

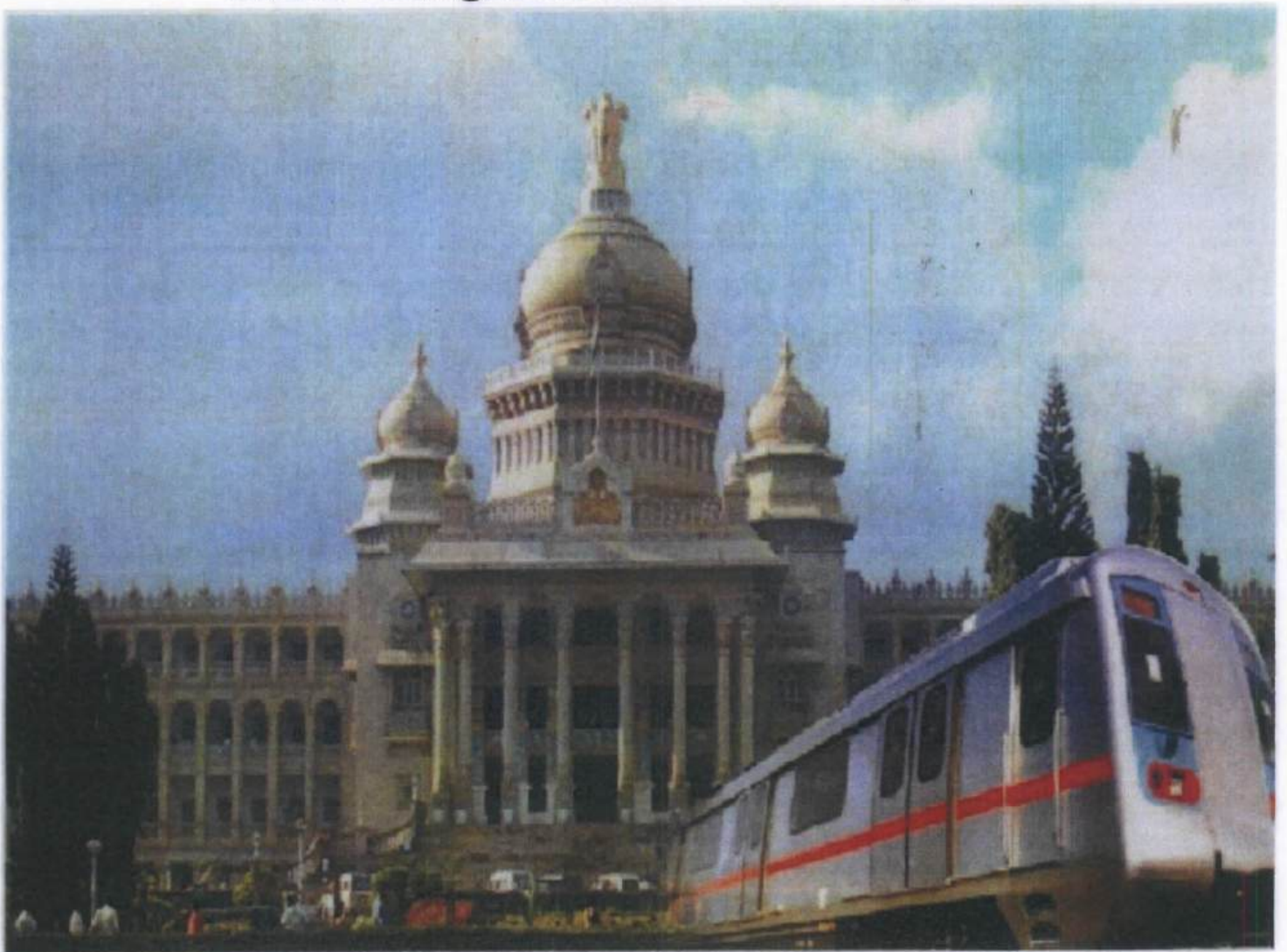
# **DETAILED PROJECT REPORT**

## **R V ROAD -BOMMASANDRA CORRIDOR**

### **OF BANGALORE METRO**

**Final DPR with BMRCL Comments**

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



**Delhi Metro Rail Corporation Ltd.**

**May 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 and II of Delhi Metro Rail Project covering approximate length of 190 Kms has already been commissioned up to February 2011. This length of 190 Kms. includes the Airport Link Express of 23 Kms also.

The Government of Karnataka availed the DMRC's expertise for the planning, investigation and preparation of a Detailed Project Report (DPR) for two metro lines in Bangalore City, one in the East West direction and the other in the North South direction for Phase – I of Bangalore Metro Rail and the DPR for the same was prepared and submitted by DMRC on 26-05-2003. Subsequently the DPR for extension of N-S line on both the ends was submitted in the year 2007 and the implementation of the phase-I comprising of about 42 kms is in progress by Bangalore Metro Rail Corporation Limited (BMRCL). BMRCL conveyed their consent to DMRC to take up the DPR work for the Phase – II of Bangalore Metro Rail vide Agreement dt.15-12-2008. DMRC earlier submitted the DPR for R. V. Road to Electronic City corridor. However, BMRCL desired the DPR for this extension should be up to Bommasandra. Accordingly, the DPR is now prepared for the corridor from R. V. Road to Bommasandra with its length of 18.82 Kms.

DMRC got carried out the topographical survey work from M/s Prime Meridian Surveys, Chennai. The detailed geo-technical studies and Environmental studies were got done through M/s SECON Pvt. Ltd, Bangalore. The detailed traffic study was got done by M/s Wilbur Smith Associates, Bangalore.

During the preparation of the Detailed Project Report there were constant interaction with BMRCL and various Governmental and City Agencies. We wish to place on record particularly the suggestions made by BMRCL in finalizing this report.

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

This report is a compendium of study results carried out by DMRC with our unique background, experience and with considerable efforts. 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.

(E. Sreedharan)  
Managing Director  
Delhi Metro Rail Corporation

New Delhi  
May, 2011



# DETAILED PROJECT REPORT

## R V ROAD TO BOMMASANDRA CORRIDOR OF BANGALORE METRO

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## SALIENT FEATURES

### R V ROAD TERMINAL TO BOMMASANDRA CORRIDOR

- |    |                                  |                          |
|----|----------------------------------|--------------------------|
| 1. | Gauge                            | Standard Gauge (1435 mm) |
| 2. | Route Length (between dead ends) | 18.82 Km (Elevated)      |
| 3. | Number of stations               | 16 Nos (All Elevated)    |
| 4. | Traffic Forecast                 |                          |

Year	Peak Hour Sectional loading	Number of passengers (Lakhs/day)	Passenger KM (Lakhs)	Mean trip length
2016	13,078	2.40	19.27	8.0
2021	17,275	3.70	30.78	8.3
2031	21,274	4.55	38.22	8.4
2041	23,442	5.02	42.14	8.4

5. **Train operation**

RV Road - Bommasandra Corridor				
YEAR	2016	2021	2031	2041
Cars/trains	6	6	6	6
Head way (Minutes)	8	6	5	4.5
Max. PHPDT Demand	13078	17275	21274	23442
PHPDT Capacity Available	12195 (15510*)	16260 (20680*)	19512 (24816*)	21680 (27573*)
Requirement of Coaches	66	90	102	114

- |    |                 |         |
|----|-----------------|---------|
| 6. | Design speed    | 80 kmph |
|    | Schedule Speed: | 34 kmph |

7. **Traction Power Supply**

- |    |                         |              |
|----|-------------------------|--------------|
| a) | Traction system voltage | 750V DC      |
| b) | Current Collection      | Third Rail   |
| c) | Sub Station             | Nagnathapura |

**8. Rolling Stock**

- |    |  |  |
|----|--|--|
| a) | 2.88 m wide modern rolling stock with stainless steel body Standard Gauge. |  |
| b) | Axle load  | - 16t  |
| c) | Seating arrangement  | - Longitudinal   |
| d) | Capacity of 6 Coach unit   | - 1626 (@ 6 Passengers /sqm)<br>2068 (@ 8 Passengers /sqm) |
| e) | Class of accommodation   | - One  |

**9. Stabling Facilities**

- |                        |   |
|------------------------|---|
| Maintenance Depot      | - Hebbagodi Depot   |
|                        | - Augmentation in existing infrastructure at Peenya Depot |
| Disabled stabling line | - provided In the Oxford station                          |

**10. Signaling, Telecommunication & Train Control**

- |     |  |  |    |  |     |  |
|-----|--|--|----|--|-----|--|
| a)  | Type of Signaling  | Cab signalling and continuous automatic train control with Automatic Train Protection (ATP)  |    |  |     |  |
| b)  | Telecommunication  | <table border="0"> <tr> <td>i)</td> <td>Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc.</td> </tr> <tr> <td>ii)</td> <td>Train information system, Control telephones and Centralized Clock System.</td> </tr> </table> | i) | Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc. | ii) | Train information system, Control telephones and Centralized Clock System. |
| i)  | Integrated System with Fibre Optic cable, SCADA, Train Radio, PA system etc. |  |    |  |     |  |
| ii) | Train information system, Control telephones and Centralized Clock System.   |  |    |  |     |  |

**11. Fare Collection**

Automatic Fare collection system with POM and Smart card etc.

**12. Construction Methodology**

Elevated viaduct consisting pre stressed concrete "U" shaped / Box Girders on Single pier/Portal with pile / Open foundations

13. Cost

- a) Estimated Cost (at January, 2011 prices)  
without taxes Rs. 3223 Crores  
with Central taxes of Rs 325 Crores Rs. 3548 Crores
- b) Completion Cost (Completion 31.03.2016, with Central Taxes) Rs. 4255 Crores

*Note by BMRCL:*

- a) *The estimated cost as per BMRCL( without taxes)* Rs. 4188.56 crores  
b) *The estimated cost as per BMRCL( with taxes)* Rs. 4778.56 crores  
c) *Completion cost as per BMRCL* Rs.5744 crores

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

- a) FIRR (With 20 ha. Land for property development) 0.83%
- b) EIRR 18.1%
- \*\*\*\*\*



## EXECUTIVE SUMMARY

### 0.1 BACKGROUND

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

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

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

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

In the DPR for the Phase-II, the south end of N-S corridor has been proposed for extension from Puttenahalli to Anjanapur Township (Nice Road x-ing) along the Kanakapura Road and from Hesaraghatta cross to Bangalore International Exhibition Center (BIEC) on Tumkur Road (NH-4). East-West Corridor is also proposed for extension on both ends. i.e. Mysore Road to Kengeri and Baiyappanahalli to White Field. Draft DPR for the four extensions has already been submitted to BMRCL in November 2010.

As regards extension of North-South corridor to Electronic City - Bommasandra Industrial Area, Government of Karnataka has desired that this line may be taken up even in parallel to Phase-I. Further extension of this line beyond Bommasandra Industrial Area may be needed in future as the city grows in this part of the city.



This DPR covers the geometric and technical features of Metro extension between R V Road Terminal and- Electronic City - Bommasandra Industrial Area.

## 0.2 Traffic Demand

Based on the detailed household surveys and traffic surveys carried out during DPR study in 2002 - 2003 and Subsequent DPR's for extension of N-S line in October & December 2007 and the latest survey done now as a part of this study, the Transport Demand Model was developed. The network for the R V Road – Electronic City - Bommasandra Industrial Area line has been developed from the primary database and used in the transport Demand Model. The Demand Model gives a Base line indication for implementation of the proposed alignment R V Road Terminal – Electronic City - Bommasandra Industrial Area via Silk Board Junction on the Hosur Road. The traffic demand on this line has been projected considering that the extensions of both the initial corridors of Phase-I i.e. North south to Anjanapur Township and BIEC and East-West to Kengeri and Whitefield and New corridor between Gottigere - IIM(B) -Nagawara are in place.

### 0.2.1 TRAFFIC DEMAND

The entire study area has been delineated into 182 zones as shown in chapter 2. Among them 172 are the internal zones and the remaining zones (10 zones) are external zones.

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

**Table 0.1 Population and Employment projection**

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

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

#### 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 Motorised Trips**

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

**Per Capita Trip Rate (PCTR)**

The per capita trip rate excluding walk trips was observed to be 0.96.

**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:

- a. Base year population 2001 and employment and their distribution have been taken from the 2001 census.
- b. Future population and employment for the horizon years 2016, 2021, 2026 and 2031 have been worked out in consultation with BDA at city level.
- c.
- d. 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 extensions, Phase-II North - South Corridor between Nagavara - IIM(B) - Gottigere along with total transport network of the city. Based on the final assignment of traffic on the total network, loading on the proposed extension between R. V. Road - Electronic City - Bommasandra Industrial Area is as follows:

**Table 0.4 Summary of transport demand projections**

Year	Peak Hour Sectional loading	Number of passengers (Lakhs/day)	Passenger KM (Lakhs)	Mean trip length
2016	13,078	2.40	19.27	8.0
2021	17,275	3.70	30.78	8.3
2031	21,274	4.55	38.22	8.4
2041	23,442	5.02	42.14	8.4

The phpdt (peak hour peak direction trips) on this extension by 2016 will be 13078 and will increase to 23442 by 2041.

### 0.3 PLANNING AND DESIGN PARAMETERS

DMRC has already implemented Phase I of Delhi Metro project. Various design norms and parameters have been firmed up by DMRC after detailed studies of norms followed by Metro systems in various countries. 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 overall top width of 9.519 m (track center 4.2 m to carry both the tracks in the portion where the viaduct is proposed on the single pillar. The total width at railing level comes to 10.620 m. However, there is scope of reduction in the width of girder top with innovative design of parapet and railings. More width of the viaduct is recommended for providing more space in the centre of tracks for cables as desired by BMRCL and to accommodate the side walkways for evacuating the passengers in emergency. The section has a walkway

at the floor level of the coach for emergency evacuation of passengers. A 16 t axle load is proposed for this extension.

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

The system is proposed to have Standard Gauge tracks as this will facilitate provision of sharp curves with radii up to 120 m. Other geometrical parameters are similar to that of Bangalore metro under execution.

It is proposed to provide 750 V dc, third rail traction system for this extension 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.

### **0.3 Alignment from R V Road to - Electronic City - Bommasandra Industrial Area**

#### **From km 0.00 point to km 4.90.**

As per DPR of Phase-I May-2003, R V Road Terminal station was planned elevated in the middle of the road. Further the alignment was extended up to Puttenahalli on the Kanakapura Road. Now the proposed RV Road Terminal station is planned as a through station towards Puttenahalli cross. The Bommasandra Industrial Area passengers have to change over to the North-South line of Phase-I by suitably crossing the Platform by means of Foot over Bridges/Escalators.

From the R V Road Terminal Station (Ch.0.00), the line traverses along the R V Road (up to Ch.0.34) and turns left to the Marenahalli road and traverses on the median of Marenahalli road up to short of Jayadeva Hospital junction flyover (ch.2.10). At the Jayadeva Hospital junction the alignment shifts to the left and traverses on the footpath of the at-grade road. After crossing the Jayadeva junction flyover the alignment comes back to the median and traverses along the median up to short of Silk Board junction (Ch.4.85). There are 5 Stations namely RV Road, Ragigudda Station, Jayadeva Hospital Station, BTM Layout Station and Silk Board Station.

At the silk Board junction, the alignment turns towards right to reach the western side of Hosur road.

#### **From km 4.90 to km 14.50.**

In the Hosur road as there is newly constructed elevated Highway by the NHAI on the existing median, it is proposed to take the Electronic City - Bommasandra

Industrial Area line on the centre of western side service lane of the Hosur road. This proposal has been finalized after consultation with the NHAI. As per this proposal, a temporary service road on the western extreme edge after the proposed Metro construction barricading area will be maintained during the construction stage. After the construction stage, a 7.0M wide service road on the western edge of proposed Metro alignment will be constructed and the balance area on eastern side of proposed Metro alignment and main carriageway will be utilized for utility corridor/footpath.

There are 11 Stations on this stretch of Hosur road from Silk Board junction to Bommasandra Industrial Area namely HSR Layout Station, Oxford College Station, Muneshwara Nagar Station, Chikka Begur Station, Basapur Road Station, Hosa Road Station, Electronic City-I Station, and Electronic City Station, Huskur Road Station, Hebbagodi Station and Bommasandra Industrial Area Station. Index Plan of the proposed R. V road – Electronic City - Bommasandra Industrial Area Corridor is shown at Fig. 0.1.

It is proposed to have a car maintenance depot of about 12 Ha at Hebbagodi.

#### 0.4 STATION PLANNING AND TRAFFIC INTEGRATION

The basic planning for stations, as proposed for East - West and North – South Corridor of Phase-I DPR of May 2003 has been used to plan all the 13 16 stations including the proposed RV Road Terminal interchange station along this extension. Out of the total 16 stations, 3 stations are on the middle of the Road and balance 13 stations are off the road. The stations along the middle of the road have been designed to fit in existing road width as far as possible.

The proposed stations along the R V Road to Bommasandra Industrial Area line are as follows:

**Table 0.2 - Stations**

SI No	Name of Station	Chainage (m)	Inter Station Distance (Km)
1.	RV Road	0.00	
2.	Ragigudda Temple	1255.50	1.256
3.	Jayadeva Hospital	2447.97	1.192
4.	BTM Layout	3582.70	1.135
5.	Silk Board	4543.10	0.960
6.	HSR Layout	5761.00	1.200
7.	Oxford College	6960.80	0.897
8.	Muneshwara Nagar	7858.20	0.897
9.	Chikka Begur	9257.50	1.399
10.	Basapura Road	11053.50	1.796
11.	Hosa Road	11998.30	0.945



12.	Electronic City -I	12990.10	0.992
13.	Electronic City	13987.20	0.997
14.	Huskur Road	15460.20	1.473
15.	Hebbagodi	16848.30	1.388
16.	Bommasandra Industrial Area	17961.40	1.113

Elevated stations are provided with side platforms.

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 area. Provision for escalators is made at all the stations in paid area for future. However at a few important stations, escalators shall be provided from the beginning itself. Lifts for disabled passengers are provided at all stations. Jeydeva Hospital metro station is largely planned in the premises of Jeydeva Hospital as there is no other location available. Moreover it will provide the better connectivity even to hospital. As concourse under the platform for this station was not possible, an independent concourse with passenger facilities and station services is proposed in a multi storey complex located nearby to the proposed station. Effort has been made to keep the acquisition of hospital property to the minimum. The proposed concourse building for this extension will also serve the metro station with the same name on the corridor between Nagavara and IIM(B) – Gottigere.

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 R V Road Terminal, Silk Board Junction, Electronic City station, and Bommasandra Industrial Area stations.

## 0.5 TRAIN OPERATION PLAN AND MAINTENANCE DEPOT

### Train Operation Plan

#### 0.5.1 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 RV Road-Electronic City –Bommasandar Corridor has been assumed as 34 kmph.

## 0.5.2 Traffic Demand

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

## 0.5.3 Train formation

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

The basic unit of 6-car train comprising of DMC + TC + MC + MC + TC + DMC configuration is selected for the Bangalore Metro Corridors for the year 2016, 2021, 2031 and 2041.

### Composition

**DMC** : Driving Trailer Car

**MC** : Motor Car

**TC** : Trailer Car

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

### Capacity @ 6 persons per sqm of standee area:

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

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

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

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

DMC : 322 Passengers (Sitting-43, Crush Standing-279)

TC/MC : 356 Passengers (Sitting-50, Crush Standing-306)

6 Car Train : 2068 Passengers (Sitting-286, Crush Standing-1782)

Train operation plan (headway and train composition) for the year 2016 and 2021 during the peak hours is given below.

#### (i) Year 2016

- 8 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 12195 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 15510 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 13078 is in the Section between Jayadev Hospital Compound and BTM and the PHPDT demand in the section between BTM and Silk Board is 12973, demand in the remaining sections is in the range of 10720 to 1086 only. The planned capacity of 12195 (15510 under dense loading) is less than the PHPDT demand in two (zero, with dense loading capacity) sections out of fifteen sections.

With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock.

**ii) Year 2021**

- 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 17275 is in the Section between Jayadev Hospital Compound and BTM and the PHPDT demand in the section between BTM and Silk Board is 17212, demand in the remaining sections is in the range of 15646 to 1906 only. The planned capacity of 16260 (20680 under dense loading) is less than the PHPDT demand in two (zero, with dense loading capacity) sections out of fifteen sections.

With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock.

Details of capacity provided are summarised below:

**R V Road – Electronic City - Bommasandra**

Bangalore Metro	YEAR			
	2016	2021	2031	2041
RV Road-Electronic City – Bommasandar Corridor				
Cars/trains	6	6	6	6
Head way (Minutes)	8	6	5	4.5
Max. PHPDT Demand	13078	17275	21274	23442
PHPDT Capacity Available	12195 (15510*)	16260 (20680*)	19512 (24816*)	21680 (27573*)

#### 0.5.4 Year wise rake Requirement

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

Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches
RV Road - Electronic City-Bommasadar Corridor	2016	8	11	6 car	66
	2021	6	15	6 car	90
	2031	5	17	6 car	102
	2041	4.5	19	6 car	114

Requirements of coaches is calculated based on following assumptions-

##### Assumptions -

- (i) Train Composition planned as under  
**6 car Train Composition: DMC + TC + MC + MC + TC + DMC**  
 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 train per section to cater to failure of train on line and to make up for operational time lost.
- (iv) Repair and maintenance reserve has been estimated as 8 % of total requirement (Bare +Traffic Reserve).
- (v) The calculated number of rakes in fraction is rounded off to next higher number.
- (vi) Schedule speed is taken as 34 kmph
- (vii) Total Turn round time is taken as 6 min at terminal station

#### 0.5.5 Maintenance Depot

A Car maintenance depot of about 12.0 Ha is planned at Hebbagodi. However a stabling /sick line is being planned at the Oxford college on Hosur Road for emergency use. Provision of stabling 2 rakes each at Electronic City and RV road terminals is also made.

#### 0.6 ROLLING STOCK

Rolling stock for R V Road – Electronic City - Bommasandra line 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.

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 about 16 t for which the structures are to be designed.

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

### Power Supply System

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

- ◆ Specific energy consumption of rolling stock – 70KWh/1000 GTKM
- ◆ Regeneration by rolling stock – 20%
- ◆ Elevated/at –grade station load – initially 250KW and finally 300 KW in the year 2021
- ◆ Underground station load – initially 1250KW and finally 1750 KW in the year 2021
- ◆ Depot auxiliary load - initially 2000KW and finally 2500 KW in the year 2021

Keeping in view the train operation plan, power requirements have been worked out for the year 2016 and 2021 which are briefly summarized below:-

**Power Demand Estimation (MVA)**

Corridor		Year			
		2016	2021	2031	2041
RV Road to Bommasandra	Traction	6.8	9.1	11	12.3
	Auxiliary	5.2	6.5	7.8	12.0
	Total	12.0	15.6	18.8	24.4

Metro systems require a very high level of reliable and quality of power supply. Therefore, it is desirable to obtain power supply at high grid voltage of 220kV or



132kV or 66kV from stable grid substation and further transmission & distribution is done by Metro Authority itself. Accordingly, two receiving sub-stations (RSS) (66/33kV) are envisaged for the R V Road –Bommasandra line and these have been located in consultation with Bangalore Power Supply Authorities. The location of RSS is:

Corridor	Grid substation (input source)	Location of RSS of Metro Authority
R V Road – Electronic City – Bommasandra Industrial Area line	Nagnathapura sub-station (220/66kV)	Basapur Road Station on Hosur Road

### System of Traction

750 V d.c. Traction as adopted for Phase-I of Bangalore Metro will also be used for this extension.

## 0.8 S&T AND FARE COLLECTION SYSTEM

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

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

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

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

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

## 0.9 OTHER ENGINEERING WORKS

### Geo Technical Investigation

Geo- technical Investigation has been carried out along the section from R V Road to Electronic City – Bommasandra Industrial Area at 26 locations up to a depth of 30 m in soil or up to a depth of 3 to 4 m Hard rock strata.

Generally the top layer of soil is reddish/yellowish/grayish/browish 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 upto 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 borelog details, test results and bearing capacity recommendations has been submitted separately in Vol-III.

### Utilities

The extended Metro alignment up to Bommasandra is passing along the centre of the Marenahalli road (South end Road) or on the west side service lane of Hosur road.

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

Two major utility of 66 KV OHE lines at an approximate chainage 10720 & 10790 are required to be shifted. These utilities may either be taken underground or their height may be increased so as to provide clearance to the MRTS alignment.

### 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.

For the alignment R V Road – Electronic City - Bommasandra the total land requirement works out to 21.250 ha and another 8.0 ha on temporary basis (for 4 yrs) for construction depots.

The land cost for the R V Road – Electronic City - Bommasandra line is Rs. 319.17 crores.

### Rehabilitation & Resettlement

The project involves displacement of about 212 properties out of which 169 are commercial, 12 residential, 6 religious and 25 others.

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

### 0.10 COST ESTIMATES

The Cost Estimates for the R V Road – Electronic City - Bommasandra line have been prepared at January 2011 prices and works out to Rs 3223.21 crores including land, but excluding taxes & duties. It is estimated that the taxes and duties will amount to Rs **496 crore** and the total cost inclusive of taxes and duties is Rs. **3719 crores** The same is summarized as below

#### Abstract Cost Estimate of R V Road - Elec City - Bommasandra line (BM Ph-II)

Total length = 18.82 km, ( Completely Elevated)

Total Station = 16nos ( all elevated)

January 2011 price level (Cost without Taxes & Duties)

S. No.	Item	Unit	As per DPR			As per BMRCL		
			Rate	Qty.	Amount (Rs in Cr.)	Rate	Qty.	Amount (Rs in Cr.)
<b>1.0</b>	<b>Land</b>							
1.1	Private land	Hect.	29.56	6.650	196.57	30.00	21.25	637.50
1.2	Govt. Land	Hect.	5.00	14.600	73.00	0.00	14.60	0.00
1.3	Railway Land	Hect.	17.70	0.000	0.00	0.00	0.00	0.00

## EXECUTIVE SUMMARY

1.4	Temporary land for casting yard, working spaces etc.	Hect.	1.20	8.000	9.60	1.20	8.00	9.60
1.5	Miscellaneous works like Boundary wall etc.	km	0.70	0.000	0.00	0.00	0.00	0.00
1.6	Cost of land for rehabilitation ( to be identified)	LS			40.00			40.0
	<b>Sub Total (1)</b>				<b>319.17</b>			<b>687.10</b>
<b>2.0</b>	<b>Alignment and Formation</b>							
2.1	Underground section by Cut & Cover excluding Station length	R. km.	101.16	0.000	0.00	0.00	0.00	0.00
2.2	Tunneling by TBM	R. km.	144.31	0.000	0.00	0.00	0.00	0.00
2.1	Elevated viaduct section	R. km.	29.87	19.320	577.14	31.50	19.320	608.58
2.1.1	Special Spans	R. km.	41.90	0.500	20.95	41.90	05.00	20.95
	<b>Sub Total (2)</b>				<b>598.09</b>			<b>629.53</b>
<b>3</b>	<b>Station Buildings</b>							
4.1	Underground Station	Each	120.75	0.000	0.00	0.00	0.00	0.00
3.1	Elevated stations (including finishes)							
a	Type (A) way side	Each	20.59	12.000	247.09	30.60	12.000	367.20
b	Type (B) Way side with signaling	Each	22.02	2.000	44.04	32.40	2.000	64.80
c	Type (C), Terminal station	Each	23.44	2.000	46.87	34.20	2.000	68.40
3.2	Interchange facilities at interchange stations	Each	5.25	1.000	5.25	5.25	1.000	5.25
3.3	Subways for stations	Each	10.00	12.000	120.00	12.00	12.000	120.00
	<b>Sub total (3)</b>				<b>463.25</b>			<b>625.65</b>
<b>4</b>	<b>E&amp;M Works</b>							
5.1	Underground station (E&M ,Lifts ,Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	0.000	0.00	0.00	0.00	0.00
4.1	Elevated station (E&M, Lifts Escalators, DG sets etc.)	Each	6.53	16.000	104.50	6.47	16.000	103.52
	<b>Sub total (4)</b>				<b>104.50</b>			<b>103.52</b>
<b>5.0</b>	<b>Depot</b>							
5.1	Depot at Hebbagodi ( i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			150.00			Civil E&M 120.00 Track 28.00 M & P 90.00

								238.00
	<b>Sub total (5)</b>				<b>150.00</b>			<b>238.00</b>
<b>6.0</b>	<b>Permanent Way</b>							
6.1	Ballastless track for elevated and at grade alignment	R. km.	6.48	19.320	125.16	6.42	19.320	124.03
	<b>Sub total (6)</b>				<b>125.16</b>			<b>124.03</b>
<b>7</b>	<b>Traction &amp; power</b>							
<b>7.1</b>	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>							
7.1.1	Elevated & at grade section	R. km.	9.36	18.820	176.16	15.62	18.820	293.97
	<b>Sub total (7)</b>				<b>176.16</b>			<b>293.97</b>
<b>8.0</b>	<b>Signalling and Telecom.</b>							
8.1	Signalling	R. km.	9.73	18.820	183.12	11.37	18.820	213.98
8.2	Telecom	Each Stn.	4.36	16.000	69.76	5.04	16.00	80.64
8.3	Automatic fare collection							
9.3.1	Underground stations	Each	2.96	0.000	0.00	0.00	0.00	0.00
8.3.2	Elevated stations	Each	2.96	16.000	47.38	2.50	16.00	40.00
9.4	PSD at various stations	LS			0.00			0.00
	<b>Sub Total (8)</b>				<b>300.26</b>			<b>334.62</b>
<b>9.0</b>	<b>R &amp; R incl. Hutments and road restoration etc.</b>	LS			59.28			59.28
	<b>Sub Total (9)</b>				<b>59.28</b>			<b>59.28</b>
<b>10.1</b>	<b>Misc. Utilities, other civil works such as median, road signages etc.</b>	R. km.	3.15	18.820	59.28	3.12	18.820	58.72
10.2	Electrical Utilities	LS			49.40			49.40
10.3	Telecom Utilities	LS			9.88			9.88
	<b>Sub Total (10)</b>				<b>118.56</b>			<b>118.00</b>
<b>11</b>	<b>Rolling Stock (SG)</b>	Each	8.40	66.000	554.40	66.00	9.50	627.00
	<b>Sub Total (11)</b>				<b>554.40</b>			<b>627.00</b>
<b>12.1</b>	<b>Barracks for CISF including security equipments</b>	LS			4.94			4.94
<b>12.2</b>	<b>Staff Quarters for O&amp;M</b>	LS			21.74			60.00
	<b>Sub Total (12)</b>				<b>26.68</b>			<b>64.94</b>



13	Total of all items except Land				2676.34			3218.54
14	General Charges incl. Design charge @ 5% on all items except land				133.82			160.93
15	Total of all items including General charges				2810.16			3379.47
16	Total of cost inclusive land cost				3129.33			4066.57
17	Contingencies @ 3 %				93.88			122.00
18	Gross Total				3223.21			4188.56

### 0.11 FINANCIAL ANALYSIS AND FINANCING PLAN

The completion cost including central taxes for R V Road - Bommasandra line of 18.82 km has been assessed as Rs. 4255 crores (Completion 31.03.2016).

Based on proposed fare structure and considering the land of 20 ha. Being available for Property Development, FIRR for the project works out as 0.83 %.

**Note by BMRCL:**

**The completion cost of this line as BMRCL's cost estimate is Rs.5744 crores and the FIRR works out to**

**Financing Plan:**

The R V Road – Electronic City – Bommasandra line of Bangalore Metro should be basically funded on the same pattern as Phase-I of Bangalore Metro. Accordingly, the funding mode as recommended is tabulated as under: -

**Table 0.4 Funding pattern under DMRC model (with central taxes)**

Particulars	% Of contribution	Amount (Rs/Crore)
VGF by GOI	20%	851.00
VGF by Karnataka State Government	61%	2620.00
Land to be provided free of cost by State	8%	329.00
Equity by Concessionaire	4%	152.00
Concessionaire's debt @11% PA	7%	303.00
<b>Total</b>	<b>100%</b>	<b>4255.00</b>

**0.12 ECONOMIC ANALYSIS**

Implementation of the proposed R V Road to Bommasandra line will result in reduction of busses, vehicles on roads and increase in the journey speed of road based vehicles. The Economic Internal Rate of Return for the project has been worked out and given in the table below.

Sl. No.	Parameter	Results
1	EIRR (%)	18.1%
2	ENPV (Rs. In crores @ 12% discount rate)	1229.7

**0.13 IMPLEMENTATION STRATEGY AND PROJECT IMPLEMENTATION**

The project is to be implemented on priority as an extension to the phase-I of the Bangalore Metro in the extended time frame i.e. by March 2016. However this section gets priority as the major portion of Electronic City, Bommasandra Industrial Area bound traffic is from the Jayanagar/J P Nagar area.

