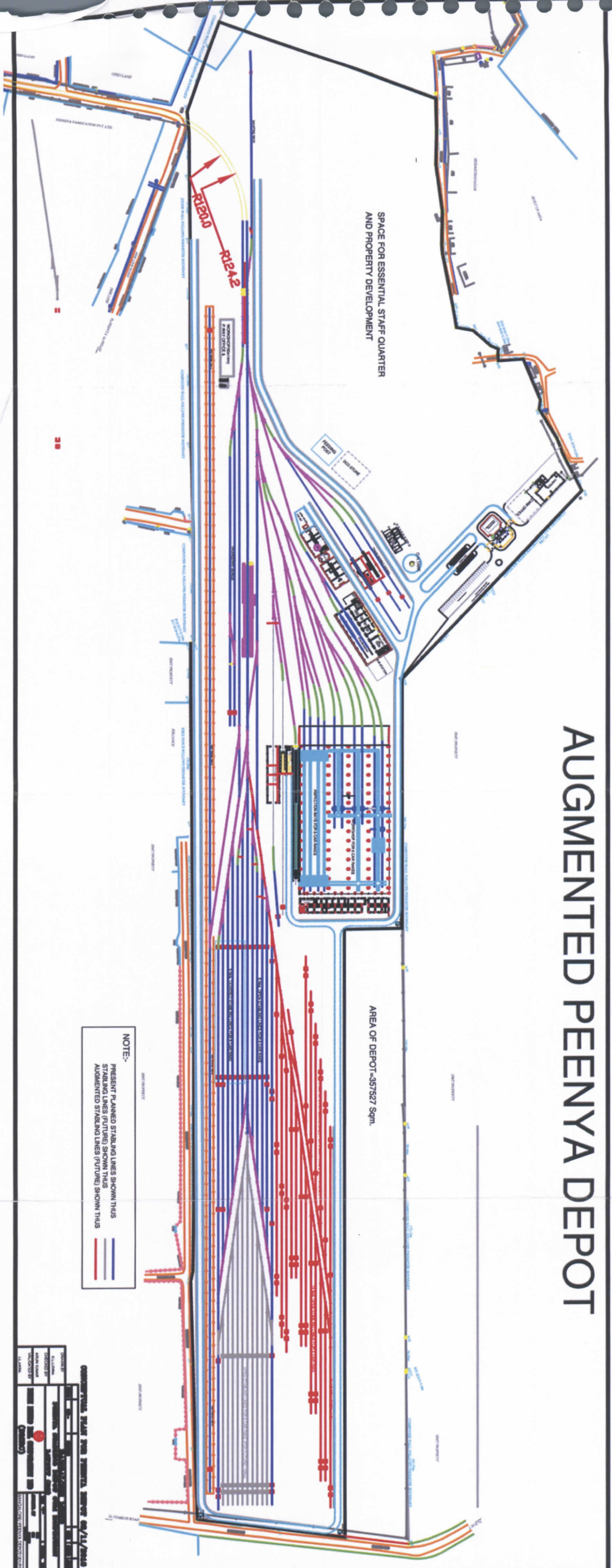
Revised Requirement of SBLs / IBLs as per revised rake requirements is as under. This supersedes the requirement of SBLs / IBLs shown in Depot Chapter advised vide DMRC/134/RS2/11/1520/2688 dtd. 31.03.11 in respect of earlier rake requirement.

At Byanappahalli Depot					To be provided at Kingri Depot		
Year	No. of Train	SBLs	IBLs	WSLs	SBLs	IBLs	WSLs
2016	32 X 6-car	16 lines X 6-car	3 lines X 6-car	4 lines X 6-car	14 lines X 6-car	2 lines X 6-car	4 lines X 6-car
2021	43 X 6-car	-do-	-do-	-do-	22 lines x 6-car	4 lines X 6-car	4 lines X 6-car
2031	56 X 6-car	-do-	-do-	-do-	35 lines x 6-car	-do-	4 lines X 6-car with provision for expansion by one bay of 2-lines
2041	-do-	-do-	-do-	-do-	-do-	-do-	-do-

S. Sandeep
SEE/RS 23/7/11

CEE/RS-I: *[Signature]*

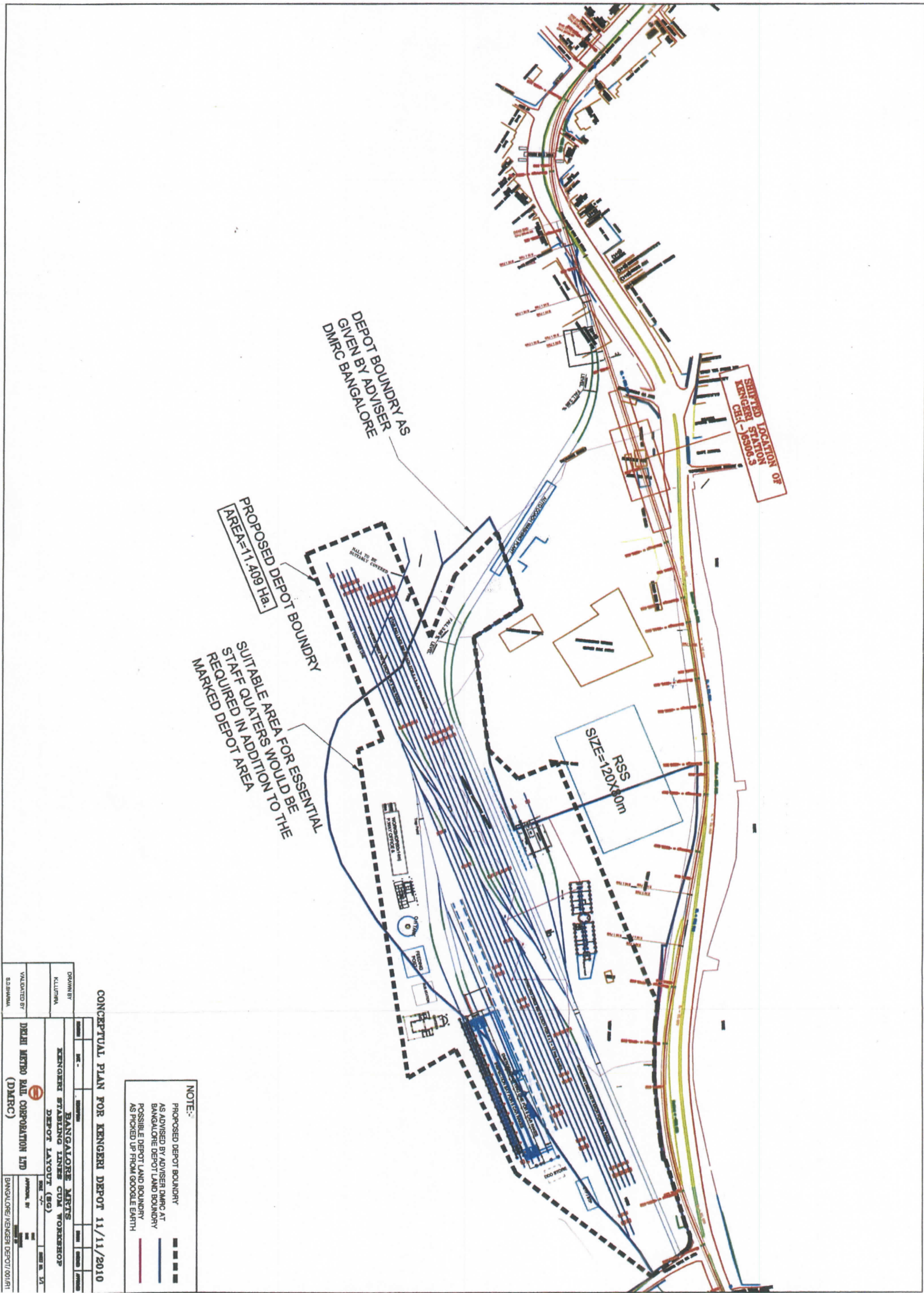
AUGMENTED PEENYA DEPOT



NOTE:-
 PRESENT PLANNED STABLING LINES SHOWN IN THIS
 STABLING LINES (FUTURE) SHOWN IN RED
 AUGMENTED STABLING LINES (FUTURE) SHOWN IN GREEN

CONSTRUCTION STAGE FROM INITIAL STAGE 04/11/2018

NO.	DESCRIPTION	STATUS	DATE
1	Site Preparation	Completed	04/11/2018
2	Foundation Work	In Progress	05/11/2018
3	Structural Framework	Not Started	06/11/2018
4	Roofing	Not Started	07/11/2018
5	Interior Finishes	Not Started	08/11/2018
6	External Works	Not Started	09/11/2018
7	Final Inspection	Not Started	10/11/2018



DEPOT BOUNDRY AS GIVEN BY ADVISER DMRC BANGALORE

PROPOSED DEPOT BOUNDRY AREA=11.409 Ha.

SUITABLE AREA FOR ESSENTIAL STAFF QUARTERS WOULD BE REQUIRED IN ADDITION TO THE MARKED DEPOT AREA

RSS SIZE=120X300m

SUITABLE LOCATION OF KENGERI STATION KENGERI CEF - 65906.3

NOTE:-
 ■■■■ PROPOSED DEPOT BOUNDRY
 ■■■■ AS ADVISED BY ADVISER DMRC AT BANGALORE DEPOT LAND BOUNDRY
 ■■■■ POSSIBLE DEPOT LAND BOUNDRY AS PICKED UP FROM GOOGLE EARTH

CONCEPTUAL PLAN FOR KENGERI DEPOT 11/11/2010

DESIGNED BY	K. LALITHA	APPROVED BY	[Signature]
VALIDATED BY	S. S. SHANMUGA	DATE	11/11/2010
BANGALORE METRO RAIL CORPORATION LTD (DMRC)		BANGALORE/KENGERI DEPOT/001/R1	
KENGERI STAGING LINES CUM WORKSHOP DEPOT LAYOUT (SG)			
SCALE	1:1000	DATE	11/11/2010

CHAPTER-11

**ENVIORNMENT & SOCIAL
IMPACT ASSESSMENT**



CHAPTER 11

ENVIRONMENTAL IMPACT ASSESSMENT

11.1.1 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, drainage 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 existing transportation systems are not sufficient to meet the need of the commuters. Public transport system which is widely used in our city is also not able to keep pace with the rapid and substantial increase in the transportation demand and it is very much essential to resolve the vital problems of the city. Hence an extension of the Bangalore Metro Phase I and a second new North South alignment is considered by Delhi Metro Rail Corporation (DMRC) in Phase II.

11.1.2 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.



11.1.3 Project Description

Bangalore Metro Phase II consist of the following corridors which are the extensions of Phase I alignments :

1. East –West Corridor Extensions

a. Mysore Road Terminal – Kengeri

The proposed extension route is 6.465 km starting from Mysore Road Terminal to Kengeri and one future station.. Entire alignment is elevated with 5 stations. The alignment runs on Mysore Road connecting many populated areas such as Nayandahalli Bus Stop, Rajarajeshwari Nagar, Bangalore University, RV Engineering College and terminating at Kengeri on Mysore Road.

b. Byappanahalli – ITPL – Whitefield

- **Byappanahalli – ITPL:** The proposed extension route is 12.45 km starting from Byappanahalli to ITPL via Doddanekkundi Industrial Estate. Entire alignment is elevated with 11 stations. The alignment runs on Whitefield Road, Graphite India Road, ITPL Main Road connecting many populated areas such as Benniganahalli, K.R. Puram, B.Narayanapura, Mahadevapura, Doddanekkundi Industrial area, Graphite India, EPIP Zone, Sri Sathya Sai Hospital and terminating at ITPL.
- **ITPL – Whitefield:** It is further planned to extend Byappanahalli to ITPL alignment till Whitefield (Kadugudi bus stop) via Hope Farm Junction with a distance of 3.05 km and this may be the Stage II extension.

2. North –South Corridor Extensions

a. Hessarghatta Cross – BIEC

The proposed extension route is 3.77 km starting from Hessarghatta Cross (8th Mile) to BIEC via Tumkur Road. Entire alignment is elevated with 3 stations. The alignment runs along the Tumkur Road (NH-4) connecting many populated areas such as Chikkabidarakallu, Anchepalya, Madanayakahalli and terminating at Bangalore International Exhibition Center (BIEC) on Tumkur Road.

b. Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)

The proposed extension route is 6.29 km starting from Puttenahalli Cross to Anjanapura Township (up to NICE road crossing). Entire alignment is elevated with 5 stations. The alignment runs on Kanakapura Road and Amruth Nagar Main Road connecting many populated areas such as Doddakallasandra, Talaghattapura on Kanakapura Road and terminates at NICE Road Junction.

The salient features of the proposed extensions of phase I alignments are given in **Table 11.1**.



Table 11.1: Important salient features of proposed alignments

Salient Features	Mysore Road Terminal to Kengeri	Byappanahalli - ITPL-Whitefield	Hesaraghatta cross to BIEC	Puttenahalli to NICE Road Junction
Length of the alignment	6.5 Km	11.50 + 02.72 km	3.044 km	6 km
Nature of alignment	Elevated – 6.5 km	Elevated – 14.22 km	Elevated – 3.04 km	Elevated – 6 km
Number of stations	5 (Elevated)	11 + 03 (Elevated)	3 (Elevated)	5 (Elevated)
Right of Way		20		
Project implementation				
- Start Date		2013		
- Completion Date		2018		
Rail capacity		2000 passenger/trip (6 coach)		
Frequency		1 train for every 4 minutes (Peak hours)		
Connecting Areas	Pantharapalya, Nayandahalli, Raja Rajeshwari Nagar, Jnana Bharathi and Kengeri	CV Raman Nagar, KR Puram, Narayanapura, Mahadevpura, Garudachar Paiya, Doddanekkundi Industrial Area, EPIP Zone, Whitefield, ITPL and Kadugodi	Hesaraghatta Cross (8 th Mile) to BIEC connecting Defence colony, Rukmini Nagar, Chikka Bidarkal, Anchepalya, Madanayakanahalli	JP Nagar, Sarakki, Jaraganahalli, Konanakunte, Dodda Kalsandra, Talaghattapura
Industry/Companies along the proposed alignment	BWSSB, SICGIL India Ltd, , TATA motors, VRL travels and Britannia Industries	Tin Factory, BESCOM, IFB Automotive Pvt Ltd, Graphite India, Perot System, SAP Labs, KTPO, DELL, SJR IT Park, TCS, ITPL and Brigade Tech Park	Karle International, Parle G Factory, Kennametal, J.L.Morison, Jindal Aluminium Ltd	Cauvery Motors, TVS Coco, Trident Hundai, Khodays Breweries, JSM International Ltd, CIPLA Pvt.
Educational Institutions along the proposed alignment	Bangalore Institute of Management Studies, Bangalore University and RV College of Engineering	Government Middle School, Brigade School, ABB India Corporate & Research Center and Gopalan International School	Chikkabidarakallu Govt School, Jindal School, Bhoruka school, Nadigar Institute of Engineering	Yellama Dasappa Institute of Technology, Sri Siddaganga Rural School, K.S. Institute of Technology, Jyothi Kendriya Vidyalaya, Govt. Middle School, Jnana



Salient Features	Mysore Road Terminal to Kengeri	Byappanahalli - ITPL-Whitefield	Hesaraghatta cross to BIEC	Puttenahalli to NICE Road Junction
Hospitals along the proposed alignment	Sanjeev Nursing Home, Sri Vinayaka Hospital and BGS Global Hospital	Sri Ramakrishna Poly clinic and Diagnostics and Shri Satya Saibaba Hospital	Manav Charitable Hospital	Siddalingappa Memorial Hospital
Flyover along the alignment	Touching Kengeri Satellite Town flyover	KR Puram bridge	NH4 elevated road running parallel	-----
Major road approach the alignment	Outer ring road, Bangalore University Road, Uttarahalli Main Road and Kengeri Satellite Town ring road	Varthur road, Outer Ring Road, Old Madras Road	Handrihalli Main Road Chikka Bidarakala Main Road	NICE Road, Amruthnagar Main Road, Vasanthpur Main Road, Chunchgatta Main Road,

**TABLE 11.2: STATIONS IN THE PROPOSED ALIGNMENTS**

Sl.No.	Station Name	Chainage (m)	Type
East – West Corridor			
Mysore Road Terminal – Kengeri			
1	Nayandanahalli	765	Elevated
2	Rajarajeshwari Nagar	1600	Elevated
3	Bangalore University	2400	Elevated
4	R V College of Engg	4400	Elevated
5	Kengeri	6.306	Elevated
Byappanahalli – ITPL – Whitefield			
Byappanahalli – ITPL			
1	Jyothipuram	19800	Elevated
2	KR Puram	20625	Elevated
3	Narayanpura	21500	Elevated
4	Mahadevpura	22400	Elevated
5	Garudacharpalya	23600	Elevated
6	Doddanekkundi Industrial Area	24635	Elevated
7	Vishweshwaraya Ind. Area	25635	Elevated
8	Kundalahalli	26500	Elevated
9	Vaidehi Hospital	27500	Elevated
10	Satya Sai Hospital	28300	Elevated
11	ITPL Terminal	29750	Elevated
ITPL-Whitefield			
12	Kadugodi	30800	Elevated
13	Ujval Vidyalaya	31800	Elevated
14	Whitefield	32800	Elevated
North – South Corridor			
Hessarghatta Cross – BIEC			
1	Manjunath Nagar	6825	Elevated
2	Jindal Metro Station	8074	Elevated
3	BIEC Station	9224	Elevated
Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)			
1	Anjanapura Road	18900	Elevated
2	Krishna Leela Park	20083	Elevated
3	Vajarahalli	21400	Elevated
4	Talaghattapura	22285	Elevated
5	Anjanapura Township	24182	Elevated

11.1.4 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

11.2 ENVIRONMENTAL BASELINE STUDIES

11.2.1 Meteorological Data

Meteorological data has been collected from Indian Meteorological Data Centre (IMD), Bangalore. The data recorded reveals that, the total annual rainfall in year 2008 is about 1286.6 mm. The annual maximum temperature ranges from 27.3°C to 34.1°C and minimum temperature ranges from 16.1°C to 21.6°C. The highest humidity of 89% was recorded during the month of August, while the lowest of about 69% was recorded during the month of March.

The wind rose diagrams available for the period 1976 – 1994 shows that easterly winds dominated over the months of December, January and February while, the westerly winds dominated over the months of May to July. The wind rose diagrams are given for day and night observations in Figure 7.1 and Figure 7.2. 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.



Figure 11.1: Wind rose diagram for Bangalore city (morning observations)

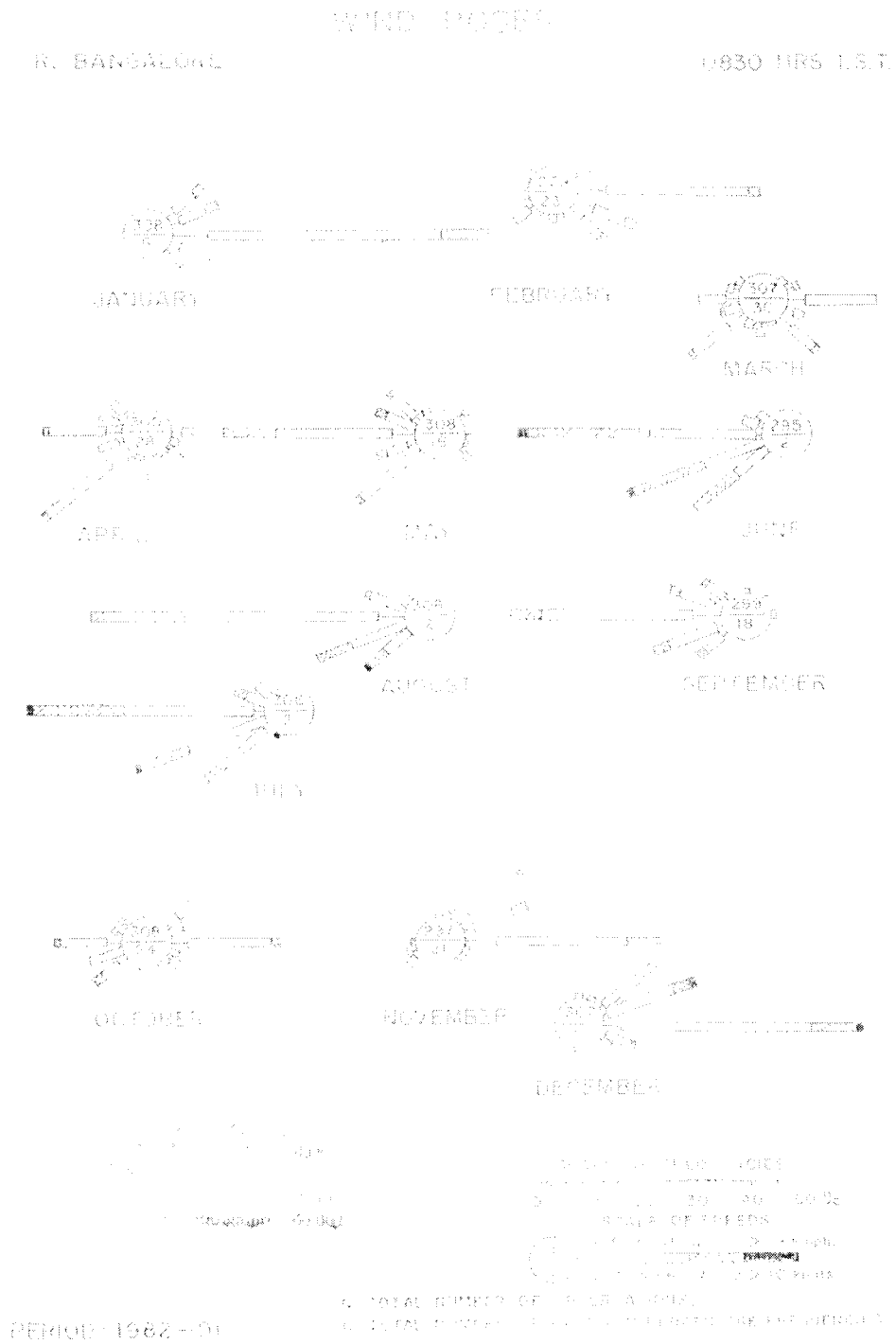
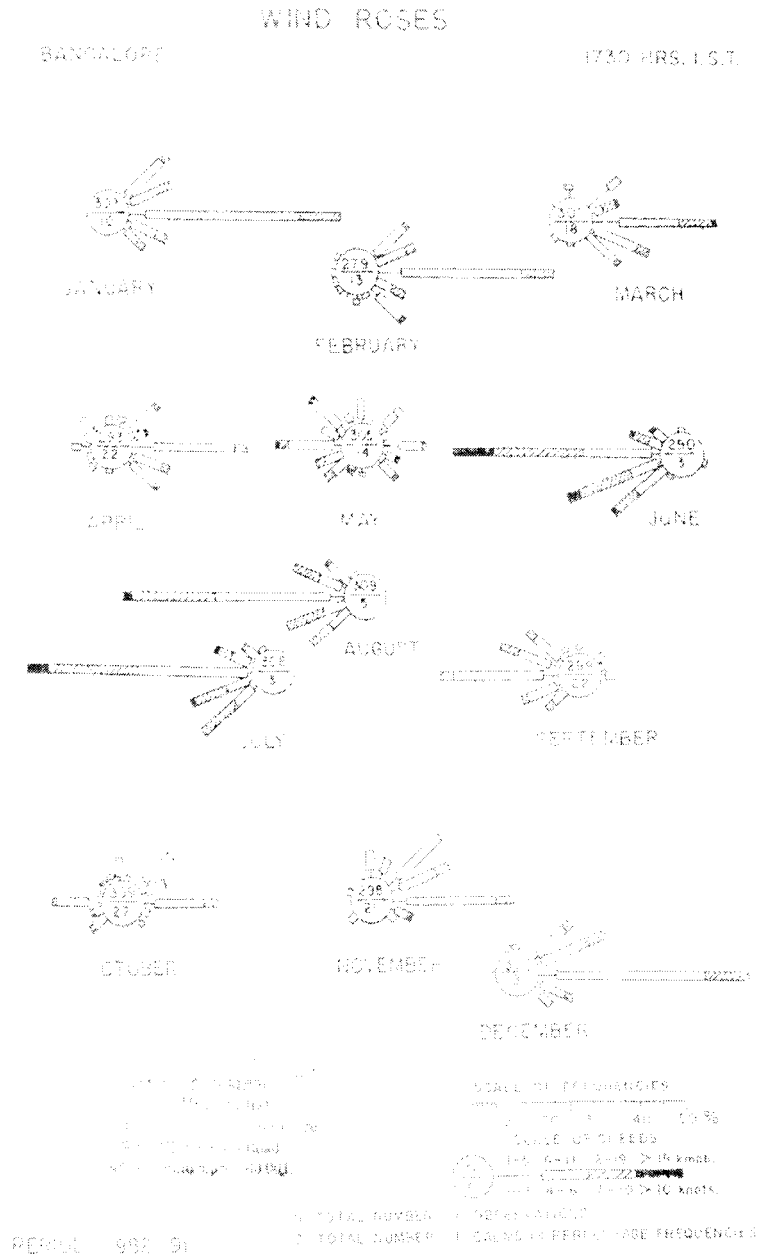




Figure 11.2: Wind rose diagram for Bangalore city (morning observations)



11.2.2 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 (SO₂), Oxides of Nitrogen (NO_x) and Carbon Monoxide (CO).