The civil works for the corridor can be implemented through 2 contract packages for the Viaduct and 4 number for stations. The contracts are recommended to be finalized on design and build basis for stations and part design build basis for viaduct.

The systems contracts may also be finalized as recommended in chapter 12.

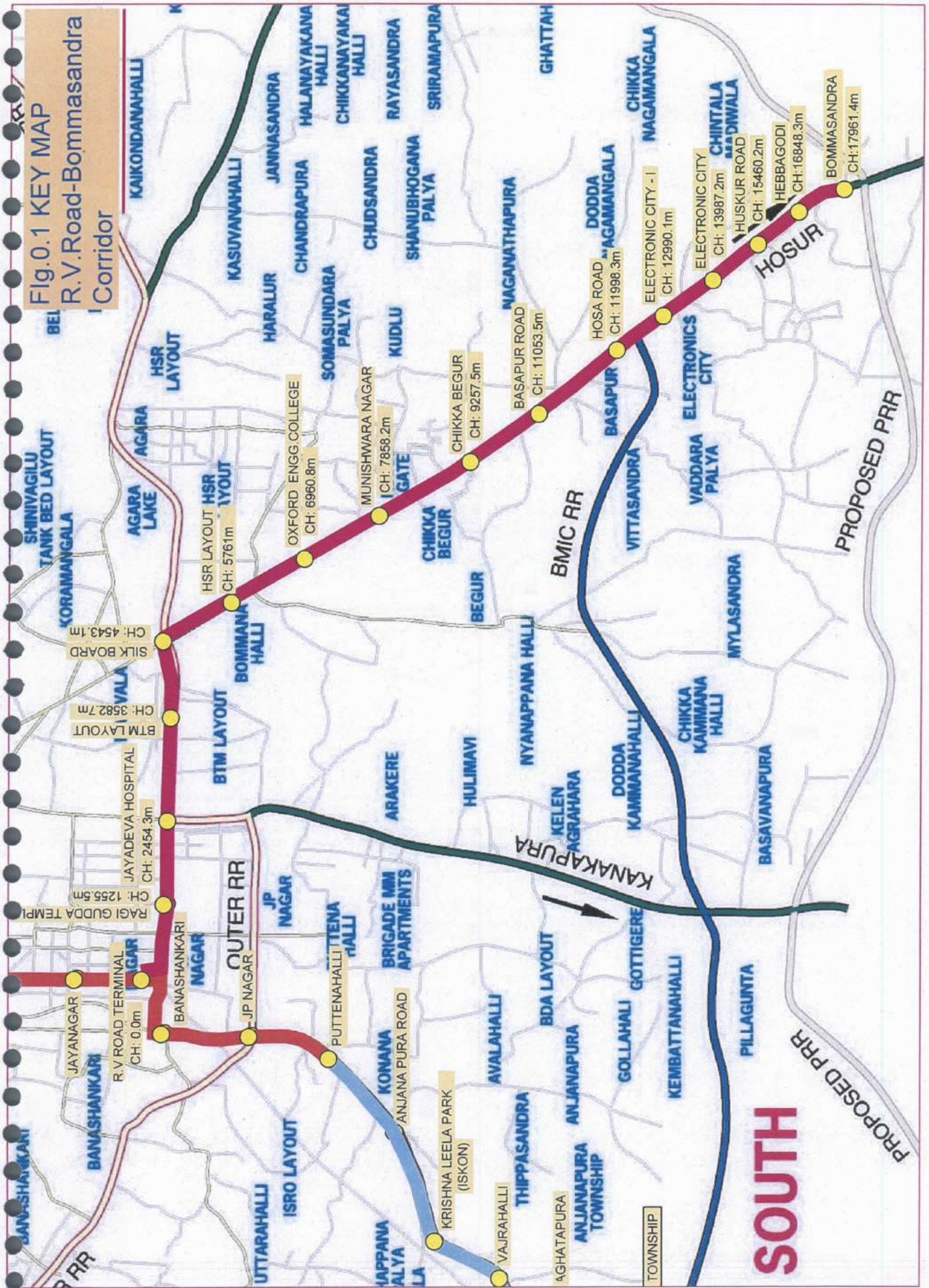
**0.14 CONCLUSIONS AND RECOMMENDATIONS**

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 an extension to Phase-I.

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**Fig.0.1 KEY MAP**  
**R.V.Road-Bommasandra**  
**Corridor**



**SOUTH**



**CHAPTER-1**

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**INTRODUCTION**



## CHAPTER 1

### INTRODUCTION

#### 1.0 INTRODUCTION

#### 1.1 Phase - I Corridors

1.1.1 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:

(ii) 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 14<sup>th</sup> 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)
	<b>TOTAL</b>	<b>24.165</b>	<b>24 (21 elevated &amp; 3 underground)</b>

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

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

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

S. No	NAME	C/L Chainage of station (in m)	Inter Station Distance (in m)
1	Mysore Road Terminal	0	-
2	Deepanjali Nagar	1117	1117
3	Vijaya Nagar	2345	1228
4	Hosahalli	3446	1101
5	Toll Gate	4448	1002
6	Magadi Road	5600	1152
7	City Railway Station	6755	1155
8	Majestic	7503	748
9	Central College	8697	1194
10	Vidhan Soudha	9318	621

11	Cricket Stadium	10643	1325
12	M G Road	11380	737
13	Trinity Circle	12522	1142
14	Ulsoor	13725	1203
15	Indira Nagar	14610	885
16	Old Madras Road	16419	1809
17	Byappanahalli	17374	955

## 1.2 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 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 8<sup>th</sup> 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. DPR for RV Road Terminal to Electronic City was submitted to BMRCL in May 2010.
- 1.2.2** The Report for the following extensions of the East-West Line and North -South Line of Phase-I in both directions (four extensions) has been submitted to BMRCL in November 2010 .

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	7.09
ii.	Extension of E-W line from Baiyyappanahalli 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
	<b>TOTAL</b>	<b>32.66</b>

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 Baiyyappanahalli 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 Baiyyappanahalli 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 Hesaraghatta Cross to Bangalore International Exhibition Center (BIEC)**

The Phase-I N-S line is already under construction up to Hesaraghatta 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.

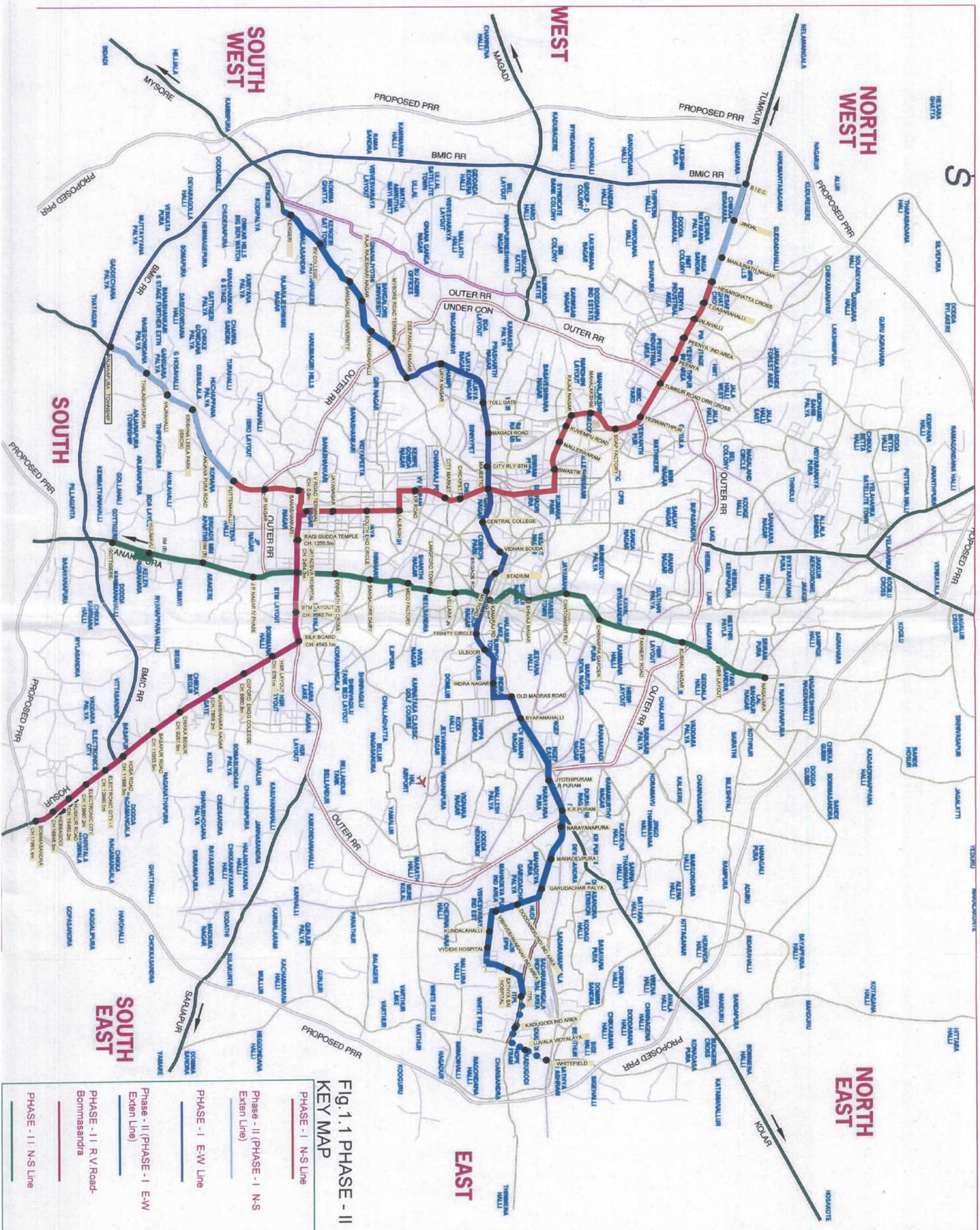
**1.3** As decided by HPC, the DPR for R.V. Road to Bommasandra in place of R. V. Road to Electronic City is now submitted. It has also been decided by BMRCL that the alignment on Hosur Road has to be on the Centre line of service road with single pier as against the portals proposed in the DPR of R. V. Road to Electronic City submitted earlier.

**1.4** This Report is structured in 12 Chapters as below:

Chapter - 1	Introduction
Chapter - 2	Traffic Forecast
Chapter - 3	System Selection
Chapter - 4	Civil Engineering
Chapter – 5	Train operation plan
Chapter – 6	Power Supply
Chapter – 7	Maintenance Depot
Chapter – 8	Environmental Impact Assessment
Chapter – 9	Cost Estimates
Chapter – 10	Financial viability, fare structure & financing options
Chapter – 11	Economical internal rate of return
Chapter – 12	Implementation plan

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**Fig. 1.1 PHASE - II  
KEY MAP**

- PHASE - I - N-S Line
- PHASE - II (PHASE - I - N-S  
Exten Line)
- PHASE - I - E-W Line
- Phase - II (PHASE - I - E-W  
Exten Line)
- PHASE - II - R.V. Road-  
Bommasandra
- PHASE - II - N-S Line



**CHAPTER-2**

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**TRAFFIC FORECAST**



## CHAPTER 2

### TRAFFIC FORECAST

#### 2.0 TRANSPORT DEMAND FORECAST

##### 2.1 Travel Characteristics

###### 2.1.1. General

Bangalore Metro Rail corporation limited has been implementing the Bangalore Metro for the city of Bangalore. It is currently implementing the Phase 1 of the Bangalore metro. A DPR was earlier submitted to supplement the Phase 1 with a proposed line from R.V road terminal (of Phase 1) to Electronic City. However, subsequently it has been decided that the DPR should be prepared for this connection up to Bommasandra in place of Electronic City with its length as 18.82 kms.

This Chapter covers the transport demand projections for the R.V Terminal to Bommasandra line and section and station loadings for the same.

###### 2.1.2. TRANSPORT DEMAND MODELLING

###### Data Base

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

The Network for the proposed R.V Road terminal to Bommasandra alignment has been developed from the same primary database and used in the Transport Demand Model

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

The basic functions included in the transportation study process are:

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

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

### 2.1.3 ZONING

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

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

**Table 2.1 Population and Employment projection**

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

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

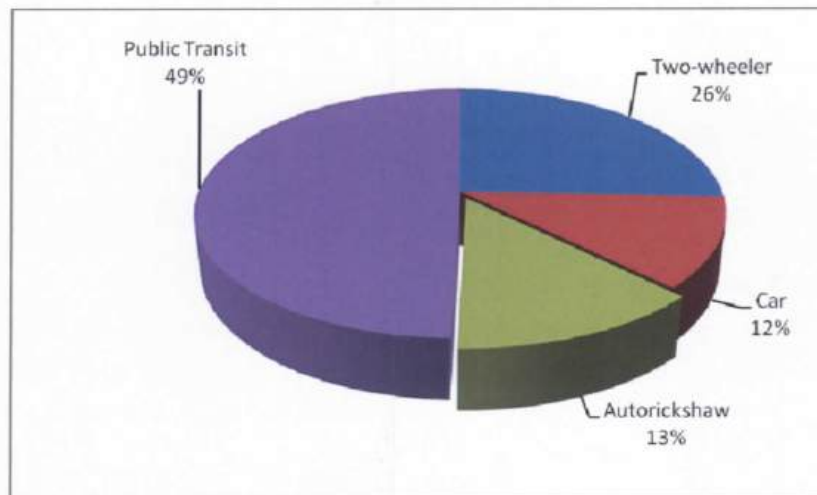
### 2.1.4 Trip Information

The trip information obtained from the survey has been analyzed with respect to distribution of total trips by mode. The daily trips by various modes are presented in **Table 2.2** and **Fig. 2.3**.

**Table 2.2 Distribution of Motorised Trips**

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

**Figure 1.3. Mode Split – Motorized**



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

## 2.2 TRANSPORT DEMAND MODEL AND PARAMETERS

### 2.2.1 Model Description

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

### 2.2.2 CAPACITY OF THE ROAD SYSTEM

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

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

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

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

### 2.2.3 Speed Flow Relationship

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

**Table 2.4: Speed Flow Relations**

S.NO	Lane Details	Equation	R <sup>2</sup>
1	6L-2W-D	$49.97-0.000001 X^2$	0.99
2	4L-2W-D	$43.03-0.001X-.0000014 X^2$	0.98
3	3L-2W-UD	$38.45-0.008X$	0.90
4	2L-2W-UD	$35.11-0.011X$	0.82

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

**Table 2.5 Free flow Speeds**

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

#### 2.2.4 TRIP CATEGORIZATION

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

#### 2.2.5 TRIP GENERATION

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

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

Mathematically, trip generation can be expressed as:

Trips Generated = Function (socio-economic, 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.
- A<sub>0</sub> = Constant term to be calibrated.
- a<sub>0</sub>, a<sub>1</sub> ..... a<sub>k</sub> = Coefficients to be determined by the regression analysis
- X<sub>1</sub>, x<sub>2</sub>. = Zonal planning input factor (independent variable)

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

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

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

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

$$Y=A+BX$$

Where Y=Trips produced or attracted

A=Constant term

B=Trip rate to be determined from least square Analysis

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

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

**Table 2.6 Generation for Total Trips**

	Co-off.
Intercept	1653
X Variable	0.037

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

**Table 2.7 Trip attraction for total trips**

	Co-off.
Intercept	1312
X Variable	0.126

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

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

**Table 2.8 Population and employment projections**

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

### 2.2.6 PER CAPITA TRIP RATE (PCTR)

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

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

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

**2.2.7 TRIP DISTRIBUTION AND MODE CHOICE**

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

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

- Where T= number of inter zonal trips between zone i & j and by mode m
- G= Total generation trip ends by zone
- A= Total attraction trip ends by zone
- i=Generation Zone
- j= Attraction Zone
- r,s=Balancing factors (constants)
- F<sub>ijm</sub>= Deterrence function for mode m

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

- 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 **Figure 2.4**.

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

### 2.2.8 Deterrence functions

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

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

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

### 2.2.9 TRIP ASSIGNMENT

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

The purposes of trip assignment are:

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

### 2.2.9.2 Assignment Procedure Adopted

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

### 2.2.9.3 PCU Conversion Factor

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

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

**TABLE 2.11 PCU CONVERSION FACTORS**

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

## 2.3 TRANSPORT DEMAND PROJECTIONS

2.3.1 The proposed stations on the R.V road terminal to Bommasandra is given in Table 2.12

Table 2.12 – Interstation distances in the extension

Station no	Name of Station	Inter Station Distance (M)
1	RV Road Terminal	-
2	Ragigudda Temple	1.256
3	Jayadev Hospital Compound	1.199
4	BTM Layout	1.128
5	Silk Board Junction	0.960
6	HSR Layout	1.218
7	Oxford College	1.200
8	Muneshwara Nagar	0.897
9	Chikka Begur	1.399
10	Basapur Road	1.796
11	Hosa Road	0.945
12	Electronic City I	0.992
13	Electronic City	0.997
14	Huskur Road	1.473
15	Hebbagodi	1.388
16	Bommasandra	1.113

The alignment is 18.83 km in length with 16 proposed stations up to Bommasandra. It may be noted that station spacing along the alignment varies from 0.79 km to 1.79 km.

### 2.3.2 Section Loading

The traffic assignment was carried out on the R.V road terminal to Bommasandra line with the phase 1 lines, its four extensions and Nagavara to IIM(B) new corridor in place. The loading on the proposed R.V Road terminal to Bommasandra line is presented in Table 2.13

Table 2.13 Summary of Transport demand projections

Year	Peak Hour Sectional loading	Number of passengers (Lakhs/day)	Passenger KM (Lakhs)	Mean trip length
2016	13,078	2.40	19.27	8.0
2021	17,275	3.70	30.78	8.3

2031	21,274	4.55	38.22	8.4
2041	23,442	5.02	42.14	8.4

The total ridership in the proposed line in the year 2016, 2021, 2031 and 2041 will be 2.40, 3.70, 4.55 and 5.02 lakhs passengers per day respectively. Based on traffic volume counts, peak hour factor of 9 has been arrived for the city.

The PHPDT on the system in 2016 will be 13078 and by 2041 it is likely to be of the order of 23442. The section wise loading and PHPDT is presented in **Annexure 2.2**.

### 2.3.3 Station loading

The daily station loading (two way boardings) of RV Road terminal to Bommasandra line on the north south corridor is presented in **Table 2.14**.

**Table 2.14 Daily Station Loading for RV Road terminal to Bommasandra line**

Phase 1 (EC Extension)				
Station Name	2016	2021	2031	2041
R.V.Road Terminal	77474	104885	129431	142618
Ragigudda temple	8342	13152	16229	17882
Jayadeva Hospital	63004	82333	101061	111357
BTM Layout	4653	6260	7671	8452
Silk board	17466	23847	28087	31834
HSR Layout	4171	8617	11283	11552
OXFORD ENGG College	2946	8161	9793	10791
Munishwara Nagar	8573	19067	23072	25422
Chikka Begur	8971	15992	19406	21383
Basapur Road	7431	13745	16580	18269
Hosa Road	9472	18173	22012	24255
Electronic City – I	6752	11481	14490	15966
Electronic City	4637	7487	9329	10280
Huskur Road	4928	11641	14782	16288
Hebbagodi	6227	10385	12966	14287
Bommasandra	4910	15247	19035	20975

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

### 2.3.4. Trip length frequency distribution

The trip length frequency distribution of the Metro trips is presented in **Annexure 2.3** it can be observed that the average trip length for the years 2016 and 2041 are 8.0 and 8.4 km respectively.

Figure 2.1: Modeling approach

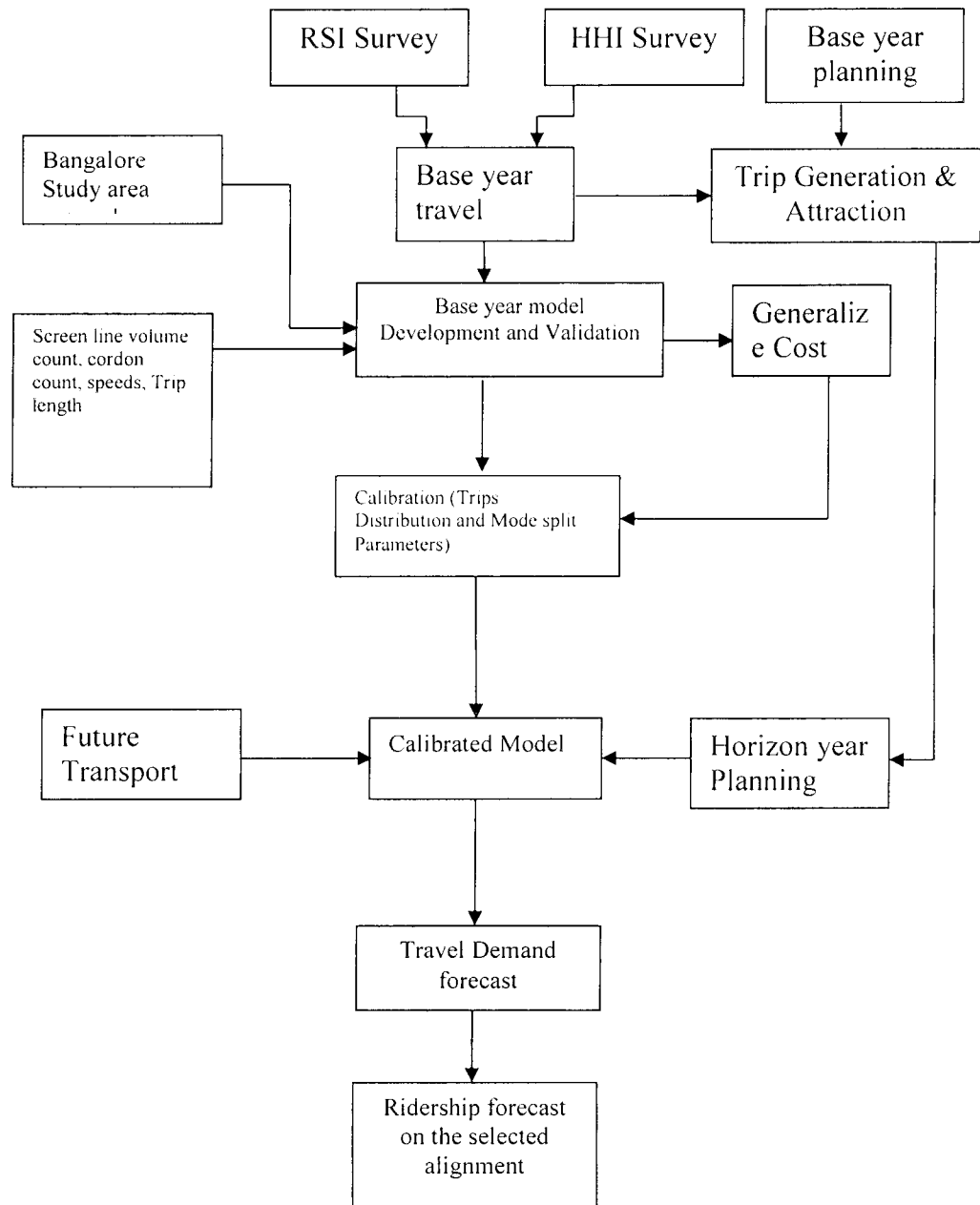




Figure 2.2: Zoning system

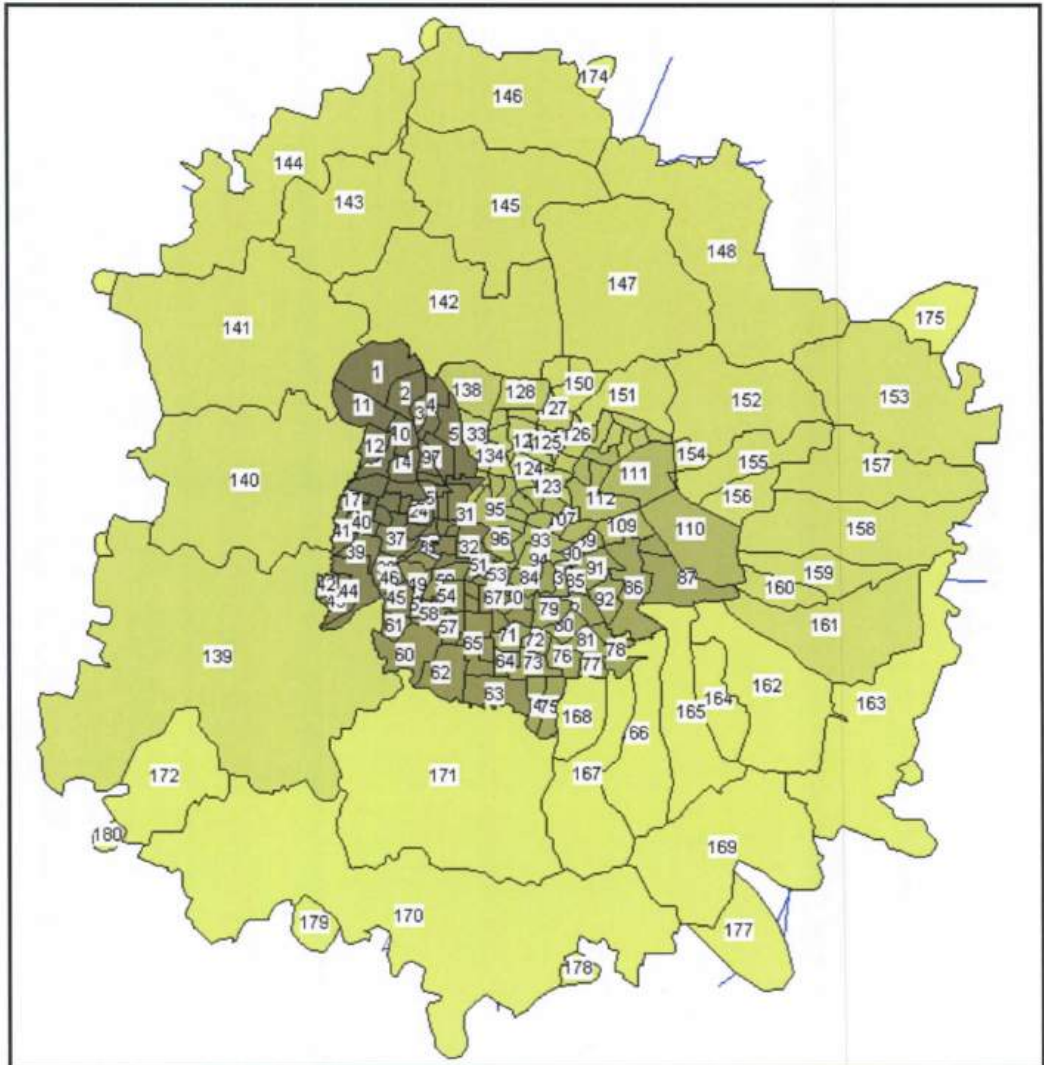


Figure 2.4: Calibration process

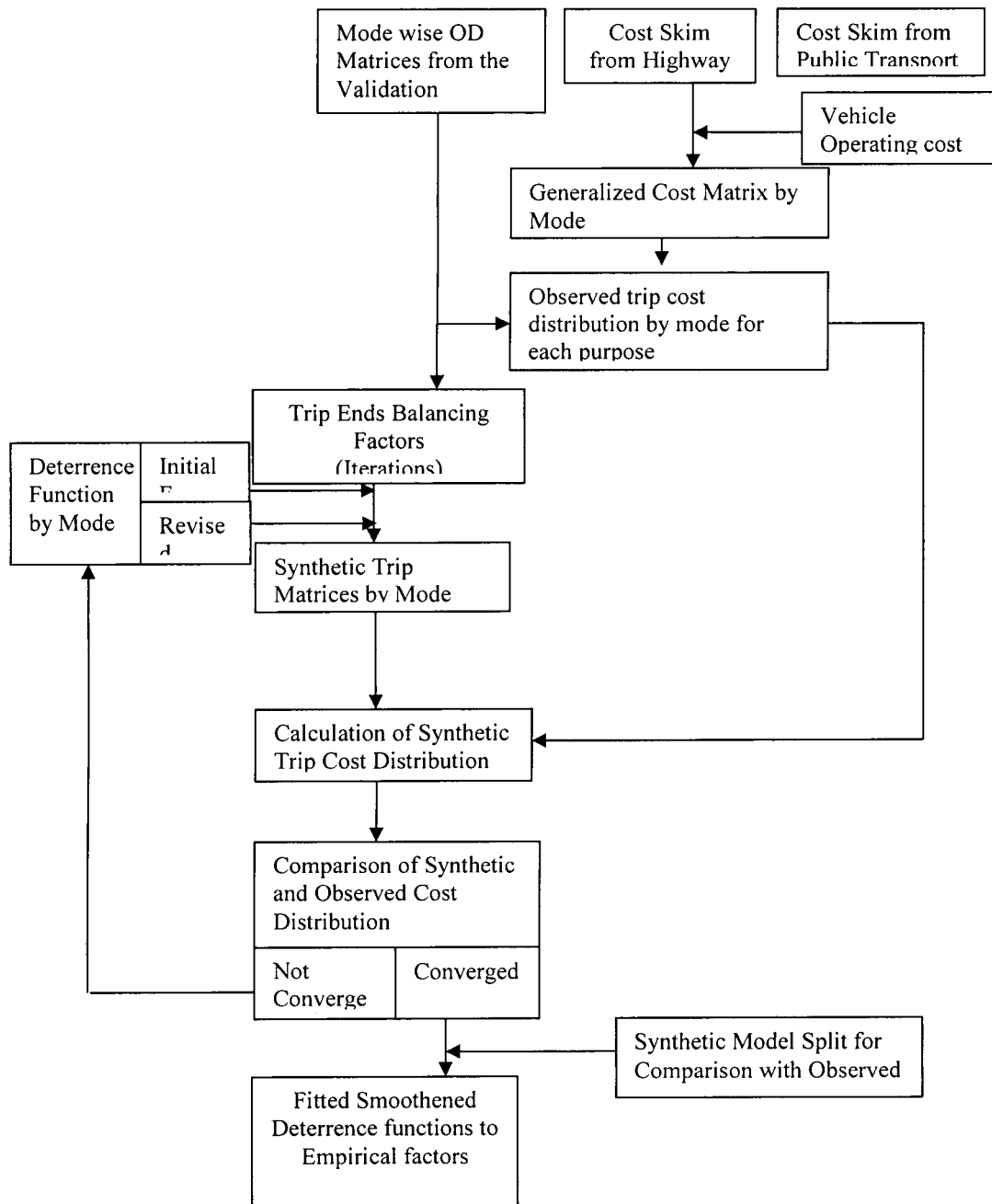
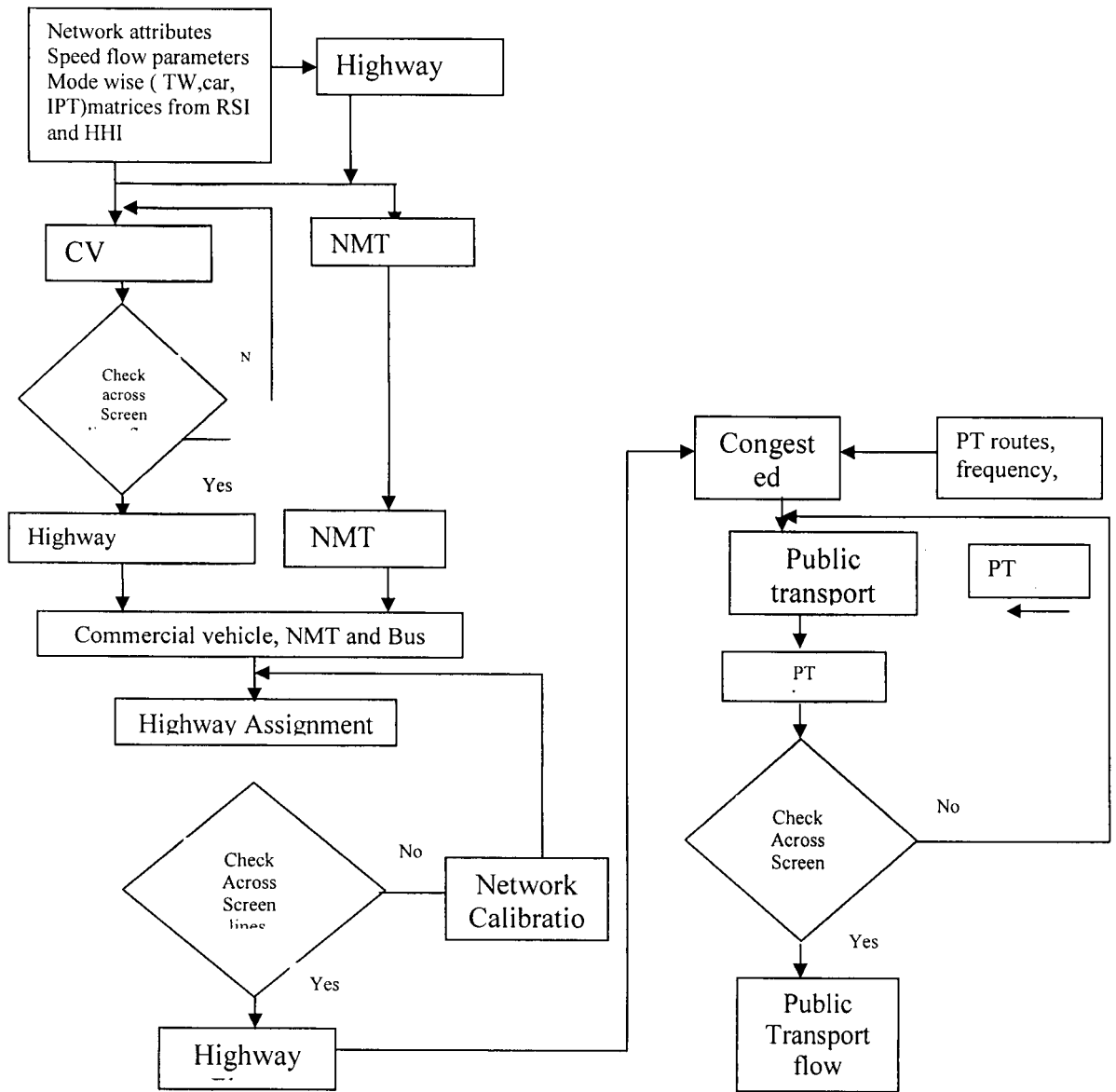