Respirable Dust Sampler 460 BL was deployed to monitor RPM, SPM, SO₂ and NO_x. 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 11.3**.

Table 11.3: Air quality parameters along the proposed alignments

Monitoring Locations	Parameters Concentration ($\mu\text{g}/\text{m}^3$)				CO (mg/m^3)
	RPM	SPM	SO ₂	NOx	
Mysore Road Terminal – Kengeri					
Near Nayandahalli Bus Stand, Mysore Road	311.51	700.66	9.6	67.22	2.2
Near University Gate, Mysore Road	283.46	477.01	8.8	53.65	2.0
Byappanahalli – ITPL – Whitefield					
Opposite to Tin Factory, Old Madras Road	357.49	803.68	11.42	68.84	2.3
Near Police Station, Mahadevpura	295.41	674.51	11.06	65.74	2.1
Near Big Bazaar, Whitefield	305.34	665.80	10.96	55.13	1.9
Hessarghatta Cross – BIEC					
Near 8 th Mile, Tumkur Road	315.42	735.35	12.62	81.24	2.3
Near Nice Road Junction, Tumkur Road	265.32	467.51	9.8	67.41	1.9
Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)					
Near Metro Shopping Mall, Kanakpura Road	317.96	440.26	8.4	55.44	2.2
Near Konankunte bus stop	235.11	365.01	7.5	57.01	2.1
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 alignments 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. This increased RPM and SPM is due to vehicular pollution which is increasing exponentially along the proposed alignments and bad maintenance of roads has influenced the rise in air pollutants.

The increased vehicular and industrial activities in Richmond road and Peenya industrial area may influenced very higher concentration of RSPM and SPM. However, the concentration of SO₂ and NOx is below permissible limits in most of sampling locations. The Bharat Stage-III emission norms have been introduced during 2005 this has drastically decreased SO₂ level in subsequent years. The decreasing levels of NOx are due to banning of old vehicles, better traffic management, introduction of improved vehicular technology, etc. The concentration of CO was slightly higher in few places compared to NAAQS Standards.

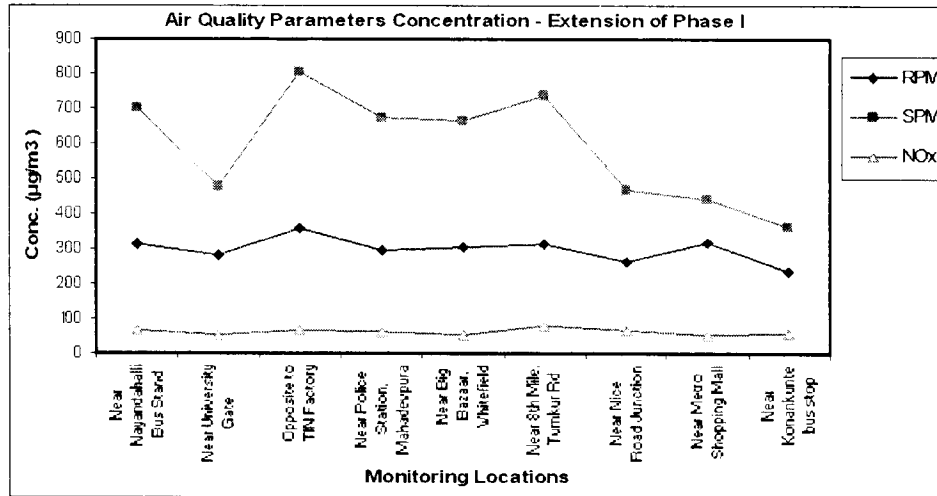


Figure 11.3: Status of Air quality along the proposed Phase I extensions

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 11.4** and **Table 11.5**

Table 11.4: 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 11.5: Air Quality Index (AQI) values and Air Quality Criteria at Extensions of Phase I

Monitoring Locations	AQI values	Air Quality Criteria
Mysore Road Terminal – Kengeri		
Near Nayandahalli Bus Stand, Mysore Road	189.47	Severe Air Pollution
Near University Gate, Mysore Road	150.01	Severe Air Pollution
Byappanahalli – ITPL – Whitefield		
Opposite to Tin Factory, Old Madras Road	214.91	Severe Air Pollution
Near Police Station, Mahadevpura	182.17	Severe Air Pollution
Near Big Bazaar, Whitefield	180.21	Severe Air Pollution
Hessarghatta Cross – BIEC		
Near 8 th Mile, Tumkur Road	200.11	Severe Air Pollution
Near Nice Road Junction, Tumkur Road	148.90	Severe Air Pollution
Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)		
Near Metro Shopping Mall, Kanakpura Road	154.47	Severe Air Pollution
Near Konankunte bus stop	124.56	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.

11.2.3 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 11.6**

TABLE 11.6: NOISE LEVELS ALONG THE PROPOSED ALIGNMENTS

Monitoring Locations	Noise level dB (A) Leq	
	Day (Leq)	Night (Leq)
Mysore Road Terminal – Kengeri		
Near Nayandahalli Bus Stand, Mysore Rd	78.7	73.3
Near University Gate, Mysore Road	76.0	72.7
Byappanahalli – ITPL – Whitefield		
Opposite to Tin Factory, Old Madras Road	82.1	76.8
Near Police Station, Mahadevpura	77.6	73.2
Near Big Bazaar, Whitefield	76.8	72.4
Hessarghatta cross – BIEC		
Near 8 th Mile, Tumkur Road	79.4	72.9
Near Nice Road Junction, Tumkur Road	76.7	71.0
Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)		
Near Metro Shopping Mall, Kanakpura Road	77.5	72.3
Near Konankunte bus stop	74.2	71.4
Ambient Noise Standards		
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45

Note: Day -- 0600 hour to 2200 hour, Night --2200 hour to 0600 hour

It is observed that noise equivalent levels along the proposed Extensions of Phase I alignment varied in the range 74.2 – 82.1 dB (A) in the day time and 68.3 – 76.8 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. While the prescribed Noise level during day time is 65 dB(A) , it is found that in all the Stations the measured Noise levels exceeded the permissible ambient



noise levels. The noise levels will significantly come down with the introduction of the metro

11.2.4 Traffic Survey

11.2.4.1 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.

11.2.4.2 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 11.7**

Table 11.7: Vehicular population in Bangalore City

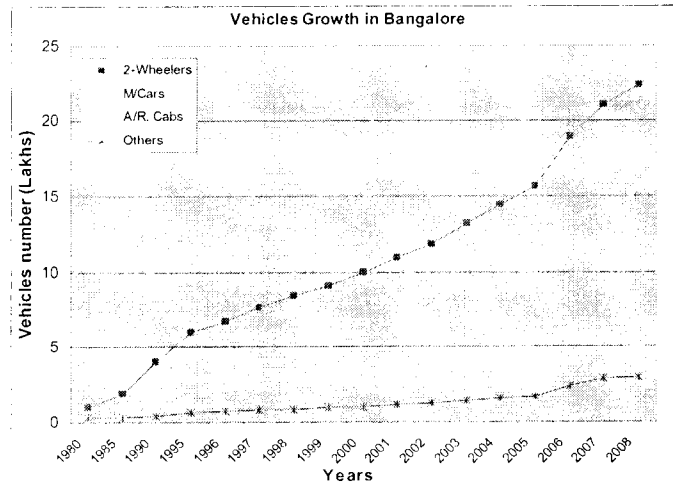
Year	2-Wheelers	M/Cars	A/R. Cabs	Others	Total
	Lakhs				
1980	0.97	0.30	0.10	0.31	1.68
1985	1.89	0.47	0.11	0.30	2.77
1990	4.01	0.71	0.15	0.41	6.28
1995	5.94	1.07	0.34	0.62	7.97
1996	6.69	1.21	0.39	0.71	9.00
1997	7.58	1.38	0.47	0.80	10.23
1998	8.39	1.52	0.54	0.84	11.29
1999	9.10	1.64	0.55	0.94	12.23
2000	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



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 11.8**.

Table 11.8: Accidents in Bangalore

Year	Fatal	Non-Fatal	Total
2001	668	8358	9026
2002	783	9073	9856
2003	843	9662	10505
2004	875	8226	9101
2005	796	6782	7578
2006	880	6681	7561
2007	957	7469	8426

Source: Bangalore Traffic Police

11.2.4.3 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 highest. The composition of traffic in the proposed alignment is presented in **Table 11.9**. The traffic compositions of light motor vehicles are found to be high in almost all roads.

TABLE 11.9: PEAK HOUR TRAFFIC MOVEMENT ALONG THE EXTENSIONS OF PHASE I

Vehicle Type	Mysore Road Terminal – Kengeri				Byappanahalli – ITPL – Whitefield				Hessarghatta Cross – BIEC				Puttenahalli Cross – Anjanapura Township			
	VC-1		VC-2		VC-3		VC-4		VC-5		VC-6		VC-7		VC-8	
	NOs	%	NOs	%	NOs	%	NOs	%	NOs	%	NOs	%	NOs	%	NOs	%
Two Wheeler	1565	40.65	898	38.67	2215	43.35	1468	38.30	571	31.72	605	26.66	1543	38.77	348	32.28
Auto Rickshaw	280	7.27	127	5.47	324	6.34	117	3.05	137	7.61	125	5.51	434	10.90	57	5.29
Car/Jeep/ Van/Taxi	1237	32.13	676	29.11	1525	29.85	1485	38.74	433	24.06	658	29.00	1267	31.83	331	30.71
Mini-Bus	132	3.43	80	3.45	305	5.97	58	1.51	60	3.33	49	2.16	111	2.79	16	1.48
Bus	364	9.45	337	14.51	300	5.87	195	5.09	240	13.33	238	10.49	262	6.58	139	12.89
LCV	141	3.66	110	4.74	227	4.44	196	5.11	217	12.06	392	17.28	160	4.02	71	6.59
2 - Axle Trucks	98	2.55	70	3.01	116	2.27	150	3.91	100	5.56	126	5.55	140	3.52	68	6.31
3 - Axle Trucks	18	0.47	12	0.52	49	0.96	55	1.43	29	1.61	64	2.82	17	0.43	31	2.88
MAV	0	0.00	2	0.09	12	0.23	15	0.39	1	0.06	6	0.26	0	0.00	14	1.30
Tractor with/with out Tractor	6	0.16	3	0.13	3	0.06	4	0.10	10	0.56	4	0.18	5	0.13	2	0.19
Bicycles	9	0.23	7	0.30	33	0.65	90	2.35	2	0.11	2	0.09	41	1.03	1	0.09
Total Vehicles	3850	100	2322	100	5109	100	3833	100	1800	100	2289	100	3980	100	1078	100
Total PCU	5068	-	3385	-	5812	-	4484	-	3020	-	3554	-	5023	-	1667	-

VC-1: Bangalore University gate, Mysore Road, VC-2: Near HP Petrol Bunk, Kengeri Bus Stop
 VC-3: Honda Showroom, Mahadevapura, VC-4: Big Bazaar, Whitefield
 VC-5: Near Parle-G, Tumkur Road, VC-6: Near Nice Road Junction, Tumkur Road
 VC-7: Near Metro shopping mall, Kanakapura Road, VC-8: NICE Road Junction Petrol Bunk

Mysore Road Terminal – Kengeri: Mysore road is the only linkage to Mysore and Ooty from Bangalore, this has increased the frequency of public transportation. It is even predicted that Mysore is the next IT destination after Bangalore. These have eventually increased the traffic congestion of road above all the road is narrow at certain points near the populated areas. It is observed that, two wheelers density is more dominated in the proposed alignment ranging from 38 % to 40 %. Bangalore University location recorded higher traffic load compare to Kengeri location.

Byappanahalli – ITPL – Whitefield: Whitefield road through Tin factory is main linkage road for commuter to reach Whitefield and International Tech Park. Due to IT growth in the particular place, there is huge traffic load especially during peak hours. Commuters on Whitefield road use more two wheelers and four wheelers mainly due to migration and growth in IT sector. It is observed that, two wheelers and four wheelers density is more dominated in the proposed alignment ranging from 38 % to 43 % and 30 % to 39% respectively. Since ITPL and Whitefield is flooded with IT Companies car, van and minibus are found in abundance.



Hesaraghatta Cross – BIEC: NH-4 is the main road for commuter to pass towards maximum portion of Karnataka and other main cities like Pune, Mumbai, Mangalore and Hubli. Peenya Industrial area is one of the Asia's biggest industrial townships located along this alignment resulting more four wheelers density in compared to other mode of transport. On Tumkur road 4-Wheelers and Public transportation is found to be more.

Puttenahalli Cross – Anjanapura Township: The alignment runs on National Highway 209 which encompasses most of the heavy motor vehicles. This is also one of the main road networks for commuter to move towards south portion of Bangalore. Residential development is more observed in the proposed alignment.

Overall, 2 wheelers and 4 wheelers are more dominant when compared to 3 wheelers and other vehicles on road. It is observed that trucks are found to be less in these alignments 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 has been considered. The Congestion Index (CI) was worked out for the proposed alignments and presented in **Table 11.10**.

TABLE 11.10: CONGESTION INDEX FOR THE PROPOSED ALIGNMENTS

Location	Peak Hour Traffic Volume in PCU	Designed Service Volume PCU	Maximum Capacity PCU	Congestion Index (CI) Based on	
				Design Service Volume	Maximum Capacity
Mysore Road Terminal – Kengeri					
VC-1	5068	3600	5143	1.41	0.99
VC-2	3385	3600	5143	0.94	0.66
Byappanahalli – ITPL – Whitefield					
VC-3	5812	3600	5143	1.61	1.13
VC-4	4484	3600	5143	1.25	0.87
Hesaraghatta Cross – BIEC					
VC-5	3020	3600	5143	0.84	0.59
VC-6	3554	3600	5143	0.99	0.69
Puttenahalli – NICE Road Junction					
VC-7	5023	3600	5143	1.40	0.98
VC-8	1667	1200	1714	1.39	0.97

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., Bangalore University gate, Mysore Road (VC-1) near Honda Showroom, Mahadevapura (VC-3 and VC-4), near Metro shopping mall, Kanakapura Road (VC-7) and NICE Road Junction Petrol Bunk (VC-8), exceeded the congestion index limit. However, the slightly lesser CI is observed in VC-2, VC-5 and VC-6. This may be due to recent widening of Tumkur road (NH4) from four lane to eight lane resulting in enhancement of Designed Service Volume and Maximum Capacity of the road. The total vehicle plying in the above three roads is low compare to other roads due to surrounding areas caters for mechanically oriented small scale and large scale industries. Such industries require more manual labours which is been fulfilled mostly by the people residing nearby areas. Overall, the most of roads are overcrowded by vehicles with higher congestion index shows prime necessary of Metro transport system.

11.2.5 Water and Soil Quality

The Ground water samples were collected from borewells at different locations along the proposed alignments 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 11.11** and **Table 11.12**.

TABLE 11.11: PHYSICO-CHEMICAL CHARACTERISTICS OF WATER ALONG THE PROPOSED ALIGNMENTS

Parameters	Mysore Road Terminal - Kengeri	Byappanahalli - ITPL - Whitefield	Hesaraghatta Cross - BIEC	Puttenahalli - NICE Road Junction	CPCB Limits (Drinking water)
Observed range					
pH	6.97 - 7.67	7.25 - 7.45	7.15 - 7.44	7.11 - 7.69	6.5-8.5
Total Chlorides (mg/l)	147 - 231	121.4 - 197	74.99 - 255	135.32 - 299	250
Total Hardness (mg/l)	174.3 - 292	179 - 267.5	132.6 - 256	152.5 - 311	300
Calcium as Ca (mg/l)	7.21 - 21.32	29.65 - 41.21	55.5 - 79.12	47.02 - 82.45	75
Magnesium as Mg (mg/l)	43.25 - 66.59	16.52 - 30.21	28.15 - 42.65	18.26 - 37.42	30



Sulphate as SO ₄ (mg/l)	18.36 – 27.95	5.55 – 15.24	11.65 – 31.25	13.75 – 55.32	200
Nitrate as NO ₃ (mg/l)	3.12 – 35.41	3.25 – 11.34	6.81 – 22.41	6.75 – 14.38	45
Total Dissolved Solids (mg/l)	355 – 700	385 – 476	403 – 785	467 – 621	500

The ground water samples were collected in the proposed alignment showed that most of the parameters were slightly higher in compared to CPCB standards. The total chlorides and total hardness are distinctly higher than standards, however, the sulphate and nitrate concentrations are below the permissible limits.

To understand the surface water Physico-chemical characteristics, the water samples were collected from nearest lakes. The surface water samples BOD value ranges from 4-72 mg/l and COD value ranges from 77 – 235 mg/l. Most the lakes BOD and COD values exceeded the CPCB standards. The water sample collected from Puttenahalli Lake showed very higher BOD value of about 72 mg/l. This indicates that the water quality of the lake is deteriorating with high algal growth. The highest BOD values are due to discharge of sewage from the surrounding habitations, which so far had not been provided with sewage treatment plants.

TABLE 11.12: PHYSICO-CHEMICAL CHARACTERISTICS OF SURFACE WATER ALONG THE PROPOSED ALIGNMENTS

Tanks	Parameters		
	pH	BOD (mg/l)	COD (mg/l)
Puttenahalli Lake	7.2	72.0	235
Anchepalya Lake	7.3	34.0	154
Bellandur Lake	7.3	11	105
KR Puram Lake	7.1	9.0	81
Kengeri Lake	7.6	4.0	77
CPCB Standards	-	4.0	10.0

Soil Quality

The surface soil samples from a depth of 0 - 20 cm were collected along the proposed alignments and collected samples were analysed for soil physico-chemical properties (**Table 11.13**).

The bulk density of soils ranged from 1.27 - 1.54 g/cm³. Thus, the porosity and water holding capacity also varied largely and found in the range of 40.2 - 50.7 % and 40.2 - 49.5 % respectively. The soil pH ranges from 6.25 - 7.52 and Electrical Conductivity (EC) ranges from 0.332 – 0.951 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 were found in the range of 0.29 - 0.45 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, P₂O₅ and K₂O are also in lesser range compare to productive soils.

TABLE 11.13: PHYSICO-CHEMICAL CHARACTERISTICS OF SOIL ALONG THE PROPOSED ALIGNMENTS

Sl. No	Parameters	Measured Range
1	pH	6.25 – 7.52
2	EC (dS/m)	0.332 – 0.951
3	Bulk Density (g/cm ³)	1.27 - 1.54
4	Porosity (%)	40.1 – 50.7
4	Water Holding Capacity (%)	40.2 – 49.5
5	Organic Carbon (%)	0.29 - 0.45
6	Available Nitrogen (kg ha ⁻¹)	215 - 385
7	Available P ₂ O ₅ (kg ha ⁻¹)	13.5 - 33.4
8	Available K ₂ O (kg ha ⁻¹)	138 – 334

contents of the study area varied to a great extent depending on the land use.

11.2.6 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 alignments. 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 present at a distance of 20 m from the central line and 200 m length was recorded.

The trees likely to be cut or trimmed due to Metro rail alignment were identified. The girth of the tree was measured at a height of 1.3 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.



11.2.6.1 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 11.14**. Trees to be cut and trimmed at stations, curves and alignment were studied as per the maps provided by DMRC.

Table 11.14: Tree population along the proposed alignments

Sl. No.	Metro Alignment	Trees found along the alignment			
		0-5m		5-10m	
		Left	Right	Left	Right
1	Mysore Road Terminal to Kengeri	0	2	6	6
2	Byappanahalli to Whitefield	17	65	38	43
3	Hessarghatta cross to BIEC	0	6	0	11
4	Puttenahalli to Anjanapura Township	1	0	88	54
Total		18	73	132	114

A total of 337 trees were recorded in the proposed alignment of which 91 trees were recorded at 0-5 m alignment and 246 at 5-10 m respectively. The survey result indicates that less number of trees 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 alignments are given in **Table 11.15**.