Figure 2.5. Trip Assignment



## ANNEXURE -2.1

## ZONE NUMBERS AND ZONE NAMES

Zone No	Zone name	Zone No	Zone name
1	HMT	39	Marenahalli
2	Jalahalli	40	Govindarajanagar
3	Yeshwanthapura	41	Amarjyothi Nagar
4	Mathikere	42	Mudala Palya
5	Kodandarampura	43	Chandra Layout
6	Dattatreya Temple	44	Attiguppe
7	Malleshwaram	45	Gali Anjaneya Temple
8	Gayathrinagar	46	Bapuji Nagar
9	Subramanyanagar	47	Padarayanapura
10	Mahalakshmpuram	48	Jagajeevanaram Nagar
11	Peenya Industrial Area	49	Azad Nagar
12	Nandini Layout	50	Chamrajpet
13	Geleyarabalaga Extension	51	Dharmarayaswamy Temple
14	Nagapura	52	Sudhamanagara
15	Rajajinagar	53	
16	Kamalanagar	54	Kempegowdanagar
17	Vrishabavathi Nagara	55	Vishweshwarapuram
18	Kamakshipalya	56	
19	Basaweshwaranagar	57	Basavanagudi
20	Shivanagar	58	Hanumantha Nagar
21		59	Srinagar
22	Industrial Town	60	Srinivasanagar
23		61	Padhmanabhanagar
24		62	Ganesha Mandir
25	Prakashnagar	63	JP Nagar
26	Bashyamanagara	64	Jayanagar
27	Ramachandrapuram	65	Yediyur
28		66	Pattabiramnagar
29	Sevashrama	67	Mavalli
30		68	Hombegowdanagar
31		69	
32	Chickpet	70	
33	Cottonpet	71	Lakkasandara
72		153	Avalahalli
73	Gurappanapalya	154	K.R.Puram
74	B.T.M. Layout	155	
117		156	

Zone No	Zone name	Zone No	Zone name
118	Kacharakannahalli	157	Sadar Mangala
119		158	Whitefield
120		159	
121		160	
122	Sagayapuram	161	Varthur
123	Pulikeshy Nagar	162	
124	Jayamahal	163	Dommasandra
125	Devarajeevanahalli	164	Begur
126	Kadugondanahalli	165	
127	Kaval Byrasandra	166	
128	Hebbal	167	
129	J.C. Nagar	168	
130	Ganga Nagar	169	Electronic City
131	Aramane Nagar	170	Bannerghatta
132		171	Anjanapura
133		172	Kumbalagoda
134		173	Towards Doddaballapur
135		174	Towards Hyderabad
136		175	Towards Kolar
137		176	Towards Sarjapur
138	Sanjayanagar	177	Towards Hosur
139	Kengeri	178	Towards Bannerghatta
140	Herohalli	179	Towards Kanakpura
180	Towards Mysore		
181	Towards Magadi		
182	Towards Tumkur		

## ANNEXURE 2.2

PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2016- METRO  
PHASE 1 EC EXTENSION

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading
1	RV Road Terminal	9684	0	9684	16	Bommasandra	614	0	614
2	Ragigudda Temple	1036	0	10720	15	Hebbagodi	778	0	1392
3	Jayadev Hospital Compound	4810	2452	13078	14	Huskur Road	581	31	1942
4	BTM Layout	227	333	12973	13	Electronic City	543	31	2454
5	Silk Board Junction	621	3118	10476	12	Electronic City - I	782	61	3175
6	HSR Layout	41	126	10391	11	Hosa Road	1011	58	4128
7	Oxford College	102	456	10037	10	Basapur Road	811	40	4899
8	Muneshwara Nagar	187	942	9283	9	Chikka Begur	808	116	5591
9	Chikka Begur	314	795	8801	8	Muneshwara Nagar	884	105	6370
10	Basapur Road	118	696	8224	7	OXFORD College	267	35	6602
11	Hosa Road	173	1227	7170	6	HSR Layout	480	103	6979
12	Electronic City I	62	2048	5184	5	Silk board	1562	474	8067
13	Electronic City	37	687	4534	4	BTM Layout	354	209	8212
14	Huskur Road	35	1845	2724	3	Jayadeva Hospital	3066	2490	8787
15	Hebbagodi	0	1638	1086	2	Ragigudda temple	7	746	8048
16	Bommasandra	0	1086	0	1	R.V.Road Terminal	0	8048	0

**PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2021- METRO  
PHASE 1 EC EXTENSION**

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading
1	RV Road Terminal	13111	0	13111	16	Bommasandra	1906	0	1906
2	Ragigudda Temple	1639	0	14749	15	Hebbagodi	1298	0	3204
3	Jayadev Hospital Compound	5933	3408	17275	14	Huskur Road	1413	28	4590
4	BTM Layout	347	411	17212	13	Electronic City	861	72	5378
5	Silk Board Junction	810	3758	14263	12	Electronic City - I	1320	122	6577
6	HSR Layout	75	466	13873	11	Hosa Road	2043	106	8514
7	Oxford College	373	598	13648	10	Basapur Road	1545	93	9966
8	Muneshwara Nagar	259	1435	12472	9	Chikka Begur	1607	166	11406
9	Chikka Begur	392	973	11892	8	Muneshwara Nagar	2124	140	13390
10	Basapur Road	173	923	11142	7	OXFORD College	647	67	13970
11	Hosa Road	229	1635	9735	6	HSR Layout	1002	650	14322
12	Electronic City I	115	2835	7016	5	Silk board	2171	682	15811
13	Electronic City	75	843	6248	4	BTM Layout	435	344	15902
14	Huskur Road	42	2536	3753	3	Jayadeva Hospital	4358	4614	15646
15	Hebbagodi	0	2416	1337	2	Ragigudda temple	5	1293	14358
16	Bommasandra	0	1337	0	1	R.V.Road Terminal	0	14358	0

**PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2031- METRO  
PHASE 1 EC EXTENSION**

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading
1	RV Road Terminal	16179	0	16179	16	Bommasandra	2379	0	2379
2	Ragigudda Temple	2022	0	18201	15	Hebbagodi	1621	0	4000
3	Jayadev Hospital Compound	7295	4221	21274	14	Huskur Road	1794	35	5759
4	BTM Layout	427	508	21193	13	Electronic City	1070	92	6737
5	Silk Board Junction	886	4527	17552	12	Electronic City - I	1663	156	8244
6	HSR Layout	191	570	17174	11	Hosa Road	2469	133	10579
7	Oxford College	456	707	16923	10	Basapur Road	1860	116	12323
8	Muneshwara Nagar	317	1717	15523	9	Chikka Begur	1942	201	14063
9	Chikka Begur	484	1170	14837	8	Muneshwara Nagar	2566	166	16463
10	Basapur Road	213	1120	13930	7	OXFORD College	768	180	17052
11	Hosa Road	283	2026	12186	6	HSR Layout	1219	685	17586
12	Electronic City I	148	3538	8797	5	Silk board	2625	818	19393
13	Electronic City	96	1049	7844	4	BTM Layout	532	423	19502
14	Huskur Road	54	3185	4713	3	Jayadeva Hospital	5338	5664	19176
15	Hebbagodi	0	3034	1679	2	Ragigudda temple	6	1585	17597
16	Bommasandra	0	1679	0	1	R.V.Road Terminal	0	17597	0



**PEAK HOUR BOARDINGS, ALIGHTING AND SECTION LOADINGS – 2041- METRO  
PHASE 1 EC EXTENSION**

Station no	Station Name	Boarding	Alighting	Sectional loading	Station no	Station Name	Boarding	Alighting	Sectional loading	
1	RV Road Terminal	1782	7	0	17827	16	Bommasandra	2622	0	2622
2	Ragigudda Temple	2228	0	20055	15	Hebbagodi	1786	0	4408	
3	Jayadev Hospital Compound	8038	4651	23442	14	Huskur Road	1976	39	6345	
4	BTM Layout	470	560	23352	13	Electronic City	1179	101	7424	
5	Silk Board Junction	1087	4988	19451	12	Electronic City - I	1832	172	9084	
6	HSR Layout	100	628	18924	11	Hosa Road	2720	147	11657	
7	Oxford College	502	779	18647	10	Basapur Road	2049	128	13578	
8	Muneshwara Nagar	350	1892	17105	9	Chikka Begur	2140	222	15496	
9	Chikka Begur	533	1289	16349	8	Munishwara Nagar	2828	183	18140	
10	Basapur Road	235	1234	15350	7	OXFORD College	847	88	18899	
11	Hosa Road	312	2232	13429	6	HSR Layout	1344	865	19377	
12	Electronic City I	163	3898	9694	5	Silk board	2892	901	21368	
13	Electronic City	106	1156	8643	4	BTM Layout	586	466	21489	
14	Huskur Road	60	3510	5193	3	Jayadeva Hospital	5882	6241	21130	
15	Hebbagodi	0	3343	1851	2	Ragigudda temple	7	1747	19390	
16	Bommasandra	0	1851	0	1	R.V.Road Terminal	0	19390	0	

## Annexure 2.3.

## Trip length distribution – Metro Phase 1 EC Extension - 2016

Trip Length in KM	Trips
0 to 3	7852
3 to 6	5968
6 to 9	3157
9 to 12	4087
12 to 15	5032
15 to 20	3899

## Trip length distribution – Metro Phase 1 EC Extension - 2021

Trip Length in KM	Trips
0 to 3	10738
3 to 6	9236
6 to 9	5372
9 to 12	6660
12 to 15	7708
15 to 20	6594

## Trip length distribution – Metro Phase 1 EC Extension - 2031

Trip Length in KM	Trips
0 to 3	13171
3 to 6	11179
6 to 9	6485
9 to 12	8163
12 to 15	9606
15 to 20	8300

## Trip length distribution – Metro Phase 1 EC Extension – 2041

Trip Length in KM	Trips
0 to 3	14512
3 to 6	12318
6 to 9	7146
9 to 12	8994
12 to 15	10584
15 to 20	9146

**CHAPTER-3**

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**SYSTEM SELECTION**



## CHAPTER 3

### SYSTEM SELECTION

#### 3.0 INTRODUCTION

R V Road – Bommasandra metro extension of extension of North – South (N-S) corridor of Bangalore Metro Phase-I is an elevated corridor with a route length of 18.82 kms. It will partly run on inner ring road, partly on Hosur road and pass through Electronic City before terminating at Bommasandra. The extended section has 12 elevated stations up to Electronic City and 16 up to Bommasandra including R.V. Road. The systems for this extension will be exactly the same as already recommended for the corridors of Phase-I. However, the same are briefly mentioned as as under.

#### 3.1 PERMANENT WAY

##### 3.1.1 CHOICE OF GAUGE

The DPR for the E-W & N-S corridors of Bangalore Metro Rail Phase-I indicated Standard Gauge (1435mm) to be adopted for reasons elaborated there in. The same has to be adopted for this line also.

##### 3.1.2 TRACK STRUCTURE

Track on Metro Rail 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 proposed is the same as in Phase-I

##### General

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 in LWR/CWR (Long Welded Rail/Continuous Welded Rail).

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

### Rail Section

Same type as used for phase-I is to be adopted i.e. keeping in view the proposed axle load and the practices followed abroad, 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 IRST- 12-96. As these rails are not manufactured in India at present, these are to be imported.

### Ballast less Track on Mainlines

#### (a) Viaducts

The entire stretch is elevated on viaducts. It is proposed to adopt plinth type ballast less track structure with RCC derailment guards integrated with the plinths (shown in **Fig.3.1**). Further, it is proposed to adopt Vossloh-336 or similar Fastenings System (shown in **Fig.3.2**) any other suitable system on ballast less track structures complying to performance criterion laid down by Railway Board vide their Circular No. 2009/Proj/MAS/9/2.dated 2.05.2010.

#### 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 m 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 m and permissible speed on divergent track as 25 km/h (shown in **Fig.3.4**).

The Scissors crossovers on Main Lines (1 in 9 type) will be with a minimum track center 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 ballast less turnouts (if required).
  - The switch rail should be with thick web sections, having forged end near heel of switch for easy connection with lead rails, behind the heel of switch. The switches should have anti creep device at heel of switch for minimizing the additional LWR forces transmitted from tongue rail to stock rail.
  - The crossings should be made of cast manganese steel and with welded leg extensions. These crossings should be explosive hardened type for main lines and without surface hardening for

Depot lines.

- The check rails should be with UIC-33 rail section without being directly connected to the running rails.

#### **Buffer Stops**

On main lines and sick siding 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.

### **3.1.3 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 ballast less track for a maximum gap of 180 mm.

#### **WELDING**

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

**NOTE:** The above are all as per requirements indicated in Phase-I Metro Rail under construction.

## **3.2 TRACTION SYSTEM**

### **3.2.1 Selection of Traction System**

There are 3 standard and proven systems of traction for use in suburban and metro lines. These are 750V dc third rail, 1500V dc overhead catenary and 25kV ac overhead catenary system. All these three systems are already in use in India. The Phase-I Metro has adopted 750 V dc third rail and the same Traction system is adopted for this line also.

750V dc third rail system has been extensively used in metros and more than 60% of existing metro systems in the world utilize 600-750V dc third rail system. The system does not affect the aesthetics of the city as it is laid alongside the track. Stray current corrosion is often encountered in dc electrified railways and therefore, suitable measures are required for protection against corrosion of metallic structures, reinforcement and utility pipes caused by dc stray current.

The traffic requirements of the Bangalore Metro Phase-I (including its extensions) have been projected to be about 45,000 PHPDT in horizon year 2021. Keeping in view of ultimate traffic requirements, and other techno-economic considerations, 750V dc type traction system was proposed for the Bangalore Metro. For the present section of R V Road –Electronic City extensions, the same 750dc third rail traction system is proposed to be used. Since the route is entirely grade separated there is no danger of safety hazard to passengers from third rail.

750V dc third rail bottom current collection is envisaged from reliability and safety considerations with the use of composite Aluminium steel third rail on main lines. Low carbon steel third rail, which is available indigenously, is proposed for depot because of reduced current requirements. The third rail will be provided with suitable shrouds for safety of passengers as well as maintenance personnel. The cross section of third rail will be about 5000 mm<sup>2</sup>. The longitudinal resistance of composite and steel third rail is about 7 and 20 mili-ohm/km respectively. The life of composite and steel third rail is expected to be 25-30 years.

### **3.3 SIGNALLING AND TRAIN CONTROL**

#### **3.3.1 Introduction**

The signaling system shall provide the means for an efficient train control, ensuring safety in train movements. It assists in optimization of rail / metro infrastructure investment and running of an efficient train services on the network. The telecommunication system acts as the communication backbone for signaling systems and provides telecommunication services to meet operational and administrative requirements of rail / metro network.

#### **3.3.2 SIGNALLING AND TRAIN CONTROL**

##### **3.3.2.1 Overview**

Metro carrying a large number of passengers at a very close headway requires a very high level of safety enforcement. 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 a State of Art Automatic Train Control and Computer based Centralized Train Operation and Management system. This will:

- i) Provide high level of safety with trains running at close headway, ensuring continuous safe train separation.
- ii) Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.
- iii) Provides safety and enforces speed limit on section having permanent and temporary speed restrictions.
- iv) Provides greater flexibility and precision in train control.
- v) Will 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.
- vi) Increased productivity of rolling stock by increasing line capacity and train speeds, the same rolling stock will arrive at its destination sooner. Hence more trips will be possible with the same number of rolling stock.
- vii) Improve maintenance of signaling and telecommunication equipments by providing new ways of monitoring system status of track side and train borne equipments and undertaking preventive maintenance.

A signaling and control system shall be provided on all running tracks of the metro including car shed except for lines used mainly for local shunting. At all stations with points and crossings, computer based interlocking will be provided for operation of points and crossings/setting of routes including track of adjacent station. The control of train operation will be done from computer backed Operation Control Center (OCC) and will be supervised by Traffic Controller. Facilities for setting of the route and clearing of the signals will also be provided from the control and supervise the movements within its yards.

To ensure safety with close headway of train services and for optimization of heavy investment in the infrastructure and rolling stock, the metro shall be provided with an automatic train control system. This will enable running of



optimum train services meeting traffic requirements in the most efficient and cost effective way.

### 3.3.2.2 Selection of System

The Signaling and Train Control system shall be as explained below:

#### a. Interlocking System:

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 work station which can be either locally (at station) operated or operated remotely from the Operation Control Centre (OCC).

***NOTE BY BMRCL:As an alternative to the existing signalling system provided in Phase-I, the signaling/Train control system for Phase-II could be of communication based train control as it has following advantages.***

- a) Higher commercial speed***
- b) Lesser wayside equipment***
- c) Shorter headway***
- d) Most resilient to operation disturbances***

#### b. Automatic Train Protection

To ensure safety in train operation and to provide optimum train services on the section the train control on the metro shall be provided with Automatic Train Control system. For this the transmission from track to train will be continuous through Coded Audio Frequency Track Circuit. The ATC system will provide on-board display of maximum safe speed, current speed and target speed / distance as deduced from ATP systems, signaling interlocks systems based on track profile and brake characteristics. Facilities for automatic enforcement of temporary / permanent speed restrictions shall also be built in to enhance safety during maintenance work.

#### c. Train Describer and Control Office

A train describer system will be installed to facilitate the monitoring of train operation and also remote control of the stations. The train describer 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.

**NOTE BY BMRCL:**

***There shall be a new OCC building to cater to the train movement control for the new line***

**d. Signaling Scheme Plan**

Conceptual Signaling Plan No. Sig 201/15 for RV Road Bommasandra Line is enclosed.

**3.3.2.3 Standards**

Table 3.1 shows the standards that will be adopted with regard to the Signaling system.

**Table 3.1 Standards Adopted With Regards To Signaling System**

Description	Standards
Interlocking	Computer Based Interlocking, adopted for station having switches and crossing. All related equipment as far as possible will be centralized in the equipment room at the station. Depot shall be interlocked except for lines mainly used for shunting..
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	Line Side signals to protect the points (switches).
UPS (uninterrupted power at stations as well as for OCC)	For Signaling and Telecommunications
Signaling along the line.	ATC with LED line side signal as fall back.
Train protection systems	Continuous Automatic train control.
Train Describer System	Movement of all trains to be logged on to a central computer and displayed on workstations in the OCC and at the SCR. Also remote control of stations from the OCC.
Redundancy for ATP/Train Describer.	Train describer shall have Hot redundancy.
Cables	Cables will be steel armoured, as far as possible.
Fail Safe Principles	Application to the signalling system – SIL4 level safety.
Immunity to External	All data transmission on telecom cables/

Interface.	OFC/Radio. All signaling and telecom cables will be separated from power cables.
Train Working Under Emergency	Running on site with line side signal.
Environmental Conditions	All equipment rooms shall be Air conditioned
Maintenance Philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of signaling equipments shall be followed. Card / module / sub-system level replacement shall be done in the field and repairs under taken in the central laboratory/ manufacturer's premises.

**NOTE BY BMRCL:**

***Axle contacts will be provided for CBTC system to aid for fallback signalling***

**3.3.2.4 Specifications****1. Automatic Train Protection**

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.

- Prevent rear-end or side collision resulting from one train trying to over-take the other.
- Prevent trains being routed on the conflicting routes.
- Prevent the possibility of points / switches moving just ahead of or under train.
- Not hindering the vehicles attaining maximum permissible speed.
- Basic sub-system will include the following modules:-
  - (i) Train detection
  - (ii) Train Protection
  - (iii) Computer based Interlocking
  - (iv) Signal and speed enforcement.
  - (v) Interface with electrical sub-systems of the vehicle like brake control.
- Track circuits shall be will be used for vehicle detection.
- Sub-system/components will conform to international standards like BS, IS, IEC, ITU-T etc.

## 2. Cab Borne Equipment

They will be of modular sub-assemblies for each function for easy maintenance and replacement. The ATP assemblers will be fitted in the vehicle integrated with other equipment of the rolling stock.

## 3. Train Describer

The system will be installed in the Operation control center and at the stations with point and crossings and will have a panoramic view of the sectional jurisdiction showing the status of tracks, points and the vehicles operating in the relevant section/ whole system. The system shall provide train information in real time and in hard copy for later analysis. It shall be possible to set route of trains at terminals, mid-terminals and runback stations, etc. both locally and remotely. It shall have audio-visual alarms for deficiencies / malfunctioning.

### **NOTE BY BMRCL:**

***The OCC will be set up in a new building and the system will be installed in the new OCC***

## 4. Computer Based Interlocking (CBI) Systems at Stations

This sub-system is used for controlling vehicle movements into or out of stations automatically from a work station. 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 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.

## 3.4 TELECOMMUNICATION

### 3.4.1 Introduction

The telecommunication system acts as the communication backbone for Signaling systems and other systems such as SCADA, AFC etc and provides telecommunication services to meet operational and administrative requirements of metro network.

### 3.4.2 Telecommunication

#### 3.4.2.1 Overview

The telecommunication facilities proposed are helpful in meeting the requirements for:

1. Supplementing the Signaling system for efficient train operation.
2. Exchange of managerial information
3. Crisis management during emergencies
4. Passenger information system.

**NOTE BY BMRCL:**

***Closed circuit television system at stations and centralized surveillance center will be set up. It will be possible to view images from train in the centralized surveillance room through Broad band Radio system (BBRS)***

The proposed telecom system will cater to the following requirements:

- Train Traffic Control
- Assistance to Train Traffic Control
- Maintenance Control
- Emergency Control
- Station to station dedicated communication
- Telephone Exchange
- Passenger Announcement System and Passenger Information and Display System within the station and from Central Control to each station.
- Centralized Clock System
- Train Destination Indicator
- Instant on line Radio Communication between Central Control and Moving Cars and maintenance personnel.
- Data Channels for Signaling, SCADA, Automatic Fare Collection etc.

#### 3.4.2.2 Telecommunication System and Transmission Media

- i) **Optical Fibre Cable - Main Telecommunication Bearer**

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a 48 Fibre optical fiber cable is proposed to be laid in ring configuration with path diversity.

Minimum SDH STM-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.

**NOTE BY BMRCL:**

***There will be 96 Fiber optical fiber cable. This may be 2x48 fibers. In addition to SDH, STM-4 Gigabit ethernet system will be provided at every station and OCC.***

**ii) Telephone Exchange**

For an optimized cost effective solution Small exchanges of 30 port each shall be planned at each station, a 60 Port Exchange at the Terminal Stations. 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.

**iii) Mobile Radio Communication**

Mobile Radio communication system having 8 channels is proposed for on-line emergency communication between Motorman (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, depending on frequency availability. The system shall provide Instant mobile radio communication between the motorman of the moving cars from any

place and the Central Control .The motorman 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, 1 Base Stations with a 40m tower shall be required for the North-South Extension. 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 OCC will have over-riding priority in all announcements.

**v) Centralized Clock System**

This will ensure an accurate display of time through a synchronization system of slave clocks driven from a Master Clock at the operation control center. The Master Clock 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, Depots and other service establishments etc.

**vi) Passenger Information Display System**

These shall be located at convenient locations at all stations to provide bilingual visual indication of the status of the running trains and will typically indicate information such as destination, arrival/departure time, and also special messages in emergencies. The boards shall be provided at all platforms and concourses of all stations.

**vii) Network Monitoring and Management**

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide a network management system (NMS), which will help in diagnosing faults immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance. The proposed NMS system will be covering radio communication, Optical Fiber Transmission system and Telephone Exchange.

**NOTE BY BMRCL:**

*In addition to the above, closed circuit television system will be provided at the stations. There will be a network of cameras at stations and picture frame recordings will be provided to enable event monitoring. It will be possible to view the pictures from the train at a centralised surveillance center by means of Broad Band Radio System*

**3.4.2.3 Standards**

The standards proposed to be adopted for telecommunication systems are shown in Table below:

<b>System</b>	<b>Standards</b>
Transmission System	<b>SDH based</b> for the entire telecom network.
Transmission Media	<b>Optical Fibre system</b> as the main bearer for bulk of the telecommunication network.
Telephone Exchange	EPABX of minimum 30 ports is to be provided at all Stations , an Exchange of 60 Ports to be provided at Terminal Stations.
Train Radio System	<b>Digital Train radio (TETRA) communication between motorman of moving cars, stations, maintenance personnel ,depots and central control.</b>
Train Destination Indicator System	<b>LED/LCD based boards</b> 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 synchronization system of slave clocks driven from a master clock at the OCC and sub –master clock in station/depots.. This shall also be used for synchronization other systems.
Passenger Announcement	<b>Passenger Announcement System</b> covering all platform and concourse areas with local



System	as well as Central Announcement.
Redundancy (Major System)	Redundancy on Radio base station equipment. Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
Environmental Conditions	All equipment rooms to be air-conditioned.
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.

**NOTE BY BMRCL:**

***The transmission system will be SDH and GE based for the entire telecom network.***

**3.4.2.4 Space Requirement for Telecom Installations**

Adequate space for proper installations of all Telecommunication equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for S & T equipment shall be generally 40 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 equipments and network configuration keeping space for further expansion.

**3.4.2.5 Maintenance Philosophy for Telecom Systems**

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signaling and telecommunication equipments shall be followed. Card / module / subsystem level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully

equipped transport vehicle for effectively carrying out the maintenance from station to station.

The defective card/ module / sub-system taken out from the section shall be sent for diagnostic and repair to a centralized S&T repair lab suitably located on the section. This lab will be equipped with appropriate diagnostic and test equipments to rectify the faults and undertake minor repairs. Cards / modules / equipments requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

### 3.5 AUTOMATIC FARE COLLECTION

#### 3.5.1 Introduction

Mass Rapid Transit Systems handle large number of passengers. Ticket issue and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. In view of above, computer based automatic fare collection system is proposed.

AFC system proves to be cheaper than semi-automatic (manual system) in long run due to reduced manpower cost for ticketing staff, reduced maintenance in comparison to paper ticket machines, overall less cost of recyclable tickets (Smart Card/Token) in comparison to paper tickets and prevention of leakage of revenue. Relative advantages of automatic fare collection system over manual system are as follows:

#### A) Manual fare collection systems have the following inherent disadvantages:

1. Large number of staff is required for issue and checking of tickets.
2. Change of fare structure is time consuming as has to be done at each station.
3. Manipulation possible by jamming of mechanical parts.
4. Staff and passenger interaction leading to more chances of confrontation.
5. 100% ticket checking at entry / exit impossible.

#### B) Automatic fare collection systems have the following advantages:

1. Less number of staff required.
2. Less possibility of leakage of revenue due to 100% 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.
8. AFC systems are the worldwide accepted systems for Metro environment.

The proposed ticketing system shall be same as that to be provided on the main North-South Line i.e of Contactless Smart Token/ Card type. The equipments for the same shall be provided at each station Counter/Booking office and at convenient locations and will be connected to a local area network with a computer in the Station Master's room. Equipment and installation cost of Contactless Smart Card /Token based AFC system is similar to magnetic ticket based AFC system, but Contactless system proves cheaper due to reduced maintenance, less wear and tear and less prone to dusty environment.

**C) Choice of Control Gates**

Retractable flap type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern metros internationally. Tripod turnstile type or flap type gates offer less throughput and require more maintenance.

**D) Passenger Operated Machine**

Space for provision of Passenger Operated Machines (Automatic Ticket Dispensing Machines) for future, shall be provided at stations.

**3.5.2 AFC equipment Requirement**

AFC equipment requirement for R V Road – Electronic City section are given in Table 3.2 as under.

**NOTE BY BMRCL:**

***Passenger operated machines will be provided at the stati***

<b>Table 3.2 AFC Equipments Estimate for Bangalore Metro N-S Extension(projection for 2016)</b>												
S.N	Station	Hourly Boarding	Hourly Alighting	Peak Min Boarding	Peak Min alighting	Gate		Disabled Gate	TOM	EFO	TR	TVM
						Entry	Exit					
<b>R V Road-Electronic city-Bommasandra Corridor</b>												

1	R V Road Terminal	9684	8048	194	161	6	5	1	10	2	4	2
2	Ragiguda Temple	1036	746	21	15	2	2	1	2	2	4	2
3	Jayadev Hospital Compound	4810	2490	96	50	3	2	1	5	2	4	2
4	BTM layout	354	333	7	7	2	2	1	2	2	4	2
5	Silk Board Junction	1562	3118	31	62	2	2	1	2	2	4	2
6	HSR layout	480	126	10	3	2	2	1	2	2	4	2
7	OXFORD ENGG college	267	456	5	9	2	2	1	2	2	4	2
8	Muneshwara Nagar	884	942	18	19	2	2	1	2	2	4	2
9	Chikka Begur	808	795	16	16	2	2	1	2	2	4	2
10	Basapur Road	811	696	16	14	2	2	1	2	2	4	2
11	Hosa Road	1011	1227	20	25	2	2	1	2	2	4	2
12	Electronic city -I	782	2048	16	41	2	2	1	2	2	4	2
13	Electronic city	543	687	11	14	2	2	1	2	2	4	2
14	Huskur Road	581	1845	12	37	2	2	1	2	2	4	2
15	Hebbagodi	778	1638	16	33	2	2	1	2	2	4	2
16	Bommasandra	614	1086	12	22	2	2	1	2	2	4	2
	<b>Total</b>					<b>37</b>	<b>35</b>	<b>16</b>	<b>43</b>	<b>32</b>	<b>64</b>	
<b>Assumptions:</b>												
	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.											
	6. For Calculation purpose, It is assumed Boarding Figure =Exit Figure.											

### 3.5.3 Standards

The standard proposed for AFC systems are as under:

Standards	Description
Gates	a) <b>Contact less smart token</b> – For single journey. They shall have stored value amount for a particular journey. Tokens are captured at the exit gate.