TABLE 11.15: OVERALL AFFECTED TREES ALONG THE PROPOSED ALIGNMENTS

Sl. No	Locations	No. of trees to be cut	No. of trees to be trimmed	Canopy area loss (m ²)
Mysore Road Terminal – Kengeri				
1	Stations	34	2	12
2	Road median	2	-	-
3	Alignment	-	12	94
Total		36	14	106
Byappanahalli – ITPL – Whitefield				
1	Stations	207	15	49
2	Road median	15	-	-
3	Alignment	67	81	539
Total		289	96	588
Hesaraghatta cross – BIEC				
1	Stations	6	3	15
2	Road median	-	-	-
3	Alignment	6	11	38
Total		12	14	53
Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)				
1	Stations	94	16	139
2	Road median	-	-	-
3	Alignment	1	142	1427
Total		95	158	1566
Grand Total		432	282	2313



A total of 432 trees will have to be cut and 282 trees will have to be pruned in proposed extension of Phase I. The 282 trees being trim attributes to loss of 2313 m² canopy area. It is observed that slightly more trees are going to be cut for construction of stations from Byappanahalli – ITPL – Whitefield road. However, the Biomass loss is comparatively less in compare to tree numbers because Byappanahalli – Whitefield alignment trees are recently planted.

It is estimated that out of 432 trees to be cut along corridor, 255 trees are big canopy trees followed by medium canopy of 128 and small canopy trees of 49 respectively. The majority of the smaller canopy trees belong to Ashoka trees planted along the proposed alignment. Maximum number of trees is going to remove at stations than alignment. Tree cutting will be minimized by proper utilization open land for station construction. The affected tree canopy is depicted in **Table 11.16**.

TABLE 11.16: AFFECTED TREE CANOPY ALONG THE PROPOSED ALIGNMENTS

Sl. No	Tree canopy	Alignment, Curves & Median		Stations	
		Number	Biomass (t)	Number	Biomass (t)
Mysore Road Terminal – Kengeri					
1	Big canopy trees with girth >70cm at GBH	-	-	22	81.46
2	Medium canopy trees with girth 40 to 70 cm at GBH	2	0.197	10	2.51
3	Small canopy trees and shrubs with girth <40 cm	-	-	2	0.25
	Total	2	0.197	34	84.22
Byappanahalli – ITPL – Whitefield					
1	Big canopy trees with girth >70cm at GBH	41	24.7	117	160.0
2	Medium canopy trees with girth 40 to 70 cm at GBH	31	7.92	55	10.0
3	Small canopy trees and shrubs with girth <40 cm	10	1.77	35	2.2
	Total	82	34.39	207	172.2
Hessarghatta Cross – BIEC					
1	Big canopy trees with girth >70cm at GBH	5	5.41	3	14.45
2	Medium canopy trees with girth 40 to 70 cm at GBH	1	0.11	3	0.41
3	Small canopy trees and shrubs with girth <40 cm	-	-	-	-
	Total	6	5.52	6	14.86
Puttenahalli – NICE Road Junction					
1	Big canopy trees with girth >70cm at GBH	1	7.74	66	241.43
2	Medium canopy trees with girth 40 to 70 cm at GBH	-	-	26	4.78
3	Small canopy trees and shrubs with girth <40 cm	-	-	2	0.14
	Total	1	7.74	94	246.35
	Grand Total	91	47.86	341	517.62



The majority of trees are of ornamental value planted along avenue by Forest Department and very few are of big canopy trees planted for shade. The average height of the trees recorded is 10-12 m and GBH is of 0.8 to 1.0 m indicating that they were planted 20-25 years back. Proper reforestation methodologies will be followed as per MoEF guide lines only to increase the ecobalance.

11.2.7 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 alignments 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. Since most of the alignments planned on the road median, property losses expected very less.

11.2.7.1 Features Identified along the Alignment and Stations

- **Mysore Road Terminal to Kengeri:** The alignment will be a fast access to Mysore. Many educational institutions are present all along the alignment, hence there is a possibilities for students to commute. There are few industrial developments, service and sales outlet are existing along the proposed alignment.
- **Baiyappanahalli to Whitefield:** The alignment links to IT and Service Sectors. Many Multinational companies are found along the alignment. Hardly few educational institutions.
- **Hessarghatta Cross to BIEC:** The presence of Bangalore International Exhibition Center has provoked the proponent to extend to another 4 km. Many International business exhibitions, trade fairs, congresses, international conferences, seminars and training programmes in India are conducted at BIEC. The extension of 4 km will facilitate people to reach their destination quickly thus promoting in economic development of the city. This alignment also links to the entire city.
- **Puttenahalli to Anjanapura Township:** The alignment was to facilitate commuters to travel to various parts of the city in short duration. This alignment is likely to be used extensively once the Anjanapura Township is filled up with occupants.

11.2.7.2 Features Identified along the Stations

- **Mysore Road Terminal to Kengeri:** There are 6 stations in this alignment. Most of the stations are planned on service road and open land. Only few structures of belonging to private owners is affected.



- **Baiyappanahalli to Whitefield:** There are 14 stations in this alignment. Most of the stations are planned on service road and open land. Only few structures belonging to private owners are affected near Mahadevpura station.
- **Hessarghatta Cross to BIEC:** There are 3 stations in this alignment. All the three stations are planned on service road and open land. Only few land belong to private property has to be acquired.
- **Puttenahalli to Anjanapura Township:** There are 5 stations in this alignment. Most of the stations are planned on service road and open land. Out of the 5 stations only 2 stations i.e. Station 4 and Station 5 have private property to be acquired while the rest of the stations have few structures to be acquired.

11.2.7.3 Socio Economic Profile of the PAPs

The proposed alignments 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. The proposed project has avoided this sector to a maximum extent.

11.2.7.4 Perception of PAPs (Rehabilitation & Resettlement)

The perception of the people was analyzed through the interview and the following inferences were observed. People were asked to share their views regarding the proposed alignments. 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 today's 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. People responded that metro rail elevates the aesthetic look of the city.

11.3 NEGATIVE ENVIRONMENTAL IMPACTS

11.3.1 Impacts due to Project Location

11.3.1.1 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 width of the alignment is 20 m while the elevated station area is 140m x 19 m. The land situated within ROW was identified as Residential, Commercial, Industrial, Institutional, Religious and the category with negligible information as others. Since the proposed alignment is elevated, the land requirement and change in land use is minimum.

The following table depicts the type of property (land and structure) to be acquired for the proposed alignment.

TABLE 11.17A: LOCATION OR AREA TO BE ACQUIRED ALONG THE EXTENSION OF METRO PHASE I

Type	Mysore Road Terminal – Kengeri		Byappanahalli – Whitefield	
	Area (sq m)	Area (%)	Area (sq m)	Area (%)
Residential	30.94	1.44	862.19	3.75
Commercial	682.96	31.74	6534.85	28.43
Industrial	473.48	22.00	3185.86	13.86
Religious places	6.74	0.31	2.47	0.01
Institutional	880.30	40.91	9920.68	43.17
Others	77.34	3.59	2475.96	10.77
Total	2151.75	100.00	22982.00	100.00

TABLE 11.17B: LOCATION OR AREA TO BE ACQUIRED ALONG THE EXTENSION OF METRO PHASE I

Type	Hesaraghatta cross – BIEC		Puttenahalli Cross – Anjanapura Township	
	Area (sq m)	Area (%)	Area (sq m)	Area (%)
Residential	-	-	57.11	0.79
Commercial	112.14	2.25	1653.67	22.81
Industrial	9.33	0.19	2299.16	31.72
Religious places	-	-	42.48	0.59
Institutional	783.38	15.73	192.96	2.66
Others	4076.67	81.84	3003.87	41.44
Total	4981.50	100.00	7249.24	100.00

It is observed that land acquisition is found to be minimal in extension of Metro Phase-I because the alignment is planned on the existing road and the existing road width meet its requirement. As per the above data, commercial properties are more affected followed by Residential. Almost all industrial, institutional, religious categories are open land while residential and commercial are structures/land.



11.3.1.2 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 alignment will affect 432 trees at alignment and stations while only 282 trees are required to be purned for the extension of Phase I. The 282 trees canopy loss constitute to about 2313m² of which major portion coming in Baiyappanahalli to Whitefield for the purpose of alignment. The 432 trees to be cut for extension of Phase I in the proposed corridor constitute about 565.48 tonnes of biomass.

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.

11.3.1.3 Utility/Drainage Problems

The proposed alignments are generally planned on road center line (divider), service roads and vacant lands. As per the land availability and topography, alignments are planned both above ground and below ground. The proposed alignments 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 alignments are listed in **Table 11.18**.

**TABLE 11.18: LIST OF PUBLIC UTILITIES TO BE SHIFTED ALONG THE PROPOSED ALIGNMENTS**

Location	Utilities (In numbers)					
	Lamp Post	Bus Stop	Manhole	Telephone cable	Power line	Drain
Mysore Road Terminal to Kengeri						
Stations	11	1	2	-	-	-
Alignment	74	-	-	3	4	2
Total	85	1	2	3	4	2
Byappanahalli to Whitefield						
Stations	1	1	-	-	6	8
Alignment	14	8	1	13	5	-
Total	15	9	1	13	11	8
Hessarghatta Cross to BIEC						
Stations	-	1	-	-	11	3
Alignment	3	-	-	-	11	-
Total	3	1	-	-	11	3
Puttenahalli to Anjanapura Township						
Stations	2	2	3	-	-	-
Alignment	3	-	-	4	35	-
Total	5	2	3	4	35	-
Grand Total	216	26	12	40	133	26

It is observed that, since the extension of Phase I is situated in urban city the, lot of utilities have to be diverted. The drain, power lines and telephone cables are a matter of concern in the above alignments. Byappanahalli to Whitefield alignment affects majority of utilities because the alignment length is large and existing road width is less resulting more damage to surrounding utilities.

In addition, Mysore Road Terminal to Kengeri – One Pylon crossing (15m width), 6 solar signals, 1 foot bridge (in Kengeri) and 1 transformer needs to be shifted. Similarly, Puttenahalli to NICE Road Junction – Two pylons are crossing (20 m width), 22 cables are going to be affected. In case of Byappanahalli – Whitefield, there four big pylons needs to be shifted. All the above utilities will be shifted with prior notice by taking short time and without damaging to any public.

11.3.2 Impacts due to Project Construction

11.3.2.1 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 80 vehicles per day in a single alignment. As the vehicle movement is of temporary nature and restricted only to the construction period, these impacts relatively would be insignificant. However efforts should be still made to minimize the dust pollution arising from these activities. Since there is no much demolition of structures along the proposed alignment, dust is not much envisaged.



11.3.2.2 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 to avoid any confusion in the traffic rules and diversions.

11.3.2.3 Soil Erosion and Health Risk at Construction Site

The extension of Phase I is entirely elevated sections, hence excavation is minimal limiting only at the pillars. From the estimations made on the basis of preliminary drawings, it is estimated that the total quantum of excavated soil will be approximately of about 8.68 lakhs cubic meters and a portion of this can be used for backfilling. Dumping of construction spoils like concrete, bricks, waste material from camps etc cause surface and ground water pollution. Movement of vehicles carrying construction materials/spoils will also cause dust to accumulate in air causing air pollution.

Health is usually affected due to lack of sanitation facilities (water supply and human waste disposal) and insect vector disease hazards of local workers. Problems could arise due to difference in cultural habits of imported workers and local residents.

11.3.2.4 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.

11.3.2.5 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 length of extension phase corridor is 30.1 km covering 29 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 $\approx 800 \text{ m}^3$. 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.



11.3.2.6 Natural Disaster

The Bangalore city is not prone to floods. The city is located in seismically stable zone (Zone II) hence there is no major threat of earthquake. Hence any disaster activity from these natural causes can be expected to be minimal. The structure should follow specific design criteria for these seismic zones.

11.3.2.7 Loss of Historical and Cultural Monuments

The proposed alignment does not involve any loss of historical/cultural monuments and alignments are not coming under any sensitive areas

11.3.3 Impacts due to Project Operation

11.3.3.1 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.

11.3.3.2 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.

11.3.3.3 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 50 nos, therefore around 2,250 liters/day of water will be required for railway staff. The water requirement for the proposed alignment having 29 stations is 63000 liters/day. In addition, water demand at stations for cleaning, sanitation, fire fighting and washing purpose will be about 700 m³/day. Municipal water or ground water supply will be tapped for drinking purposes. The sewage treated water from the nearest water treatment plant has been proposed for toilets cleaning, washing etc. As per the waste water discharge, about 0.7MLD 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.

11.3.3.4 Solid Waste Generation

The solid waste generated from stations and rail includes garbage, rubbish from wrappers, discarded boxes, rags etc. Based on the data generated, it is estimated that about 6 gm of refuse will be generated per person per day at Indian Railway Stations. There is no shop or cafes at these stations hence there is no much generation of garbage. Due to unavailability of solid waste data, it is assumed about 3g/ person/ day of refuse generation at the proposed Metro



stations. Thus, it is estimated that about 3.85 tonnes of solid waste is likely to be generated from the proposed Metro alignments. There has to be storage containers of 50 litres capacity for temporarily storing refuse and it should be equipped with side handles to facilitate handling. Generated solid waste will be disposed through approved solid waste recycling agencies.

11.4 POSITIVE ENVIRONMENTAL IMPACTS

11.4.1 Employment Opportunities

The proposed Metro construction work is expected to commence from mid of 2010 and is expected to be operated completely by 2016. There will be provision for employment during construction and operational phases of the project. During peak hour of the construction phase, manpower requirement will be more. Further, there will be several ancillary activities which give rise additional employment. It is estimated that, about 3500 people per day are expected to be deployed during the peak period of construction activity for the project. On an average 4 lakhs mandays are required annually. During operational phase, there will be employment generation for about 400 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.

11.4.2 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.

11.4.3 Reduction in Number of Vehicles on Road

The existing road network is used by pedestrians, cyclists, motorists, buses and trucks etc, this has caused traffic congestion. According to the survey carried out on extension of Phase I from, the vehicle movement of two wheelers ranges from 348 to 2215, three wheelers ranges from 57 to 434, four wheelers ranges from 1557 to 2567 and buses ranges from 331 to 450 during peak hours.

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 year (2009-10) 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 11.19**.

Table 11.19: Present and projected traffic volume in extensions of Phase I alignments

Place	Year	Vehicle Type						Total Vehicles*
		Two Wheeler	Auto Rickshaw	Car/Jeep/ Van/Taxi	Mini-Bus	Bus	Other Four Wheelers	
		Vehicles / day**						
Mysore Road Terminal to Kengeri								
VC-1	2009	11282	1867	9637	600	2715	3399	29500
	2016	15875	2627	13560	844	3820	4783	41509
VC-2	2009	9873	1503	7749	580	3183	3094	25982
	2016	13892	2115	10904	816	4479	4354	36559
Byappanahalli to Whitefield								
VC-3	2009	16778	2549	13918	1655	1412	3689	40001
	2016	23608	3587	19584	2329	1987	5190	56285
VC-4	2009	12706	1569	12862	983	2153	4485	34758
	2016	17879	2208	18099	1383	3029	6311	48908
Hessarghatta cross to BIEC								
VC-5	2009	6311	1243	4569	549	2352	4327	19351
	2016	8880	1749	6429	772	3309	6088	27229
VC-6	2009	7901	1436	6671	591	2438	5733	24770
	2016	11117	2020	9387	831	3430	8067	34854
Puttenahalli to NICE Road Junction								
VC-7	2009	14590	5471	9765	742	1824	2260	34652
	2016	20530	7698	13740	1044	2566	3180	48759
VC-8	2009	4419	624	3950	217	899	1532	11641
	2016	6218	878	5558	305	1265	2156	16380

Note: Annual 5% traffic growth is considered as per norms of Planning Commission

* 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 alignments is given **Table 11.20**



Table 11.20: Expected reduction of vehicles on road due to the proposed alignments

Place	Year	Vehicle Type						Total
		Two Wheeler	Auto Rickshaw	Car/Jeep/ Van/Taxi	Mini-Bus	Bus	Other Four Wheelers	
% Shift to Metro		35	20	25	5	20	0	-
Mysore Road Terminal to Kengeri								
VC-1	2016*	15875	2627	13560	844	3820	4783	41509
	2016**	10319	2101	10170	802	3056	4783	31232
VC-2	2016*	13892	2115	10904	816	4479	4354	36559
	2016**	9030	1692	8178	775	3583	4353	27612
Byappanahalli to Whitefield								
VC-4	2016*	23608	3587	19584	2329	1987	5191	56285
	2016**	15345	2870	14689	2213	1590	5191	41895
VC-5	2016*	17879	2208	18098	1383	3029	6311	48908
	2016**	11621	1766	13573	1314	2423	6310	37009
Hessarghatta cross to BIEC								
VC-4	2016*	8880	1749	6429	772	3310	6089	27229
	2016**	5772	1399	4822	734	2648	6088	21463
VC-5	2016*	11118	2021	9387	832	3431	8067	34854
	2016**	7226	1616	7040	790	2744	8067	27484
Puttenahalli to NICE Road Junction								
VC-6	2016*	20530	7698	13740	1044	2567	3180	48759
	2016**	13344	6158	10305	992	2053	3180	36033
VC-7	2016*	6218	878	5558	305	1265	2156	16380
	2016**	4042	702	4168	290	1012	2156	12370

Note: * -No. of Vehicles without Metro 2016

** - No. of Vehicles with Metro 2016

11.4.4 Less Fuel Consumption

The main fuels used in vehicles are petrol, diesel and CNG. About two million vehicles are registered in Bangalore ply on its roads. Annual consumption of diesel and petrol is in the range of 4,50,000 and 2,50,000 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.

The projected vehicles in the proposed alignment from Mysore Road Terminal to Kengeri will save 3197 liters / day of petrol and 1960 liters/ day of diesel after initiation of Metro rail. Similarly, the projected vehicles from Byappanahalli to Whitefield will save 10856 liters / day of petrol and 3760 liters/ day of diesel. The projected vehicles from Hesaraghatta to BIEC will save 1385 liters / day of petrol and 1244 liters/ day of diesel while Puttenahalli to NICE Road Junction will save



2750 liters/day of petrol and 980 liters / day of diesel. Thus, the projected vehicles in the extension of Phase I alignments will save 18188 liters / day of petrol and 7944 liters/ day of diesel after initiation of Metro rail.

Table 11.21: Expected fuel and their cost savings from the proposed alignment

Savings	VC-1	VC-2	VC-3	VC-4	VC-5	VC-6	VC-7	VC-8	Total
Total Petrol (lt) saved / day	3197		10856		1385		2750		18188
Total Diesel (lt) saved / day	1960		3760		1244		980		7944
Total Petrol Cost (Rs.) saved / day	166267		564490		72036		142985		945779
Total Diesel Cost (Rs.) saved / day	72529		139115		46035		36245		293924
Total Petrol Cost (crores) saved / year	6.07		20.60		2.63		5.22		34.52
Total Diesel Cost (crores) saved / year	2.65		5.08		1.68		1.32		10.73
Total Fuel Cost (crores) savings / year	8.72		25.68		4.31		6.54		45.25

The reduction in fuel consumption after commissioning of Metro reduces the burden on State economy. Considering the present cost of petrol (Rs. 52/lit) and diesel (Rs. 37/lit), an amount of Rs. 6.07 crores from petrol and Rs. 2.65 crores from diesel can be saved per year from Mysore Road Terminal to Kengeri (Table 4.5). Similarly, Rs. 20.60 crores from petrol and Rs. 5.08 crores from diesel can be saved per year from Byappanahalli to Whitefield alignment. The alignment Hesarhatta Cross to BIEC will save 2.63 crores from petrol and Rs. 1.68 crores from diesel annually while Puttenahalli to NICE Road Junction will save 5.22 crores from petrol and 1.32 crores diesel annually. Thus, the proposed Metro will save annual fuel cost nearly Rs. 8.72 crores from Mysore Road Terminal to Kengeri, Rs. 25.68 crores from Byappanahalli to Whitefield, Rs. 4.31 crores from Hesarhatta cross to BIEC and Rs. 6.54 crores from Puttenahalli to NICE Junction. Hence, the overall fuel cost savings is about Rs. 45.25 crores / year due to Extension of Phase I alignments. In addition, the expansion of Metro in adjacent area will further reduce the fossil fuel cost at a greater extent.

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. 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.

11.4.5 Reduction in Air Pollution

The urban air pollution generally means unacceptable levels of pollutants emitted from vehicles such as Carbon Monoxide (CO), Hydro Carbons (HC), Nitrogen oxides (NOx), Sulphur Dioxide (SO₂) 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_x and HC of vehicles plying on road is within the CPCB standard while particulate matter found to be exceeded the permissible limit. An attempt has been made to estimate the pollution load by colligating exhaust emission factor and the petrol consumption. The reduction in air pollution after commissioning of Metro is depicted in **Table 11.22**. It is observed that the proposed project will reduce nearly 8.95 tonnes of pollutants per day.

Table 11.22: 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	VC-4	Total
Carbon Monoxide	391	1.250	4.245	0.542	1.075	7.12
Hydrocarbons	34	0.109	1.180	0.047	0.094	1.43
Oxides of Nitrogen	19.2	0.061	0.208	0.027	0.053	0.35
Oxides of sulphur	1.5	0.005	0.016	0.002	0.004	0.03
Particulate matter	1.9	0.006	0.021	0.003	0.005	0.03
Total		1.43	5.67	0.62	1.23	8.95

* Exhaust emission factor as per H.B. Mathur, 1984.

11.4.6 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 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 13.76 lakhs passenger/day is expected.

The existing transportation system on the city roads takes 2.0 to 2.5 hours to reach Whitefield from City Bus Station, while the estimated travel time using Metro rail takes < 1 hour to cover the same distance. Thus, the Metro rail used can thus cut down travel time by more than half which works out to a substantial saving on productive man hours and improve working efficiency. Considering an average 30 minutes time savings / passenger / trip, per day can save approximately 7.0 lakhs man hours.



11.4.7 Reduction in Accidents

As per the Bangalore traffic data, nearly 5802 deaths and 56251 accidents were reported in Bangalore during 2001-2007. According to the statistics obtained, the accidents in 2007 was in peak. But in the last three years, between 2008 and 2010, accidents have come down. During 2008, fatal ones decreased to 864 from 957 in 2007. Subsequently, number of persons killed decreased to 892 as against 981 in 2007. However the traffic offenders 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.