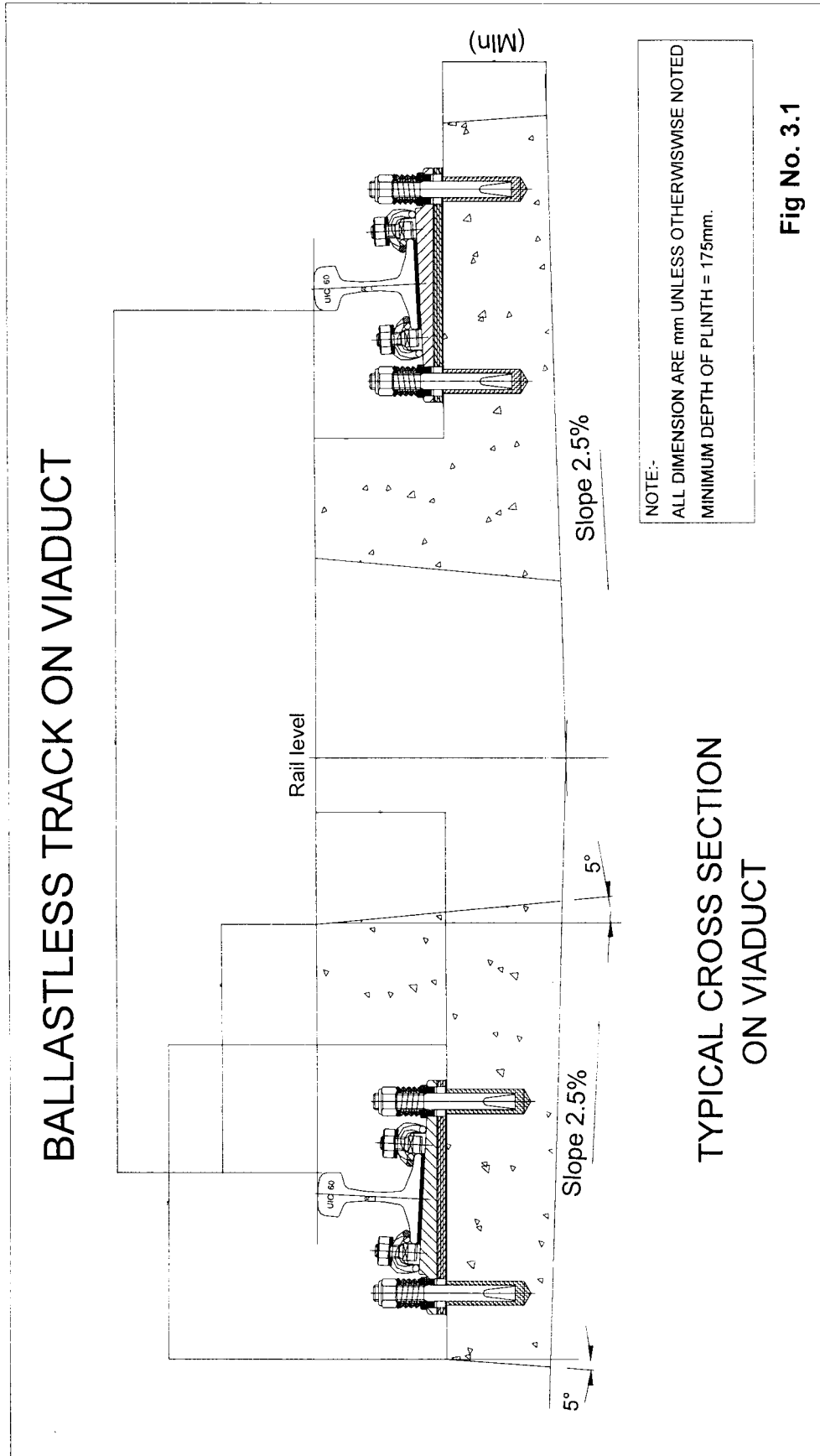
	b) <b>Contact less smart card</b> – For multiple journeys.
Gates	Computer controlled retractable flap type automatic gates at entry and exit. There will be following <b>types of gates</b> : <input type="checkbox"/> <b>Entry</b> <input type="checkbox"/> <b>Exit</b> <input type="checkbox"/> <b>Reversible – can be set to entry or exit</b> <input type="checkbox"/> <b>Wide reversible</b> -gate for disabled people.
Station computer, Central computer and AFC Net work	All the <b>fare collection equipments</b> shall be connected in a <b>local area network</b> with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control center through the optic fibre communication channels. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.
Ticket office machine (TOM/EFO)	Manned <b>Ticket office machine</b> shall be installed in the stations for selling cards/ tokens to the passengers.
Ticket Reader and Portable Ticket Decoder.	<b>Ticket reader</b> shall be installed near EFO for passengers to check information stored in the token / cards.
UPS (uninterrupted power at stations as well as for OCC).	<b>Common UPS of S&amp;T system will be utilized.</b>
Maintenance Philosophy	Being fully Contact less 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.

### 3.5.4 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 require 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.

**NOTE BY BMRCL:**

*There will be a limited Bus- Metro integration similar to the Phase-I integration.*



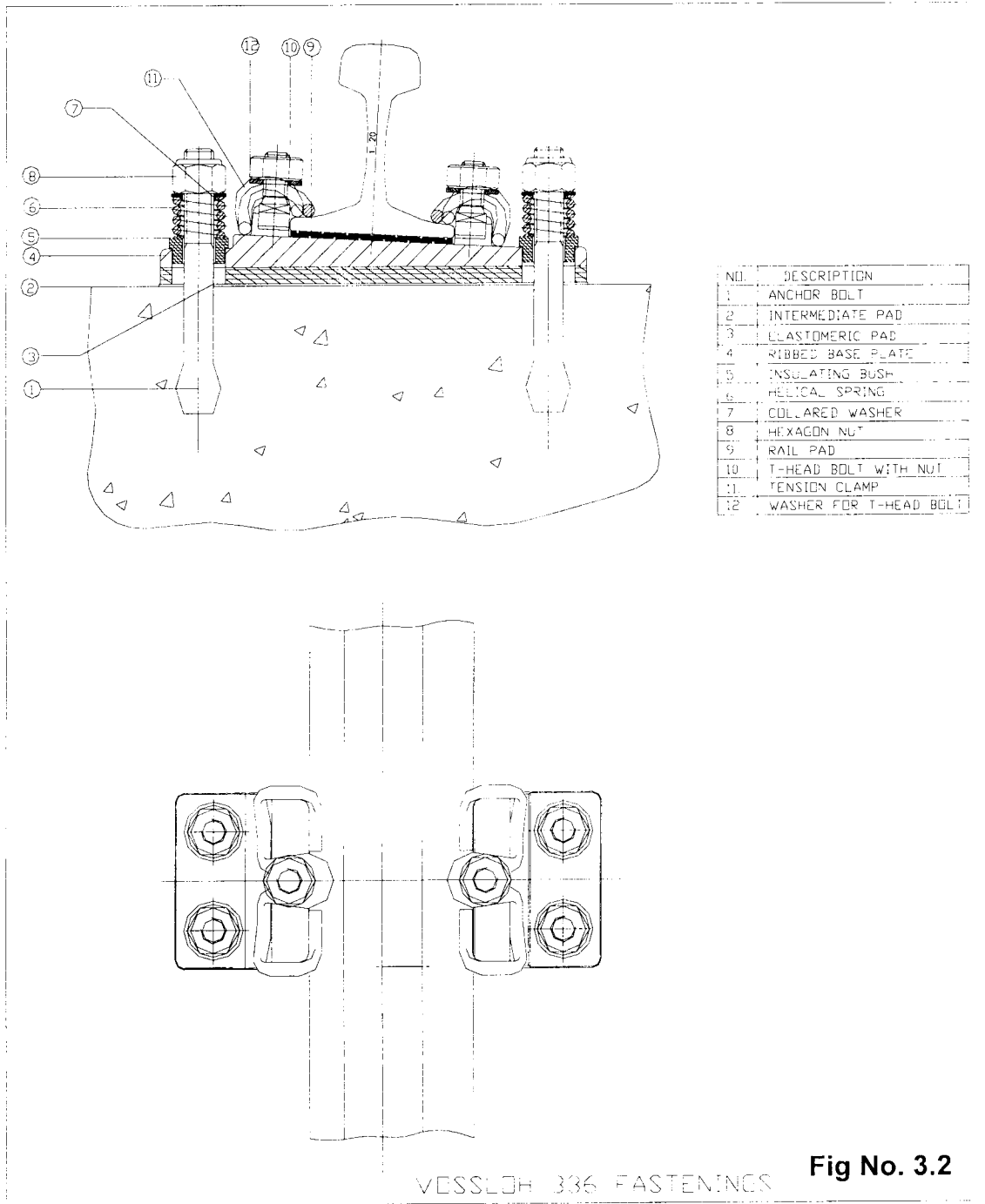


Fig No. 3.2



**TURNOUT TO R**  
**GEOMETRY**  
**GEOMETRY**

140 m

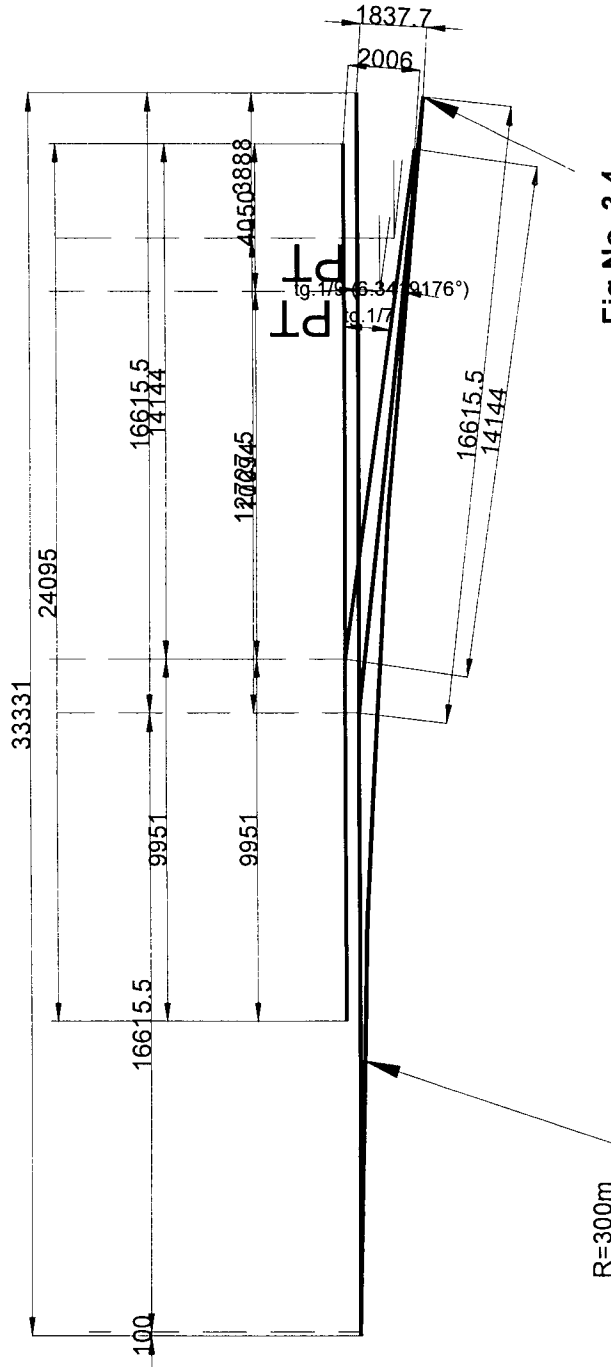


Fig No. 3.4

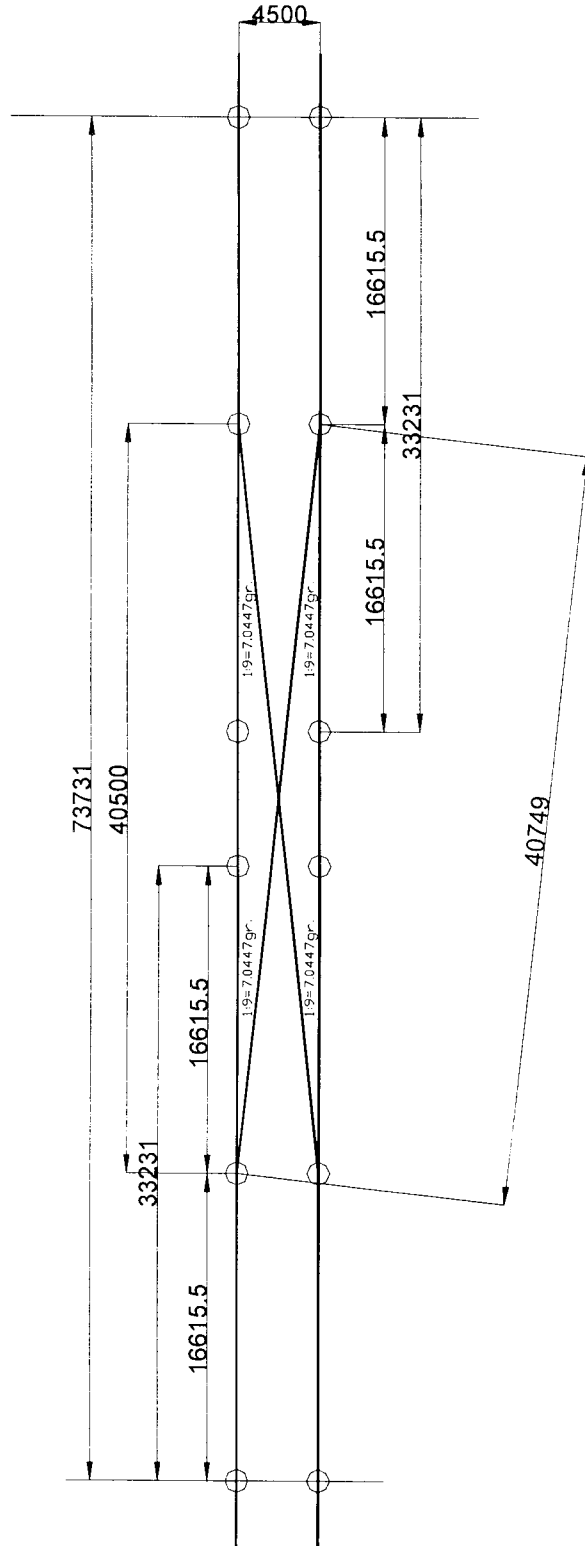
R:

FIG. NO 3.3



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

**AXLE SCHEME**



**Fig No. 3.5**

**CHAPTER-4**

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**CIVIL ENGINEERING**



## CHAPTER 4

### CIVIL ENGINEERING

#### 4.1 GEOMETRIC DESIGN NORMS

##### 4.1.1 General

The design parameters related to the Metro system 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.

##### 4.1.2 Horizontal Alignment

As far as possible, the alignment follows the existing roads. This leads to introduction of many horizontal curves. On consideration of maximum allowable cant of 120 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 200m, 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 on this project, 2 curves of 122 m radius and 162 m radius (safe speed of 40 km/h) have been adopted.

For maximum permissible speed on curve with various radii, Table 4.1 may be referred.

##### 4.1.3 Horizontal Curves

Description	Elevated Section
Desirable Minimum radius	200 m
Absolute minimum radius	120 m
Minimum curve radius at stations	1000 m
Maximum permissible cant (Ca)	120 mm
Desirable cant (Ca)	110 mm
Maximum cant deficiency (Cd)	85 mm

##### 4.1.4 Transition Curves

The existing roads along which the metro is proposed have frequent curves. However, it is necessary to provide transition curves at both ends of the circular curves. Due to change in gradients at various locations in the corridor, it is necessary to provide frequent vertical curves along the alignment. In case of ballast-less track, it is desirable that the vertical curves and transition curves of horizontal curves do not



overlap. These constraints may lead to reduced lengths of transition curves. The transition curves have certain minimum parameters:

- Length of Transitions of Horizontal curves (m)

Minimum : 0.44 times actual cant or cant deficiency (in mm),  
whichever is higher.

Desirable : 0.72 times actual cant or cant deficiency, (in mm),  
whichever is higher.

- Overlap between transition curves and vertical curves not allowed.
- Minimum straight between two Transition curves: either 25 m or Nil.
- Minimum curve length between two transition curves: 25 m

#### 4.1.5 Vertical Alignment and Track Centre for Elevated Section

The viaducts carrying the tracks will have a vertical clearance of minimum 5.5 m above road level. For meeting this requirement with the 'Box' shaped pre-stressed concrete girders, the rail level will be about 9.8 m above the road level. However, at stations which are located above central median, the rail level will be 12.5 m above the road level with concourse at mezzanine. These levels will, however, vary marginally depending upon where the stations are located.

The track center on the elevated section is kept as 4.2 m uniform throughout the corridor to standardize the superstructure, except at few locations, wherever scissors crossovers are planned, it is kept 4.5 meter.

##### (a) Gradients

Normally the stations shall be on level stretch. In limited cases, station may be on a grade of 0.1 %. Between stations, generally the grades may not be steeper than 3.0 %. However, where existing road gradients are steeper than 2 %, or for Switch Over Ramps gradient up to 4% (compensated) can be provided in short stretches on the main line.

##### (b) 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.

##### Radius of vertical curves:

- On main line (desirable) : 2500 m
- (Absolute minimum) : 1500 m
- Other Locations : 1500 m
- Minimum length of vertical curve : 20 m

#### 4.1.6 Design Speed

The maximum sectional speed will be 80 km/h. However, the applied cant, and





#### 4.1.6 Design Speed

The maximum sectional speed will be 80 km/h. However, the applied cant, and length of transition will be decided in relation to normal speeds at various locations, as determined by simulation studies of alignment, vertical profile and station locations. Computerized train simulation studies need to be conducted with proposed gradients at the time of detailed design stage. This is with the objective of keeping down the wear on rails on curves to the minimum.

**Table 4.1**  
**Cant, Permitted Speed & Minimum Transition Length for Curves**

<b>RADIUS</b>	<b>CANT</b>	<b>MAXIMUM PERMISSIBLE SPEED</b>	<b>MINIMUM DISTANCE BETWEEN ADJACENT TRACKS FOR ELEVATED AND AT-GRADE SECTION</b>
meters	mm	kmph	mm
3000	15	80	3650
2800	15	80	3650
2400	20	80	3650
2000	20	80	3650
1600	25	80	3650
1500	30	80	3650
1200	35	80	3650
1000	45	80	3700
800	55	80	3700
600	70	80	3750
500	80	80	3750
450	85	80	3800
400	110	80	3800
350	110	75	3800
300	110	70	3850
200	110	55	3950
150*	110	45	4050
150*	0	30	4050
120*	110	40	4150
120*	0	25	4150

- Notes:**
- The track spacing is without any column/structure between two tracks and is with equal cant for both outer and inner tracks.
  - Track spacing shown is not applicable to stations which should be calculated depending on specific requirement.
  - Figures for any intermediate radius of curvature may be obtained by interpolating between two adjacent radii. For higher radii, values may be extrapolated..

#### 4.1.7 Station Locations

Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport. However effort has also



been made to propose station locations, such that inter station distances are as uniform as possible. The average spacing of stations is kept close to 1.0 km.

#### 4.2 DESCRIPTION OF CORRIDOR

The line from R V Road to Bommasandra via Jayadeva hospital, Silk Board junction & Electronic City is an elevated standard gauge corridor with double line section having a route length of 18.82 km and 16 stations. In due course this may have to be extended beyond with further growth in this part of the city.

DPR for extending the Metro line from R V Road Terminal to Puttenahalli Cross was submitted in June 2008 and is under implementation in Phase-I. Further, the DPR for extension of this line from Puttenahalli Cross to NICE Road xing on Kanakapura Road (6.0 kms) is under preparation as part of Phase-II. The DPR for this line i.e. R V road to Bommasandra is being taken up on priority basis ahead of Phase-II DPR so that the same may be included as a part of Phase-I N-S line for implementation.

- R.V.Road Terminal station at the south end of N–S corridor is located at the end of the R.V. Road as elevated Terminal Station.
- The majority of the catchments of traffic of Electronic City are concentrated in the heavily built up areas on both sides of Jaya Nagar, J.P. Nagar, BTM Layout – I, II & III Stage, Tavarkere, HSR Layout etc. These are comparatively heavily populated areas besides the existence of Offices, Business houses, Comercial complexes, hospitals, hotels etc. This facility of Metro rail link is thus expected to attract users from all sides of R V Road, Jayadeva Hospital, Silk Board Junctions – Begur, and various Layouts etc. on Hosur Road stretch – Electronic City. Apart from these a large number of persons visit the Electronic City from the city and beyond including the world over for business and service etc.
- The stretch up to Bommasandra Industrial area located about 4.0 kms beyond Electronic City on Hosur Road is a growing suburb of South Bangalore including the planned development area of KIADB which is developing fast and is expected to attract a substantial number of commuters in future. Bommasandra Industrial Estate is also connected to Jigani area where a number of Industries are located and developing.
- Further beyond is a well known Narayana Hrudayalaya Hospital which attracts large number of patients not only from Bangalore and Karnataka but also from all over India and abroad.
- Accordingly, the alignment of R V Road to Bommasandra line has been proposed as an extension of Metro from R V Road Terminal to Bommasandra. This extension has been so planned that the passengers coming from Majestic or back will have to get down for inter-change of line at R V Road and take the train towards Bommasandra.



#### 4.2.1 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 R V Road – Bommasandra Corridor.

The new R V Road Station platforms will be by the side of existing platforms, parallelly across. The passengers will have to get down and change over to the Bommasandra line. The line starting from R V Road Station takes a turn to the left and joins the median of the Marenahalli road (South end road) up to short of Jayadeva Hospital junction, where the alignment is taken on the footpath of the road and after crossing the Jayadeva Hoospital flyover the alignment turns back to the median of the road up to short of Silk Board Junction. From here the alignment takes a right turn to reach the Hosur Road. On the Hosur road, as the Elevated Road of NHAI is under construction along the central median, the alignment is taken on the median specially provided in the middle of service road on the west side of NH-7 with the viaduct supported in Drawing. No. DMRC/ X-SECTION /BAN EXT./2011 sheet No. 1 to 5,X-sections at various locations).

#### 4.3 REFERENCE POINT

The centre line of R V Road Terminal Metro station has been taken as 0.00 km for reckoning of chainage on R V Road – Bommasandra line. Chainage increases from R V Road Terminal Metro station towards Bommasandra Terminal Metro station.

##### 4.3.1 REFERENCE LINE

Line from R V Road Terminal station to Bommasandra Terminal station has been named 'Up Line' and from Bommasandra Terminal to R V Road Terminal has been named as 'Down Line'.

4.3.2 Index Plan of the alignment from the Centre line of R V Road Terminal Metro station to Dead end of Bommasandra Terminal Metro station is given at **Figure 4.1**.

##### 4.3.3 TERMINAL STATION

It is proposed to plan elevated terminal station at Bommasandra, 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-overs and dead end. The C/L of the station is at chainage 17.961 km whereas the Dead End is at chainage 18.366 km.

##### 4.3.4 HORIZONTAL ALIGNMENT

The new R V Road Station platforms will be by the side of existing platforms, parallelly across. The passengers will have to get down and change over to the Bommasandra line. The line starting from R V Road Station takes a turn to the left



and joins the median of the Marenahalli road (South end road) and traverse along the median up to short of Jayadeva Hospital junction. At the Jayadeva Hospital junction the alignment is taken to the left of the flyover and runs on the footpath of the road till it crosses the Bannerghatta road and then taken on the road median of the Marenahalli road (South End Road) up to short of Silk Board Junction. From here the alignment takes a right turn to reach the Hosur Road. There are 4 stations on this stretch up to Silk Board namely Ragigudda Station (Ch.1255.50), Jayadeva Hospital Station (Ch.2454.30), BTM Layout Station (Ch.3582.70) and Silk Board Station (Ch.4543.10). On the Hosur road, as the Elevated Road of NHAI is under construction along the central median, the alignment is taken on to the west service road of NH-7 with a portal beam arrangement. This portal beam arrangement is proposed to minimize the land/property acquisition on the Hosur road stretch and also to ensure that the newly constructed service road of NH-7 is clear of any obstruction through out the elevated corridor stretch. On this stretch of Hosur road there are 8 Stations up to the Electronic City namely HSR Layout (Ch.5761.00), OXFORD College (Ch.6960.80), Muneshwara Nagar (Ch.7858.20), Chikka Begur (Ch.9257.50), Basapur Road (Ch.11053.50), Hosa Road (Ch.11998.30), Electronic City – I (Ch.12990.10) and Electronic City (Ch.13987.20). Extension beyond Electronic City up to Bommasandra Industrial area will have 3 Stations namely Huskur Road Station (Ch.15560.20), Hebbagodi (Ch.16848.30) and Bommasandra (Ch.17961.40). In future this line will need to be extended up to Narayana Hrudayalaya Hospital (about 1.50km beyond Bommasandra).

Schematic Plan of the alignment is placed.

#### 4.3.5 VERTICAL ALIGNMENT

Track supporting structures on elevated sections are to permit a vertical clearance of 5.50M above road level. For meeting this requirement with 'U' shaped structural design the rail level shall be at least 8.50M above the road level. Similarly, the rail level for the stations on road locations (with concourse on sides on ground) shall be at least 10.50M above the road level in the central portion and 9.50M at ends. With elevated concourse the rail level at stations shall be at least 12.5 M. For tracks carried on portals on roads, the minimum rail level shall be 9.50M above the road level. An alternative structural sections with pre stressed box is also designed which can be used with minimum rail level of 9.30 M above road level. The rail level at stations with elevated concourse will be 12.5 M.

The track center on entire elevated section has been kept as 4.2 M for this corridor.

#### 4.4 CURVES

Total number of 38 horizontal curves has been provided up to Electronic City dead end. The radius of curves varies from 122m to 20002m. Hence, the sharpest curve is 122 m. A statement of curves is given at Table 4.2:



**TABLE 4.2 STATEMENT OF CURVES**

Curve No	Direction	Radius	Deflection Angle			Transition Length		Curve Length	Total Curve Length	Straight between
			D	M	S					
										(Start of Alignment - 450)
										783.246
1	Left	122.05	88	7	25	60	60	127.719	247.719	1479.888
2	Left	802.05	5	23	31	40	40	35.477	115.477	16.459
3	Right	1002.05	2	48	40	25	25	24.165	74.165	14.951
4	Right	2002.05	2	15	22	15	15	63.838	93.838	32.490
5	Right	6002.05	0	9	47	15	15	2.095	32.095	406.931
6	Right	1002.05	4	59	26	35	35	52.282	122.282	39.049
7	Left	1002.05	4	41	38	25	25	57.092	107.092	644.717
8	Left	3002.05	1	18	57	15	15	53.938	83.938	65.050
9	Right	3002.05	1	23	58	20	20	53.325	93.325	68.892
10	Right	1002.05	4	16	7	35	35	39.654	109.654	137.309
11	Left	802.05	7	13	2	40	40	61.031	141.031	167.117
12	Left	302.05	16	23	42	45	45	41.431	131.431	89.086
13	Right	162.05	76	49	50	60	60	157.301	277.301	270.334
14	Left	2502.05	0	44	27	20	20	12.349	52.349	230.076
15	Right	7502.05	1	9	47	15	15	137.286	167.286	264.532
16	Left	5002.05	1	10	49	15	15	88.039	118.039	158.771
17	Right	3002.05	0	48	55	15	15	27.718	57.718	355.645
18	Left	7502.05	0	10	46	15	15	8.509	38.509	351.313
19	Right	10002.05	0	6	54	15	15	5.078	35.078	774.229
20	Left	15002.05	0	2	8	0	0	9.289	9.289	927.342
21	Left	50002.05	0	1	5	0	0	15.86	15.86	571.580
22	Left	20002.05	0	1	0	0	0	5.826	5.826	579.331
23	Left	502.05	5	41	32	40	40	9.877	89.877	33.258
24	Left	602.05	4	32	23	35	35	12.703	82.703	304.628
25	Right	2002.05	2	46	36	15	15	82.027	112.027	106.134
26	Right	5002.05	0	41	56	15	15	46.011	76.011	375.676
27	Left	90002.05	0	0	25	0	0	10.909	10.909	1000.968
28	Left	40002.05	0	2	29	10	10	18.849	38.849	1004.979
29	Right	1002.05	2	23	12	25	25	16.741	66.741	74.875
30	Left	1002.05	2	24	26	25	25	17.102	67.102	969.747
31	Right	3602.05	0	36	16	15	15	22.994	52.994	472.626
32	Right	20002.05	0	5	41	10	10	23.06	43.06	469.459
33	Right	552.05	16	51	43	40	40	122.467	202.467	350.105



34	Right	2002.05	3	32	27	20	20	103.721	143.721	209.073
35	Left	50002.05	0	6	36	10	10	86.054	106.054	205.024
36	Left	1262.05	20	15	2	20	20	426.058	466.058	0.492
37	Left	1802.05	6	22	1	20	20	180.251	220.251	210.264
38	Right	2002.05	0	49	5	15	15	13.596	43.596	0.007
									End of Alignment	18366.222

**4.3 GRADIENTS**

The detail statement of gradients is placed in tables 4.3:

**TABLE 4.3 STATEMENT OF GRADIENTS**

S. No.	Chainage		Length	Rail Level		Gradient	Remarks
	From	To		From	To		
1	-450	100	550.000	932.388	932.388	0.000	Level
2	100	500	400.000	932.388	929.8	-0.006	Fall
3	500	850	350.000	929.8	922.1	-0.022	Fall
4	850	1170	320.000	922.1	918.3	-0.012	Fall
5	1170	1390	220.000	918.3	918.3	0.000	Level
6	1390	1560	170.000	918.3	914.1	-0.025	Fall
7	1560	1930	370.000	914.1	924.2	0.027	Rise
8	1930	2350	420.000	924.2	918.7	-0.013	Fall
9	2350	2590	240.000	918.7	918.7	0.000	Level
10	2590	3005	415.000	918.7	914.6	-0.010	Fall
11	3005	3420	415.000	914.6	918.3	0.009	Rise
12	3420	3740	320.000	918.3	918.3	0.000	Level
13	3740	4140	400.000	918.3	906.46	-0.030	Fall
14	4140	4405	265.000	906.46	897.185	-0.035	Fall
15	4405	4710	305.000	897.185	897.185	0.000	Level
16	4710	5200	490.000	897.185	891.3	-0.012	Fall
17	5200	5660	460.000	891.3	897.6	0.014	Rise
18	5660	5880	220.000	897.6	897.6	0.000	Level
19	5880	6260	380.000	897.6	898.7	0.003	Rise
20	6260	6600	340.000	898.7	896.9	-0.005	Fall
21	6600	6875	275.000	896.9	897.8	0.003	Rise
22	6875	7080	205.000	897.8	897.8	0.000	Level
23	7080	7380	300.000	897.8	893.9	-0.013	Fall
24	7380	7680	300.000	893.9	903.6	0.032	Rise
25	7680	8100	420.000	903.6	903.6	0.000	Level
26	8100	8400	300.000	903.6	910.04	0.021	Rise
27	8400	8700	300.000	910.04	913.7	0.012	Rise
28	8700	9020	320.000	913.7	906.8	-0.022	Fall
29	9020	9160	140.000	906.8	911.4	0.033	Rise



30	9160	9380	220.000	911.4	911.4	0.000	Level
31	9380	9680	300.000	911.4	914.1	0.009	Rise
32	9680	10020	340.000	914.1	922.65	0.025	Rise
33	10020	10235	215.000	922.65	929.2	0.030	Rise
34	10235	10685	450.000	929.2	936.8	0.017	Rise
35	10685	10970	285.000	936.8	934	-0.010	Fall
36	10970	11350	380.000	934	934	0.000	Level
37	11350	11600	250.000	934	934.4	0.002	Rise
38	11600	11900	300.000	934.4	933.3	-0.004	Fall
39	11900	12120	220.000	933.3	933.3	0.000	Level
40	12120	12420	300.000	933.3	924.1	-0.031	Fall
41	12420	12850	430.000	924.1	925	0.002	Rise
42	12850	13110	260.000	925	925	0.000	Level
43	13110	13448	338.000	925	923.5	-0.004	Fall
44	13448	13820	372.000	923.5	932	0.023	Rise
45	13820	14080	260.000	932	932	0.000	Level
46	14080	14325	245.000	932	941	0.037	Rise
47	14325	14775	450.000	941	924.5	-0.037	Fall
48	14775	14900	125.000	924.5	922.7	-0.014	Fall
49	14900	15180	280.000	922.7	920.1	-0.009	Fall
50	15180	15375	195.000	920.1	921.3	0.006	Rise
51	15375	15610	235.000	921.3	921.3	0.000	Level
52	15610	15900	290.000	921.3	924.4	0.011	Rise
53	15900	16180	280.000	924.4	921	-0.012	Fall
54	16180	16500	320.000	921	912.1	-0.028	Fall
55	16500	16720	220.000	912.1	910.9	-0.005	Fall
56	16720	16950	230.000	910.9	910.9	0.000	Level
57	16950	17280	330.000	910.9	911.3	0.001	Rise
58	17280	17560	280.000	911.3	913.8	0.009	Rise
59	17560	17860	300.000	913.8	919.2	0.018	Rise
60	17860	18366.222	506.222	919.2	919.200	0.000	Level

4.3.1 Detailed Alignment Plans are given in Drawing No. Phase-I Extn/N-S (R V Road – Bommasandra )/AL/GAD line/2011 (Sheet No. 1 – 19).

#### 4.4 LAND

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

- Metro Structure (including Route Alignment), station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities, etc.
- Receiving/Traction Sub-stations





- Radio Towers
- Property Development.

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

Out of the total land requirement of 212552.00 Sqm, the Private Land is 66518 sq.m and the Government Land is 146034 Sqm. This Government land **includes the 12 ha. of the land required for depot at Hebbagodi.** Section-wise land requirement for elevated section and ownership of the land is given at table 4.4.