11.4.8 Improve City Aesthetic Value

Metro rail project will increase the city aesthetic value and will attract the investors from other parts of the city. Similarly, the construction of Metro rail will encourage the economic opportunities of the people residing along alignment by promoting both business establishments and tourism. The architecturally designed elevated corridor above the median of the road could be aesthetically pleasing to the people.

11.5 ENVIRONMENTAL ASSESSMENT

11.5.1 Checklist for impact identification

Assessment of the environmental impacts is conducted using Checklist. The checklist portrays environmental parameters or impact indicators and helps in identifying the potential impacts of the project. A typical checklist identifying the anticipated environmental impacts is shown in **Table 11.23**.

Table 11.23: Checklist for impact identification

SI No	Parameters	No Impact	Negative Impact	Positive Impact	Remarks
1.0	<i>Impacts Due to Project Location</i>				
1.1	Projected Affected People		*		R&R will be according to NRRP 2003
1.2	Land Acquisition		*		Land requirement planned based on availability of open land
1.3	Loss of Trees/Forests		*		Afforestation @ 10 trees per tree cut. Green belt will be developed
1.4	Utility/Drainage Problems		*		Utility diversion will be taken care



					without any adverse effect
1.5	Aesthetics	*			
1.6	Natural Disasters	**			
2.0	Impacts due to Project Construction				
2.1	Air Pollution		*		The emission of vehicles will be monitored regularly
2.2	Noise Pollution		*		Noise reduction levels will be taken care
2.3	Soil Erosion and Health Risk at Construction Site		*		Reuse methods will be adapted
2.4	Traffic Diversion		*		Traffic management will be taken care
2.5	Impact on Water Quality		*		Water management practices
2.6	Construction Spoils		*		Disposed as per approved agencies
2.7	Loss of Historical and Cultural Monuments	**			
2.8	National Park/ZOO/Any other similar	**			
2.9	Water Requirements		*		Recycled water will be used for construction
3.0	Impacts due to Project Operation				
3.1	Oil Pollution		*		Waste management plan will be adapted
3.2	Noise Pollution		*		Not much envisaged
3.3	Water Supply and Sanitation at Stations		*		Water and waste management plan will be adapted
3.4	Employment Opportunities			**	
3.5	Benefits of Economy			**	
3.5.1	Reduction in number of vehicles on the road			**	
3.5.2	Less Fuel			**	



	Consumption				
3.5.3	Reduction Air Pollution			**	
3.5.4	Carbon-di-Oxide Reduction			**	
3.5.5	Reduction in Passenger Time			**	
3.5.6	Reduction in Accidents			**	
3.5.7	Reduction in road maintenance cost			**	
3.5.8	Improve city aesthetic value			*	

* Less Impact; ** More Impact

11.5.2 Impact Quantification

The impact of the proposed Metro rail project on the environment has been quantified based on the environmental parameters and public perception at site using Parameter Importance Units (PIU) or Weighting Techniques. Impact evaluation has been accomplished as per Batelle Environmental Evaluation System (BEES), USA. 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^{th} factor of j^{th} alternative

PIU_i = Parameter Importance Unit for i^{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 11.24**.

It is observed that the initiation of the Metro rail system would be beneficial against an ideal of 1000 units. Currently, the EIU stands at 603 units in Extension of Metro Phase-I alignments 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 +258 (43 % 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 603 units in Extension of Metro Phase – I alignments (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 603



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 %.

TABLE 11.24: 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)
i. Physical				
Air Quality	345	180	243	+63
Water Quality	114	111	113	+2
Land	65	62	61	-1
ii. Biological				
Terrestrial Ecosystem	205	186	201	+15
Aquatic Ecosystem	22	21	22	+1
iii. Socio Economic				
Traffic Congestion, Fossil Fuels, Quality of life, Comforts etc	249	43	221	+178
Total EIU	1000	603	861	+258

11.6 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) and the management plan should be integrated in all phases of the project. An adequate amount of fund is essential to implement management plan. Environment Management Cell should be setup to provide training for employees to carryout out post monitoring actives. Environmental Management Plan discussed in the following section is to mitigate the adverse impacts caused by implementation of the proposed



project and to maintain the quality of safe environment. It covers all aspects of planning, construction and operation of the project.

11.6.1 Mitigation Measures

11.6.1.1 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 from Mysore Road Terminal to Kengeri is 0.22 ha. The land to be acquired for the proposed alignment from Byappanahalli to Whitefield is 2.58 ha. Similarly, the land to be acquired from Hesaraghatta cross – BIEC is 0.42 ha and from Puttenahalli Cross – Anjanapura Township is 0.66 ha. The land area to be acquired for the extension of Phase I is 3.89 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 area of structures to be acquired for the proposed alignments is 0.53 ha. The compensation varies with respect to the property cost. Individual beneficiaries will be identified and their compensation will be taken care without any misuse.

11.6.1.2 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 432 trees are likely to be lost due to the proposed extension alignments and the total value of these trees lost is Rs. 3.5 lakhs. According to the MoEF guidelines for compensatory afforestation, ten trees have to be planted for each tree cut. Hence, 4320 trees will be planted along the corridor. These trees would have occupied about 4.5 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 reafforestation cost for the proposed alignments will be 43.2 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



project and to maintain the quality of safe environment. It covers all aspects of planning, construction and operation of the project.

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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 4320 trees in 11.10 acres of land under compensatory afforestation can sequester 1110 metric tonnes of carbon in 50 years, thus the proposed project can sequester 22.2 metric tones of carbon in a year.

11.6.1.3 Green Belt Development

In addition to the compensatory plantation, green belt area can be developed for the total 30.1 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 7.25.

- 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/m² to cover balance 0.75 m width
Rs. 50 x 0.75 m² x 2000 m = **Rs. 75000.00.**

**Table 11.25: Cost Estimate for Green Belt Development along the proposed alignments**

Green belt type	Small trees	Shrubs	Grass/herbs	Total
	Cost in Rs.			
Establishment cost for 1 km	41600	133300	75000	2,49,900
Mysore Road Terminal to Kengeri (6.1 km)	253760	813130	457500	15,24,390
Byappanahalli - ITPL-Whitefield (14 km)	582400	1866200	1050000	34,98,600
Hesaraghatta cross to BIEC (4.0 km)	166400	533200	300000	9,99,600
Puttenahalli to NICE Road Junction (6.0 km)	249600	799800	450000	14,99,400
Total	12,52,160	40,12,330	22,57,500	75,21,990

The total cost for green belt development under the elevated track is about 75.22 lakhs for the entire 30.1 km. Whereas from Mysore Road Terminal to Kengeri the cost would be Rs. 15.24 lakhs, from Byappanahalli to Whitefield the cost will be 34.98 lakhs, from Hesaraghatta cross to BIEC is 10.00 lakhs and Puttenahalli to NICE Road Junction will be 14.99 lakhs.

11.6.1.4 Translocation of trees

Among the 432 trees to be cut, about 47 trees can be translocated to nearby park, which are having shallow root systems. This requires Rs. 5,000 tree towards translocation expense resulting in total Rs. 2,35,000 is required to translocate 47 trees without any damage.

Note by BMRCL:

The proposal to translocate 47 trees is found to be not feasible. The cost of translocation of each tree comes to nearly Rs. 1 lakh and the success rate of survival of translocated trees is also very less. Compensatory afforestation in the ratio of 1:10 will be done for each of the tree species of these 47 trees

11.6.1.5 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. According to the survey majority houses affected in



Byappanahalli to Whitefield alignment compare to other alignments.

Compensatory land records for each person have been updated to give compensation to the right persons and to avoid misuse of any property. About 2000 workers per day will be employed for the construction work and during peak working days it may reach 3500. 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.

11.6.1.6 Water Supply and Sanitation

The water demand for the proposed project is expected to be around 800 m³ and 600 m³ 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.

11.6.1.7 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.

11.6.1.8 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 mufflers, sound barriers etc. Vehicles used for transportation of construction materials would be equipped with proper silencers. Careful planning has been made to operate the construction 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.

11.6.1.9 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.

11.6.1.10 Soil Disposal

The construction activities will generate approximately 8.68 lakhs cubic meter of soil/debris causing soil erosion during excavation. This can be mitigated by utilizing around 35 % of excavated soil for land filling purposes. The excavated top fertile soil is suggested to be preserved and used later for gardening and lawn establishment. Soil erosion by runoff will be controlled by installing proper drainage systems using contour information. Proper land use plan has been suggested with technical evaluation. It is suggested to avoid bringing soil from outside the project boundary and to use the excavated mounds for filling low laying area where it is necessary. Thus, both cost and time saving suggestions have been made in land leveling and soil transportation.

11.6.1.11 Rain Water Harvesting

Roof top rain water harvesting can be carried out at all stations. The rooftop of the stations will become catchment area for rain. Rain water will be collected and stored in a tank or diverted into artificial recharge tanks. This method is less expensive and very effective to augment the ground water level of the area. Rain Water Harvesting potential for 1000 sqm roof area will be 7,68,000 liters annually based on the rainfall characteristics. Therefore around 13200 sqm of the station area can harvest approximately 7.85 million liters of rainwater annually in the proposed alignment from Mysore Road Terminal to Kengeri. Similarly, around 30800 sqm of the station area will harvest 18.30 million liters of rainwater annually from Byappanahalli to Whitefield. While, Hesaraghatta cross to BIEC and Puttenahalli to NICE road Junction can harvest 4.46 million liters and 7.85 million liters respectively.

Table 1126: Rain Water Harvesting potential along the proposed alignment

Items	Mysore Road Terminal to Kengeri (6)	Byappanahalli - ITPL- Whitefield (14)	Hesaraghatta cross to BIEC (3)	Puttenahalli to NICE Road Junction (6)
Stations Roof area (sq m)	13200	30800	7500	13200



Total rainfall available for harvest (Million liters)	7.85	18.33	4.46	7.85
Total (Million liters)	38.50			

Note: Avg. annual rainfall - 850 mm; Rainfall availability for harvest – 70 %

11.6.1.12 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 along the road sides.

11.6.1.13 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.

11.6.1.14 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 water spills, adopt disease control measures and employment of local labour.

11.7 ENVIRONMENTAL MONITORING PROGRAMME

Environmental Monitoring Programmes are vital to assess the effectiveness of Environmental Management Plans. The monitoring will be required during construction and operational phases for the following activity,

- Rehabilitation and Resettlement programme
- Ambient Air and Noise Level Monitoring
- Afforestation Programme
- Water Quality Monitoring
- Sanitation and Solid Waste Disposal
- Soil Disposal and Conservation
- Occupational Safety and Health

An Environment Management Cell (EMC) is proposed to MRTS Authority to effectively carry out above activities. The task of the personnel in the cell would be to supervise and implement mitigation measures based on necessity.

Similarly periodic Environmental Auditing is proposed to ensure the Environmental Management Plans and corrective measures at appropriate time during operation phase.

11.8 ENVIRONMENTAL COSTS

All costs involved in Environmental Management and monitoring is likely to be 7.61 Crores which has been taken into account in cost chapter.

CHAPTER-12

COST ESTIMATES



CHAPTER 12

COST ESTIMATES

12.1 INTRODUCTION

12.1.1 Detailed cost estimates for Bangalore Metro Phase-II (four extensions) have been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, etc. considering 750v DC Traction at July 2010 price level.

12.1.2 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, third rail, 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.

12.1.3 In order to arrive at realistic cost of various items, costs have been assessed on the basis of accepted rates in various contracts recently awarded by DMRC for their ongoing works. A suitable escalation factor has been applied to bring these costs to July 2010-price level. In some of these tenders, there is an element of Customs Duty (CD) on the equipment/components to be imported for the work, VAT, etc. built in the quoted rates. The element of customs duty and works tax has been excluded for working out the project cost. However, the details of taxes and duties are worked out separately.

Note by BMRCL

The cost estimate proposed in the DPR has been duly considered with reference to the cost of similar works in Bangalore Metro Phase -1. There are major differences in the cost estimate of station buildings, viaduct, construction of depot and land acquisition. The details of these are given in para concerned.

12.1.4 The overall capital cost for Bangalore Metro Phase-II (four extensions), at July 2010 price level, works out to Rs. 5505 Crores for the 4 extensions. 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 12.1

TABLE 12.1
ABSTRACT OF COST ESTIMATE FOR FOUR EXTENSIONS
(Inclusive of land cost for alignment & Stations)

Sl.No.	Description	As per DPR			As per BMRCL		
		Cost excluding taxes & Duties Rs. Crores	Details of taxes & Duties Rs. Crores	TOTAL in Rs. Crores	Cost excluding taxes & Duties Rs. Crores	Details of taxes & Duties Rs. Crores	TOTAL in Rs. Crores
1	Mysore Road Terminal – Kengeri	1146.64	182.00	1328.64	1340.84	207.00	1547.84
2	Baiyappanahalli – ITPL – White field	2820.24	444.00	3264.24	3483.59	532.00	4015.59
3	Puttenahalli Cross – Anjanapur Township (up to NICE Road crossing)	937.81	142.00	1079.81	1279.97	193.00	1472.97
4	Hesaraghatta Cross - BIEC	600.19	88.00	688.19	847.68	117.00	964.68
GRAND TOTAL		5504.88	856.00	6360.88	6945.08	1049.00	7994.08
Say Rs.6361.00 Crores					Say Rs.7994.00 Crores		

ABSTRACT OF COST ESTIMATE FOR LAND (Only 9.82 Ha.) FOR PD (FOUR EXTENSIONS)

Sl. No.	Description	Cost Rs. Crores
1	Mysore Road Terminal – Kengeri	44.00
2	Baiyappanahalli -ITPL - Whitefield	14.00
3	Puttenahalli Cross – Anjanapur Township (up to NICE Road x-ing)	53.00
4	Hesaraghatta Cross - BIEC	28.00
GRAND TOTAL		139.00



The above cost has however not taken in evaluating the financial viability of the project

Abstract Capital Cost Estimate for Bangalore Phase – II extensions								
EXTENSION OF PHASE - I LINES (four Extensions)								
(i) Extension of E-W line from Mysore Road to Kengeri								
Total length = 6.465 km (completely elevated) No. of Stations = 5								
		As per Final DPR				As per BMRCL		
	Item	Unit	Rate	Qty	Amount (Rs. in crores)	Rate	Qty	Amount (Rs. in crores)
1.0	Land							
1.1	(a) land for alignment and stations	Ha	13.45	1.46	19.63	30.00	1.46	43.80
	(b) (i) Land for Depot Pvt. Land	Ha.	13.45	4.00	53.80	13.45	4.00	53.80
	(c) Land for Construction Depot (Land on lease for four years)	Ha.	3.23	4.00	12.91	3.23	4.00	12.92
	Sub Total (1)				86.34			110.52
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R.Km	32.55	6.47	210.44	31.50	6.47	203.81
	Sub Total (2)				210.44			203.81
3.0	Station Buildings							
3.1	Elevated Stations							
A	Type (A) Way side	Each	14.15	4	56.60	30.60	4	122.40
B	Type (c) Terminal & Junction	Each		1	16.97	34.20	1	34.20
C	Architectural finishing	Each	4.00		20.00			
	Sub Total (3)				93.57			156.60
4.0	E & M Works							
4.1	Elevated Stations							
C	Type (A) Way side – E & M works	Each	6.47	5	32.35	6.47	4	25.88
D	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				38.82			32.35
5.0	Depot at Kengeri /Future Station							
	Civil Works				24.00			24.00
	E & M Works				16.00			16.00
	Sub Total (5)				40.00			40.00
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	6.47	41.51	6.42	6.47	41.54
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	2.00	4.00	2.00	2.00	4.00
	Sub Total (6)				45.51			45.54
7.0	Traction & Power Supply							



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7.1	Traction & Power supply including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	6.47	60.51	13.00	6.47	84.11
	Sub Total (7)				60.51			84.11
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	6.47	51.85	9.89	6.47	63.99
8.2	Telecom	Each Stn.	2.76	6.00	16.56	5.04	5.00	25.20
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	6.00	17.58	2.93	5.00	14.66
	Sub Total (8)				85.99			103.84
9.0	R & R including Hutments and road restoration etc	LS			26.00			26.00
	Sub Total (9)				26.00			26.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	6.47	20.18	3.12	6.47	20.18
10.2	Electrical Utilities	LS			25.00			18.00
10.3	Telecom Utilities	LS			4.00			4.00
	Sub Total (10)				49.17			42.18
11.0	Rolling Stock (SG)	Each	10.40	30.00	312.00	9.50	38.00	361.00
	Sub Total (11)				312.00			361.00
12.1	Barracks for CISF including Security equipments	LS			3.00			3.00
12.2	Staff Quarters for O & M	LS			13.00			36.10
	Sub Total (12)				16.00			39.10
13.0	Total of all items except Land				978.00			1134.54
14.0	General Charges incl. Design charges @ 5% on all items except land				48.90			56.73
15.0	Total of all items including General charges				1026.90			1191.27
16.0	Total of Cost inclusive land cost				1113.24			1301.79
17.0	Contingencies @ 3%				33.40			39.05
18.0	Gross Total				1146.64			1340.84



(ii) Extension of Phase-I E-W line Baiyappanahalli to White Field

Total length = 15.5 km No. of Stations = 14

Sl. No.	Item	Unit	As per Final DPR			As per BMRCL		
			Rate	Qty	Amount Rs. in crores)	Rate	Qty	Amount Rs. in crores)
1.0	Land							
1.1	(a) land for alignment and stations	Ha	16.13	7.79	125.61	30.00	7.79	233.70
	(b) Land for RSS	Ha.	16.13	0.40	6.45	16.13	0.40	6.45
	(c) Land for Depot	Ha.	13.45	8.00	107.60	13.45	8.00	107.60
	(d) Land for construction Depot (on lease for four years)	Ha.	3.87	4.00	15.48	3.87	4.00	15.48
	Sub Total (1)				255.15			363.23
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R. Km	32.55	15.50	504.53	31.50	15.50	488.25
	Sub Total (2)				504.53			488.25
3.0	Station Buildings							
3.1	Elevated Stations							
a	Type (A) Way side	Each	14.15	11	155.65	30.60	11	336.60
b.	Type (b) Way side with signaling	Each	15.56	2	31.12	32.40	2	64.80
c	Type (c) Terminal & Junction	Each	16.97	1	16.97	34.20	1	34.20
d	Architectural finishing	Each	4.00	14.00	56.00			-
	Sub Total (3)				259.74			435.60
4.0	E & M Works							
4.1	Elevated Stations							
d	Type (A) Way side – E & M works	Each	6.47	11	71.17	6.47	11	71.17
e	Type (B) Way side with signaling E & M works	Each	6.47	2	12.94	6.47	2	12.94
f	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				90.58			90.58
5.0	Depot at Kengeri /Future Station							
	Civil Works				48.00			48.00
	E & M Works				32.00			32.00
	Sub Total (5)				80.00			80.00
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	15.50	99.51	6.42	15.50	99.51
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	3.00	6.00	2.00	3.00	6.00
	Sub Total (6)				105.51			105.51
7.0	Traction & Power Supply							
7.1	Traction & Power supply including OHE, ASS etc.							