**Table 4.4 LAND REQUIREMENT & OWNERSHIP**

DETAILS OF LAND PERMANENTLY REQUIRED FOR RUNNING SECTION					LAND REQUIRED FOR STATIONS			
S. NO.	PLOT NO.	LOCATION	AREA (m <sup>2</sup> )	OWNER-SHIP	S. NO.	PLOT NO.	AREA (m <sup>2</sup> )	OWNER SHIP
1	RS 1	R.V.Road Terminal to Ragigudda	402.06	Private	1	RV-1	3669.7	Govt.
2	RS 2	Ragigudda to Jayadeva Hospital	1.23	Private	2	RV-2	312.4	Govt.
3	RS 3	Ragigudda to Jayadeva Hospital	114.93	Private	3	RV-3	760.1.	Govt.
4	RS 4	Ragigudda to Jayadeva Hospital	190.02	Private	4	RAG-1	3587.9	Govt.
5	RS 5	Ragigudda to Jayadeva Hospital	48.06	Private	5	RAG-2	229.2	Govt.
6	RS 6	Ragigudda to Jayadeva Hospital	111.13	Private	6	RAG-3	518	Govt.
7	RS 7	Ragigudda to Jayadeva Hospitalr	137.08	Private	7	RAG-4	2477.4	Pvt.
8	RS 8	Jayadeva Hospital to BTM Layout	269.86	Private	8	JAY-1	239.2	Pvt.
9	RS 9	Jayadeva Hospital to BTM Layout	207.16	Private	9	JAY-2	289.7	Pvt.
10	RS 10	Jayadeva Hospital to BTM Layout	186.25	Private	10	JAY-3	504.7	Govt.
11	RS 11	Jayadeva Hospital to BTM Layout	200.03	Private	11	JAY-4	144.5	Govt.
12	RS 12	Jayadeva Hospital to BTM Layout	87.1	Private	12	JAY-5	2293.1	Pvt.
13	RS 13	Jayadeva Hospital to BTM Layout	189.81	Private	13	JAY-6	460.5	Govt.
14	RS 14	Jayadeva Hospital to BTM Layout	21.26	Private	14	JAY-7	910.4	Govt.
15	RS 15	Jayadeva Hospital to BTM Layout	86.47	Private	15	JAY-8	594.1	Govt.



16	RS 16	Jayadeva Hospital to BTM Layout	190.07	Private	16	BTM-1	59.5	Govt.
17	RS 17	Jayadeva Hospital to BTM Layout	84.56	Private	17	BTM-2	1084.5	Govt.
18	RS 18	Jayadeva Hospital to BTM Layout	156.06	Private	18	BTM-3	468	Govt.
19	RS 19	Jayadeva Hospital to BTM Layout	27.36	Private	19	BTM-4	383.9	Pvt.
20	RS 20	Silk Board Junction to HSR Layout	151.94	Private	20	BTM-5	824.9	Govt.
21	RS 21	Silk Board Junction to HSR Layout	459.3	Private	21	BTM-6	2027.9	Govt.
22	RS 22	Silk Board Junction to HSR Layout	26.73	Private	22	SBJ-1	84.8	Govt.
23	RS 23	Silk Board Junction to HSR Layout	2.95	Private	23	SBJ-2	397.4	Pvt.
24	RS 24	Silk Board Junction to HSR Layout	0.76	Private	24	SBJ-3	339.3	Govt.
25	RS 25	Silk Board Junction to HSR Layout	34.19	Private	25	SBJ-4	849.5	Govt.
26	RS 26	Silk Board Junction to HSR Layout	22.98	Private	26	SBJ-5	82.1	Govt.
27	RS 27	Silk Board Junction to HSR Layout	18.5	Private	27	SBJ-6	425.3	Pvt.
28	RS 28	HSR Layout to Oxford College	0.34	Private	28	SBJ-7	168.1	Pvt.
29	RS 29	HSR Layout to Oxford College	16.78	Private	29	HSR-1	1976.1	Pvt.
30	RS 30	HSR Layout to Oxford College	9.02	Private	30	HSR-2	468	Pvt.
31	RS 31	HSR Layout to Oxford College	1.68	Private	31	OXF-1	194.7	Pvt.
32	RS 32	HSR Layout to Oxford College	3.87	Private	32	OXF-2	457.3	Govt.
33	RS 33	HSR Layout to Oxford College	36.11	Private	33	OXF-3	360.5	Pvt.
34	RS 34	HSR Layout to Oxford College	10.12	Private	34	OXF-4	433.3	Govt.
35	RS 35	HSR Layout to Oxford College	3.98	Private	35	OXF-5	1586.1	Pvt.
36	RS 36	HSR Layout to Oxford College	5.73	Private	36	OXF-6	2116.2	Govt.
37	RS 37	HSR Layout to Oxford College	9.82	Private	37	MN-1	322.2	Pvt.
38	RS 38	HSR Layout to Oxford College	3.43	Private	38	MN-2	1013.8	Pvt.
39	RS 39	HSR Layout to Oxford College	2.73	Private	39	MN-3	601	Pvt.



40	RS 40	HSR Layout to Oxford College	2.8	Private	40	MN-4	220.9	Pvt.
41	RS 41	HSR Layout to Oxford College	5.5	Private	41	CB-1	1665.3	Pvt.
42	RS 42	Oxford College to Muneshwara Nagar	7.3	Private	42	CB-2	468	Pvt.
43	RS 43	Oxford College to Muneshwara Nagar	5.08	Private	43	CB-3	11808.4	Pvt.
44	RS 44	Oxford College to Muneshwara Nagar	2.09	Private	44	BR-1	872.8	Govt.
45	RS 45	Muneshwara Nagar to Chikka Begur	27.82	Private	45	BR-2	717.4	Pvt.
46	RS 46	Muneshwara Nagar to Chikka Begur	17.93	Private	46	BR-3	468	Govt.
47	RS 47	Muneshwara Nagar to Chikka Begur	7.41	Private	47	BR-4	726.5	Govt.
48	RS 48	Muneshwara Nagar to Chikka Begur	25.48	Private	48	HR-1	326.3	Pvt.
49	RS 49	Muneshwara Nagar to Chikka Begur	23.8	Private	49	HR-2	2459	Pvt.
50	RS 50	Muneshwara Nagar to Chikka Begur	80.94	Private	50	HR-3	468	Pvt.
51	RS 51	Muneshwara Nagar to Chikka Begur	16.23	Private	51	HR-4	725.6	Pvt.
52	RS 52	Muneshwara Nagar to Chikka Begur	47.16	Private	52	EC1-1	2021.3	Pvt.
53	RS 53	Muneshwara Nagar to Chikka Begur	5.3	Private	53	EC1-2	468	Pvt.
54	RS 54	Muneshwara Nagar to Chikka Begur	23.36	Private	54	EC1-3	409.1	Govt.
55	RS 55	Muneshwara Nagar to Chikka Begur	3.59	Private	55	EC1-4	6145.1	Pvt.
56	RS 56	Muneshwara Nagar to Chikka Begur	5.59	Private	56	EC-1	480.3	Pvt.
57	RS 57	Muneshwara Nagar to Chikka Begur	1.46	Private	57	EC-2	468	Pvt.
58	RS 58	Muneshwara Nagar to Chikka Begur	2.33	Private	58	EC-3	91.3	Pvt.
59	RS 59	Muneshwara Nagar to Chikka Begur	18.97	Private	59	EC-4	156	Pvt.
60	RS 60	Muneshwara Nagar to Chikka Begur	1.83	Private	60	EC-5	612.1	Pvt.
61	RS 61	Muneshwara Nagar to Chikka Begur	33.54	Private	61	HUR-1	374.6	Govt.
62	RS 62	Muneshwara Nagar to Chikka Begur	49.53	Private	62	HUR-2	688.6	Pvt.
63	RS 63	Muneshwara Nagar to Chikka Begur	2.2	Private	63	HUR-3	468	Pvt.



64	RS 64	Muneshwara Nagar to Chikka Begur	2.5	Private	64	HUR-4	280.3	Govt.
65	RS 65	Muneshwara Nagar to Chikka Begur	10.36	Private	65	HUR-5	16.9	Pvt.
66	RS 66	Muneshwara Nagar to Chikka Begur	1.36	Private	66	HEB-1	1594.2	Govt.
67	RS 67	Chikka Begur to Basapur Road	32.17	Private	67	HEB-2	1274.9	Pvt.
68	RS 68	Chikka Begur to Basapur Road	12.03	Private	68	BOM-1	16309.1	Pvt.
69	RS 69	Chikka Begur to Basapur Road	50.08	Private	69	BOM-2	412.8	Pvt.
70	RS 70	Chikka Begur to Basapur Road	3.09	Private	70	BOM-3	468	Pvt.
71	RS 71	Chikka Begur to Basapur Road	5.91	Private	71	BOM-4	790.4	Govt.
72	RS 72	Chikka Begur to Basapur Road	39.62	Private	Total		87410.4	
73	RS 73	Chikka Begur to Basapur Road	0.03	Private				
74	RS 74	Electronic City - I to Electronic City	1.56	Private				
75	RS 75	Electronic City - I to Electronic City	1.35	Private				
76	RS 76	Electronic City - I to Electronic City	2.41	Private				
77	RS 77	Electronic City - I to Electronic City	4.22	Private				
78	RS 78	Electronic City - I to Electronic City	1.88	Private				
79	RS 79	Electronic City - I to Electronic City	5.83	Private				
80	RS 80	Electronic City - I to Electronic City	14.36	Private				
81	RS 81	Electronic City - I to Electronic City	30.12	Private				
82	RS 82	Electronic City - I to Electronic City	0.73	Private				
83	RS 83	Electronic City - I to Electronic City	8.46	Private				
84	RS 84	Electronic City - I to Electronic City	17.07	Private				
85	RS 85	Electronic City - I to Electronic City	0.54	Private				
86	RS 86	Electronic City - I to Electronic City	4.86	Private				
87	RS 87	Electronic City - I to Electronic City	3.15	Private				



88	RS 88	Electronic City to Huskur Road	47.79	Private				
89	RS 89	Electronic City to Huskur Road	79.43	Private				
90	RS 90	Electronic City to Huskur Road	8.1	Private				
91	RS 91	Huskur Road to Hebbagodi	2.29	Private				
92	RS 92	Huskur Road to Hebbagodi	3.55	Private				
93	RS 93	Huskur Road to Hebbagodi	5.55	Private				
94	RS 94	Hebbagodi to Bommasandra	36.92	Private				
95	RS 95	Hebbagodi to Bommasandra	322.7	Private				
96	RS 96	Hebbagodi to Bommasandra	11.54	Private				
97	RS 97	Hebbagodi to Bommasandra	36.1	Private				
98	RS 98	Hebbagodi to Bommasandra	71.9	Private				
99	RS 99	Hebbagodi to Bommasandra	35.8	Private				
100	RS 100	Hebbagodi to Bommasandra	7.02	Private				
101	RS 101	Hebbagodi to Bommasandra	270.79	Private				
<b>Total</b>			<b>5141.87</b>					

4.4.3 Proposed Land Plan for stations showing Government and Private Land is given at Figure 4.2/1 & 4.2/16. The land to be acquired for the viaduct between stations is shown in General Arrangement Drawings (GADs). It may be seen that at the proposed Jayadev Hospital metro Station site, acquisition of the land will be needed in the premises of hospital. In fact this is needed to provide the station building and also platforms. This acquisition will also enable the integration of two corridors. The acquisition of large number of building is needed after Jayadev hospital on Silk Board junction side.

#### 4.4.4 Land for Property Development

It is proposed that vacant plot of an area of 2,320 sq.m near BTM Layout Station (Chainage 3582.70), 19,200Sqm near Chikka Begur Station (Chainage 9257.50), 10,450 Sqm near Hosa Road Station (Chainage 11998.30) and 17,000Sqm near Electronic City-I Station (Chainage 12990.10) would be utilized for Property Development (Total of **48,970Sqm**). Similarly, it is proposed to acquire 10,650Sqm of land behind Bommasandra station for utilization of Property Development. **Thus the total land available for the property development is 59,620 Sqm (59.62ha).**



4.4.5 The important locations and reference points along the corridor is presented in table 4.5 as under :

**TABLE 4.5**

S.No	Chainages		Important Locations / reference points	Locations w.r.t alignment
	From	To		
1.	0.00	600.00	R V Road (4 <sup>th</sup> Main Road) (Laxman Rao Park on either side)	-
			40 <sup>th</sup> cross road	-
2.	600.00	2500.00	Marenahalli road (South end road)	-
			Jaya Nagar 2 <sup>nd</sup> cross road	-
			Jaya Nagar 5 <sup>th</sup> block	-
			4 <sup>th</sup> Main road	
			5 <sup>th</sup> Main road	
			6 <sup>th</sup> Main road	
			7 <sup>th</sup> Main road	
			9 <sup>th</sup> Main road	
			10 <sup>th</sup> Main road	
			11 <sup>th</sup> Main road, Arbindo Marg (24 <sup>th</sup> Main)	
			11 <sup>th</sup> A Main road	
			25 <sup>th</sup> Main	
			28 <sup>th</sup> Main	
		East End road		
		Bannerghatta road		
3.	2500	4700	Outer Ring Road	-
			7 <sup>th</sup> Main road	right
			Tavarkere Main road, 16 <sup>th</sup> Main	-
			20 <sup>th</sup> Main	left
			29 <sup>th</sup> Main	right
			Tank shore road	right
4	4700	18100	Hosur road	-
			Ramp of Elevated highway starts	left
			Begur road	right
			27 <sup>th</sup> cross road	Left
			Bandepalya road	Left
			7 <sup>th</sup> cross	Right
			Kudlu road	left
			Chik Begur road	Right



#### 4.4.6 Relocation / Resettlement

The project involves relocation of few shops, commercial cum residential buildings and hutments along the alignment. Compensation for relocation of these affected structures shall be paid and it has been considered in the project cost estimate. The alignment has been so chosen, that it remains mostly within the government land. However, at certain locations while negotiating the curves, the land acquisition became inevitable. It is proposed to invite bids from private developers to offer constructed tenements against TDR and cash components in their own land.

#### 4.5 STATION PLANNING

R V Road to Bommasandra alignment covers 18.82 km and consists of the following 16 stations including R. V. Road:

<b>Bangalore Metro Rail Project ( Phase II)</b>			
<b>S.No</b>	<b>Station Name</b>	<b>Chainage</b>	<b>Inter Distance Between Two Stations.</b>
	DEAD END	(-)450	
0	R.V.Road Terminal	0	450
1	Ragigudda temple	1255.5	1255.5
2	Jayadev Hospital	2454.3	1198.8
3	BTM Layout	3582.7	1128.4
4	Silk Board Junction	4543.1	960.4
5	HSR Layout	5761	1217.9
6	OXFORD College	6960.8	1199.8
7	Muneshwara Nagar	7858.2	897.4
8	Chikka Begur	9257.5	1399.3
9	Basapur Road	11053.5	1796
10	Hosa Road	11998.3	944.8
11	Electronic City - I	12990.1	991.8
12	Electronic City	13987.2	997.1
13	Huskur Road	15460.2	1473
14	Hebbagodi	16848.3	1388.1
15	Bommasandra	17961.4	1113.1
	DEAD END	18366.222	405





#### 4.5.1 Station Design

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

The stations will have following category:

1. on the middle of the road – Ragigudda, BTM Layout, Silk Board
2. partially on the road – Jayadeva Hospital, HSR Layout
3. On Service road of NH-7 (Hosur Road) – Oxford College, Muneshwara Nagar, Chikka Begur, Basapur Road, Hosur Road, Electronic City – I, Electronic City, Huskur Road, Hebbagodi and Bommasandra

#### 4.5.2 Platforms

Stations have been planned with side platforms to avoid the viaduct structure from flaring in and out at stations, which obstructs the road traffic below. Care has been taken to locate stations on straight alignment. However, in some stations, site constraints have become the deciding criteria and a curve of 1000 m radius has been introduced.

#### 4.5.3 Station Facilities

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

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

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

The proposed 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.



### 4.5.3 Station Locations

#### 1. R.V. Road

This is the Station on North south Line from where the extension to Bommasandra is proposed to taker off. The Schematic Plan of RV. Road Station is given at **Figure 4.2/1**.

#### 2. Ragigudda

Ragigudda is the first station on R V Road –Electronic City line. The elevated station has been proposed on the middle of Marenahalli Main Road leading towards Silk Board. The station is located on the LHS on the vacant land & a part of Park. The chainage of the station is 1255.50. The main access to the station has been provided from the traffic integration area, which is proposed on the open land. The other access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in traffic integration area.

Schematic Plan of the station is placed at **Figure 4.2/2**.

#### 3. Jayadeva Hospital

This is an elevated station, off the road and partially on the Marenahalli road and on the Jayadeva hospital compound. The station is located at the edge of Jayadeva compound. It is a interchange Station with the N-S line (Bannerghatta Road) Station which will also be accommodated on the edge of the Jayadeva Hospital compound and the platforms of the two stations will be interconnected in “L” shape at two different levels & connected through escaaloers/staircases. This area will also serve for locating ancillary structures required for operational activities and for parking of vehicles. The chainage of the station is 2454.30.

Schematic Plan of the station is placed at **Figure 4.2/3**.

#### 4. BTM Layout

This is the third station on R V Road – Electronic City line. The elevated station has been proposed on the middle of Outer Ring Road leading towards Silk Board. The station is located on the LHS on the vacant land & Pvt Property, (Petrol Bunk). The chainage of the station is 3582.70. 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.

Schematic Plan of the station is placed at **Figure 4.2/4**.

#### 4. Silk Board

This is the 4<sup>th</sup> station on R V Road – Electronic City line. The elevated station has been proposed on the middle of Outer Ring Road leading towards Silk Board. The station is located on the RHS on the vacant land. The chainage of



the station is 4543.10. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area.

Schematic Plan of the station is placed at **Figure 4.2/5**.

#### **5. HSR Layout:**

This is the 5<sup>th</sup> station on R V Road – Electronic City line & is the first station on the Hosur Road (NH-7). The elevated station has been proposed on the west side service road of Hosur road & on Pvt Compounds and is near to the approach ramp of Elevated Corridor of NH-7. The chainage of the station is 5761. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in adjacent area.

Schematic Plan of the station is placed at **Figure 4.2/6**.

#### **7. to 16. Oxford College, Muneshwara Nagar, Chikka Begur, Basapur road, Hosa road, Electronic City-I & Electronic City,Huskur Road,Hebbagodi and Bommasandra Stations on the Hosur Road**

These are elevated stations off the road and partially on the service road of Hosur road and on the Pvt Compounds. The station areas will also serve for locating ancillary structures required for operational activities and for parking of vehicles. The chainage of these stations are 6960.80, 7858.20, 9257.50, 11053.50, 11998.30, 12990.10 and 13987.20, 15460.2,16848.3 and 17961.4. The Chikka Begur Station at chainage 9257.50 is planned to have a stabling/sick line for emergency parking of the trains.

Schematic Plan of a typical station is placed at **Figure 4.2/7 to 4.2/16**

#### **4.5.4 Architectural Finishes**

A light weight and sleek steel structures has 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.

#### **4.6 PLANNING AND DESIGN CRITERIA FOR STATIONS**

1. The stations can be divided into public and non-public areas (those areas where access is restricted). The public areas can be further subdivided into paid and unpaid areas.



2. The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario.
3. The platform level at elevated stations is determined by a critical clearance of 5.5 m under the concourse above the road intersection, allowing 3.5 m for the concourse height, about 1 m for concourse floor and 1.5 m for structure of tracks above the concourse. Further, the platforms are 1.09 m above the tracks. This would make the rail level in an elevated situation at least 12.5m above ground.
4. In the underground stations, platform level is determined by a critical clearance of 2.50 m above the station box, which would be 13.7 m high. Allowing about 80 cm for the box structure, 70 cm for rails /supporting structure and 1.09 m for rail to platform ht, would make the platforms in an underground situation at least 13.5 m below ground.
5. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms.
6. The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space.
7. Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.
8. Station entrances are located with particular reference to passenger catchment points and physical site constraints within the right-of-way allocated to the MRTS.
9. Office accommodation, operational areas and plant room space is required in the non-public areas at each station. The functions of such areas are given in Table 4.6
10. The DG set, bore well pump houses and ground tank would be located generally in one area on ground.
11. The system is being designed to maximize its attraction to potential passengers and the following criteria have been observed:



- Minimum distance of travel to and from the platform and between platforms for transfer between lines.
  - Adequate capacity for passenger movements.
  - Convenience, including good signage relating to circulation and orientation.
  - Safety and security, including a high level of protection against accidents.
12. Following requirements have been taken into account:
- Minimum capital cost is incurred consistent with maximizing passenger attraction.
  - Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers.
  - Flexibility of operation including the ability to adapt to different traffic conditions changes in fare collection methods and provision for the continuity of operation during any extended maintenance or repair period, etc.
  - Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
  - Provision of display of passenger information and advertising.
13. The numbers and sizes of staircases/escalators are determined by checking the capacity against AM and PM peak flow rates for both normal and emergency conditions such as delayed train service, fire etc.
14. In order to transfer passengers efficiently from street to platforms and vice versa, station planning has been based on established principles of pedestrian flow and arranged to minimize unnecessary walking distances and cross-flows between incoming and outgoing passengers.
15. Passenger handling facilities comprise of stairs/escalators, lifts and ticket gates required to process the peak traffic from street to platform and vice-versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit).



#### 4.7 TYPICAL ELEVATED STATION

The station is generally located on the road median except Forits, World Trade Park, Malviya Nagar and Jawahar Kala Kendra are located on green strip separating main road and service road. Total length of the station is 140m. All the stations are two-level stations. The concourse is concentrated in a length of about 70 to 80 m in the middle of the station, with staircases leading from either side of the road. The maximum width of the station at concourse is 25 m and at the narrowest part is 16.5 m. Passenger facilities like ticketing, information, etc as well as operational areas are provided at the concourse level. Typically, the concourse is divided into public and non-public zones. The non-public zone or the restricted zone contains station operational areas such as Station Control Room, Station Master's Office, Waiting Room, Meeting Room, UPS & Battery Room, Signaling Room, Train Crew Room & Supervisor's Office, Security Room, Station Store Room, Staff Toilets, etc. The public zone is further divided into paid and unpaid areas. Auxiliary Service station is provided on the ground nearby as per availability of land.

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

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

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



**Table 4.6**  
**STATION ACCOMMODATION**

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

#### 4.8 PASSENGER AMENITIES

Passenger amenities such as ticketing counters/automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Uniform numbers of these facilities have been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station. The same applies to provision of platform widths and staircase/escalators. Maximum capacity required at any station by the year 2031 for normal operation has been adopted for all stations. For this purpose, peak minute traffic is assumed to be 2% of the peak hour traffic. For checking the adequacy of platform area, stair widths and requirement additional of emergency evacuation stairs, a maximum accumulation of passengers in the station has been considered to be comprising waiting passengers at the platform (including two missed headways) and section load expected to be evacuated at the station in case of an emergency.

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

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

##### 4.8.1 Concourse

Concourse forms the interface between street and platforms. In elevated stations, this is contained in a length of 70 - 80 m in the middle of the station. This is where all the passenger amenities are provided. The concourse contains automatic fare



collection system in a manner that divides the concourse into distinct paid and unpaid areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms. The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow has been allowed in front of the AFCs.

#### **4.8.2 Ticketing Gates**

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

#### **4.8.3 Ticket Counters and Ticket Issuing Machines (TIMs)**

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

#### **4.8.4 Platforms**

A uniform platform width of 8 to 12 m wide is proposed for the underground stations. In elevated stations, 4.5m wide side platforms have been proposed. These platform widths also have been checked for holding capacity of the platform for worst-case scenario.

#### **4.8.5 Stairs, Escalators and Lifts**

Provision has been made for escalators in the paid area i.e. from concourse to platforms. On each platform, one escalator has been proposed. In addition, two staircases with a combined width of 6 m are provided on each platform connecting to the concourse. These stairs and escalator together provide an escape capacity





adequate to evacuate maximum accumulated passengers in emergency from platforms to concourse in 5.5 minutes. Lifts have been provided one each on either platform, to provide access for elderly and disabled.

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

## 4.9 TRAFFIC INTEGRATION

### 4.9.1 Concept of Traffic Integration

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

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

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

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

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

### 4.9.2 Approach Adopted in Planning Traffic Integration Facilities

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



assuming that park and ride commuters will shift to which ever station such a facility is available.

## 4.10 CIVIL STRUCTURES

### 4.10.1 Elevated Section

#### **Choice of Superstructure**

The choice of superstructure has to be made keeping in view the ease of constructability and the maximum standardization of the formwork for a wide span ranges.

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

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



- During construction, the technique shows an exceptionally high record of safety.

#### 4.10.2 Types of Superstructures for Elevated Section

1. Pre-cast segmental box girder using external unbonded tendon

(B) Pre-cast segmental U-Channel Superstructure with internal pre-stressing.

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

##### A. Precast Segmental Box Girder using External Unbonded Tendon.

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

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

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



Precast Segmental Box Girder using internal tendon is also use.

### **B. Precast Segmental U-Channel Superstructure with Internal Pre-stressing.**

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

1. Built in sound barrier.
2. Built in cable support and system function.
3. Possibility to lower the longitudinal profile by approximately 1m compared to conventional design.
4. Built in structural elements capable to maintain the trains on the bridge in case of derailment (a standard barrier design allow this)
5. Built in maintenance and evacuation path on either side of the track.

**However, 'U' section has following disadvantages:**

- (i) Inefficient structure sections
- (ii) Requires cross pre-stressing of pier segments
- (iii) At X-over locations the girders are to be connected at slab level hence changing of bearing at later stage becomes very difficult.
- (iv) Costly than Box girder.

## **4.11 CONSTRUCTION METHODOLOGY**

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

- Reduction in construction period due to concurrent working for substructure and superstructure.
- For segmental, pre-cast element (of generally 3.0m length), transportation from construction depot to site is easy and economical.



- Minimum inconvenience is caused to the public utilising the road as the superstructure launching is carried out through launching girder requiring narrow width of the road.
- As the pre-cast elements are cast on production line in a construction depot, very good quality can be ensured.
- The method is environment friendly as no concreting work is carried at site for the superstructure.

#### 4.12 Pre-Cast Construction

##### **Casting of Segments**

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

For casting of segments both long line and short line method can be adopted. However the long line method is more suitable for spans curved in plan while short line method is good for straight spans. A high degree of accuracy is required for setting out the curves on long line method for which pre calculation of offsets is necessary. Match casting of segments is required in either method. The cast segments are cured on the bed as well as in stacking yard. Ends of the segments are to be made rough through sand blasting so that gluing of segments can be effective.

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

##### **Launching Scheme**

Launching girder is specially designed for launching of segments. The suggested launching scheme is designed in such a way that initially the launching girder is erected on pier head at one end of the work. The segments are lifted in sequence and when the lifting is over, they are dry matched while hanging from the launching girder. After dry matching, the segments are glued with epoxy and pre-stressed from one end. The girder is lowered on the temporary / permanent bearings after pre-stressing. The launching girder then moves over the launched span to next span and the sequences continue. Launching Scheme concept is given in Fig No. 4.3/1 to 4.3/4



#### 4.13 Structural System of Viaduct

##### Superstructure

The superstructure of a large part of the viaduct comprises of simply supported spans. However at major crossing over or along existing bridge, special steel or continuous unit will be provided.

Normally the Box Girder having a soffit width of about 4.0 m (approx) accommodates the two tracks situated at 4.2 m center to center (c/c). The Box Girder superstructure for almost all the simply supported standard spans will be constructed by precast prestressed segmental construction with epoxy bonded joints.

The standard spans c/c of piers of simply supported spans constructed by precast segmental construction technique has been proposed as 28.0m. The usual segments shall be 3.0m in length except the Diaphragm segments, which shall be 2.0m each. The other spans (c/c of pier) comprises of 31.0 m, 28m 25.0 m, 22.0 m, 19.0 m & 16.0 m, which shall be made by removing/adding usual segments of 3.0 m each from the center of the span.

The pier segment will be finalized based on simply supported span of 31.0m and the same will be also kept for all simply supported standard span.

For major crossing having spans greater than 31.0m, special continuous units normally of 3 span construction or steel girders have been envisaged.

All these continuous units (in case provided at obligatory location) will be constructed by cast-in-situ balanced cantilever construction technique.

##### Substructure

The viaduct superstructure will be supported on single cast-in-place RC pier.

The shape of the pier follows the flow of forces. For the standard spans, the pier gradually widens at the top to support the bearing under the box webs.

At this preliminary design stage, the size of pier is found to be limited to 1.8m to 2.0 m diameter of circular shape for most of its height so that it occupies the minimum space at ground level where the alignment often follows the central verge of existing roads.

To prevent the direct collision of vehicle to pier, a Jersey Shaped crash barrier of 1.0 m height above existing road level has been provided all around the pier. A gap of 25 mm has also been provided in between the crash barrier and outer face of pier. The shape of upper part of pier has been so dimensioned that a required clearance of 5.5 m is always available on road side beyond vertical plane drawn on outer face of crash barrier. In such a situation, the minimum height of rail above the existing road is 8.4 m.



The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.8 m. The space between the elastomeric bearings will be utilized for placing the lifting jack required for the replacement of elastomeric bearing. An outward slope of 1:200 will be provided at pier top for the drainage due to spilling of rainwater, if any. The transverse spacing between bearings would be 3.2 m (to be studied in more details).

The orientation and dimensions of the piers for the continuous units or steel girder (simply supported span) have to be carefully selected to ensure minimum occupation at ground level traffic. Since the vertical and horizontal loads will vary from pier to pier, this will be catered to by selecting the appropriate structural dimensions.

#### **Foundation Recommendation**

Substratum consists of top 1 meter as filled up soil followed by sand, silty sand, silty sand mixed with gravel up to 25 meter depth. From Ajmer Puliya to Government Hostel weathered/hard rock beyond 12 meter depth was met. Pile foundations have been recommended for the foundations as per the stratum encountered. Hence, pile foundations with varying pile depths depending on soil characteristic have to be provided on a case-by-case basis.

#### **Deck – Simple Spans**

Salient features of the precast segmental construction method technique as envisaged for the project under consideration are indicated below:

The superstructure shall be constructed “span by span” sequentially, starting at one end of a continuous stretch and finishing at the other end. Nos. of launching girders may be required so as to work on different stretches simultaneously to enable completion of the project in time.

The number of “breaks” in the stretch can be identified by Nos. of continuous units & stations.

The suggested method of erection will be detailed in drawings to be prepared, at the time of detailed design. The launching girder (or, more accurately, the “assembly truss”) is capable of supporting the entire dead load of one span and transferring it to the temporary brackets attached to the pier. The governing weight of the segments will be of the order of 50t (to be finalized). The launching girder envisaged will be slightly longer than two span lengths. It must be able to negotiate curves in conjunction with temporary brackets.

Transportation of segments from casting yard to the point of erection will be effected by appropriately designed low-bedded trailers (tyre-mounted). The segments can be lifted and erected using erection portal gantry moving on launching girder.



Box girder segments shall be match cast at the casting yard before being transported to location and erected in position. Post-tensioned cables shall be threaded in-situ and tensioned from one end. It is emphasized that for precast segmental construction only one-end pre-stressing shall be used.

The pre-stressing steel and pre-stressing system steel accessories shall be subjected to an acceptance test prior to their actual use on the works. The tests for the system shall be as per FIP Recommendations as stipulated in the special specifications. Only multi-strand jacks shall be used for tensioning of cables. Direct and indirect force measurement device (e.g. Pressure Gauge) shall be attached in consultation with system manufacturer.

The Contractor shall be responsible for the proper handling, lifting, storing, transporting and erection of all segments so that they may be placed in the structure without damage. Segments shall be maintained in an upright position at all times and shall be stored, lifted and/or moved in a manner to prevent torsion and other undue stress. Members shall be lifted, hoisted or stored with lifting devices approved on the shop drawings.

#### **Epoxy Bonded Joints and Shear Keys**

A minimum compressive stress of 3 kg/sq cm shall be provided uniformly over the cross-section for the closure stress on the epoxied joint until the epoxy has set. The curing period for application of the compressive stress, method of mixing and application of epoxy and all related aspects including surface preparation shall be as per approved manufacturer's specifications.

The purpose of the epoxy joint, which is about 1mm on each mating surface, shall be to serve as lubricant during segment positioning, to provide waterproofing of the joints for durability in service conditions and to provide a seal to avoid cross-over of grout during grouting of one cable into other ducts. The epoxy shall be special purpose and meet requirements of relevant provision of FIP (International Federation of Pre-stressed Concrete).

The temporary compressive stress during the curing period shall be applied by approved external temporary bar pre-stressing (such as Macalloy or Diwidag bar systems or approved equivalent).

#### **4.14 Construction of Stations**

It is proposed to construct the elevated stations with elevated concourse over the road at most of the locations to minimize land acquisition. To keep the rail level low,





it is proposed not to take viaduct through the stations. Thus a separate structural configuration is required (although this may necessitate the break in the launching operations at each station location)

Sub-structure for the station portion will also be similar to that of viaduct and will be carried out in the same manner. However, there will be single viaduct column in the station area, which will be located on the median and supporting the concourse girders by a cantilever arm so as to eliminate the columns on right of way.

Super-structure will consist of 3 precast U Girders for supporting the track structure and I Girder / Double T Girders for supporting the platform and concourse areas. A pre-cast or cast in situ prestressed cross girder will be required over the middle piers for supporting platform structure. Box shaped in situ prestressed cantilever cross girders are planned for supporting the concourse girders and escalators at mezzanine level. All the members will be pre-cast in a construction depot and launched at site through cranes.

#### 4.14.1 Grade of Concrete

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

i) Piles	-	M -35
ii) Pile cap and open foundation	-	M -35
iii) Piers	-	M -40
iv) All precast element for viaduct and station	-	M -45
v) Cantilever piers and portals	-	M -45
	-	M -60
vi) Other miscellaneous structure	-	M -30

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

#### 4.14.2 Reinforcement and pre-stressed Steel

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

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

#### **NOTE BY BMRCL:**

***Fe 415 rebars are not easily available. So Fe 500 should normally be used***



#### 4.14.3 Road width required during construction

As most of the construction is to be carried out on the middle of the road, central two lanes including median will be required for construction activities. During piling and open foundation work, a width of about 9 m will be required for construction and the same will be barricaded. It is proposed that two lanes are provided for traffic on either sides during construction by widening of roads, if necessary. In certain cases, one way traffic may be resorted to.

All these actions will require a minimum period of about 4 to 6 months. During this period, the implementing agency can go ahead with the following preliminary works:

- i) Preliminary action for diversion of utility and preparation of estimates thereof.
- ii) Reservation of land along the corridor, identification and survey for acquisition.

#### 4.15 UTILITIES AND SERVICES

The proposed alignment of R V Road to Electronic City - Bommasandra Industrial Area is traversing along the R V Road, Marenahalli road, outer ring road and Hosur road. Number of sub-surface, surface and over head utility services viz. sewers, water supply lines, storm water drains, telephone cables, overhead electrical transmission lines, electric poles, traffic signals etc. are existing along the proposed alignment. These utility services are essential and have to be maintained in working order during different stages of construction by temporary / permanent diversions or by supporting in position. As such, these may affect construction and project implementation time schedule / costs, for which necessary planning / action needs to be initiated in advance.

Organisations / Departments responsible for concerned utility services are provided in **Table 4.7**.

**Table 4.7**

#### ORGANISATION RESPONSIBLE FOR UTILITIES AND SERVICES

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



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

#### 4.15.1 Diversion of Utilities

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

- i) Utility services have to be kept operational during the entire construction period and after completion of project. All proposals should therefore, ensure their uninterrupted functioning.
- ii) The elevated viaduct does not pose any serious difficulty in negotiating the underground utility services, especially those running across the alignment. In such situation, the planning arrangement of the viaduct may be suitably adjusted to ensure that no foundation need be constructed at the location, where utility is crossing the proposed Metro alignment. In case of utility services running along the alignment either below or at very close distance, the layout of piles in the foundations is to be suitably modified such that the utility service is either encased within the foundation piles or remains clear of them.

#### 4.15.2 Major Utility Diversion

Since the alignment is elevated, most of the utilities will not be affected. The list of major electrical wires crossing is given below. These are to be replaced by underground cabling.

S. No.	Chainage	Voltage	Remark
1	2280	33 KV	Short of Jayadeva Hospital
2	10600	66 KV	Short of Basapur Station
3	10700	66 KV	Short of Basapur Station
4	14970	66 KV	Short of Huskur Road Station



#### 4.16. General Geology:

**4.16.1 Geology-** Bangalore is existing on a gneissic terrain of peninsular origin. The soil formation is due to physical weathering of parent rock caused by temperature changes accompanied by chemical transformations. Climate has played an important role in the weathering of rock. Except for the material met with in the tank beds in the nearby localities, the soil is residual in nature with increase in strength with depth.

The Geology here dates back to the Archean formations. These include the oldest rocks of the earth crust found at the bottom of stratified deposits. They are crystalline in nature and exhibit high compressive strengths. They generally have a well defined foliated structure. The Archean gneiss generally consist of orthoclase, oligoclase or microcline, quartz, muscovite, biotite and hornblende with a variety of other accessory minerals. The types of hard rock encountered in this region are generally hard granites with low permeability and good strength characteristics forming ideal founding strata.

#### 4.16.2 Field Investigation

Field Investigation consisted of borehole exploration to a maximum depth of 30m. If rock was encountered within 30m, drilling was carried to a depth of 3m in intact hard rock. Boreholes were generally located at about 500 m to 1000 m interval along the alignment.

Borehole exploration was carried out by deploying conventional rotary drilling rigs. Methodologies followed conform to IS: 1892. Drilling in soil was carried out by core barrels having suitable cutting edges. In soft rock where the strata are very dense, advancement of bore holes was done by TC Bits of Nx size. In weathered rock and hard rock, core drilling was progressed using Nx size diamond bits with double tube core barrel.

Standard Penetration tests (SPT) were carried out as per IS: 2131-1981 at regular intervals of generally 1.5 to 3.0 m. Undisturbed soil samples were collected using thin walled steel tubes of 100mm diameter, 450mm long as per IS:2132-1986 wherever required. Both SPT and undisturbed soil samples were sealed and labeled properly and brought to 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 recovery and RQD (Rock Quality Designation) have been recorded. The rock cores were stored in core boxes and brought to laboratory for further testing.

The depth of ground water table was monitored daily after 24 hours of drilling operation in the bore holes and depth of water level was recorded after it stabilised.

The details of stratification, SPT Values, Ground Water Table etc. are indicated in the Stratigraphy enclosed.



#### 4.16.3 LABORATORY TESTING:

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

##### **Tests on soil samples:**

- (i) Insitu density and moisture content.
- (ii) Grain size analysis.
- (iii) Liquid Limit and Plastic Limit
- (iv) Triaxial Shear
- (v) Direct Shear
- (vi) Consolidation
- (vii) Permeability
- (viii) Chemical analysis to determine pH, Chlorides and sulphates

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

- (i) Density
- (ii) Water absorption
- (iii) Specific gravity
- (iv) Hardness
- (v) Abrasion
- (vi) Unconfined Compressive strength
- (vii) Point load index
- (viii) Determination of modulus of elasticity

##### **Tests on Water Samples for Chemical analysis to determine pH, Chlorides and Sulphates.**

The above tests were carried out as per the relevant Indian and International standards and indicated in bore logs.

#### 4.16.4 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 silty sand with clay or yellowish / greyish clayey sand / sandy clay. This layer is medium dense and is underlain by medium dense to dense greyish / whitish / yellowish silty sand / sandy silt layer. This is followed by soft rock made up of very dense silty sand / sandy silt layer. Weathered rock with degree of weathering varying from slight to high followed the soft rock layer and under lain by more compact hard rock.

The Rock strata was encountered in all the bore holes except in BH1, BH7, BH8, BH11 and BH25.



#### 4.16.5 ANALYSIS OF RESULTS

The stratification encountered along the proposed route mostly consists of medium dense to dense silty sand with clay or sandy clay / clayey sand at shallow depths. This layer is followed by medium dense to dense silty sand or sandy silt, which is non-plastic to moderately plastic. Density of this layer is increasing with depth. This layer is followed by soft rock consisting of very dense silty sand / sandy silt. Weathered rock and hard rock layers underlay this soft rock layer.

The formation of successive layers is varying along the route. The yellowish silty sand layer is encountered from ground level itself at a few locations. In general, the stratification follows regular pattern as described above.

Standard penetration tests (SPT) in the soft rock indicate very high 'N' values of 100 and more with virtually no penetration of SPT tube in this layer. The color and structure of soil samples collected in the split spoon closely resembles the underlying mineralogical constituents of weathered rock / hard rock.

Index properties such as grain size distribution and liquid limit and plastic limit values indicate that, plasticity characteristics of the soil is low to moderate. Hydrometer tests conducted on selected soil samples show that finer fraction predominantly consists of silt and is non-expansive in nature.

Chemical analysis of soil and water samples show that pH, chlorides and sulphates are well within permissible limits and do not call for any special treatment.

Rock cores extracted from the bore holes show the presence of gray granite with pockets of amphibolites, granodiorite and mylonite rock. The rock is intruded with pegmatite veins at some places. The granite rock shows gneissic texture due to metamorphic activity.

The details of soil strata met are given in the Geotechnical investigation report.

- 4.16.6 Seismicity**-Bangalore falls in seismic zone II. Suitable seismic coefficient may be adopted in the design of structures commensurate with the Indian Standard seismic zoning of the country IS.1893-2002.

#### 4.16.7 RECOMMENDATIONS

The type of foundation depends on stratification, type of structure, loading, allowable settlement, etc. In the present case, the structure is Metro railway system, which is a elevated corridor. The various structures envisaged in the system include Elevated tracks supported on piers, Elevated stations. The loads coming on to the foundation system will be considerable, from the structures.



### Shallow Foundations

Shallow Foundations are recommended wherever the hard strata (soft rock / weathered rock / hard rock) are encountered within 4m depth below ground level. Based on field and laboratory test results, an allowable bearing pressure of 45 T/sqm is recommended. The hard strata are usually overlain by a medium dense soil 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.

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

#### 4.16.8 Deep Foundations

Deep foundations, in the form of bored cast in-situ piles are recommended where the hard strata is encountered at considerable depths. The columns supporting the elevated rail track and elevated station are recommended to be supported on pile foundations. In particular, bored cast in-situ piles are recommended keeping in view the site locations, 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 rock, weathered rock and hard rock. Past experience indicate that the piles socketed in soft rock have performed satisfactorily. In view of this, it is recommended to anchor the pile in soft rock layer itself, wherever the thickness of soft rock is considerable. The soft rock layer encountered in the pile bore can be verified through SPT tests in the pile bore. Further, while chiseling 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:

Type of strata	Depth of socketing (D = Dia of pile)
Soft Rock	3 to 4 D
Weathered Rock	2 to 3 D
Hard Rock	1 D

The length of piles considering the strata at pile termination at various bore hole 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, 1250 mm and 1500 mm are considered for evaluation. The safe load carrying capacity of piles in this case is generally governed by structural capacity of pile.

The recommended safe load on piles considering piles with M25 concrete are as follows:

<b>Pile dia (mm)</b>	<b>Recommended Safe Load (Tonnes)</b>
900	380
1000	470
1250	730
1500	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 pile bore. Further, in soft rock, the capacities are also governed by the properties of soft rock at termination. Hence, it is preferable to limit the safe loads as recommended above.

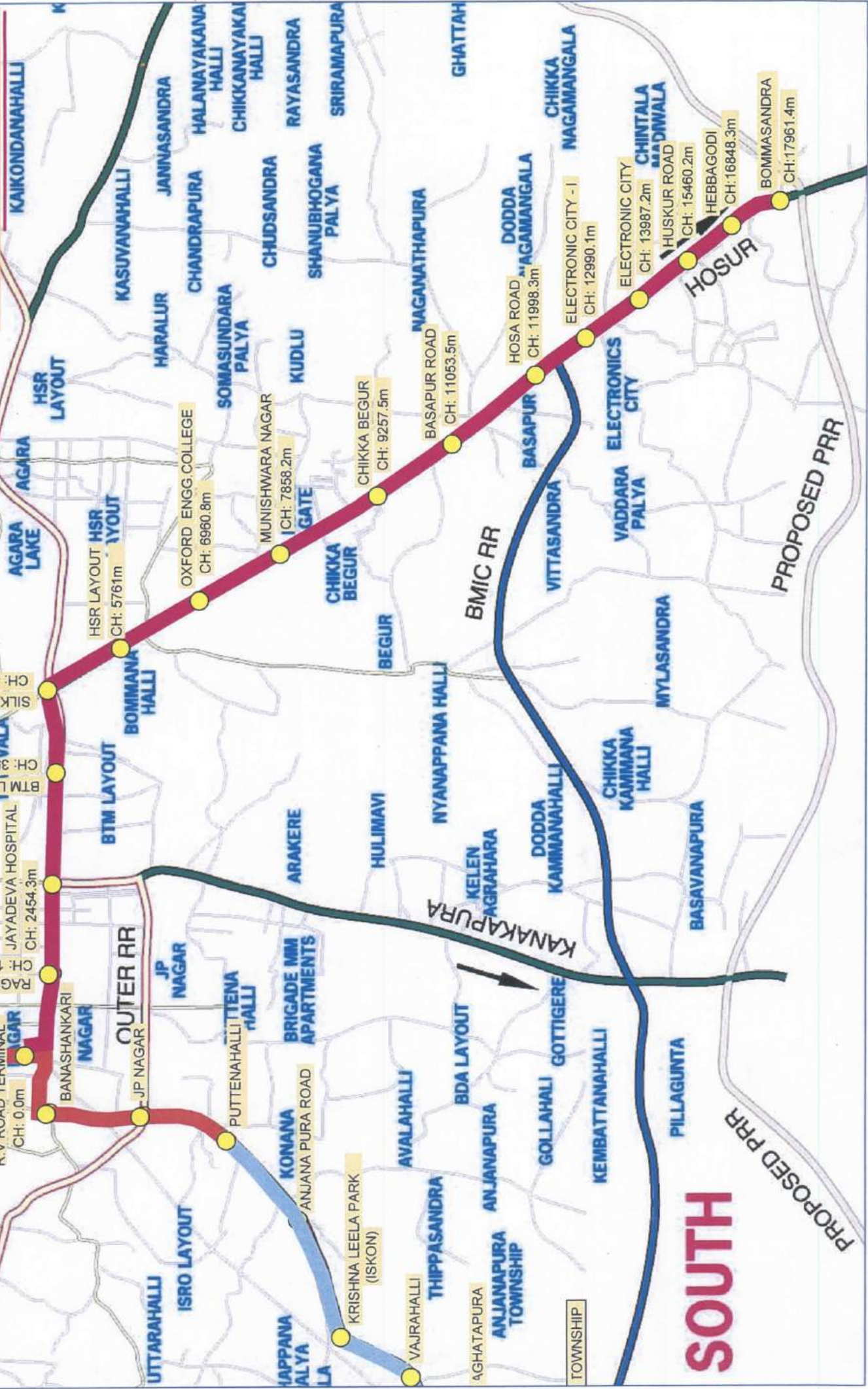
The uplift capacity of piles can be taken as 10 % of safe vertical load and the safe horizontal load can be taken as 5 % of safe vertical load.

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

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



**Fig.4.1 KEY MAP**  
**R.V.Road-Bommasandra**  
**Corridor**



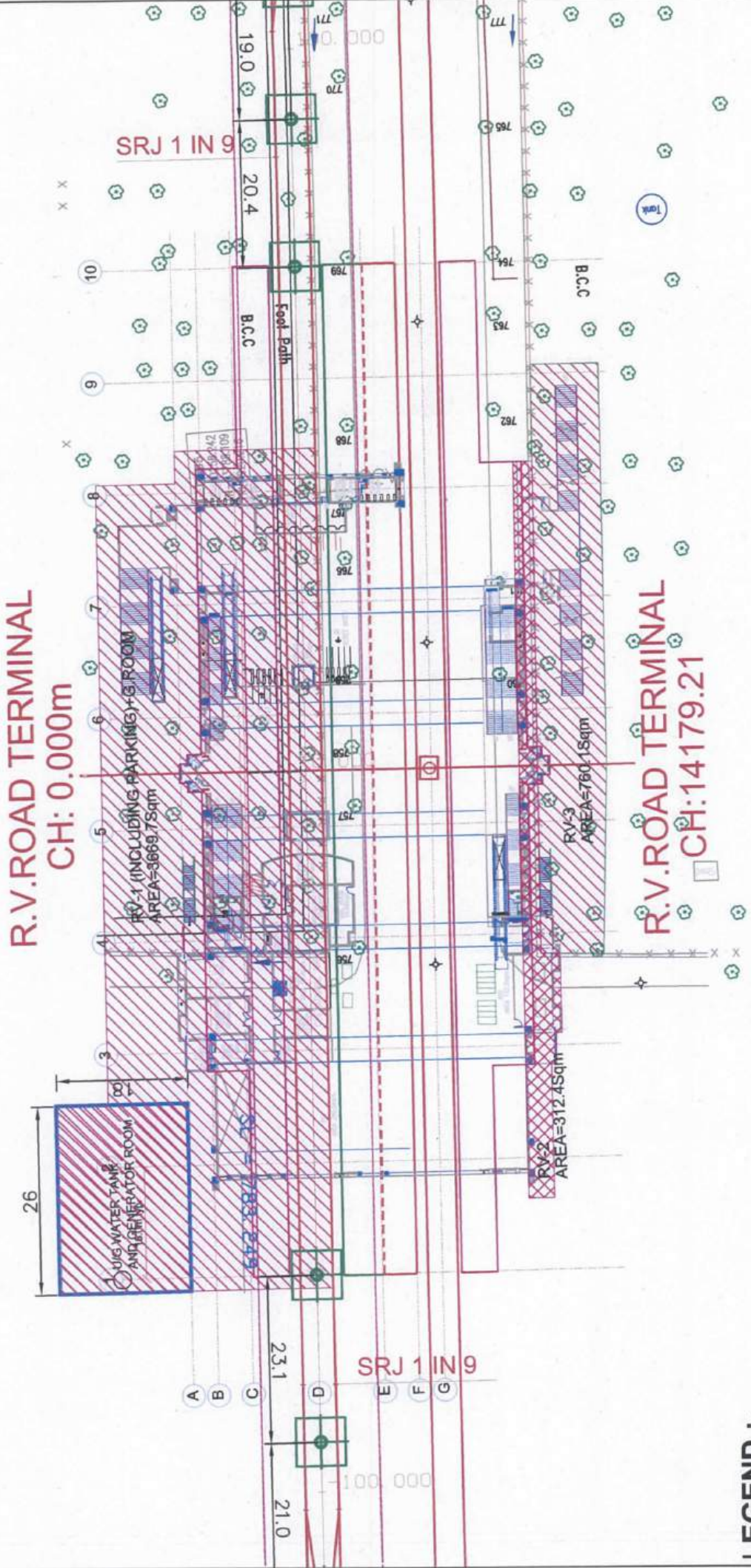
**SOUTH**

PROPOSED PRR

PROPOSED PRR



Fig.No. 4.2/1



R.V. ROAD TERMINAL  
CH: 0.000m

R.V. ROAD TERMINAL  
CH:14179.21

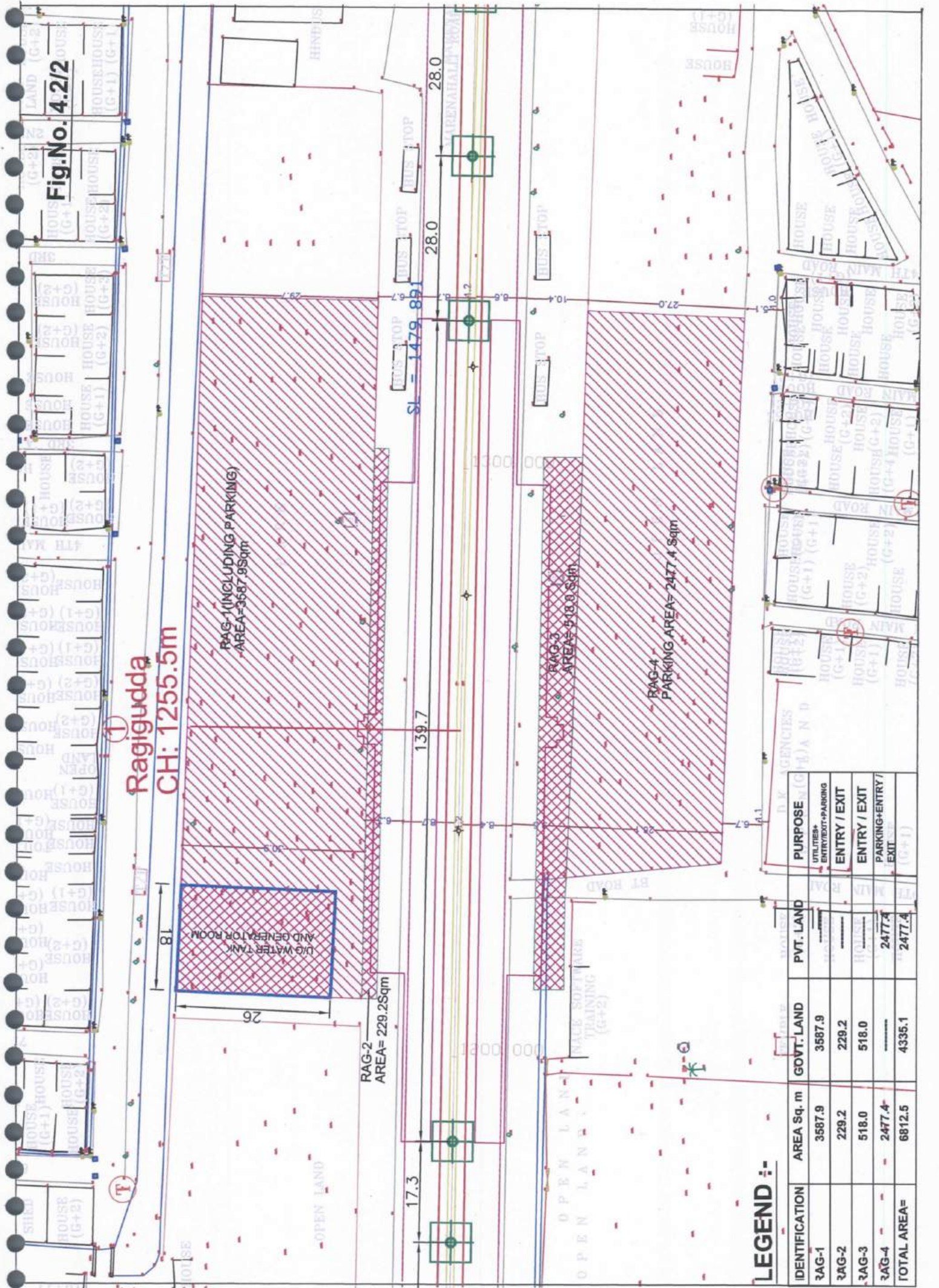
**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
RV-1	3669.7	3669.7	-----	UTILITIES+ ENTRY/EXIT+PARKING
RV-2	312.4	312.4	-----	ENTRY / EXIT
RV-3	760.1	760.1	-----	ENTRY / EXIT
TOTAL AREA=	4742.2	4742.2		



Fig.No. 4.2/2

**Ragigudda**  
CH: 1255.5m

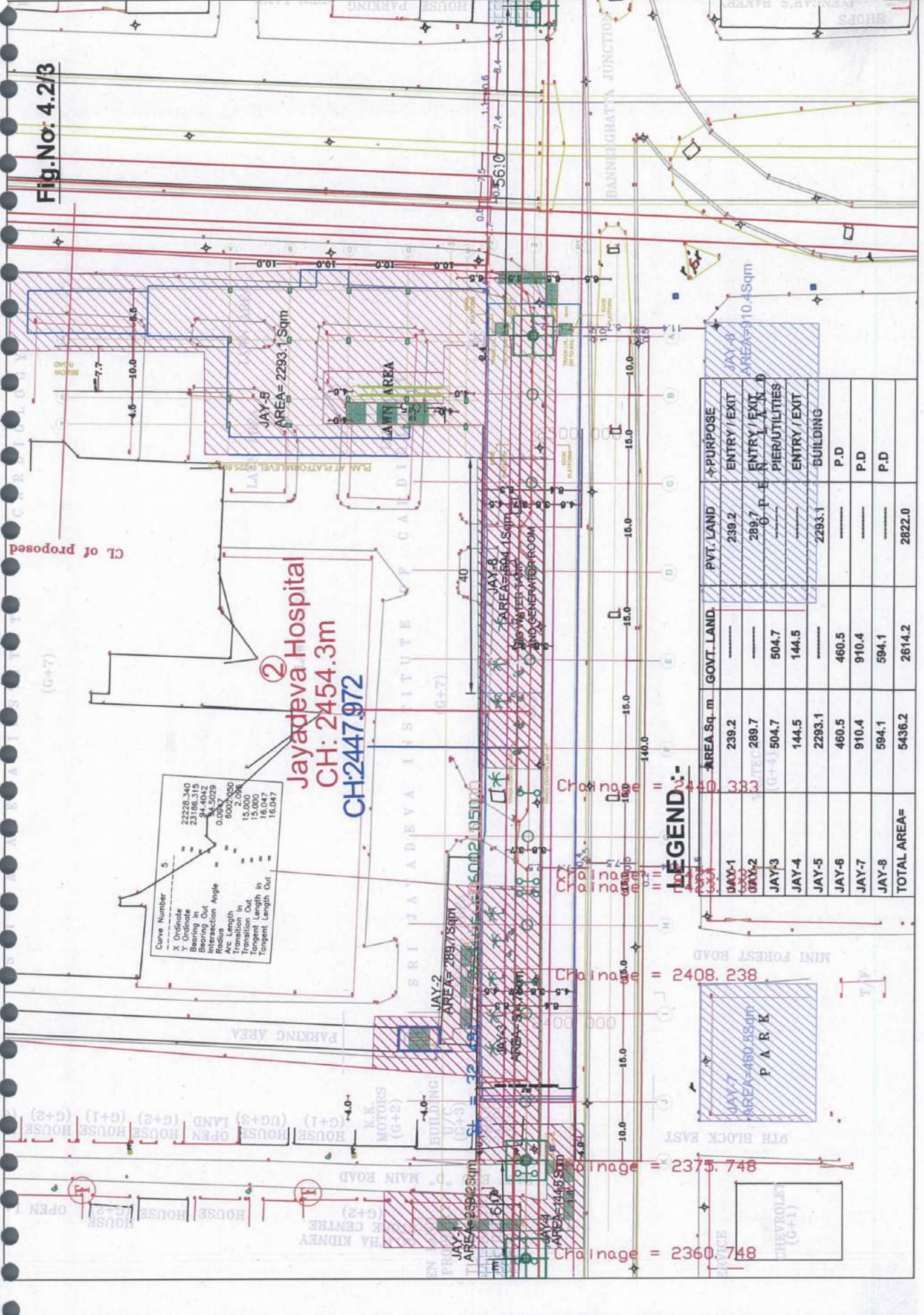


**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
RAG-1	3587.9	3587.9		UTILITIES+ ENTRY+EXIT+PARKING
RAG-2	229.2	229.2		ENTRY / EXIT
RAG-3	518.0	518.0		ENTRY / EXIT
RAG-4	2477.4	2477.4		PARKING+ENTRY/EXIT
<b>TOTAL AREA=</b>	<b>6812.5</b>	<b>4335.1</b>	<b>2477.4</b>	



Fig. No: 4.2/3



**Jayadeva Hospital**  
**CH: 2454.3m**  
**CH: 2447.972**

Curve Number 5

X Ordinate	22226.340
Y Ordinate	23186.315
Bearing In	94.4042
Bearing Out	94.4042
Intersection Angle	0.0000
Radius	600.0000
Transition Length In	2.0000
Transition Length Out	2.0000
Tangent Length In	15.0000
Tangent Length Out	16.0477

**LEGEND:-**

NO	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
JAY-1	239.2		239.2	ENTRY / EXIT
JAY-2	289.7		289.7	ENTRY / EXIT
JAY-3	504.7	504.7		PIER/UTILITIES
JAY-4	144.5	144.5		ENTRY / EXIT
JAY-5	2293.1		2293.1	BUILDING
JAY-6	460.5	460.5		P.D
JAY-7	910.4	910.4		P.D
JAY-8	594.1	594.1		P.D
<b>TOTAL AREA=</b>	<b>5436.2</b>	<b>2614.2</b>	<b>2822.0</b>	

Chainage = 2408.838

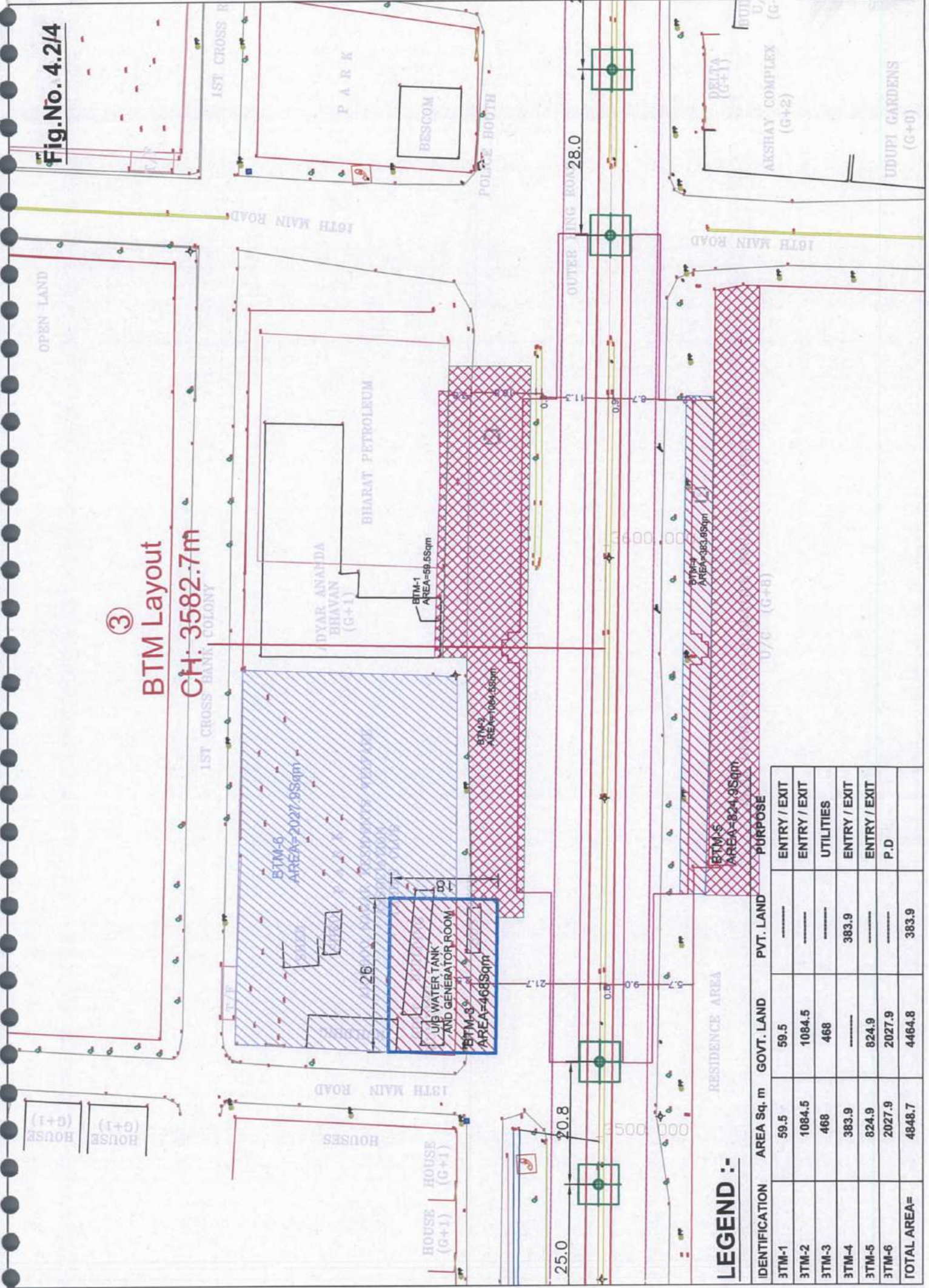
Chainage = 2375.748

Chainage = 2360.748



Fig.No. 4.2/4

③  
BTM Layout  
CH: 3582.7m

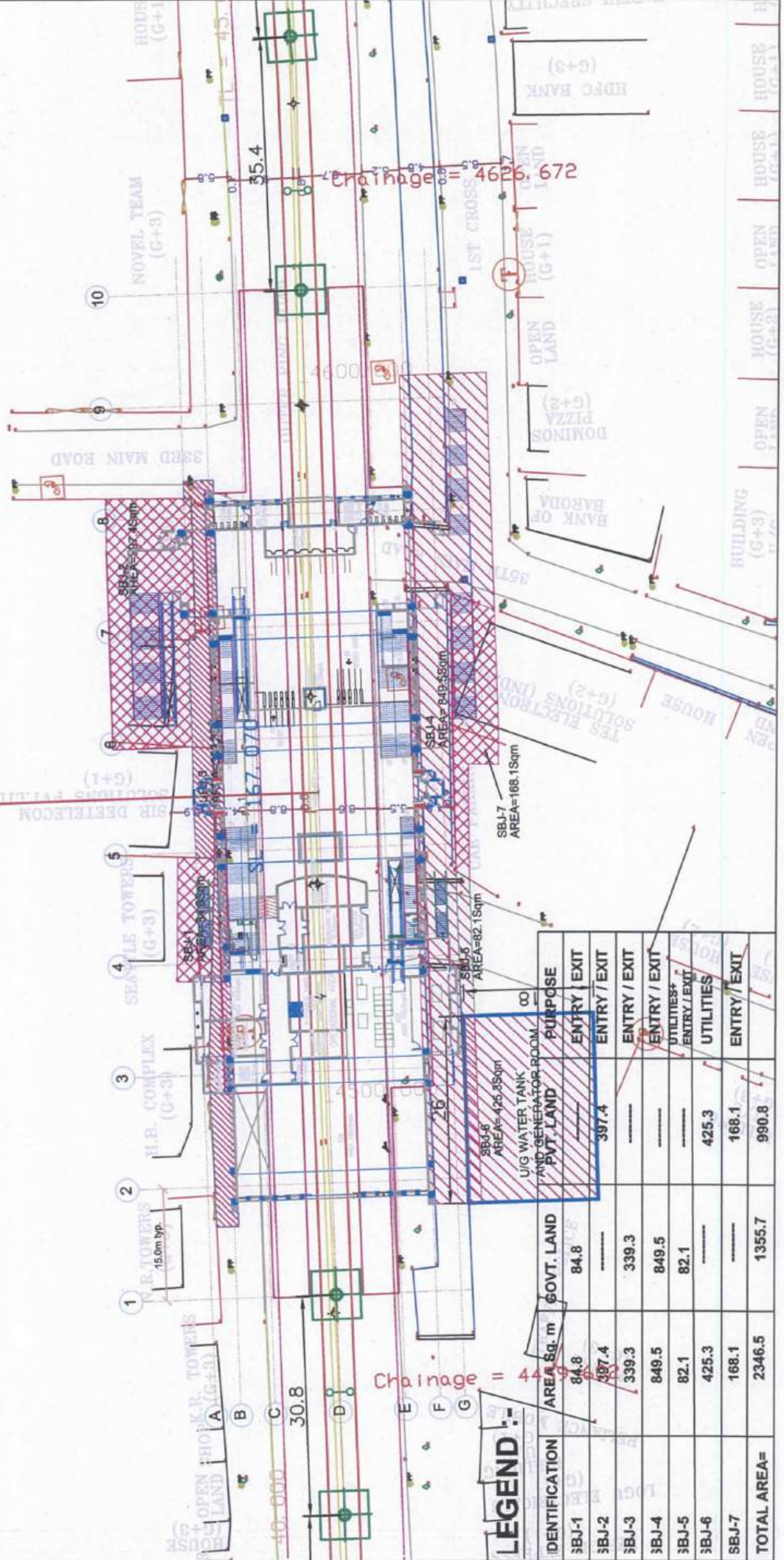


**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
3TM-1	59.5	59.5	-----	ENTRY / EXIT
3TM-2	1084.5	1084.5	-----	ENTRY / EXIT
3TM-3	468	468	-----	UTILITIES
3TM-4	383.9	-----	383.9	ENTRY / EXIT
3TM-5	824.9	824.9	-----	ENTRY / EXIT
3TM-6	2027.9	2027.9	-----	P.D
<b>TOTAL AREA=</b>	<b>4848.7</b>	<b>4464.8</b>	<b>383.9</b>	