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7.1.1	Elevated station	R. Km	9.36	15.50	145.08	10.00	15.50	155.00
	Sub Total (7)				145.08			155.00
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	15.50	124.31	9.89	15.50	153.30
8.2	Telecom	Each Stn.	2.76	14.00	38.64	5.04	14.00	70.56
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	14.00	41.02	2.93	14.00	41.02
	Sub Total (8)				203.97			264.88
9.0	R & R including Hutments and road restoration etc	LS			42.00			42.00
	Sub Total (9)				42.00			42.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	15.50	48.36	3.12	15.50	48.36
10.2	Electrical Utilities	LS			41.50			125.81
10.3	Telecom Utilities	LS			6.50			6.50
	Sub Total (10)				96.36			180.67
11.0	Rolling Stock (SG)	Each	10.40	78	811.20	9.50	100.00	950.00
	Sub Total (11)				811.20			950.00
12.1	Barracks for CISF including Security equipments	LS			4.75			4.75
12.2	Staff Quarters for O & M	LS			21.00			77.90
	Sub Total (12)				25.75			82.65
13.0	Total of all items except Land				2364.72			2875.14
14.0	General Charges incl. Design charges @ 5% on all items except land				118.24			143.76
15.0	Total of all items including General charges				2482.95			3018.90
16.0	Total of Cost inclusive land cost				2738.10			3382.13
17.0	Contingencies @ 3%				82.14			101.46
18.0	Gross Total				2820.24			3483.59



(iii) Extension of Phase-I N-S line Puttenahalli Cross to Anjanapura Township

Total length = 6.292km (entire Corridor is elevated) No. of Stations = 5

Sl.No.	Item	Unit	As per Final DPR			As per BMRCL		
			Rate	Qty	Amount (Rs. in crores)	Rate	Qty	Amount (Rs. in crores)
1.0	Land							
1.1	(a) land for alignment and stations	Ha	15.05	2.23	33.62	30.00	2.23	66.90
	(b) Land for Depot Pvt. Land	Ha.	15.05	3.00	45.15	15.05	3.00	45.15
	(c) Land for construction Depot (on lease for four years)	Ha.	3.61	4.00	14.45	3.61	4.00	14.44
	Sub Total (1)				93.22			126.49
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R. Km	32.55	6.29	204.80	31.50	6.29	198.14
	Sub Total (2)				204.80			198.14
3.0	Station Buildings							
3.1	Elevated Stations							
a	Type (A) Way side	Each	14.15	4	56.60	30.60	4	122.40
b	Type (c)Terminal & Junction	Each	16.97	1	16.97	34.20	1	34.20
C	Architectural finishing	Each	4.00		20.00			
	Sub Total (3)				93.57			156.60
4.0	E & M Works							
4.1	Elevated Stations							
c	Type (A) Way side – E & M works	Each	6.47	4	25.88	6.47	4	25.88
d	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				32.35			32.35
5.0	Stabling Depot at Anjanapura with washing facilities							
	Civil Works				36.00			36.00
	E & M Works				24.00			24.00
	Sub Total (5)				60.00			60.00
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	6.29	40.39	6.42	6.29	40.38
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	2.00	4.00	2.00	2.00	4.00
	Sub Total (6)				44.39			44.38
7.0	Traction & Power Supply							
7.1	Traction & Power supply including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	6.29	58.89	10.00	6.29	62.90
	Sub Total (7)				58.89			62.90
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	6.29	50.46	11.64	6.29	73.22
8.2	Telecom	Each Stn.	2.76	5.00	13.80	5.68	5.00	28.40
8.3	Automatic fare collection							



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8.3.1	Elevated Stations	Each	2.93	5.00	14.65	2.93	5.00	14.65
	Sub Total (8)				78.92			116.27
9.0	R & R including Hutments and road restoration etc	LS			22.00			22.00
	Sub Total (9)				22.00			22.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	6.29	19.63	3.12	6.29	19.63
10.2	Electrical Utilities	LS			22.00			21.00
10.3	Telecom Utilities	LS			3.50			3.50
	Sub Total (10)				45.13			44.13
11.0	Rolling Stock (SG)	Each	10.40	12.00	124.80	9.50	30	285.00
	Sub Total (11)				124.80			285.00
12.1	Barracks for CISF including Security equipments	LS			2.50			2.50
12.2	Staff Quarters for O & M	LS			11.00			32.30
	Sub Total (12)				13.50			34.80
13.0	Total of all items except Land				778.36			1056.50
14.0	General Charges incl. Design charges @ 5% on all items except land				38.92			52.83
15.0	Total of all items including General charges				817.27			1109.40
16.0	Total of Cost inclusive land cost				910.49			1235.80
17.0	Contingencies @ 3%				27.31			37.00
18.0	Gross Total				937.81			1272.97



(iv) Extension of Phase-I N-S line Hesaraghatta Cross to BIEC

Total length = 3.774km (entire Corridor is elevated) No. of Stations = 3

Sl. No.	Item	Unit	As per Final DPR			As per BMRCL		
			Rate	Qty	Amount	Rate	Qty	Amount (Rs. In crores)
1.0	Land							
1.1	(a) land for alignment and stations							
	Govt. Land	Ha	5.00	0.49	2.44	5.00	0.49	2.45
	Pvt. Land	Ha	12.90	4.09	52.78	30.00	4.09	122.70
	(b) Land for Depot Pvt. Land	Ha.	15.05	1.00	15.05	15.05	1.00	15.05
	(c) Land for construction Depot (on lease for four years)	Ha.	3.10	4.00	12.38	3.10	4.00	12.40
	Sub Total (1)				82.66			152.60
2.0	Alignment and Formation							
2.1	Elevated section including viaduct length in stations	R. Km	32.55	3.77	122.84	31.50	3.77	118.76
	Sub Total (2)				122.84			118.76
3.0	Station Buildings							
3.1	Elevated Stations							
a	Type (A) Way side	Each	14.15	2	28.30	30.60	2	61.20
b	Type (c) Terminal & Junction	Each	16.97	1	16.97	34.20	1	34.20
c	Architectural finishing	Each	4.00	3	12.00			
	Sub Total (3)				57.27			95.40
4.0	E & M Works							
4.1	Elevated Stations							
c	Type (A) Way side – E & M works	Each	6.47	2	12.94	6.47	2	12.94
d	Type (c) Terminal & Junction – E & M works	Each	6.47	1	6.47	6.47	1	6.47
	Sub Total (4)				19.41			19.41
5.0	Stabling Depot at Anjanapura with washing facilities							
	Civil Works				18.00			18.00
	E & M Works				12.00			12.00
	Sub Total (5)				30.00			30.00
6.0	Permanent Way							
6.1	Ballastless track for elevated Section	R. Km	6.42	3.77	24.23	6.42	3.77	24.20
6.2	Ballasted track for sidings etc. in Depot	R. Km	2.00	2.00	4.00	2.00	2.00	4.00
	Sub Total (6)				28.23			28.20
7.0	Traction & Power Supply							
7.1	Traction & Power supply including OHE, ASS etc.							
7.1.1	Elevated station	R. Km	9.36	3.77	35.32	9.36	3.77	35.29
	Sub Total (7)				35.32			35.29
8.0	Signaling and Telecom							
8.1	Signaling	R.Km	8.02	3.77	30.27	9.89	3.77	37.29



8.2	Telecom	Each Stn.	2.76	3.00	8.28	5.04	3.00	15.12
8.3	Automatic fare collection							
8.3.1	Elevated Stations	Each	2.93	3.00	8.79	2.93	3.00	8.79
	Sub Total (8)				47.34			61.20
9.0	R & R including Hutments and road restoration etc	LS			11.00			11.00
	Sub Total (9)				11.00			11.00
10.1	Misc. Utilities, other civil works such as median, road signals etc.	R.Km	3.12	3.77	11.77	3.12	3.77	11.76
10.2	Electrical Utilities	LS			11.00			6.00
10.3	Telecom Utilities	LS			1.70			1.70
	Sub Total (10)				24.47			19.46
11.0	Rolling Stock (SG)	Each	10.40	9.00	93.60	9.50	21	199.50
	Sub Total (11)				93.60			199.50
12.1	Barracks for CISF including Security equipments	LS			1.25			1.25
12.2	Staff Quarters for O & M	LS			5.50			19.00
	Sub Total (12)				6.75			20.25
13.0	Total of all items except Land				476.24			638.47
14.0	General Charges incl. Design charges @ 5% on all items except land				23.81			31.92
15.0	Total of all items including General charges				500.05			670.39
16.0	Total of Cost inclusive land cost				582.71			822.99
17.0	Contingencies @ 3%				17.48			24.69
18.0	Gross Total				600.19			847.68

12.2 CIVIL ENGINEERING WORKS

12.2.1 Land

- i) Land requirements have been kept to the barest minimum & worked out on area basis. For the portion of the elevated alignment on Eastern side of NH-4 [due to planned elevated road in the middle of Tumkur road (NH-4) by NHAI] some land for alignment as well as for stations required to be acquired.
- ii) Total land requirements for the alignment & Stations of four extensions have been worked out to **16.07 Ha** out of which **0.50 Ha** is govt. land and balance **15.57Ha** is private land.
- iii) Total land requirements for the property developments of four extensions have been worked out to **9.82 Ha** of Pvt. land.

**Note by BMRCL**

The cost of land proposed for acquisition for alignment and stations proposed in the DPR ranges from Rs. 12.90 Crores to Rs.16.13 per hectare. It may be noted here that the alignment of all the four Phase –II extensions will be along the NH/SH or on the main urban road. The entire length of the alignment passes through well developed commercial / residential areas. The land to be acquired for these extensions is mostly non agricultural land. The cost of land proposed in the DPR ranges to Rs. 12900 to 16300 per Sqm (Rs. 1200 to 1500 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 exiting rate of 30%. If the new law comes in to effect the cost of land will further go up.

So considering all these factors the land cost is calculated at the rate of Rs. 30 Crores per hectare as against Rs.12.90 to Rs.16.13 Crores per hectare given in the DPR.

Summary of the land cost is placed at Table 12.2

12.2.2 Alignment

- i) **Elevated Section:** Rates are based on accepted rates for on going works of Delhi Metro, duly updated to July 2010 price level. Cost of viaduct length for station has been included in elevated section.

Note by BMRCL

The cost of elevated section proposed in the DPR is Rs. 32.55 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.



12.2.3 Station Buildings

- i) **Elevated Stations:** Estimated rate is based on accepted rates for stations by DMRC for similar works for 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.

Note by BMRCL

The cost of 'A' type station building as per DPR is Rs. 18.15 Crores (14.15+4.00) and for terminal station, it is Rs. 20.97 Crores (16.97 + 4.00). Where as 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. The rates of BMRCL are based on contract value of similar works of Bangalore Metro Phase-I works. Hence the cost estimate of station building proposed in DPR is not realistic and as such can not be adopted. So the cost estimate as proposed by BMRCL may be accepted.

- 12.2.4 **Permanent Way** - For elevated sections, ballast less track has been planned. Rates adopted are based on accepted rates of Delhi Metro, for ballast less tracks.

Note By BMRCL:

The rate for permanent way is Rs.6.42 crores per km. this is based on Bangalore Metro Phase-I works.

12.3 UTILITY DIVERSIONS

- 12.3.1 The costs of utility diversions involved in elevated stretches 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.

Note by BMRCL

The cost of electrical utility shifting as proposed in the DPR is Rs.99.50 crores. As per BMRCL the cost estimate of electrical utility shifting comes to Rs.170.81 crores. The extension wise breakup is Rs.18.00 crores for Mysore road to Kengeri, Rs.125.81 crores for Baiyappanahalli to Whitefield, Rs.21.00 crores for Puttenahalli to Anjanapur Township and Rs. 6.00 crores for Hesaraghatta to BIEC. The major difference is in Baiyappanahalli to Whitefield section. The



DPR proposes a diversion of alignment after Ch.26800. The alignment up to this Chainage runs on the median of road 2. At Chainage 26800 it has to cross two 220 KV HT lines. Hence the DPR proposes to take this alignment on the right side of the road. If this proposal is to be accepted we have to shift the alignment to a distance of 23 Meters (18 meters as per KPTCL norms + 5 meters for our viaduct) and the HT line runs for a distance of 2.50 km. This will result in acquisition of large extent of built up area and land of about 5.7 Hectares. The cost acquisition of above mentioned land will be around Rs.171 crores. Apart from this we have to acquire large amount of built up area which will not only cost money but also causes lot of hardship and misery to the public. So it is decided to shift the 220 KV HT line by taking it underground and having the Metro alignment on the median of the road. The shifting of 220 KV HT line will cost Rs. 84.00 crores (as per the estimate of KPTCL). This, in our view, is justified when compared to the cost of additional land acquisition if the alignment is taken on the right side of the road. So, in our view, it would be prudent to take the alignment along the median of the road by shifting the 220 KV HT line.

12.4 ENVIRONMENTAL IMPACT ASSESSMENT

12.4.1 Provision for environmental impacts of this Metro corridor has been made to cover various protection works, additional compensatory measures, compensation for loss of trees, compensatory a forestation and fencing, monitoring of water quality, air/noise pollution during construction, establishment of Environmental Division.

12.5 REHABILITATION & RESETTLEMENT

12.5.1 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.

12.6 TRACTION & POWER SUPPLY

12.6.1 Provisions have been made to cover following subheads:

- Third Rail
- 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.



12.6.2 The rates adopted for various items are based on the accepted contract rates for similar works being done for Delhi Metro.

12.7 ELECTRICAL SERVICES AT STATIONS

12.7.1 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 third rail.

12.8 SIGNALLING & TELECOMMUNICATION WORKS

12.8.1 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 by BMRCL

The rates adopted by BMRCL are different and are based on contract awarded for similar works of Bangalore metro- Phase-I. So it is realistic to adopt these rates.

12.9 AUTOMATIC FARE COLLECTION

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.

12.10 ROLLING STOCK

12.10.1 The base cost is taken on the basis of previous contracts finalized by DMRC during Phase 1 and 2.

Note by BMRCL

As per the train operation plan contained in chapter 5 of DPR the requirement of coaches in the year 2016 is 189. However in this chapter the cost of only 129 coaches is taken into consideration. This has been brought to the notice of DMRC and in their reply they have stated that the 60 coaches required for operations in Phase-1 route is not considered in DPR and have further suggested that BMRCL should make necessary arrangements for cost of 60 coaches. So the additional cost of 60 coaches is added to the phase – II cost itself as



no such provision has been made in DPR of Phase-1. Consequently the cost of rolling stock will be Rs.1934.40 crores as against Rs.1341.60 crores indicated in DPR.

Staff Quarters

Note by 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. 13 Crores as per DPR. As the number of staff quarters to be provided will be substantially more the cost in our view will Rs. 36.10 Crores.

12.11 TAXES AND DUTIES

Estimate for taxes and duties are given in **Table 12.3**. It is estimated that the taxes and duties will amount to **Rs 856 Crores** and the total cost inclusive of taxes and duties is **Rs.Rs.6361 Crores**.

Note By BMRCL:

The total cost of these four extensions as per BMRCL's estimate comes to Rs6945.08 crores. The taxes and duties will amount to Rs.1049.00 crores and the total cost including taxes and duties will be Rs.7994.08 crores.

Table 12.3 Details of Taxes and Duties B M PHASE-II (FOUR EXTENSIONS)

(i) Extension of E-W line from Mysore Road to Kengeri – As per DPR						
Details of Taxes and Duties						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
Sl. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
1	Alignment & Formation					
	Elevated, at grade & entry to Depot	210.44		15.17	20.31	35.48
2	Station Buildings					
	c) Elevated station - civil works	93.57		6.75	9.03	15.78



	d) Elevated station-EM works	38.82	1.63	2.72	3.64	7.98
3	Depot					
	Civil works	24.00	1.51	1.21	1.62	4.34
	EM works	16.00	0.67	1.12	1.50	3.29
4	P-Way	45.51	7.63	0.80	1.07	9.49
5	Traction & power supply					
	Traction and power supply	60.51	5.07	3.18	4.26	12.50
6	S and T Works					
	S & T	68.41	11.46	1.41	1.89	14.76
	AFC	17.58	2.76	0.45	0.61	3.82
7	R & R hutments	26.00			1.63	1.63
8	Misc.					
	Civil works	20.17		1.45	1.95	3.40
	EM works	29.00		2.54	3.40	5.94
9	Rolling stock	312.00	57.51	2.51	3.36	63.37
	Total	962.00	88.24	39.31	54.24	181.78
	Total taxes & Duties					182

Extension of E-W line from Mysore Road to Kengeri – As per BMRCL

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
2	Alignment & Formation					
	Underground		0.00	0.00	0.00	0.00
	Elevated, at grade & entry to Depot	203.81		14.69	19.67	34.36
3	Station Buildings					
	a) Underground station-civil works		0.00	0.00	0.00	0.00
	b) Underground station-EM works		0.00	0.00	0.00	0.00
	c) Elevated station - civil works	156.60		11.29	15.11	26.40
	d) Elevated station-EM works	32.35	1.36	2.27	3.03	6.65
5	Depot					
	Civil works	24.00	1.51	1.21	1.62	4.34
	EM works	16.00	0.67	1.12	1.50	3.29



6	P-Way	45.54	7.63	0.80	1.07	9.50
7	Traction & power supply					
	Traction and power supply	84.11	7.05	4.42	5.91	17.38
8	S and T Works					
	S & T	89.19	14.95	1.84	2.46	19.24
	AFC	14.65	2.30	0.38	0.50	3.18
9	R & R hutments	26.00			1.63	1.63
10	Misc.					
	Civil works	20.19		1.46	1.95	3.40
	EM works	22.00		1.93	2.58	4.50
11	Rolling stock	361.00	66.54	2.90	3.88	73.33
	Total	1095.44	102.00	44.30	60.92	207.22
	Total taxes & Duties					207

ii) Extension of Phase-I E-W line Baiyappanahalli to White Field – As per DPR

Details of Taxes and Duties						
	Customs duty =	20.9464	%			
	Excise duty =	10.3	%			
	Sale tax =	6.25	%			
	Works tax =	6.25	%			
	VAT =	12.5	%			
Sl. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
1	Alignment & Formation					
	Elevated, at grade & entry to Depot	504.53		36.38	48.69	85.07
2	Station Buildings					
	c) Elevated station - civil works	259.74		18.73	25.07	43.80
	d) Elevated station-EM works	90.58	3.79	6.34	8.49	18.63
3	Depot					
	Civil works	48.00	3.02	2.42	3.24	8.68
	EM works	32.00	1.34	2.24	3.00	6.58
4	P-Way	105.51	17.68	1.85	2.47	22.00



5	Traction & power supply					
	Traction and power supply	145.08	12.16	7.62	10.20	29.98
6	S and T Works					
	S & T	162.95	27.31	3.36	4.49	35.16
	AFC	41.02	6.44	1.06	1.41	8.91
7	R & R hutments	42.00			2.63	2.63
8	Misc.					
	Civil works	48.36		3.49	4.67	8.15
	EM works	48.00		4.20	5.63	9.83
9	Rolling stock	811.20	149.53	6.52	8.72	164.77
	Total	2338.97	221.26	94.20	128.72	444.18
	Total taxes & Duties					444

Extension of Phase-I E-W line Baiyappanahalli to White Field – As per BMRCL

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
2	Alignment & Formation					
	Underground		0.00	0.00	0.00	0.00
	Elevated, at grade & entry to Depot	488.25		35.20	47.12	82.33
3	Station Buildings					
	a) Underground station-civil works		0.00	0.00	0.00	0.00
	b) Underground station-EM works		0.00	0.00	0.00	0.00
	c) Elevated station - civil works	435.60		31.41	42.04	73.45
	d) Elevated station-EM works	90.58	3.79	6.34	8.49	18.63
5	Depot					
	Civil works	48.00	3.02	2.42	3.24	8.68
	EM works	32.00	1.34	2.24	3.00	6.58
6	P-Way	105.51	17.68	1.85	2.47	22.00
7	Traction & power supply					
	Traction and power supply	155.00	12.99	8.14	10.90	32.03



8	S and T Works					
	S & T	223.86	37.51	4.61	6.17	48.30
	AFC	41.02	6.44	1.06	1.41	8.91
9	R & R hutments	42.00			2.63	2.63
10	Misc.					
	Civil works	48.36		3.49	4.67	8.15
	EM works	132.31		11.58	15.51	27.09
11	Rolling stock	950.00	175.11	7.63	10.22	192.96
	Total	2792.49	257.89	115.98	157.87	531.74
	Total taxes & Duties					532

(iii) Extension of Phase-I N-S line Puttenahalli Cross to Anjanapur Township –As per DPR						
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.)	
1	Alignment & Formation					
	Elevated, at grade & entry to Depot	204.80		14.77	19.77	34.53
2	Station Buildings					
	c) Elevated station - civil works	93.57		6.75	9.03	15.78
	d) Elevated station-EM works	32.35	1.36	2.27	3.03	6.65
3	Depot					
	Civil works	36.00	2.26	1.82	2.43	6.51
	EM works	24.00	1.01	1.68	2.25	4.94
4	P-Way	44.39	7.44	0.78	1.04	9.26
5	Traction & power supply					
	Traction and power supply	58.89	4.93	3.09	4.14	12.17



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6	S and T Works					
	S & T	64.26	10.77	1.32	1.77	13.86
	AFC	14.65	2.30	0.38	0.50	3.18
7	R & R hutments	22.00			1.38	1.38
8	Misc.					
	Civil works	19.63		1.42	1.89	3.31
	EM works	25.50		2.23	2.99	5.22
9	Rolling stock	124.80	23.00	1.00	1.34	25.35
	Total	764.86	53.07	37.50	51.57	142.14
	Total taxes & Duties					142

Extension of Phase-I N-S line Puttenahalli Cross to Anjanapur Township –As per BMRCL

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
2	Alignment & Formation					
	Underground		0.00	0.00	0.00	0.00
	Elevated, at grade & entry to Depot	198.14		14.29	19.12	33.41
3	Station Buildings					
	a) Underground station-civil works		0.00	0.00	0.00	0.00
	b) Underground station-EM works		0.00	0.00	0.00	0.00
	c) Elevated station - civil works	156.60		11.29	15.11	26.40
	d) Elevated station-EM works	32.35	1.36	2.27	3.03	6.65
5	Depot					
	Civil works	36.00	2.26	1.82	2.43	6.51
	EM works	24.00	1.01	1.68	2.25	4.94
6	P-Way	44.38	7.44	0.78	1.04	9.25
7	Traction & power supply					
	Traction and power supply	62.90	5.27	3.30	4.42	13.00
8	S and T Works					
	S & T	101.62	17.03	2.09	2.80	21.92
	AFC	14.65	2.30	0.38	0.50	3.18



9	R & R hutments	22.00			1.38	1.38
10	Misc.					
	Civil works	19.63		1.42	1.89	3.31
	EM works	24.50		2.14	2.87	5.02
11	Rolling stock	285.00	52.53	2.29	3.06	57.89
	Total	1021.77	89.19	43.74	59.93	192.86
	Total taxes & Duties					193

iv) Extension of Phase-I N-S line Hesaraghatta Cross to BIEC – As per DPR

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.)	
1	Alignment & Formation					
	Elevated, at grade & entry to Depot	122.84		8.86	11.86	20.71
2	Station Buildings					
	c) Elevated station - civil works	57.27		4.13	5.53	9.66
	d) Elevated station-EM works	19.41	0.81	1.36	1.82	3.99
3	Depot					
	Civil works	18.00	1.13	0.91	1.22	3.26
	EM works	12.00	0.50	0.84	1.13	2.47
4	P-Way	28.23	4.73	0.49	0.66	5.89
5	Traction & power supply					
	Traction and power supply	35.32	2.96	1.86	2.48	7.30
6	S and T Works					
	S & T	38.55	6.46	0.79	1.06	8.32
	AFC	8.79	1.38	0.23	0.30	1.91



Chapter 12 - Cost Estimates

7	R & R hutments	11.00			0.69	0.69
8	Misc.					
	Civil works	11.77		0.85	1.14	1.99
	EM works	12.70		1.11	1.49	2.60
9	Rolling stock	93.60	17.25	0.75	1.01	19.01
	Total	469.49	35.23	22.18	30.37	87.78
	Total taxes & Duties					88

Extension of Phase-I N-S line Hesaraghatta Cross to BIEC – As per BMRCL

S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
2	Alignment & Formation					
	Underground		0.00	0.00	0.00	0.00
	Elevated, at grade & entry to Depot	118.76		8.56	11.46	20.02
3	Station Buildings					
	a) Underground station-civil works		0.00	0.00	0.00	0.00
	b) Underground station-EM works		0.00	0.00	0.00	0.00
	c) Elevated station - civil works	95.40		6.88	9.21	16.09
	d) Elevated station-EM works	19.41	0.81	1.36	1.82	3.99
5	Depot					
	Civil works	18.00	1.13	0.91	1.22	3.26
	EM works	12.00	0.50	0.84	1.13	2.47
6	P-Way	28.20	4.73	0.49	0.66	5.88
7	Traction & power supply					
	Traction and power supply	35.29	2.96	1.85	2.48	7.29
8	S and T Works					
	S & T	52.41	8.78	1.08	1.45	11.31
	AFC	8.79	1.38	0.23	0.30	1.91
9	R & R hutments	11.00			0.69	0.69
10	Misc.					
	Civil works	11.76		0.85	1.13	1.98
	EM works	7.70		0.67	0.90	1.58
11	Rolling stock	199.50	36.77	1.60	2.15	40.52



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	Total	618.22	57.07	25.33	34.59	116.98
	Total taxes & Duties					117



Table 12.2 LAND REQUIREMENT FOR B M PHASE-II (FOUR EXTENSIONS)