④  
 Silk Board Junction  
 CH: 4543.1m



**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PURPOSE
SBJ-1	84.8	84.8	ENTRY / EXIT
SBJ-2	397.4		ENTRY / EXIT
SBJ-3	339.3	339.3	ENTRY / EXIT
SBJ-4	849.5	849.5	ENTRY / EXIT
SBJ-5	82.1	82.1	UTILITIES / ENTRY / EXIT
SBJ-6	425.3		UTILITIES
SBJ-7	166.1		ENTRY / EXIT
<b>TOTAL AREA=</b>	<b>2346.5</b>	<b>1355.7</b>	

Chainage = 4499.600

Chainage = 4626.672

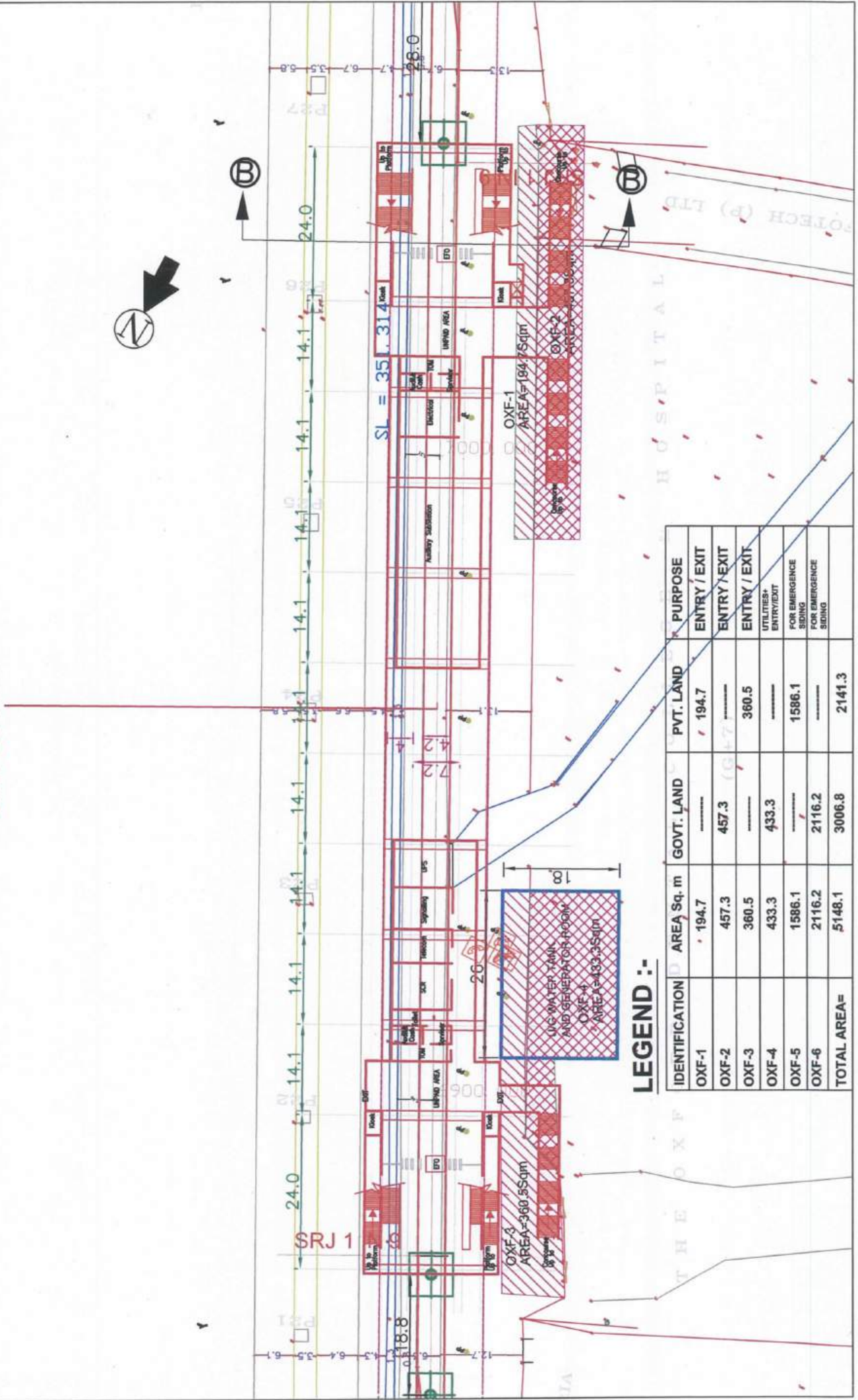






**Fig.No. 4.2/7**

**OXFORD College**  
**CH: 6960.8m**



**LEGEND :-**

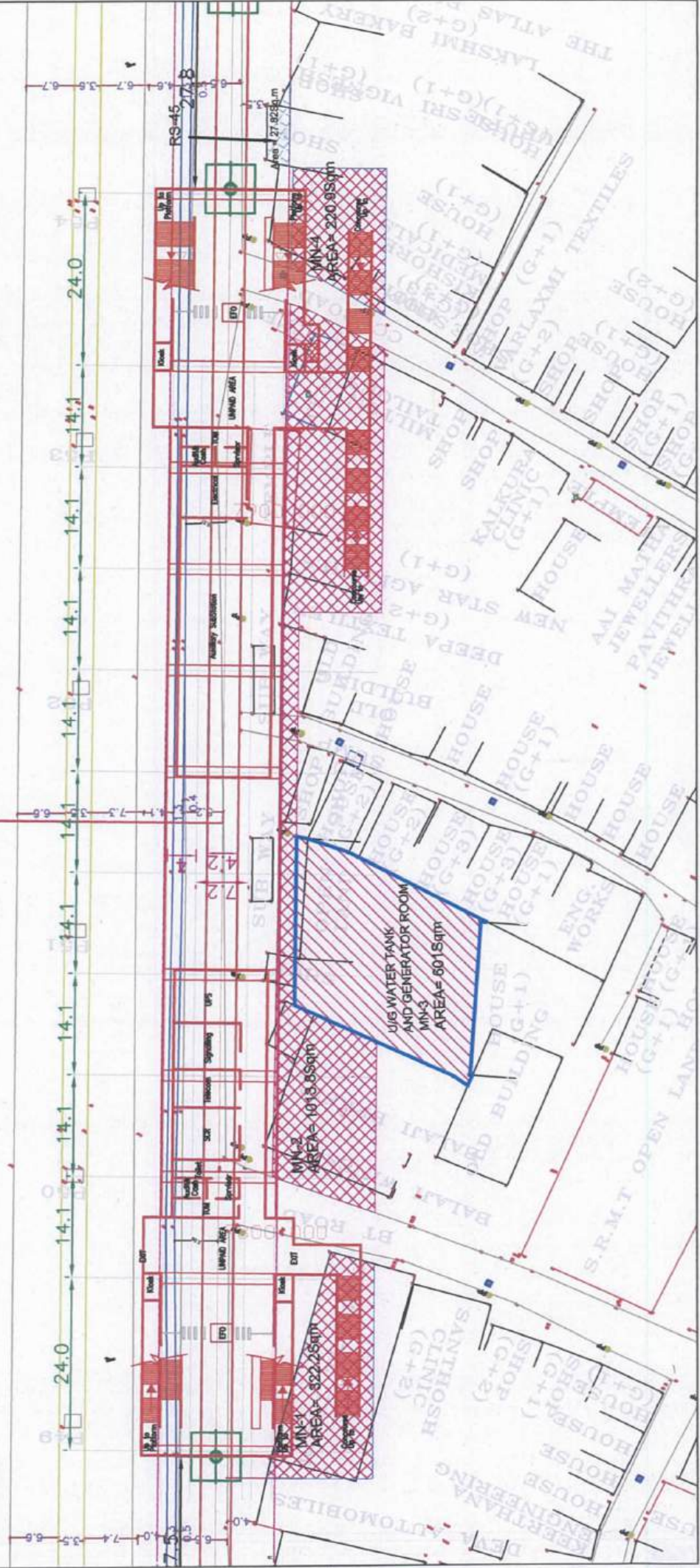
IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
OXF-1	194.7	-----	194.7	ENTRY / EXIT
OXF-2	457.3	-----	457.3	ENTRY / EXIT
OXF-3	360.5	-----	360.5	ENTRY / EXIT
OXF-4	433.3	-----	-----	UTILITIES+ ENTRY/EXIT
OXF-5	1586.1	-----	1586.1	FOR EMERGENCY SIDING
OXF-6	2116.2	-----	-----	FOR EMERGENCY SIDING
<b>TOTAL AREA=</b>	<b>5148.1</b>	<b>3006.8</b>	<b>2141.3</b>	



**LEGEND :-**

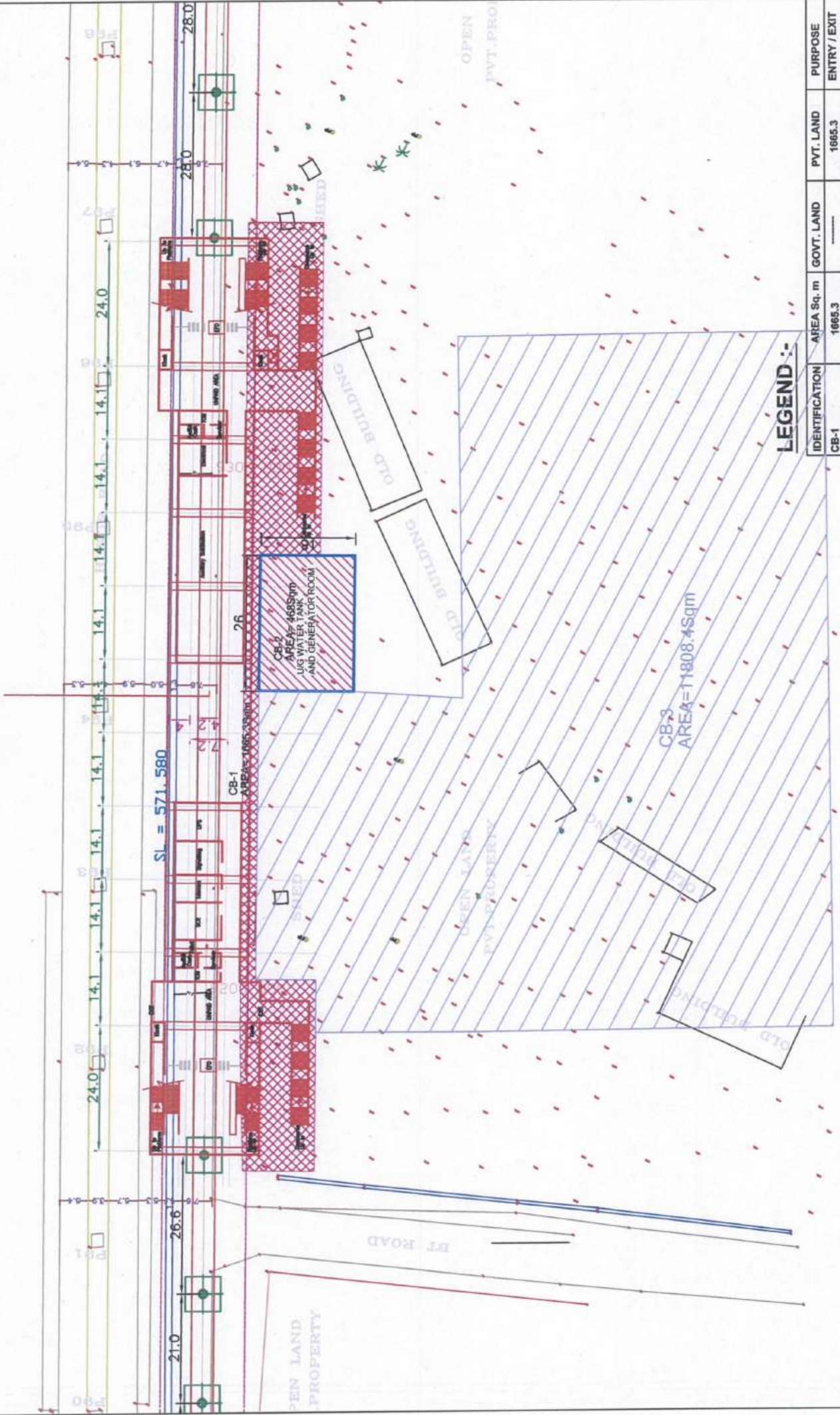
**7**  
**Muneshwara Nagar**  
**CH: 7858.2m**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
MN-1	322.2	-----	322.2	ENTRY / EXIT
MN-2	1013.8	-----	1013.8	ENTRY / EXIT
MN-3	601.0	-----	601.0	UTILITIES
MN-4	220.9	-----	220.9	ENTRY / EXIT
<b>TOTAL AREA=</b>	<b>2157.9</b>			





⑧ Chikka Begur  
CH: 9257.5m



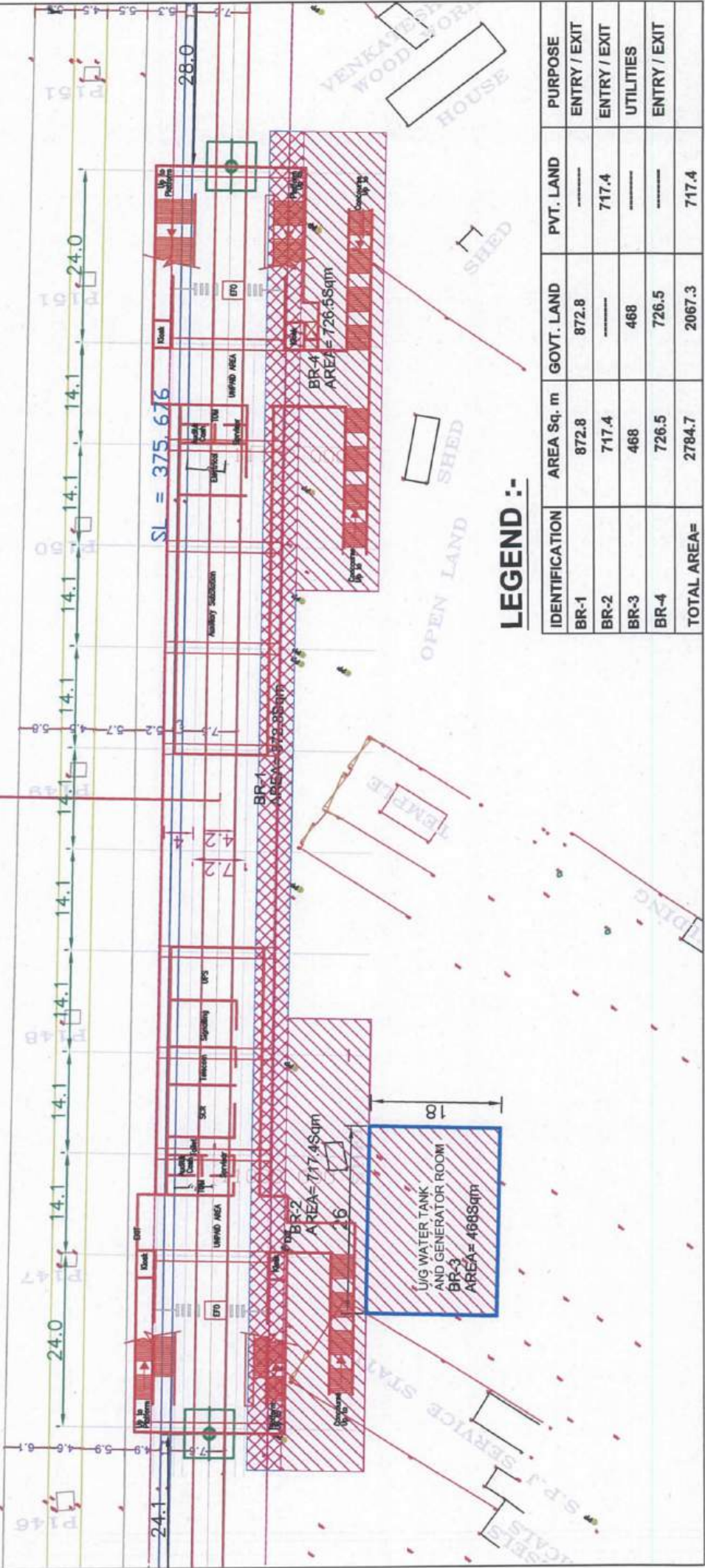
LEGEND :-

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
CB-1	1065.3	-----	1065.3	ENTRY / EXIT
CB-2	468	-----	468	UTILITIES
CB-3	11808.4	-----	11808.4	P.D
TOTAL AREA=	13941.7		13941.7	



**Fig.No. 4.2/10**

**Basapur Road  
CH: 11053.5m**



**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
BR-1	872.8	872.8	-----	ENTRY / EXIT
BR-2	717.4	-----	717.4	ENTRY / EXIT
BR-3	468	468	-----	UTILITIES
BR-4	726.5	726.5	-----	ENTRY / EXIT
<b>TOTAL AREA=</b>	<b>2784.7</b>	<b>2067.3</b>	<b>717.4</b>	

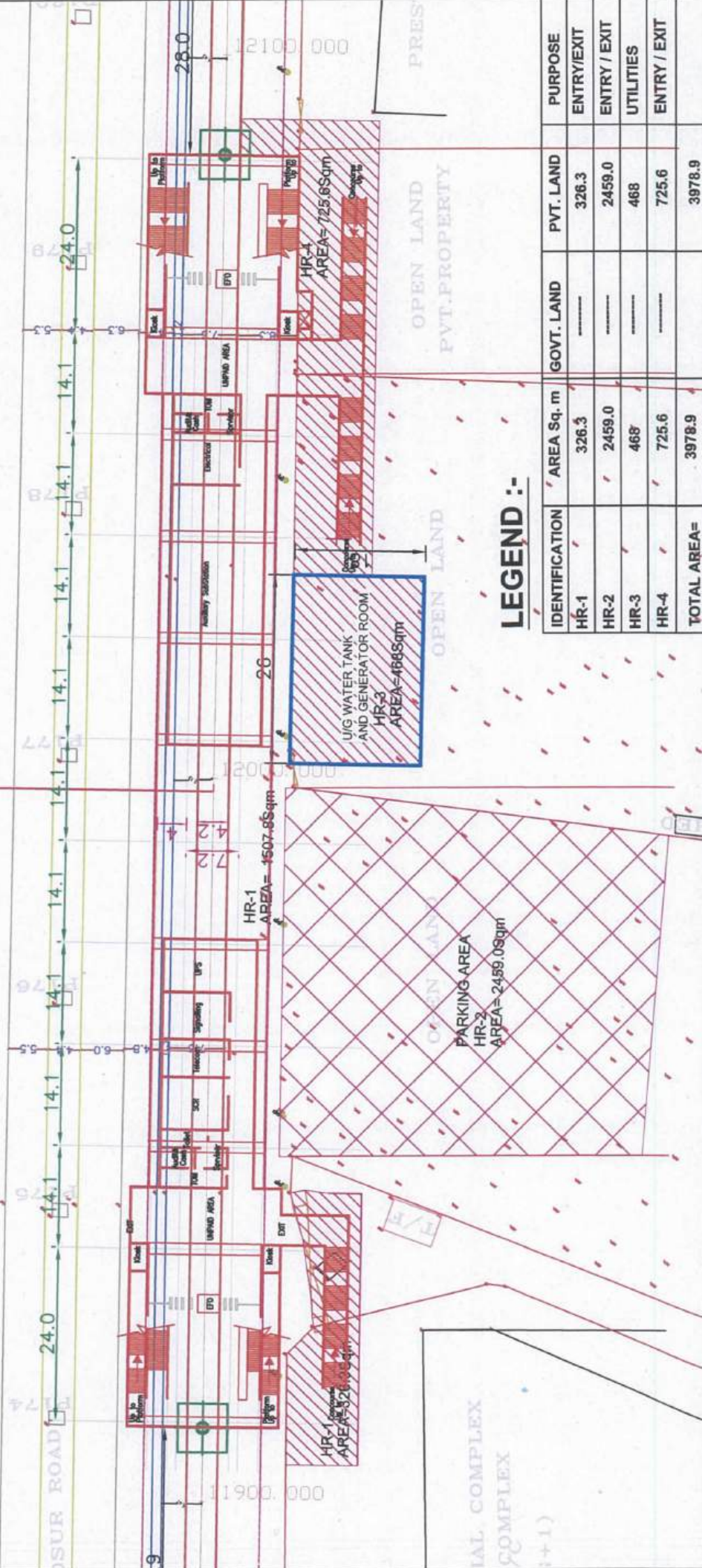


**Fig.No. 4.2/11**

**Hosa Road  
CH: 11998.3m**

**10**

ELEVATED FLY OVER BRIDGE U/C



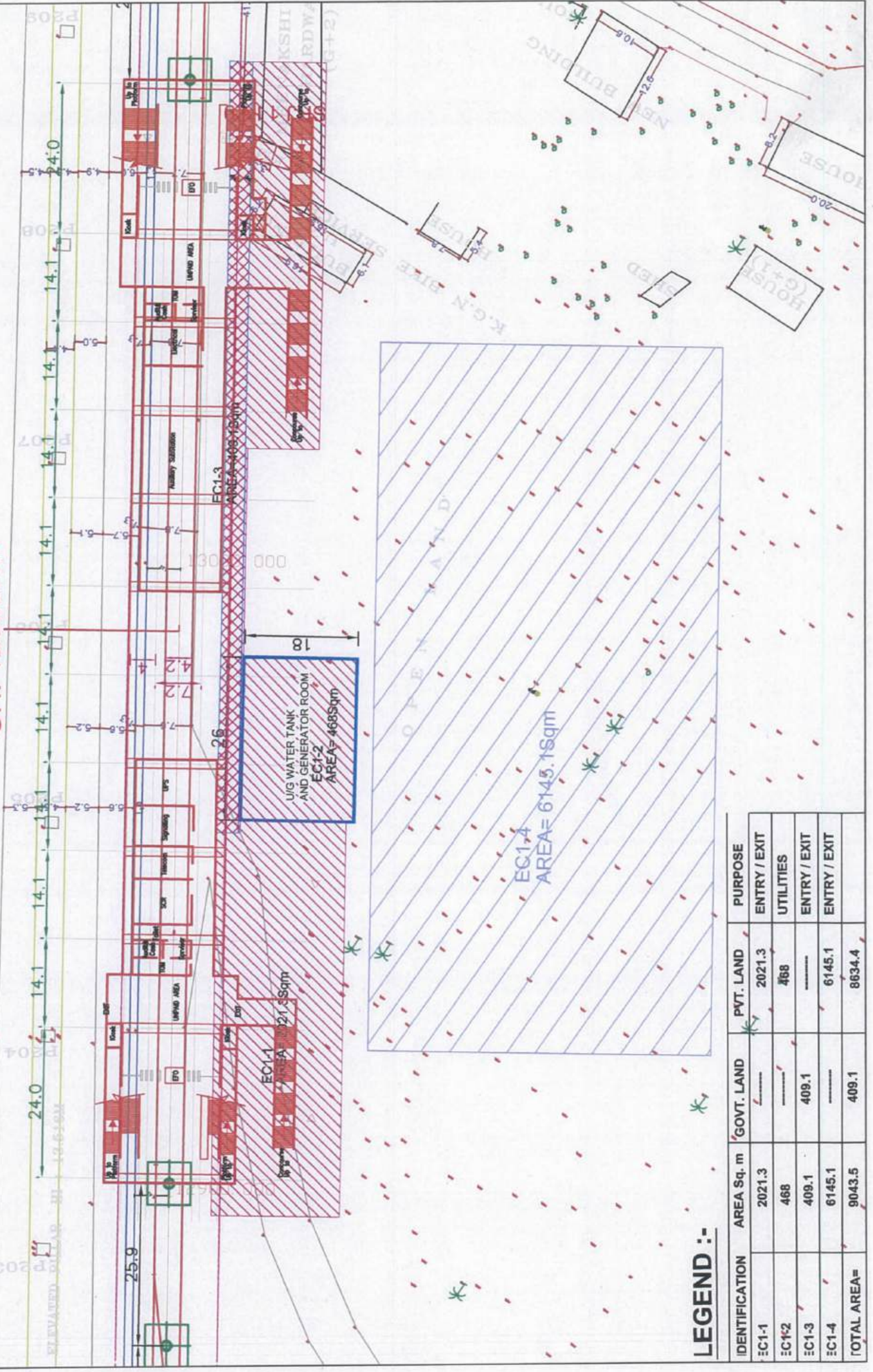
**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
HR-1	326.3	-----	326.3	ENTRY / EXIT
HR-2	2459.0	-----	2459.0	ENTRY / EXIT
HR-3	468	-----	468	UTILITIES
HR-4	725.6	-----	725.6	ENTRY / EXIT
<b>TOTAL AREA=</b>	<b>3978.9</b>		<b>3978.9</b>	



Electronic City - I  
CH: 12990.1m

ELEVATED FLY OVER BRIDGE H: 16.25m



LEGEND :-

IDENTIFICATION	AREA Sq. m	GOVT. LAND		PVT. LAND		PURPOSE	
						ENTRY / EXIT	UTILITIES
EC1-1	2021.3			2021.3		ENTRY / EXIT	
EC1-2	468			468		UTILITIES	
EC1-3	409.1		409.1			ENTRY / EXIT	
EC1-4	6145.1			6145.1		ENTRY / EXIT	
TOTAL AREA=	9043.5		409.1	8634.4			

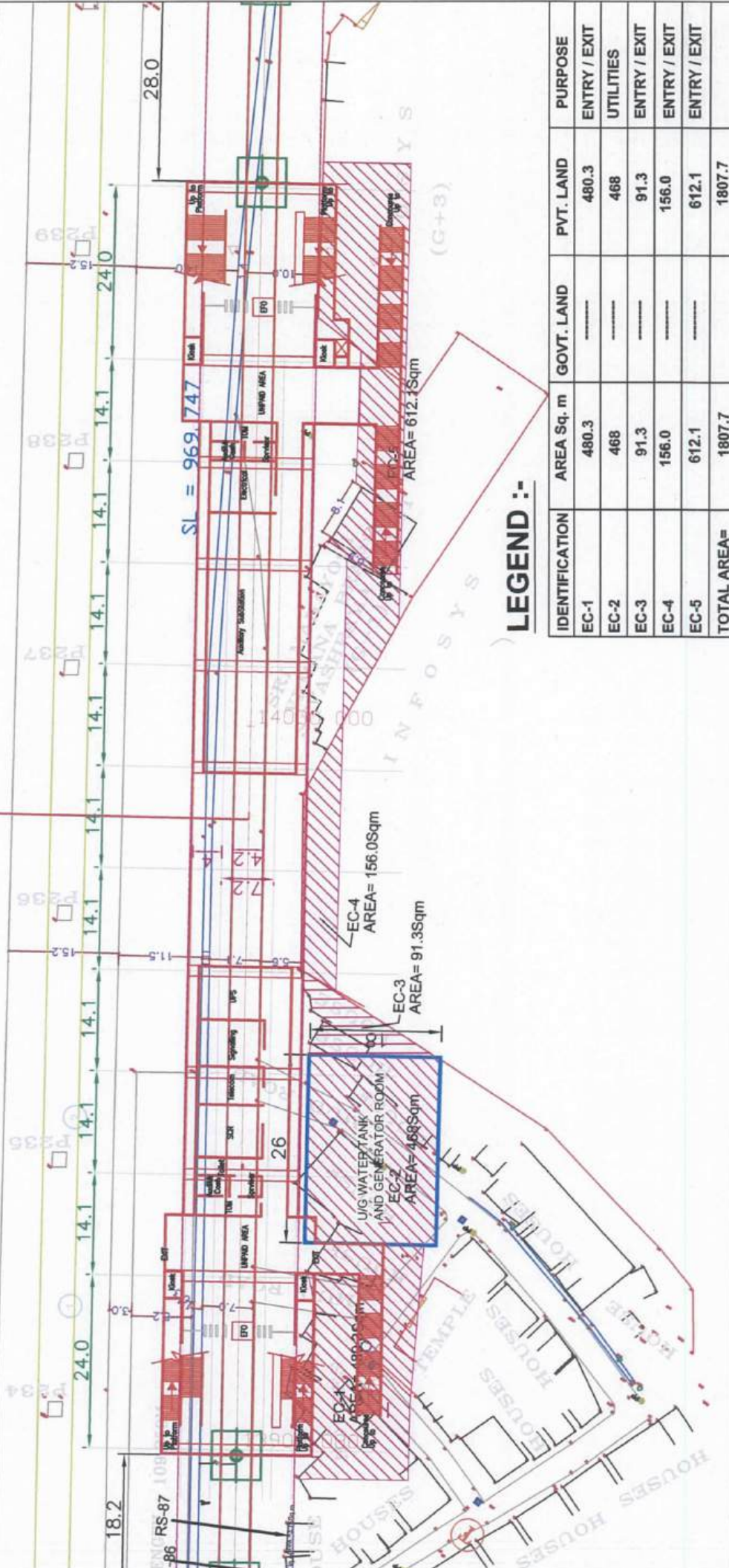


12

Electronic City  
CH: 13987.2m



ELEVATED FL



**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
EC-1	480.3	-----	480.3	ENTRY / EXIT
EC-2	468	-----	468	UTILITIES
EC-3	91.3	-----	91.3	ENTRY / EXIT
EC-4	156.0	-----	156.0	ENTRY / EXIT
EC-5	612.1	-----	612.1	ENTRY / EXIT
<b>TOTAL AREA=</b>	<b>1807.7</b>		<b>1807.7</b>	