Sl No	Location	Chainage		Area in (Sqm)				Rate for Private/Govt Land (Per Sqm)	Amount for Private Land (Rate Rs 13450/- Per Sqm)	Govt Land (Rate Rs 5000 Per Sqm)	Total Land cost
		From	To	Alignment		Station					
				Private	Govt	Private	Govt				
(i) Mysore Road Terminal to Kengeri											
1	Alignment	(-) 554	(-) 694.50	877.12	0	0	0	13450.00	11797264.00	0	11797264.00
2	Nayandanahalli Station	(-) 694.50	(-) 834.50	0	0	3041.37	0	13450.00	40906426.5	0	40906426.5
3	Alignment	(-) 834.50	(-) 1560	447.63	0	0	0	13450.00	6020623.5	0	6020623.5
4	Rajarajeshwari Nagar Station	(-) 1560	(-) 1700	0	0	2544.37	0	13450.00	34221776.5	0	34221776.5
5	Alignment	(-) 1700	(-) 2271	593.88	0	0	0	13450.00	7987686.00	0	7987686
6	Bengaluru University Station	(-) 2271	(-) 2411	0	0	1508.25	0	13450.00	20285962.50	0	20285962.50
7	Alignment	(-) 2411	(-) 4327.10	0	0	0	0	13450.00	0	0	0
8	R V College of Engg	(-) 4327.10	(-) 4467.10	2529.85	0	0	0	13450.00	34026482.50	0	34026482.50
9	Alignment	(-) 4467.10	(-) 6115	1016.39	0	0	0	13450.00	13670445.5	0	13670445.5
10	Kengeri Station	(-) 6115	(-) 6255	0	0	2031.29	0	13450.00	27320850.5	0	27320850.5
11	Alignment	(-) 6255	(-) 6500	0	0	0	0	13450.00	0	0	0
TOTAL				5464.87	0	9125.28	0		196237517.50	0	196237517.50
Land for PD						33042.00		13450.00	444414900.00		SAY 20 crores
											444414900
											Say 44 Crores
12	Depot near Kengeri Station (BMTc depot)		120000		0	0	0	13450.00	1614000000	0	1614000000
											say 161 Crores



Sl No	Location	Chainage		Area in (Sqm)				Rate for Private/Govt. Land (Per Sqm)	Amount for Private Land (Rate Rs 16125/- Per Sqm)	Amount for Govt. Land (Rate Rs 5000 Per Sqm)	Total Land cost
		From	To	Alignment		Station					
				Private	Govt.	Private	Govt.				
(ii)a. Baiyappanahalli to ITPL											
1	Alignment	18595	18750	1723.10	0	0	0	16125.00	27784987.50	0	27784987.50
2	Alignment	18920	18990	951.95	0	0	0	16125.00	15350193.75	0	15350193.75
3	Alignment	19200	19245	520.48	0	0	0	16125.00	8392740.00	0	8392740.00
4	Alignment	19300	19400	2127.33	0	0	0	16125.00	34303196.25	0	34303196.25
5	Jyothispuram Station	19730	19870	0	0	0	0	16125.00	0	0	0
6	Alignment	19870	20555	5968.52	0	0	0	16125.00	96242385.00	0	96242385.00
7	Alignment	20555	20695	3525.56	0	0	0	16125.00	56849655.00	0	56849655.00
8	Alignment	20695	21430	3839.85	60	0	0	16125.00	61917581.25	300000	62217581.25
9	Narayanapura Station	21430	21570	0	0	1034.37	0	16125.00	16679216.25	0	16679216.25
10	Alignment	21570	22330	87.8	0	0	0	16125.00	1415775.00	0	1415775.00
11	Mahadevapura Station	22330	22470	0	0	3362.65	0	16125.00	54222731.25	0	54222731.25
12	Alignment	22470	23530	0	0	0	0	16125.00	0	0	0
13	Garudacharpalya Station	23530	23670	0	0	3443.45	0	16125.00	55525631.25	0	55525631.25
14	Alignment	23670	24565	3866.54	0	0	0	16125.00	62347957.50	0	62347957.50
	Dodanekkundi Industrial Area Station	24565	24705	0	0	3957.54	0				
15	Alignment	24705	25565	382.15	0	0	0	16125.00	63815332.50	0	63815332.50
16	Alignment	24705	25565	382.15	0	0	0	16125.00	6162168.75	0	6162168.75



17	Doddenakkundi Industrial Area	25565	25705	0	0	3906.22	0	16125.00	62987797.50	0	62987797.50
18	Alignment Kundalahalli Station	25705 26430	26430 26570	1752.4 0	0 0	0 3603.91	0 0	16125.00 16125.00	28257450.00 58113048.75	0 0	28257450.00 58113048.75
19	Alignment	26570	27430	1547.64	0	0	0	16125.00	24955695.00	0	24955695.00
20	Vydehi Hospital	27430	27570	0	0	2560.6	0	16125.00	41289675.00	0	41289675.00
21	Alignment	27570	28230	1990.73	0	0	0	16125.00	32100521.25	0	32100521.25
22	Sathya Sai Hospital Station	28230	28370	0	0	3330.99	0	16125.00	53712213.75	0	53712213.75
23	Alignment	28370	29680	5681.87	0	0	0	16125.00	91620153.75	0	91620153.75
24	ITPL Station	29680	29820	0	0	3517.09	0	16125.00	56713076.25	0	56713076.25
25	Alignment	29820	30100	0	0	0	0	16125.00	0	0	0.00
26	Total			33965.92	60	28716.82	0	16125.00	1010759182.50	300000	1011059182.50
											say 101 Crores
	Land for PD			0		8800.00		16125.00	141900000.00		141900000.00
											Say 14 Crores



(ii)b. Future Extension: ITPL - Whitefield												
1	Alignment	30100	30730	0	0	0	0	0	0	16125.00	0	0
2	Kadugodi Station	30730	30870	0	0	3389.71	0	0	0	16125.00	54659073.75	0
3	Alignment	30870	31730	2188.54	0	0	0	0	0	16125.00	35290207.50	0
4	Ujwala Vidyalaya Station	31730	31870	0	0	3506.95	0	0	0	16125.00	56549568.75	0
5	Alignment	31870	32730	1705.58	0	0	0	0	0	16125.00	27502477.50	0
6	Whitefield Station	32730	32870	0	0	4438.64	0	0	0	16125.00	71573070.00	0
Total				3894.12	0	11335.3	0	0	0		245574397.50	0
											say 25 Crores	0.00
Land for PD				0	0	0.00	0	0.00	0	16125.00	0.00	



Sl No	Location	Chainage		Area (In Sqm)				Rate for Private/Govt. Land (Per Sqm)	Amount for Private Land (Rate Rs 15050/- Per Sqm)	Govt. Land (Rate Rs 5000 Per Sqm)	Total Land cost
		From	To	Private	Govt.	Private	Govt.				
(iii) Puttenahalli to Anjanapura Township (NICE Road x-ing)											
1	Alignment	18289.97	18820	18820	18.88	0	0	0	284144.00	0	284144
2	Anjanapura Road Station	18820	18960	18960	0	0	3782.93	0	56933096.50	0	56933096.50
3	Alignment	18960	20030	20030	419.82	0	0	0	6318291.00	0	6318291
4	Krishna Leela Park Station	20030	20170	20170	0	0	403.93	0	6079146.50	0	6079146.5
5	Alignment	20170	21351	21351	325.35	0	0	0	4896517.50	0	4896517.50
6	Vajarahalli Station	21351	21491	21491	0	0	4015.89	0	60439144.50	0	60439144.50
7	Alignment	21491	22330	22330	677.67	0	0	0	10198933.50	0	10198933.5
8	Thalaghattapura Station	22330	22470	22470	0	0	4267.66	0	64228283.00	0	64228283.00
9	Alignment	22470	23805	23805	2884.81	0	0	0	43416390.50	0	43416390.5
10	Anjanapur Township Station	23805	23945	23945	0	0	4270.73	0	64274486.50	0	64274486.50
11	Alignment	23945	24290	24290	1272.78	0	0	0	19155339.00	0	19155339
			TOTAL	TOTAL	5599.31	0	16741.14	0	336223772.50	0	336223772.50
											say 34 Crores
							35000.00		526750000.00		526750000.00
											say 53 Crores
12	Depot after crossing NICE road on RHS			40000		0	0	0	602000000.00	0	602000000.00
											say 60 Crores



Sl No	Location	Chainage		Area (In Sqm)				Rate for Private/Govt. Land (Per Sqm)	Amount for Private Land (Rate Rs 12900/- Per Sqm)	Amount for Govt. Land (Rate Rs 5000 Per Sqm)	Total Land cost
		From	To	Alignment		Station					
				Private	Govt.	Private	Govt.				
(iv) Hesaraghatta Cross to BIEC											
1	Alignment	(-) 6400	(-) 6755	3427.64	0		0	12900.00	44216556.00	0	44216556.00
2	Manjunatha Nagar Station	(-) 6755	(-) 6895		0	4083.04	0	12900.00	52671216.00	0	52671216.00
3	Alignment	(-) 6895	(-) 8005	10598.78	0		0	12900.00	136724262.00	0	136724262.00
4	Jindal Station	(-) 8005	(-) 8145		0	4376.49	0	12900.00	56456721.00	0	56456721.00
5	Alignment	(-) 8145	(-) 9130	16036.60	0		0	12900.00	206872140.00	0	206872140.00
6	BIEC Station	(-) 9130	(-) 9270	0	0		4242.14	12900.00	0	21210700.00	21210700.00
7	Alignment	(-) 9270	(-) 9451.64	2394.07	643.70		0	12900.00	30883503.00	3218500.00	34102003.00
	TOTAL			32457.09	643.70	8459.53	4242.14		527824398.00	24429200.00	552253598.00
	Land for PD					21400.00		12900.00			276060000.00
											Say 28 Crores



DPR BM Ph-II (four extensions) - DETAILS OF LAND													
Sl. No.	Description	Alignment			Stations			Total for Alignment & Stations (1)	Property Development (PD)			Grand Total (1+2)	Remarks
		Private	Govt	Total	Private	Govt	Total		Private	Govt.	Total for PD (2)		
1	Mysore Road Terminal - Kengeri	5464.87	0	5464.87	9125.28	0	9125.28	14590.15	33042	0	33042	47632.15	
2 (a)	Baiyappanahalli - ITPL	33965.92	60	34025.92	28716.82	0	28716.82	62742.74	8800	0	8800	71542.74	
2 (b)	ITPL - Whitefield	3894.12	0	3894.12	76335.30	0	76335.30	80229.42	0	0	0	80229.42	
	Total	37860.04	60	37920.04	105052.1	0	105052.12	142972.2	8800	0	8800	151772.16	
3	Puttenahalli - Anjanapur Township	5599.31	0	5599.31	16741.14	0	16741.14	22340.45	35000	0	35000	57340.45	
4	Hesaraghatta Cross - BIEC	32457.09	643.7	33100.79	8459.53	4242.14	12701.67	45802.46	21400	0	21400	67202.46	
	Grand - Total (up to ITPL)	77487.19	703.7	78190.89	63042.77	4242.14	67284.91	145475.8	98242	0	98242	243717.80	
	Grand - Total (up to Whitefield)	81381.31	703.7	82085.01	139378.1	4242.14	143620.21	225705.2	98242	0	98242	323947.22	



Corridor Name	Total Estimated Cost in 'Rs. Crores'			GRAND TOTAL (in Rs. Crores)
	for alignment & Stations	for Depot	for PD	
(i) Mysore Road Terminal to Kengeri	33	54	44	131
(ii) Baiyyappanahalli – ITPL - Whitefield	148	107	14	269
(iii) Puttenahalli to Anjanapura Township (NICE Road x-ing)	48	45	53	146
(iv) Hesaraghatta Cross to BIEC	67	15	28	110
TOTAL COST	296	221	139	656

CHAPTER-13

**FINANCIAL VIABILITY, FARE
STRUCTURE & FINANCING OPTIONS**



CHAPTER 13

FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

13.1 INTRODUCTION

The East West & North South Corridor Bengaluru Phase-II Metro is proposed to be constructed with an estimated cost of Rs 5504.88 Crore at January 2010 price level without state taxes but including land cost of Rs. 533 crore. The estimated cost with central taxes is Rs. 6096 crore.

The estimated cost at January-2010 price level includes an amount of Rs.11.50 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.

13.2 Costs

13.2.1 Investment Cost

13.2.1.1 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 31.03.2016 and Revenue Opening Date (ROD) has been assumed as 01.04.2016. The total completion costs duly escalated and shown in the table 13.1 have been taken as the initial investment. The cash flow of investments separately is placed in Table –13.1 as below.

**Table 13.1 Corridor-wise & Year wise Investment-With Central Taxes**

Figs in Rs. Cr.

Financial Year	Estimated Cost	Completion Cost
2012-13	823.00	895.00
2013-14	1379.00	1587.00
2014-15	1391.00	1733.00
2015-16	1113.00	1456.00
2016-17	556.00	763.00
2017-18	556.00	802.00
2018-19	278.00	421.00
Total	6096.00	7657.00

13.2.1.2 Although the construction is expected to get over by 31st March 2016, 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.

13.2.1.3 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.

13.2.1.4 The escalation factor used is 5% p.a.

Note by BMRCL

The estimated cost of these four extensions as per BMRCL's due diligence exercise will be RS.6945.08 crores and central taxes & duties would be RS.1049.00 crores. Consequently, the completion cost as per BMRCL will be Rs.9647.05 crores. The break-up of year wise investment and completion cost is shown below:

Financial Year	Estimated Cost	Completion Cost
2012-13	1036.87	1127.32
2013-14	1737.33	1999.37
2014-15	1752.71	2183.65
2015-16	1402.48	1834.66
2016-17	700.48	961.24
2017-18	700.48	1010.40
2018-19	350.23	530.41
Total	7680.58	9647.05



13.2.2 Additional Investment

Total investment provided in the FIRR calculation towards requirement of additional rolling stock duly escalated @5% PA is placed in table 13.2 as under: -

Table 13.2 Additional Investment towards Rolling Stock (Rs/Crore)

With Taxes & Duties					
2021-22		2031-32		2041-42	
No of Cars	Amount	No of Cars	Amount	No of Cars	Amount
57	1161.00	48	1592.00	6	324.00

13.2.3 Operation & Maintenance (O&M) Costs

13.2.3.1 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. 2.30 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.

12.2.3.4 The total O&M cost of both the corridors have been tabulated in Table 13.3 as below:

**Table 13.3 Operation and Maintenance Costs**

Figs in Rs. Cr.

YEAR			Staff	Maintenance Expenses	Energy	Total
2016	-	2017	77.87	51.25	36.13	165.25
2017	-	2018	84.88	53.81	37.95	176.64
2018	-	2019	92.52	56.50	39.83	188.86
2019	-	2020	100.85	59.33	41.86	202.03
2020	-	2021	109.92	62.29	43.94	216.16
2021	-	2022	119.82	65.41	61.79	247.01
2022	-	2023	130.60	68.68	64.85	264.13
2023	-	2024	142.35	72.11	68.10	282.57
2024	-	2025	155.17	75.72	71.53	302.41
2025	-	2026	169.13	79.51	75.14	323.77
2026	-	2027	184.35	83.48	78.93	346.76
2027	-	2028	200.95	87.65	82.89	371.49
2028	-	2029	219.03	92.04	87.04	398.11
2029	-	2030	238.74	96.64	91.37	426.76
2030	-	2031	260.23	101.47	95.97	457.67
2031	-	2032	283.65	106.55	120.41	510.61
2032	-	2033	309.18	111.87	126.45	547.50
2033	-	2034	337.01	117.47	132.81	587.28
2034	-	2035	367.34	123.34	139.49	630.17
2035	-	2036	400.40	129.51	146.50	676.40
2036	-	2037	436.43	135.98	153.83	726.24
2037	-	2038	475.71	142.78	161.48	779.98
2038	-	2039	518.52	149.92	169.57	838.01
2039	-	2040	565.19	157.42	178.09	900.69
2040	-	2041	616.06	165.29	187.03	968.38
2041	-	2042	671.50	173.55	229.75	1074.81

13.2.4 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.

13.2.5 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.

13.3 Revenues

The Revenue of Bangalore metro mainly consists of fare box collection and other incomes from property development, advertisement, parking etc.

13.3.1 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.

13.3.2 Traffic

13.3.2.1 a. The projected ridership figures years are as indicated in table 13.4 as below: -

Table 13.4 Projected Ridership

Year	Trips per day (lakhs)
2016-17	4.08
2021-22	6.45
2031-32	8.44
2041-42	9.87

13.3.2.1 b. The corridor-wise growth rate for traffic is assumed at 11% Per Annum upto 2021-22, @ 2.75% upto 2031-32 and thereafter @ 1.50% per annum..

13.3.2.2 Trip Distribution

The trip distribution has been worked out by considering average lead of 16.94 KM, which is placed in Table 13.5 below: -

Table 13.5 Trip Distribution

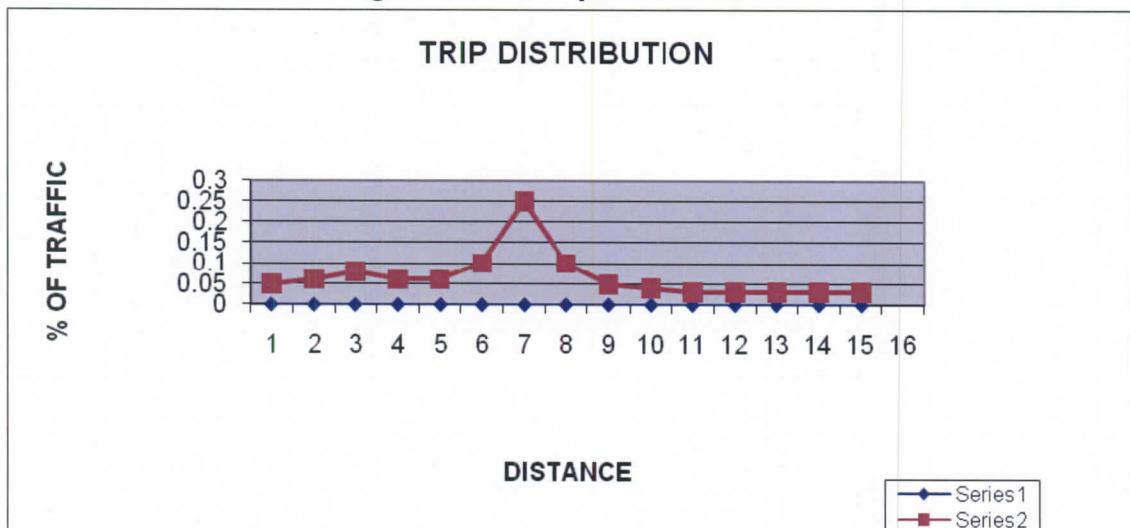
Distance in kms.	Percent distribution
0-2	5.00%
2-4	6.00%
4-6	8.00%
6-9	6.00%
9-12	6.00%



12-15	10.00%
15-18	25.00%
18-21	10.00%
21-24	5.00%
24-27	4.00%
27-31	3.00%
31-35	3.00%
35-39	3.00%
39-44	3.00%
>44	3.00%
Total	100.00%

The graphic presentation of the same is placed below in Figure-13.1.

Figure 13.1 –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 13.6.

Table 13.6 Fare Structure in 2016-17

Distance in kms.	Metro Fare (Rs.)
0-2	9.00
2-4	12.00
4-6	14.00
6-9	17.00
9-12	19.00
12-15	21.00
15-18	22.00
18-21	24.00



21-24	25.00
24-27	27.00
27-31	29.00
31-35	31.00
35-39	32.00
39-44	34.00
>44	35.00

Note by BMRCL

The fare structure of Bangalore Metro as approved by its Board are as shown below:

Distance in kms	Fare	Distance in kms	Fare
1	10.00	14	23
2	10.00	15	23
3	12.00	16	25
4	12.00	17	26
5	14.00	18	27
6	14.00	19	28
7	15.00	20	29
8	17.00	21	30
9	17.00	22	31
10	19.00	23	32
11	19.00	24	33
12	21.00	25	34
13	21.00		

Note by BMRCL

It may be noted that from 16th Km onwards, fare increases by Rs.1 for every additional 1 Km. Keeping this in view, the fare from 26th Km. onwards up to 44 Km. is assumed to increase by Rs. 1 for every additional Km.

13.3.3 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 i.e., -3.10% if additional residual rental income as detailed in the table 13.7 accrue from Property Development is not considered. Therefore, the State Government should provide sufficient land for PD activity to the Bengaluru Metro Phase-II as detailed below: -

Bengaluru Metro requires 15 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 BMRC as 12% Market Debt. The estimated development cost will be Rs.1084 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 BMRC, which has been taken into account in the FIRR calculations.

The details of PD income accrue to BMRC is shown Table 13.12.5.

12.4 Financial Internal Rate of Return (FIRR)

The FIRR with Central taxes only is produced in Table 13.7.



Table 13.7 FIRR:

Particulars	Completion Cost With Central Taxes (Without additional PD)	Completion Cost With Central Taxes (With Additional PD income from 15 Ha.)
FIRR (%)	-3.10 %	2.23%

Note by BMRCL

The FIRR will change as the completion cost as per BMRCL is Rs.9647.05 crores. The FIRR with average Fare in the distance range and 5% escalation every year will be 6.70%.

13.4.1 The Financial Internal Rate of Return (FIRR) obtained with the above revenues and costs for 30 years are placed in table 13.8: -

Table 13.8 –FIRR (with Central taxes)

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	895		0		895	0	0	0	-895
2013	-	2014	1587		0		1587			0	-1587
2014	-	2015	1733		0		1733			0	-1733
2015	-	2016	1456		0		1456			0	-1456
2016	-	2017	763		165.25		928	321.82	32	354	-574
2017	-	2018	802		176.64		979	357.22	-63	294	-685
2018	-	2019	421		188.86		610	416.56	-23	393	-217
2019	-	2020	0	0	202.03		202	462.38	-38	425	223
2020	-	2021	0	0	216.16		216	538.64	-1	538	321
2021	-	2022	0	1161	247.01		1408	560.92	44	605	-803
2022	-	2023	0	0	264.13		264	603.56	58	662	398
2023	-	2024	0	0	282.57		283	620.16	105	725	443
2024	-	2025	0	0	302.41		302	666.99	159	826	523
2025	-	2026	0	0	323.77		324	685.34	211	896	572
2026	-	2027	0	0	346.76		347	735.66	268	1003	656
2027	-	2028	0	0	371.49		371	755.89	324	1079	708
2028	-	2029	0	0	398.11		398	811.36	343	1155	756
2029	-	2030	0	0	426.76		427	833.68	362	1196	769
2030	-	2031	0	0	457.67		458	896.27	384	1280	822
2031	-	2032	0	1592	510.61		2103	918.73	401	1320	-783
2032	-	2033	0	0	547.50		548	973.83	435	1409	862
2033	-	2034	0	0	587.28		587	988.44	451	1440	853



2034	-	2035	0	0	630.17		630	1055.87	522	1577	947
2035	-	2036	0	0	676.40		676	1071.71	531	1603	926
2036	-	2037	0	0	726.24	1558	2284	1146.36	549	1695	-589
2037	-	2038	0	0	779.98	1636	2416	1163.55	559	1723	-693
2038	-	2039	0	0	838.01		838	1242.43	575	1818	980
2039	-	2040	0	0	900.69		901	1261.06	587	1848	947
2040	-	2041	0	0	968.38		968	1346.50	606	1952	984
2041	-	2042	0	324	1074.81		1399	1377.16	618	1995	596
Total			7657	3077	12609.69	3194	26538	21812	7999	29811	2.23%

The various sensitivities with regard to increase/decrease in capital costs, O&M costs and revenues are placed in Table 13.9 below :-

Table 13.9 –FIRR Sensitivity

CAPITAL COSTS with Central Taxes			
10% increase in capital cost	20% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
1.60%	1.05%	2.93%	3.74%
REVENUE			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue
-1.32%	0.66%	3.55%	4.71%
O&M COSTS			
10% increase in O&M cost		10% decrease in O&M cost	
1.45%		2.92%	

These sensitivities have been carried out independently for each factor.

13.5 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.

13.5.1 ALTERNATIVE MODELS OF FINANCING

13.5.2 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.533.00 Crore 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. 3318 Crore. 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. IIFCL can fund the total requirement of loan funds after obtaining approval from their Board and Empowered Committee. IIFCL provides loan funds separately for INR portion and Foreign Currency portion with applicable interest rate ranging from 10% to 12% for INR portion and with LIBOR + 300 base points in respect of Foreign Currency portion.. 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.

13.5.3 The funding pattern assumed under this model (SPV) is placed in table 13.10 as under: -

Table 13.10 Funding pattern under DMRC model (with central taxes)



Particulars	Government of India		Government of Karnataka		Total	
	%	Rs/Crore	%	Rs/Crore	%	Rs/Crore
Equity by GOI & GO Karnataka	20%	1532.00	20%	1532.00	40%	3064.00
SD for land cost by GO Karnataka	0%	0.00	7%	533.00	7%	533.00
Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	8%	594.00	2%	148.00	10%	742.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	43%	3318.00	0%	0.00	43%	3318.00
Total	71.00%	5444.00	29.00%	2213.00	100.00%	7657.00

13.5.4 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-

13.5.5 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 14% to 18% or a comfort of guaranteed ridership.

13.5.6 The funding pattern assumed under this model including the cost of land to ensure 14% post tax return on operators equity i.e. Equity Internal Rate of Return (EIRR) is placed in table 13.11 tabulated as under: -

**Table 13.11 Funding pattern under BOT model
(With central taxes but excluding state taxes)**

Particulars	% Of contribution	Amount (Rs/Crore)
-------------	-------------------	-------------------



VGF by GOI 20% (Excluding Land Cost)	20%	1531.00
VGF by Karnataka State Government	49%	3736.00
Land to be provided free of cost by State	7%	533.00
Equity by Concessionaire	8%	619.00
Concessionaire's debt @11% PA	16%	1238.00
Total	100%	7657.00

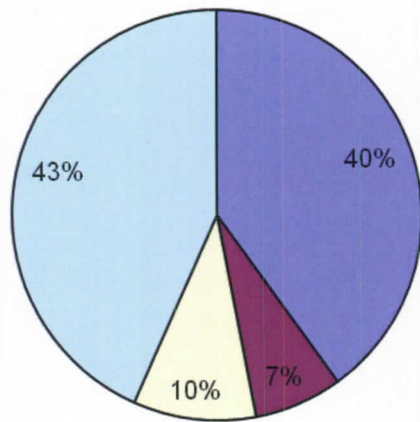
13.6.1 Recommendations: - The FIRR of subject metro with taxes is 2.23% (with 15 Ha. PD) Hence, the corridors are recommended for implementation.

13.6.2 The total contribution of GOI & Government of Karnataka under the SPV model excluding PTA to be repaid latter is Rs.4339 Crore only (excluding state taxes to be exempted of Rs.265 Crore at Jan-2010 level) as against Rs. 5800 crore under BOT model. Since the Bangalore 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 under the existing SPV owned by GOI and Government of Karnataka.

13.6.3 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 13.12.1, 13.12.2 and 13.12.3. The cash flow of PD is shown in table 13.12.4 and with JICA Loan without additional PD is shown in table 13.12.5.

13.6.4 The funding pattern assumed under DMRC/BMRC/CMRC model is depicted in the pie chart i.e., Figure 13.2 as under.

Fig 13.2



- Equity by GOI & State
- Land free of cost by State
- SD for Central Taxes (80% by GOI & 20% by State)
- JICA Loan/Market Debt



Table 13.12.1

Bangalore Phase-II Extension of EW & NS corridors		WITH CENTRAL TAXES ONLY										1.40%										
CAPITAL COST-FIXED		6096										7657										
CAPITAL COST - CURRENT		7657																				
Year	Completion Cost	Additional Capital	Running Expenditure	DEPRECIATION	REPLACEMENT ENT.	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT REVENUE	TOTAL REVENUE	NET CASH FLOW FOR	Funds other than loan i.e.	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl.	INTEREST	PROFIT BEFORE	CASH BALANCE	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
1	2012	895	0	0	0	895	0	0	0	-895	1251	356	356	0	0	0	0	0	0	0	356	356
2	2013	1587	0	0	0	1587	0	0	0	-1587	1250	-337	19	0	0	0	0	0	0	0	-337	19
3	2014	1733	0	0	0	1733	0	0	0	-1733	613	-1120	1101	1101	1101	0	7.71	1109	0	0	-19	0
4	2015	1456	0	0	0	1456	0	0	0	-1456	613	-843	1944	1944	843	0	21.42	1973	0	0	0	0
5	2016	763	165.25	227.00	928	321.82	32	354	354	-574	612	-151	-2095	2095	151	0	28.68	2153	0	-38	189	189
6	2017	802	176.64	227.00	979	357.22	36	393	393	-566	0	-802	-2897	2897	802	0	35.75	2991	0	-11	216	405
7	2018	421	188.86	227.00	610	416.56	42	458	458	-152	0	-421	-3318	3318	421	0	0	3412	45	-2	225	630
8	2019	0	202.03	227.00	202	462.38	46	509	509	307	0	0	-3318	3318	0	0	0	3412	48	32	259	888
9	2020	0	216.16	227.00	216	538.64	54	593	593	376	0	0	-3318	3318	0	0	0	3412	48	102	329	1217
10	2021	0	1161	247.01	1408	560.92	56	617	617	-791	0	0	-3318	3318	0	0	0	3412	48	95	-839	378
11	2022	0	264.13	227.00	264	603.56	50	664	664	400	0	0	-3318	3318	0	171	0	3412	48	125	181	559
12	2023	0	282.57	227.00	283	620.16	62	682	682	400	0	0	-3318	3318	0	171	0	3241	48	125	181	741
13	2024	0	302.41	227.00	302	666.99	67	734	734	431	0	0	-3318	3318	0	171	0	3070	45	159	215	956
14	2025	0	323.77	227.00	324	685.34	69	754	754	430	0	0	-3318	3318	0	171	0	2900	43	160	217	1172
15	2026	0	346.76	227.00	347	735.65	74	809	809	462	0	0	-3318	3318	0	171	0	2729	41	195	251	1424
16	2027	0	371.49	227.00	371	755.89	76	831	831	460	0	0	-3318	3318	0	171	0	2559	38	195	251	1675
17	2028	0	398.11	227.00	398	811.36	81	893	893	494	0	0	-3318	3318	0	171	0	2386	36	232	288	1963
18	2029	0	426.76	227.00	427	833.88	83	917	917	490	0	0	-3318	3318	0	171	0	2218	33	230	286	2249
19	2030	0	457.67	227.00	458	896.27	90	986	986	528	0	0	-3318	3318	0	171	0	2047	31	270	327	2576
20	2031	0	510.61	227.00	510	919.73	92	1011	1011	-1092	0	0	-3318	3318	0	171	0	1876	28	244	-1291	1285
21	2032	0	547.50	227.00	548	973.83	97	1071	1071	524	0	0	-3318	3318	0	171	0	1706	26	270	327	1611
22	2033	0	587.28	227.00	587	988.44	99	1087	1087	500	0	0	-3318	3318	0	171	0	1535	24	249	306	1917
23	2034	0	630.17	227.00	630	1055.87	106	1161	1161	531	0	0	-3318	3318	0	171	0	1365	21	283	339	2256
24	2035	0	676.40	227.00	676	1071.71	107	1179	1179	502	0	0	-3318	3318	0	171	0	1194	19	256	313	2569
25	2036	0	726.24	273.74	1558	1146.36	115	1261	1261	-1023	0	0	-3318	3318	0	171	0	1023	17	244	-1211	1358
26	2037	0	779.98	322.82	1656	1163.55	116	1280	1280	-1136	0	0	-3318	3318	0	171	0	853	14	163	-1321	37
27	2038	0	838.01	322.82	838	1242.43	124	1367	1367	529	0	0	-3318	3318	0	171	0	682	12	194	346	384
28	2039	0	900.69	322.82	901	1261.06	126	1387	1387	486	0	0	-3318	3318	0	171	0	512	10	154	306	690
29	2040	0	968.38	322.82	968	1346.50	135	1481	1481	513	0	0	-3318	3318	0	171	0	341	7	183	335	1025
30	2041	0	1074.81	322.82	1399	1377.16	138	1515	1515	116	0	0	-3318	3318	0	171	0	171	5	112	-59	965
31	2042	0	324	6428	3194	26538	21812	2181	23993	-3.10%	4339	0	0	0	3318	0	0	94	57693	736	4221	965
		7657	3078	12610	6428	26538	21812	2181	23993	-3.10%	4339	0	0	0	3318	3318	3412	94	57693	736	4221	965



Table 13.12.2

Bangalore Phase-II Extension of EW & NS corridors											WITH CENTRAL TAXES ONLY											
CAPITAL COST - FIXED											1.40%											
CAPITAL COST - CURRENT																						
Year	Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT. REVENUE	TOTAL REVENUE	NET CASH FLOW	Funds other than loan i.e.	Availability of cash	Cumulative cash	Cum. Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan incl. IDC	INTEREST	PROFIT BEFORE TAX	CASH BALANCE	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	895						895	0	0	0	-895	1251	356	0	0	0	0	0	0	0	0	356
2013	1587						1587	0	0	0	-1587	1250	-337	19	0	0	0	0	0	0	0	-337
2014	1733						1733	0	0	0	-1733	613	-1120	1101	1101	0	7	7	1109	0	0	-15
2015	1456						1456	0	0	0	-1456	613	-1944	1944	843	0	21	21	1973	0	-38	189
2016	763		165.25	227.00		928	321.82	32	354	-574	612	-151	-2095	2095	151	0	28	28	2153	0	0	189
2017	802		176.64	227.00		978	357.22	63	294	-685	0	-802	-2897	2897	802	0	35	35	2891	0	-110	306
2018	421		188.86	227.00		610	416.55	-23	393	-217	0	-421	-3318	3318	421	0	35	35	2991	0	-67	466
2019	0		202.03	227.00		202	462.38	-38	425	223	0	0	-3318	3318	0	0	0	3412	45	-52	175	
2020	0		216.16	227.00		216	538.64	-1	538	321	0	0	-3318	3318	0	0	0	3412	48	47	274	
2021	0		247.01	227.00		1408	560.92	44	605	-803	0	0	-3318	3318	0	17	17	3241	48	123	179	
2022	0		264.13	227.00		264	603.56	58	662	398	0	0	-3318	3318	0	17	17	3070	45	251	307	
2023	0		282.57	227.00		283	620.16	105	725	443	0	0	-3318	3318	0	17	17	2900	43	302	359	
2024	0		302.41	227.00		302	666.99	159	826	523	0	0	-3318	3318	0	17	17	2729	41	389	445	
2025	0		323.77	227.00		324	688.34	211	896	572	0	0	-3318	3318	0	17	17	2559	38	443	499	
2026	0		346.76	227.00		347	735.66	268	1003	656	0	0	-3318	3318	0	17	17	2388	36	494	550	
2027	0		371.49	227.00		371	755.89	324	1078	708	0	0	-3318	3318	0	17	17	2218	33	509	565	
2028	0		398.11	227.00		398	811.36	343	1155	756	0	0	-3318	3318	0	17	17	2047	31	564	621	
2029	0		426.76	227.00		427	833.68	362	1196	769	0	0	-3318	3318	0	17	17	1876	29	553	-982	
2030	0		457.67	227.00		458	896.27	384	1280	822	0	0	-3318	3318	0	17	17	1706	26	608	665	
2031	0	1592	510.61	227.00		2103	918.73	401	1320	-783	0	0	-3318	3318	0	17	17	1535	24	602	658	
2032	0		547.50	227.00		548	973.83	435	1409	862	0	0	-3318	3318	0	17	17	1365	21	699	755	
2033	0		587.28	227.00		587	988.44	451	1440	853	0	0	-3318	3318	0	17	17	1194	19	680	737	
2034	0		630.17	227.00		630	1055.87	522	1577	947	0	0	-3318	3318	0	17	17	1023	17	678	-777	
2035	0		676.40	227.00		676	1071.71	531	1603	926	0	0	-3318	3318	0	17	17	853	14	606	-878	
2036	0		726.24	273.74	1558	2294	1146.36	549	1695	-589	0	0	-3318	3318	0	17	17	682	12	645	797	
2037	0		779.98	322.82	1636	2416	1163.55	559	1723	-693	0	0	-3318	3318	0	17	17	512	10	615	767	
2038	0		838.01	322.82		838	1242.43	575	1818	960	0	0	-3318	3318	0	17	17	341	7	654	806	
2039	0		900.69	322.82		901	1261.06	587	1848	947	0	0	-3318	3318	0	17	17	171	5	592	421	
2040	0		968.38	322.82		968	1346.50	606	1952	984	0	0	-3318	3318	0	17	17	0	0	0	0	0
2041	0	324	1074.81	322.82		1399	1377.16	618	1995	596	0	0	-3318	3318	0	17	17	0	0	0	0	0
2042	0										4338	0										
		7657	3078	12610	6428	26538	21812	7998	29810	2.23%					3318	3412	94	57693	735	10037	6782	



Table 13.13.2

Bangalore Phase-II Extension of EW & NS corridors													WITH CENTRAL TAXES ONLY												
CAPITAL COST - FIXED													11.00%												
CAPITAL COST - CURRENT																									
Year	Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT REVENUE	TOTAL REVENUE	NET CASH FLOW FOR	Funds other than loans	Availability of cash	Cumulative cash	Cum Loan	Loan	REPAYMENT OF LOAN	IDC	Cumulative loan	INTEREST	PROFIT BEFORE TAX	CASH BALANCE	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	895	0	0	0	0	895	0	0	0	-895	1251	356	356	0	0	0	0	0	0	0	356	356			
2013-2014	1587	0	0	0	0	1587	0	0	0	-1587	1250	-337	19	0	0	0	0	0	0	0	-337	19			
2014-2015	1733	0	0	0	0	1733	0	0	0	-1733	613	-1120	-1101	1101	1101	0	60.56	1162	0	0	-19	0			
2015-2016	1456	0	0	0	0	1456	0	0	0	-1456	613	-843	-1944	1944	843	0	174.14	2179	0	0	0	0			
2016-2017	763	165.25	227.00	0	0	928	321.92	32	354	-574	612	-151	-2095	2095	151	0	247.96	2578	0	-38	189	189			
2017-2018	802	176.64	227.00	0	0	979	357.22	-63	294	-685	0	-802	-2897	2897	802	0	327.65	3707	0	-110	117	306			
2018-2019	421	188.86	227.00	0	0	610	416.56	-23	393	-217	0	421	-3318	3318	421	0	0	4128	431	454	-227	79			
2019-2020	0	202.03	227.00	0	0	202	462.38	-38	425	223	0	0	-3318	3318	0	413	0	4128	454	459	-845	-565			
2020-2021	0	216.16	227.00	0	0	216	538.64	-1	538	321	0	0	-3318	3318	0	413	0	3715	454	-360	-546	-1111			
2021-2022	0	1161	247.01	227.00	0	1408	560.92	44	605	-803	0	-3318	0	3318	0	413	0	3302	409	-278	-1825	-2736			
2022-2023	0	0	264.13	227.00	0	264	603.56	58	682	398	0	-3318	0	3318	0	413	0	2889	353	-192	-378	-3114			
2023-2024	0	0	282.57	227.00	0	283	620.16	105	725	443	0	-3318	0	3318	0	413	0	2476	318	-102	-288	-3403			
2024-2025	0	0	302.41	227.00	0	302	666.99	159	826	523	0	-3318	0	3318	0	413	0	2063	272	24	-162	-3565			
2025-2026	0	0	323.77	227.00	0	324	685.34	211	896	572	0	-3318	0	3318	0	413	0	1650	227	118	-66	-3633			
2026-2027	0	0	346.76	227.00	0	347	735.66	268	1003	656	0	-3318	0	3318	0	413	0	1237	182	248	62	-3571			
2027-2028	0	0	371.49	227.00	0	371	755.89	324	1079	708	0	-3318	0	3318	0	413	0	824	136	345	159	-3412			
2028-2029	0	0	398.11	227.00	0	398	811.36	343	1155	756	0	-3318	0	3318	0	411	0	411	91	439	254	-3157			
2029-2030	0	0	426.76	227.00	0	427	833.68	362	1196	789	0	-3318	0	3318	0	0	0	0	45	497	724	-2433			
2030-2031	0	0	457.67	227.00	0	458	896.27	384	1280	822	0	-3318	0	3318	0	0	0	0	0	595	822	-1611			
2031-2032	0	1592	510.61	227.00	0	2103	918.73	401	1320	-783	0	-3318	0	3318	0	0	0	0	0	582	-783	-2394			
2032-2033	0	0	547.50	227.00	0	548	973.83	435	1409	862	0	-3318	0	3318	0	0	0	0	0	635	862	-1532			
2033-2034	0	0	587.28	227.00	0	587	988.44	451	1440	853	0	-3318	0	3318	0	0	0	0	0	626	853	-680			
2034-2035	0	0	630.17	227.00	0	630	1055.87	522	1571	947	0	-3318	0	3318	0	0	0	0	0	720	947	267			
2035-2036	0	0	675.40	227.00	0	676	1071.71	531	1603	926	0	-3318	0	3318	0	0	0	0	0	699	926	1194			
2036-2037	0	0	725.24	273.74	1558	2284	1146.36	549	1695	-593	0	-3318	0	3318	0	0	0	0	0	695	-589	605			
2037-2038	0	0	779.98	322.82	1638	2416	1163.55	559	1729	-693	0	-3318	0	3318	0	0	0	0	0	620	-693	-88			
2038-2039	0	0	838.01	322.82	0	838	1242.43	575	1818	960	0	-3318	0	3318	0	0	0	0	0	657	960	891			
2039-2040	0	0	900.69	322.82	0	901	1261.06	587	1948	947	0	-3318	0	3318	0	0	0	0	0	625	947	1839			
2040-2041	0	0	968.38	322.82	0	968	1346.50	606	1952	984	0	-3318	0	3318	0	0	0	0	0	661	984	2822			
2041-2042	0	324	1074.81	322.82	0	1399	1377.16	618	1995	596	0	-3318	0	3318	0	0	0	0	0	597	596	3418			
		7657	3078	6428	3194	26538	21812	7998	29810	2223	4339			3318	4128	810	36452	3382	7390	3418					

CHAPTER 13 - FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

Table 13.12.4

BOT (WITH CENTRAL TAX)

Grant

5900

76%

1857

Concess Equity

619

7657

1857

Concess Equity

619

Market Lx. 11.00%
for Debt

Year	Completion Cost (Total)	Additional Cost	Running Expenses	Depreciation	Replacement	Total Cost	Fare Box Revenue	PP & ADVT. Revenue	Total Revenue	Net Concess. Available	Funds Available	Govt. Subsidy	Loan	Cumulative Loan	IDC	Repaym. of Concess.	Interest	PBT	Cash Balances	Cumulative Cash	Return on Equity	Tax on Profit	Equity IRR	
1	2012	194.00	0	0	0	194.00	0	0	0	0	0	0	16	17	18	22	23	24	26	27	28	29	30	31
2	2013	311.99	0	158.1	0	470.09	0	0	0	155.00	-209.09	0	44	44	44	0	0	0	0	0	-155.00	0	-155.00	-155.00
3	2014	356.03	0	173.3	0	529.33	0	0	0	155.00	-374.33	0	244	446	446	22	0	0	0	0	-155.00	0	-155.00	-155.00
4	2015	351.30	0	147.6	0	498.90	0	0	0	154.00	-344.90	0	200	646	646	0	0	0	0	0	-154.00	0	-154.00	-154.00
5	2016	183.00	0	165	22	348.00	321.81612	12.18388	354.00000	0.00	0.00	0.00	0	183	303	74	0	38.2%	168.75	188.75	188.75	0	188.75	
6	2017	222.00	0	177	227	401.227	352.21527	613.78411	703.94	0.00	-104.00	0	227	1195	99	99	132	-109.70	117.30	117.30	117.30	0	117.30	
7	2018	186.00	0	18	227	204.00	416.55595	-21.54447	393.51	216.65	-12.88	0	186	1487	1487	0	0	154.54	-76.54	90.75	-76.54	0	-26.54	
8	2019	2020	0	202	227	0	202.031415	462.3783261	424.61	222.59	0	0	0	1289	1388	164	164	-169.03	40.03	50.73	-40.03	0	-40.03	
9	2020	2021	0	218	227	0	218.163525	518.67673	-1.1363127	517.50	321.34	0	0	1289	1388	164	164	-169.03	40.03	50.73	-40.03	0	-40.03	
10	2021	2022	0	247	227	0	1408.41549	560.929095	44.092361	605.02	809.40	0	0	1190	1190	142	142	-1044.23	-923.88	-1044.23	0	-1044.23		
11	2022	2023	0	264	227	0	264.134441	803.562963	861.92	397.78	0	0	0	1091	892	99	99	38.85	167.85	-756.03	167.85	13	154.85	
12	2023	2024	0	283	227	0	283.773916	686.33544	158.69931	825.69	523.28	0	0	863	863	109	109	187.12	217.26	315.12	62	293.12		
13	2024	2025	0	302	227	0	302.41493	666.993129	158.69931	825.69	523.28	0	0	794	794	99	99	246.83	374.83	157.47	374.83	62	293.83	
14	2025	2026	0	324	227	0	346.759453	735.669497	267.596	1033.23	955.47	0	0	695	695	67	67	342.09	470.09	627.56	470.09	114	356.09	
15	2026	2027	0	347	227	0	371.464119	755.881624	323.58917	1078.48	701.99	0	0	596	596	76	76	404.50	532.50	1160.05	532.50	532.50		
16	2027	2028	0	371	227	0	398.111162	811.36432	343.19844	1154.50	756.39	0	0	487	487	66	66	463.78	581.78	1751.84	581.78	581.78		
17	2028	2029	0	398	227	0	426.75538	833.676994	362.3677	1196.04	769.29	0	0	398	398	44	44	487.58	615.58	2087.42	615.58	615.58		
18	2029	2030	0	427	227	0	457.67448	896.273142	389.62731	1279.90	822.23	0	0	299	299	33	33	549.06	673.41	3048.83	673.41	673.41		
19	2030	2031	0	458	227	0	487.67448	896.273142	389.62731	1279.90	822.23	0	0	200	200	0	0	549.06	673.41	3048.83	673.41	673.41		
20	2031	2032	0	511	227	0	2102.58116	918.27338	439.87273	1319.60	-182.98	0	0	101	101	22	22	612.61	738.31	2870.23	738.31	738.31		
21	2032	2033	0	548	227	0	547.60117	973.829029	435.3829	1409.21	861.71	0	0	0	0	11	11	614.39	841.39	3711.62	841.39	841.39		
22	2033	2034	0	587	227	0	597.281136	988.436464	451.38365	1439.82	852.54	0	0	0	0	0	0	720.29	947.29	4659.90	947.29	947.29		
23	2034	2035	0	630	227	0	630.189537	1056.9711	521.59971	1577.45	947.29	0	0	0	0	0	0	699.47	926.47	5896.38	926.47	926.47		
24	2035	2036	0	676	227	0	676.402748	1071.70512	531.17051	1602.88	926.47	0	0	0	0	0	0	695.01	989.29	4996.12	989.29	989.29		
25	2036	2037	0	726	274	1558	2284.24413	1146.35542	548.65542	1894.98	-588.29	0	0	0	0	0	0	620.11	1048.83	5282.71	1048.83	1048.83		
26	2037	2038	0	780	323	1638	2415.97589	1163.55075	550.35508	1722.91	693.07	0	0	0	0	0	0	620.11	1048.83	5282.71	1048.83	1048.83		
27	2038	2039	0	835	323	0	835.013997	1242.42614	575.24261	1817.67	979.65	0	0	0	0	0	0	620.11	1048.83	5282.71	1048.83	1048.83		
28	2039	2040	0	901	323	0	900.893317	1261.06253	587.10625	1848.17	947.49	0	0	0	0	0	0	620.11	1048.83	5282.71	1048.83	1048.83		
29	2040	2041	0	968	323	0	968.378788	1346.49761	605.64976	1923.15	947.49	0	0	0	0	0	0	620.11	1048.83	5282.71	1048.83	1048.83		
30	2041	2042	0	1075	323	0	1068.96533	1377.16448	1894.88	595.93	0	0	0	0	0	0	0	620.11	1048.83	5282.71	1048.83	1048.83		
Total	1857	3076	12619	6428	3194	26538	21812	7998	28610	2231	619	0.00	1238	15381	24938	1487.4	1443	9329.7	7998.6	15244	1332	1410%		

DETAILED PROJECT REPORT FOR BENGALURU METRO (PHASE-II) July 2011

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CHAPTER-14

ECONOMICAL INTERNAL RATE OF RETURN



CHAPTER 14

ECONOMIC ANALYSIS

14.1. INTRODUCTION

The following extensions of the East-West Line and North -South Line of Phase-I in both directions. (four extensions) are proposed as a part of Bangalore Metro Phase-II.

Sl. No	Extension of Phase -I Corridors in Phase-II	Length (Km)
i.	Extension of E-W line from Mysore Road to Kengeri	6.465
ii.	Extension of E-W line from Baiyappanahalli to ITPL - Whitefield	15.50
iii.	Extension of N-S line from Puttenahalli to Anjanapura Township	6.29
iv.	Extension of N-S line from Hesaraghatta Cross to BIEC	3.77
	TOTAL	32.025

Before performing economic analysis, basic input i.e. all useful information pertaining to traffic demand (metro rider ship) for the selected horizon years was estimated.

14.2 ECONOMIC ANALYSIS

The objective of the cost- benefit analysis is to identify and quantify the economic benefits and costs associated with the project (with respect to the implementation of above Metro extensions for route length of 32.66 Km, 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.



14.2.1 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

14.2.2 Analysis Period

The analysis period of the project is taken as 37 years from the base year 2009 as follows:

- Base Year 2010
- Construction period – 2012 to 2015 (4 years)
- Project opening for traffic – 31.03.2016
- End of the analysis period –2045
- No. of operating years, considered for economic analysis – 30 years

Thus, 30 years of operation, in effect, from the start of operation i.e. 2016, has been considered for economic evaluation for the project.

14.2.3 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 without taxes and duties is Rs. 5505 Crores. This cost has been converted to economic price by applying a factor of 0.85. The Operation & Maintenance Cost (O & M cost) in the year 2016 is Rs 148.84 crores.

The implementation of metro is proposed in four years. The proposed phasing of investment are given in Table 14.1.

**Table 14.1: Year wise Investment**

Financial Year	Phasing of Investment	
2012-13	14%	655
2013-14	23%	1076
2014-15	22%	1029
2015-16	18%	842
2016-17	9%	421
2017-18	9%	421
2018-19	5%	234
Total	100%	4678

14.2.4 Estimation of Benefits

The proposed metro between R V Road and Electronic City 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 Metro project is not taken up.
- Savings in operating costs of all buses and other vehicles due to decongestion including those that would continue to use the existing transport network even after the Metro services are introduced.
- Savings in time of commuters using the Metro System over the existing transport modes because of faster speed of Metro System.
- Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of accidents and pollution with introduction of Metro System.
- Savings in road infrastructure and development costs that would be required to cater to increase in traffic, in case Metro System is not introduced.
- Savings in fuel consumption on account of less number of vehicles on road and decongestion effect with introduction of Metro System 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:

- Reduced road stress
- Reduction in accidents
- Reduction in air pollution
- 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.

14.2.5 Transport Demand on Proposed four Metro Extensions

At present mostly bus system is meeting the transport demand in the study area. Part of the demand is also met by auto modes and private modes. As explained in Chapter 2 on traffic, the transport demand for various years is given in Table 14.3.

Table 14.3 Transport Demand Forecast on four extensions of Bangalore Metro Phase-2

ITEM	2016	2021	2031	2041
Trips on metro / day (Lakh)	4.08	6.45	8.44	9.87

14.2.6 Reduction in Traffic Congestion and Fuel Consumption

The traffic on the metro is expected to shift from buses, auto rickshaw, car, taxi and two wheeler. 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. 475 Crores in the year 2016 towards the vehicle operating cost (VoC).

14.2.7 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. 540 Crore for the year 2016.



14.2.8 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 14.4.

Table 14.4: Results of Economic Analysis

Sl. No.	Parameter	Value
1	EIRR (%)	16%
2	ENPV (Rs. In crores @ 12% discount rate)	1452

The EIRR for the proposed four extensions of Bangalore Metro phase-II project works out to be 16%.

Note: As the completion cost comes to Rs.9647.05 crores the revised EIRR comes to ...%

14.3 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 14.5. Details are presented in Annexure 14.1.

Table 14.5 Results of Sensitivity Analysis

Scenario	EIRR (%)	ENPV(Rs. in crores @ 12% discount rate)
Normal Scenario	16%	1452
Sensitivity I: 10% increase in cost	15%	1125
Sensitivity II: 10% reduction in benefits	15%	904
Sensitivity III: 10% increase in cost and 10% reduction in Benefits	14%	577



In the sensitivity analysis, the EIRR is found to be at 14%, 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.

Cost and Benefit Stream : Normal Scenario Units: Rs in Crores							Annexure 14.1
YEAR	CAPITAL	O & M Cost	TOTAL COSTS	SAVINGS FROM		TOTAL	NET CASH
				TIME	VOC	SAVINGS	FLOW
2010	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0
2012	-655	0	-654.976	0	0	0	-655
2013	-1076	0	-1076.032	0	0	0	-1076
2014	-1029	0	-1029.248	0	0	0	-1029
2015	-842	0	-842.112	0	0	0	-842
2016	-421	-148.84	-569.896	0	0	0	-570
2017	-421	-148.84	-569.896	539.59	474.64	1014.23	444
2018	-234	-148.84	-382.76	556.7	490.34	1047.04	664
2019	0	-148.84	-148.84	573.81	506.04	1079.85	931
2020	0	-148.84	-148.84	590.92	521.75	1112.67	964
2021	0	-148.84	-148.84	608.02	537.45	1145.48	997
2022	0	-148.84	-148.84	625.13	553.16	1178.29	1029
2023	0	-148.84	-148.84	635.63	562.21	1197.84	1049
2024	0	-148.84	-148.84	646.12	571.26	1217.39	1069
2025	0	-148.84	-148.84	656.62	580.31	1236.93	1088
2026	0	-148.84	-148.84	667.12	589.37	1256.48	1108
2027	0	-148.84	-148.84	677.61	598.42	1276.03	1127
2028	0	-148.84	-148.84	688.11	607.47	1295.58	1147
2029	0	-148.84	-148.84	698.6	616.52	1315.12	1166
2030	0	-148.84	-148.84	709.1	625.57	1334.67	1186
2031	0	-148.84	-148.84	719.6	634.62	1354.22	1205
2032	0	-148.84	-148.84	730.09	643.68	1373.77	1225
2033	0	-148.84	-148.84	737.73	650.41	1388.14	1239
2034	0	-148.84	-148.84	745.37	657.14	1402.51	1254
2035	0	-148.84	-148.84	753.01	663.88	1416.89	1268
2036	0	-148.84	-148.84	760.64	670.61	1431.26	1282
2037	0	-148.84	-148.84	768.28	677.35	1445.63	1297
2038	0	-148.84	-148.84	775.92	684.08	1460	1311
2039	0	-148.84	-148.84	783.56	690.82	1474.38	1326
2040	0	-148.84	-148.84	791.2	697.55	1488.75	1340



2041	0	-148.84	-148.84	798.84	704.28	1503.12	1354	
2042	0	-148.84	-148.84	806.48	711.02	1517.49	1369	
2043	0	-148.84	-148.84	814.54	718.13	1532.67	1384	
2044	0	-148.84	-148.84	822.69	725.31	1548	1399	
2045	0	-148.84	-148.84	830.91	732.56	1563.48	1415	
2046	0	-148.84	-148.84	839.22	739.89	1579.11	1430	
Total	-4678.4	-4614.04	-8929.49	21351.15	18835.85	40187	30894.58	
						IRR %	16%	
ENPV (Rs. In crores @ 12% discount rate)								1452.21

CHAPTER-15

IMPLEMENTATION PLAN



CHAPTER 15

IMPLEMENTATION PLAN

15.1 WAY FORWARD FOR IMPLEMENTING BANGALORE PHASE- II METRO PROJECT

BMRCL is already implementing the Phase-I of Bangalore Metro Project comprising of North –South and East- West Corridor totalling to 42.26 Kms. Hence, on receipt of the Detailed Project Report, following actions will be required for implementing the proposed 4-extensions totalling to 32.025 Kms as a part of Phase-II of Bangalore Metro project.

- Approval to the Detailed Project Report to be obtained from Karnataka State Government (Cabinet Approval).
- The DPR to be forwarded to the Ministry of Urban Development(GOI), Planning Commission and Finance Ministry with the request for approving the Metro project and for financial participation through equity contribution in the SPV.
- Signing of an MOU between Karnataka State Government and Government of India giving all details of the Joint Venture bringing out the financial involvement of each party, liability for the loans raised, the administrative control in the SPV, policy in regard to fare structure, operational subsidy, if any, etc.
- Bangalore Metro Rail Corporation Ltd (BMRCL), the Special Purpose Vehicle (SPV) has already been set up for implementing the project and for its subsequent Operation & Maintenance activity.
- The State Government should formulate the funding plan for executing these extensions and get the same approved by the Government of India. The loan portion of the funding will have to be tied up by State Government in consultation with the Government of India.



- The State Government should freeze all developments along the proposed extensions. For any constructions within 50 m. of the proposed alignments, a system of 'No Objection Certificate' should be introduced so that infructuous expenditure at a later stage is avoided.

15.2 INSTITUTIONAL ARRANGEMENTS

Institutional arrangements already existing for implementing Phase-1 of Bangalore Metro to continue for execution of Phase-2 Metro works also.

15.2.1 IMPLEMENTATION

BMRCL has to take the actions for appointment of General Consultants for project management including preparation of tender documents. Till the General Consultants are in position, BMRCL should appoint an Interim Consultant for all preliminary and enabling jobs such as land acquisition, detailed design of civil structures, utility diversions, etc.

A suggested project implementation schedule is given below. The proposed date of commissioning of the section with suggested dates of important milestones is given in Table 15.1

Table 15.1
Implementation Schedule

S. No.	Item of Work	Completion Date
1.	Date of Submission of Final DPR to Karnataka State Government	D
2.	Approval of DPR by Karnataka State Government	D+ 6 Months
3.	Approval of DPR by Central Government	D+ 12 Months
4.	Appointment of Interim Consultant for preliminary works	D+ 6 Months
5.	Appointment of General Consultant	D+ 18 Months



S. No.	Item of Work	Completion Date
6.	Tendering, execution of works and procurement of equipment, coaches and installations	D+60 Months
7.	Testing and Commissioning	D+62 Months
8.	Revenue Operation	From D+63 rd Month

*D : Date of submission of Final DPR

All the corridors can be divided into sections for the purpose of commercial opening in stages. The depot shall also be available for commercial operation.

15.2.2 ORGANISATIONAL SET-UP OF BMRCL

The BMRCL Organization as already existing, as stated earlier, will take faster decisions in making the constructions and implementation of the project for the proposed 4-extensions of North-South and East-West Corridors.

Implementing a metro project in a congested metropolis is indeed a challenge. In sheer size, magnitude and technical complexity there are no parallels to metro projects. Further, these projects are to be carried out in difficult urban environment without dislocating city life, while at the same time preserving the environment. The project involves integration of a number of complex technical systems. Interfacing various system contracts is a difficult and highly skilled exercise. Side by side, timely and adequate funds have to be assured for implementation and lands, without encumbrances, have to be taken possession of in time. Clearances from the local authorities have to be taken which includes permission to cut trees, diversion of utilities, management of road traffic, etc., all of which will call for an efficient and competent project implementing agency.



Since BMRCL may engage Prime Consultants from the very start of GC's assignment who will render technical advice to BMRCL on various matters referred to them by GC. DMRC's services as Prime Consultant is being availed by BMRCL for Phase -1 and the same may be continued on the agreed terms and conditions, if desired by BMRCL.

15.3 CONTRACTS

15.3.1 CIVIL WORKS

Elevated viaduct will be part design and built basis while the elevated stations will be constructed on design and built basis.

North-South Corridor extensions on both ends will have two packages for the elevated viaduct and three packages for the elevated stations.

East-West Corridor extensions on both ends will have three packages for the elevated viaduct and three packages for the elevated stations.

Architectural finishes, fire fighting arrangements and general electrification, will form part of civil contracts.

15.3.2 SYSTEM CONTRACTS

- 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.
- Design and supply of rolling stock.
- Installation of track in Depot and on main line.
- Design and installation of Signages.



15.3.3 DEPOT CONTRACTS

The contracts for Depot are required for Civil and E&M works near Kengeri on East-West Corridor and Anjanapura Township on North-South Corridor. Each Depot will have one package for civil works.

The number of contracts for supply of Depot Equipment may be decided as and when the work is in progress.

15.4. HIGH POWER COMMITTEE

During the implementation of the project several problems with regard to acquisition of land, diversion of utilities, shifting of structures falling on the project alignment, rehabilitation of project affected persons, etc. are likely to arise. For expeditious resolution of these problems, an institutional mechanism needs to be set up at the State Government level. Towards this end, it is recommended that a High Power Committee under the chairmanship of Chief Secretary, Karnataka is already existing for Phase-I of Bangalore Metro and same arrangement has to be continued for Phase-II project also.

15.5 EMPOWERED COMMITTEE AND GROUP OF MINISTERS

Empowered Committee and Group of Ministers are already existing for Phase-I of Bangalore Metro and same arrangement has to be continued for Phase-II project also.

15.6 LEGAL FRAMEWORK

The Metro Railways (Amendment) Act -2009 as passed by Parliament will provide Legal cover for Phase-II of Bangalore Metro.

15.7 CONCESSIONS FROM GOVERNMENT

Metro rail projects need very heavy investment. Loans have invariably to be taken to fund a part of the capital cost of the projects. These projects yield low financial internal rate of return. With reasonable fare level, servicing of these loans often pose problems. To make the project financially viable, therefore, the fares need to be substantially increased to socially un-acceptable levels. This results in the ridership coming down significantly, as it is sensitive to increases in the fare level. Thus, the very objective of constructing the metro rail system to provide an affordable mode of mass travel for public is defeated. It,



therefore, becomes necessary to keep the initial capital cost of a metro project as low as possible so that the fare level of the metro system can be kept at reasonable level.

15.7.1 The State Government should exempt/reimburse the Karnataka Value Added Tax (VAT) to Bangalore Metro Phase II. It should also exempt the following: -

- Tax on electricity required for operation and maintenance of the metro system.
- Municipal Taxes.

15.7.2 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 Phase-II of Bangalore Metro.

15.8 NEED FOR DEDICATED FUND FOR METRO PROJECTS

To enable the State Governments to provide their share of equity in the Special Purpose Vehicles set up for such projects, it would be necessary to constitute a Special Metro Fund at the State Government level. The State Government should resort to imposition of dedicated levies for raising resources for these Funds. Areas where such dedicated levies are possible are given below:

- A 50% cess on the tax levies for registration of road vehicles.
- A Green Surcharge on fuel (petrol, diesel).

The above two levies would also assist to discourage the use of personalized motorized vehicles and encourage the use of public transport, which would not only reduce the pollution level in the city but also reduce traffic congestion on the road.

- one time Green Tax (Rs. 5000 to Rs. 10000 for four wheelers and Rs. 2000 for two wheelers) on existing vehicles registered in the City.
- All receipts from traffic challans to be channeled to this Fund.
- 1 % turnover Tax on all shops, restaurants and hotels on a monthly basis.
- 20 % surcharge on Property Tax within the Corporation limits.



- Metro Tax @ 2% on pay rolls of all establishments having more than 100 employees. Such cess is in existence in a number of Western countries for raising resources for metro rail. The employers' benefit a good deal by good Metro System.
- Surcharge @ 10% on luxury tax on the earning of all Star Hotels. At present level, the luxury tax is 10%. The surcharge will raise the level to only 11%. Chinese cities have adopted this scheme.

Karnataka State Government has already started building up funds for Phase-I of Bangalore Metro project and this will continue for phase-II project also.

Note by BMRCL:

The suggestions made for raising resources for funding Metro Phase-II work have been noted. A suitable decision will be taken by the State Govt. to address the projects funding requirement. BMRCL has made specific proposal to state govt. and the same is being examined by the Govt.

CHAPTER-16

CONCLUSIONS



CHAPTER 16

CONCLUSIONS AND RECOMMENDATIONS

- 16.1** 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 is projected to exceed 8 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 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.

16.2 Project Description

Bangalore Metro Phase II consist of the following corridors which are the extensions of Phase I alignments :

1. East –West Corridor Extensions

a. Mysore Road Terminal – Kengeri

The proposed extension route is 6.465 km starting from Mysore Road Terminal to Kengeri and one future station.. Entire alignment is elevated with 5 stations. The alignment runs on Mysore Road connecting many populated areas such as Nayandahalli Bus Stop, Rajarajeshwari Nagar, Bangalore University, RV Engineering College and terminating at Kengeri on Mysore Road.

b. Baiyappanahalli – ITPL – Whitefield

- **Byappanahalli – ITPL:** The proposed extension route is 12.45 km starting from Byappanahalli to ITPL via Doddanekkundi Industrial Estate. Entire alignment is elevated with 11 stations. The alignment runs on Whitefield Road, Graphite India Road, ITPL Main Road connecting many populated areas such as Benniganahalli, K.R. Puram, B.Narayanapura, Mahadevapura, Doddanekkundi Industrial



area, Graphite India, EPIP Zone, Sri Sathya Sai Hospital and terminating at ITPL.

- **ITPL – Whitefield:** It is planned to extend Byappanahalli to ITPL alignment till Whitefield (Kadugudi bus stop) via Hope Farm Junction with a distance of 3.05 km.

2. North –South Corridor Extensions

a. Hessarghatta Cross – BIEC

The proposed extension route is 3.77 km starting from Hessarghatta Cross (8th Mile) to BIEC via Tumkur Road. Entire alignment is elevated with 3 stations. The alignment runs along the Tumkur Road (NH-4) connecting many populated areas such as Chikkabidarakallu, Ancephalya, Madanayakahalli and terminating at Bangalore International Exhibition Center (BIEC) on Tumkur Road.

b. Puttenahalli Cross – Anjanapura Township (NICE Road Crossing)

The proposed extension route is 6.29 km starting from Puttenahalli Cross to Anjanapura Township (up to NICE road crossing). Entire alignment is elevated with 5 stations. The alignment runs on Kanakapura Road and Amruth Nagar Main Road connecting many populated areas such as Doddakallasandra, Talaghattapura on Kanakapura Road and terminates at NICE Road Junction.

- 16.3** 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.
- 16.4** 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.
- 16.5** 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.
- 16.6** 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.



- 16.7** 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.
- 16.8** While the Financial Internal Rate of Return (FIRR) for the project has been assessed as 2.23%(With PD from 15 Ha. Land) and the Economic Internal Rate of Return (EIRR) works out to 16 %.
- 16.9** 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.
- 16.10** Meanwhile the State Government should freeze all future developments along the proposed route of metro corridors to avoid infructuous expenditure.
- 16.11** 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.
- 16.12** 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.