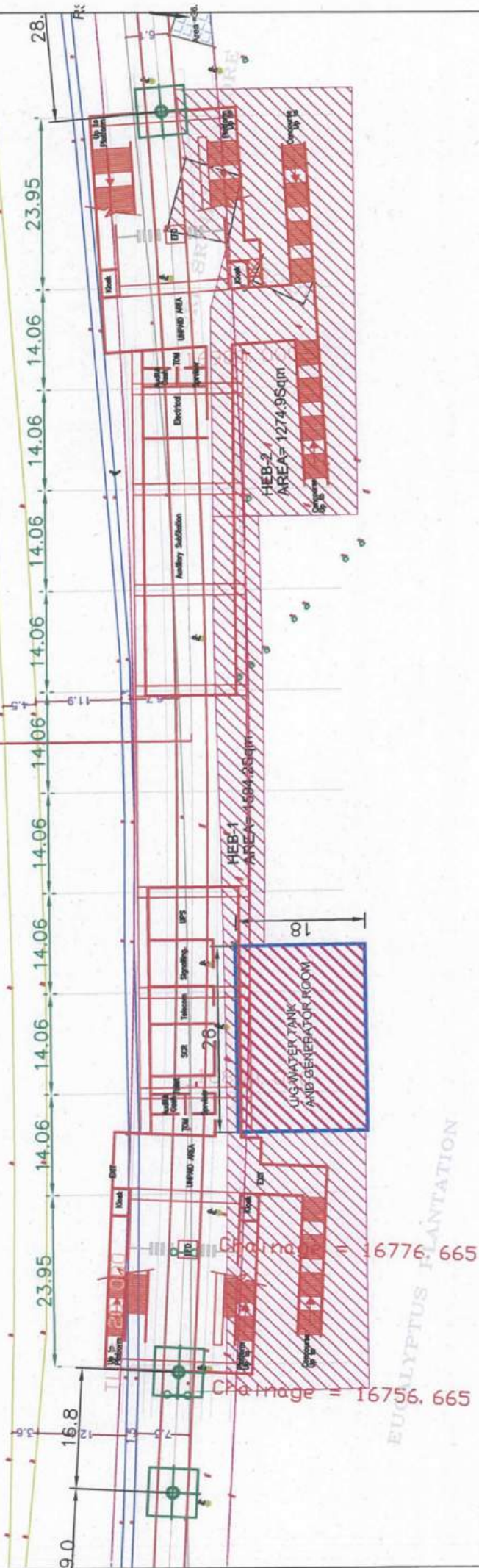


**Fig.No. 4.2/15**

14

Hebbagodi  
CH: 16848.3m

AD



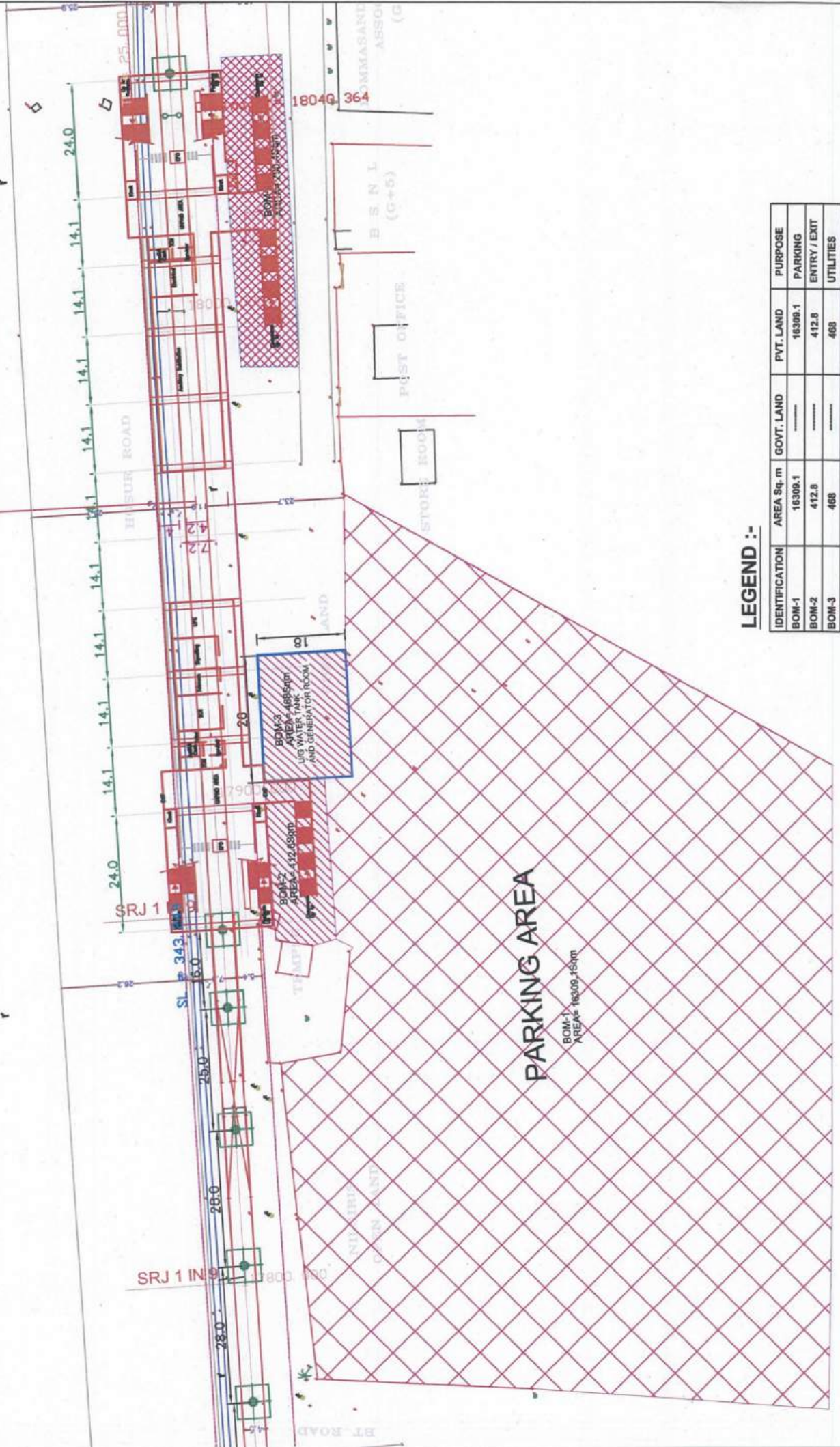
**LEGEND :-**

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
HEB-1	1594.2	1594.2	-----	UTILITIES+ ENTRY/EXIT+PARKING
HEB-2	1274.9	-----	1274.9	ENTRY / EXIT
TOTAL AREA=	2869.1	1594.2	1274.9	



Fig.No. 4.2/16

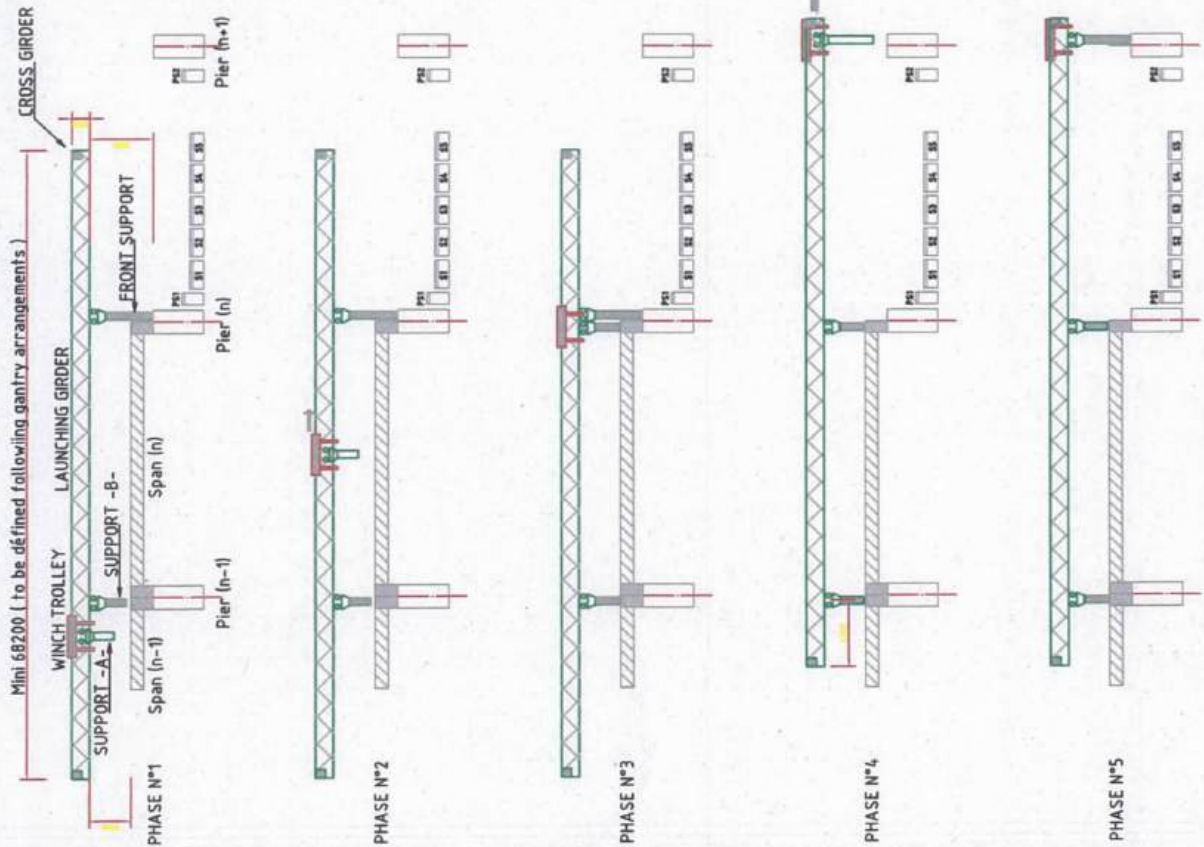
15  
Bommasandra  
CH: 17961.4m



LEGEND :-

IDENTIFICATION	AREA Sq. m	GOVT. LAND	PVT. LAND	PURPOSE
BOM-1	19309.1	-----	19309.1	PARKING
BOM-2	412.8	-----	412.8	ENTRY / EXIT
BOM-3	468	-----	468	UTILITIES
BOM-4	790.4	790.4	-----	ENTRY / EXIT
TOTAL AREA <sup>W</sup>	17980.3	790.4	17189.9	





**GENERAL NOTE**

- ( 1 ) THE FOLLOWING SEQUENCES DESCRIBE THE LAUNCHING AND ASSEMBLY OF SEGMENTS OF A 25m SPAN IN STRAIGHT OR CURVED ALIGNMENT .  
FOR SMALLER SPANS THE SEQUENCES ARE IDENTICAL.
- ( 2 ) THESE SEQUENCES DO NOT REFLECT THE FIRST AND LAST SPANS OF THE SECTION.

1 : THE TWO PIER SEGMENTS AND FIVE TYPICAL SEGMENTS OF 25m SPAN ( n+1 ) STORED BETWEEN PIERS SPAN ( n ) PRESTRESSED.

2 : A-SUPPORT LIFT UP AND TRANSFERRED BY THE WINCH TROLLEY.

3 : A-SUPPORT PUT ON THE RIGHT PIER SEGMENT OF SPAN ( n ) . TENSIONING OF SUPPORT JACKS OF A-SUPPORT.

4 : RELEASE OF SUPPORT JACKS OF FRONT SUPPORT . FRONT SUPPORT HANGED UP TO LAUNCHING GIRDER . LAUNCHING OF THE GANTRY UP TO PIER ( n+1 )

5 : TENSIONING OF SUPPORT JACKS OF FRONT SUPPORT.

ALL DIMENSIONS ARE TENTATIVE AND LIKELY TO CHANGE DURING DETAIL DESIGN		Certified that this document has been designed and checked in accordance with DMRC Quality Assurance Plan		(Name and Designation) Authorised Signatory for DMRC	
DRAWN BY		<b>BANGALORE METRO PROJECT</b> LAUNCHING SCHEME OF PRE CAST SEGMENTAL CONSTRUCTION OF SUPERSTRUCTURE Fig : 4.3/1 REV.      SCALE ----- STATUS			
CHECKED BY					
VERIFIED BY					
DATE					

**DELHI METRO RAIL CORPORATION LTD.**  
 METRO BHAWAN, BARAKHAMBHA ROAD,  
 NEW DELHI - 110 001

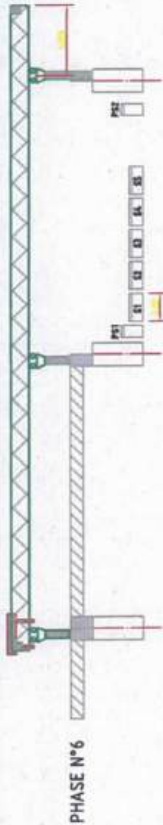
REF. NO.	DESCRIPTION

REV.	PARTICULARS	DRN.	CHGD.	VER.	DATE

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**GENERAL NOTE**

- (1) THE FOLLOWING SEQUENCES DESCRIBE THE LAUNCHING AND ASSEMBLY OF SEGMENTS OF A 25 m SPAN IN STRAIGHT OR CURVED ALIGNMENT. FOR SMALLER SPANS THE SEQUENCES ARE IDENTICAL.
- (2) THESE SEQUENCES DO NOT REFLECT THE FIRST AND LAST SPANS OF THE SECTION.



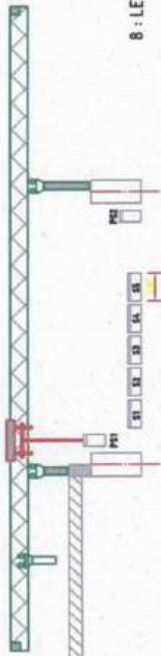
PHASE N°6

6 : LAUNCHING OF THE GANTRY ON 4.20m.



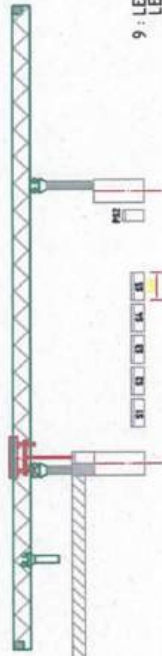
PHASE N°7

7 : RELEASE OF SUPPORT JACKS OF B-SUPPORT. TRANSPORTATION OF B-SUPPORT BY WINCH TROLLEY. LAUNCHING OF THE GANTRY TO THE ASSEMBLY POSITION.



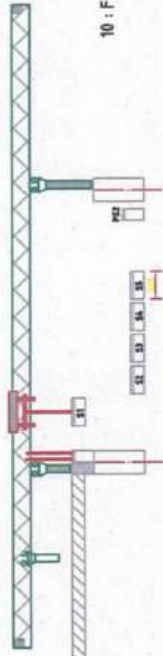
PHASE N°8

8 : LEFT PIER SEGMENT PS1 OF SPAN ( n+1 ) LIFT UP BY WINCH TROLLEY.



PHASE N°9

9 : LEFT PIER SEGMENT PS1 OF SPAN ( n+1 ) POSITIONNED TO DECK LEVEL. LEFT PIER SEGMENT PS1 OF SPAN ( n+1 ) HANGED UP TO GIRDERS BY HANGING BARS.



PHASE N°10

10 : FIRST TYPICAL SEGMENT S1 OF SPAN ( n+1 ) LIFT UP BY WINCH TROLLEY.

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 NEW DELHI - 110 003

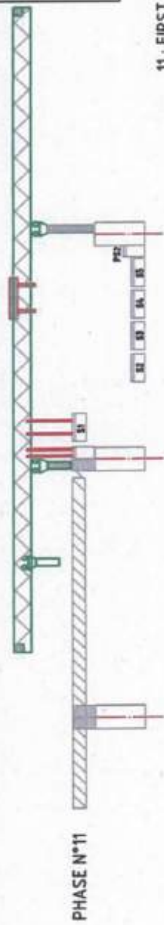
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<b>BANGALORE METRO PROJECT</b>	
LAUNCHING SCHEME OF PRE CAST SEGMENTAL CONSTRUCTION OF SUPERSTRUCTURE	
REV.	SCALE
-----	-----
STATUS	

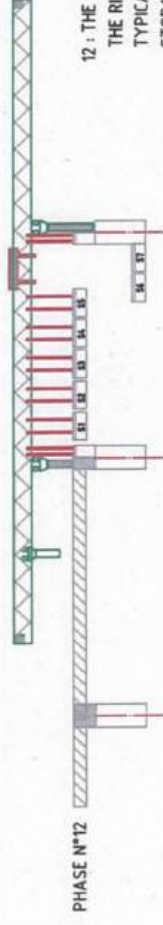


**GENERAL NOTE**

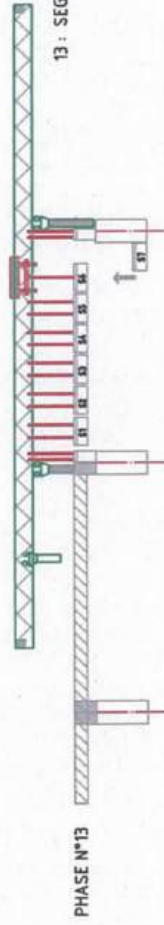
- (1) THE FOLLOWING SEQUENCES DESCRIBE THE LAUNCHING AND ASSEMBLY OF SEGMENTS OF A 25m SPAN, IN STRAIGHT OR CURVED ALIGNMENT. FOR SMALLER SPANS THE SEQUENCES ARE IDENTICAL.
- (2) THESE SEQUENCES DO NOT REFLECT THE FIRST AND LAST SPANS OF THE SECTION.



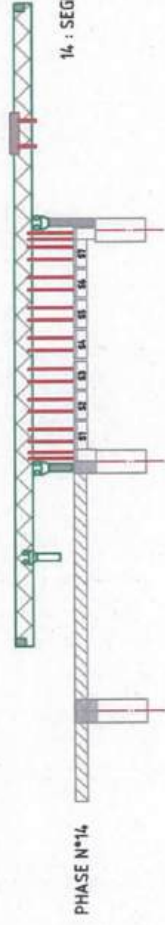
11 : FIRST TYPICAL SEGMENT S1 OF SPAN ( n+1 ) POSITIONED TO DECK LEVEL.  
FIRST TYPICAL SEGMENT S1 OF SPAN ( n+1 ) HANGED UP TO GIRDERS BY HANGING BARS.



12 : THE TWO PIER SEGMENTS AND FIVE TYPICAL SEGMENTS POSITIONED AND HANGED UP BY HANGING BARS.  
THE RIGHT PIER SEGMENTS PS2 OF SPAN ( n+1 ) IS POSITIONED 0.40m AHEAD OF ITS DEFINITIVE POSITION.  
TYPICAL SPACE BETWEEN SEGMENTS : e = 0.30m.  
STORAGE OF THE FOUR REMAINING TYPICAL SEGMENTS UNDER THE SPAN.



13 : SEGMENT S6 LIFT UP BY WINCH TROLLEY.



14 : SEGMENTS S7 LIFT UP BY WINCH TROLLEY.



15 : POSITIONING OF SEGMENTS S6, S7  
DISPLACEMENT OF S7 CLOSE TO PIER (n+1)  
APPLICATION OF EPOXY GLUE BETWEEN SEGMENTS

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<b>BANGALORE METRO PROJECT</b>	
LAUNCHING SCHEME OF PRE CAST SEGMENTAL CONSTRUCTION OF SUPERSTRUCTURE	
Fig - 4.3/3	
REV.	SCALE
STATUS	

STRUCTURAL

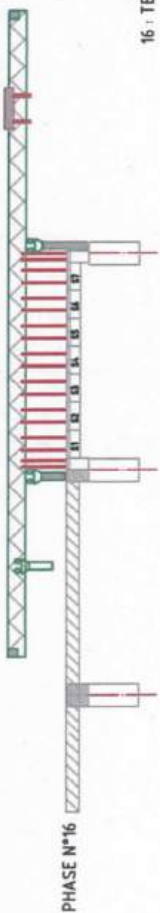
**GENERAL NOTE**

( 1 ) THE FOLLOWING SEQUENCES DESCRIBE THE LAUNCHING AND ASSEMBLY OF SEGMENTS OF A 25m SPAN, IN STRAIGHT OR CURVED ALIGNMENT.

FOR SMALLER SPANS THE SEQUENCES ARE IDENTICAL.

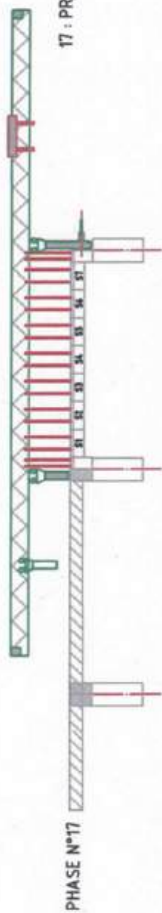
( 2 ) THESE SEQUENCES DO NOT REFLECT THE FIRST AND LAST SPANS OF THE SECTION.

16 : TEMPORARY CLAMPING OF SEGMENTS (CLOSURE OF JOINTS BY TEMPORARY PT BARS OR STRANDS).



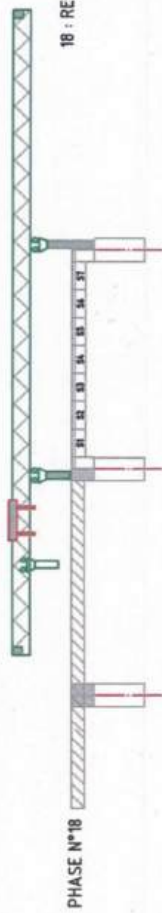
PHASE N°16

17 : PRESTRESSING OF THE ENTIRE SPAN ( n+1 ).



PHASE N°17

18 : RELEASE OF HANGING BARS.



PHASE N°18

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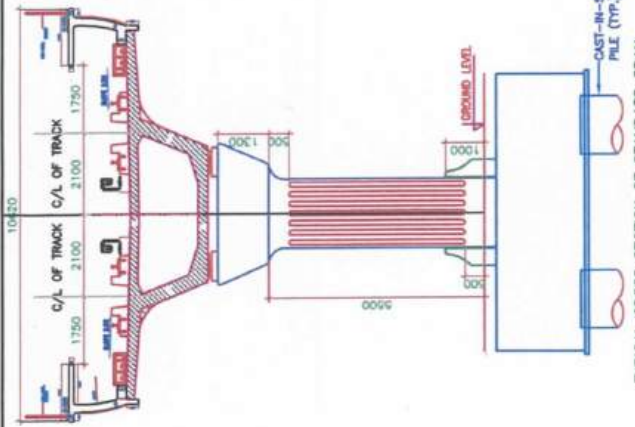
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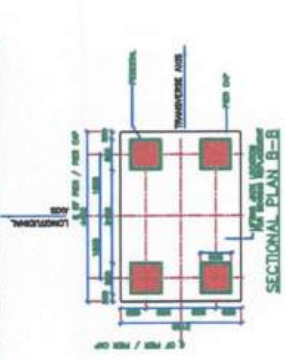
<b>BANGALORE METRO PROJECT</b>	
LAUNCHING SCHEME OF PRE CAST SEGMENTAL CONSTRUCTION OF SUPERSTRUCTURE	
Fig : 4.3/4	
REV.	SCALE
	STATUS

STRUCTURAL

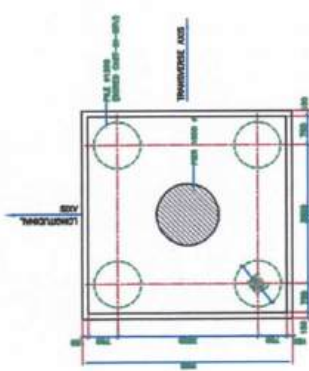




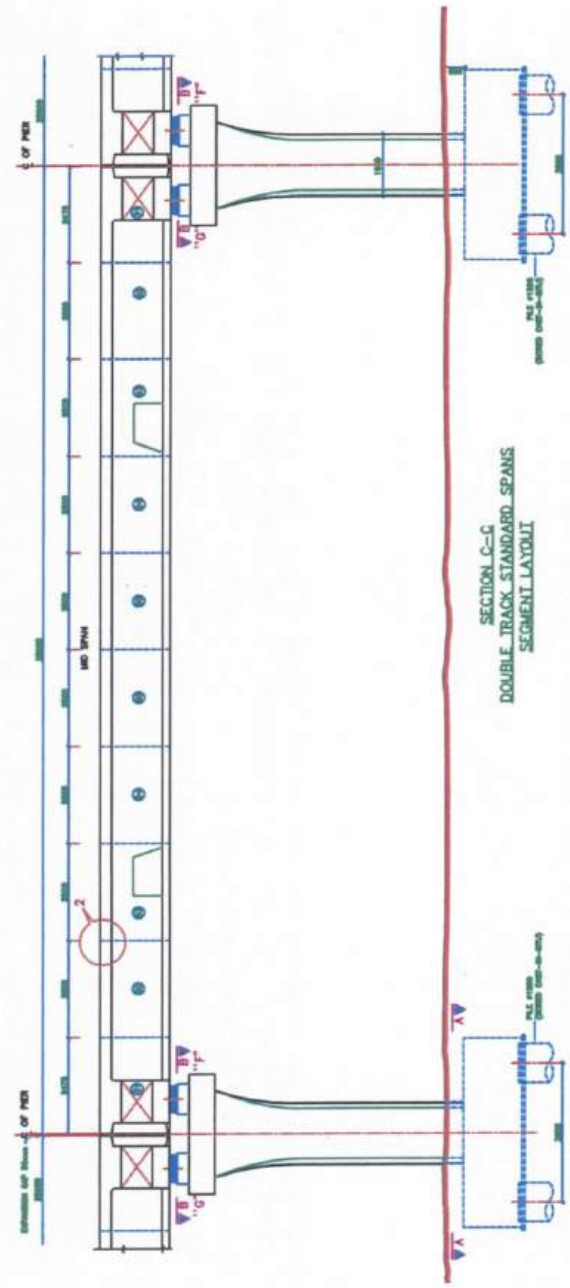
TYPICAL CROSS SECTION OF STANDARD SPAN



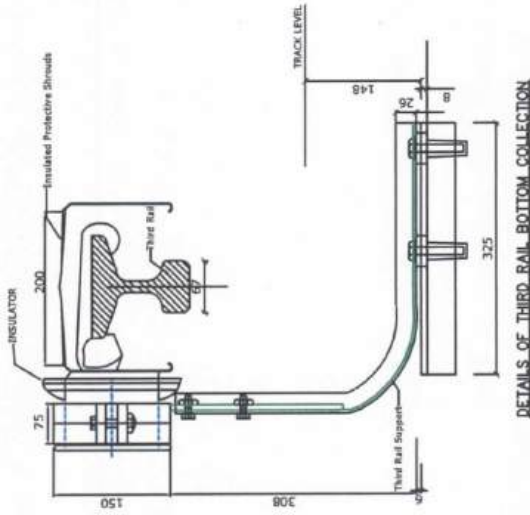
SECTIONAL PLAN B-B



SECTIONAL PLAN A-A



SECTION C-C  
DOUBLE TRACK STANDARD SPANS  
SEGMENT LAYOUT



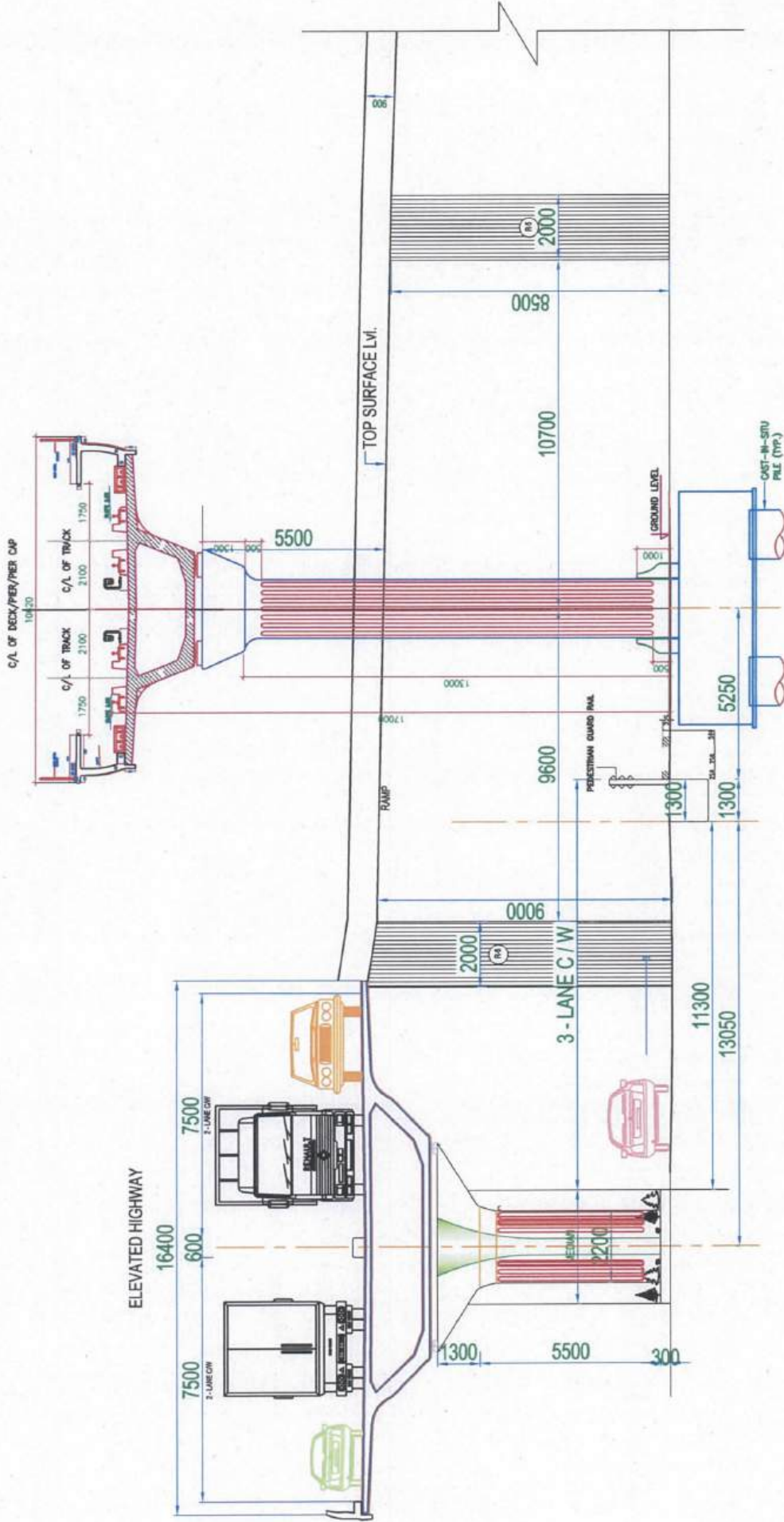
DETAILS OF THIRD RAIL BOTTOM COLLECTION

NOTE  
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PROPERTY OF DMRC PROPERTY OF DMRC LTD.	ARTICULARS	DATE	CHKD	VER	DATE	<p><b>DELHI METRO RAIL CORPORATION LTD.</b> METRO BHAWAN, BHAIKARHATIA ROAD NEW DELHI - 110 003</p>	DATE	VERIFIED BY	SCALE	<p><b>BANGALORE METRO PROJECT</b> GENERAL ARRANGEMENT OF STANDARD SPAN BOX GIRDER WITH EXTERNAL PRESTRESSING</p>	<p>FIGURE - 4.3/5/23</p>
	REFERENCE DRAWINGS	DESCRIPTION	DRAWN BY	CHECKED BY	DATE		DRG. NO.	REV	STATUS		

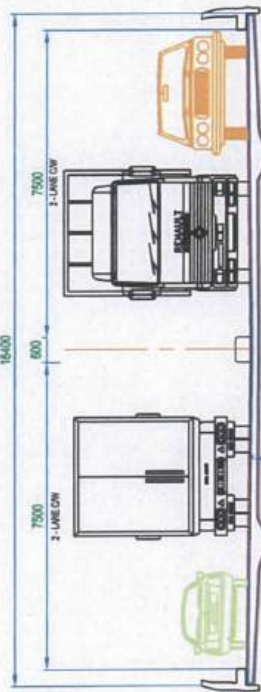


(SECTION E - E)  
 Cross Section at the location of Ramp to Bommasandra

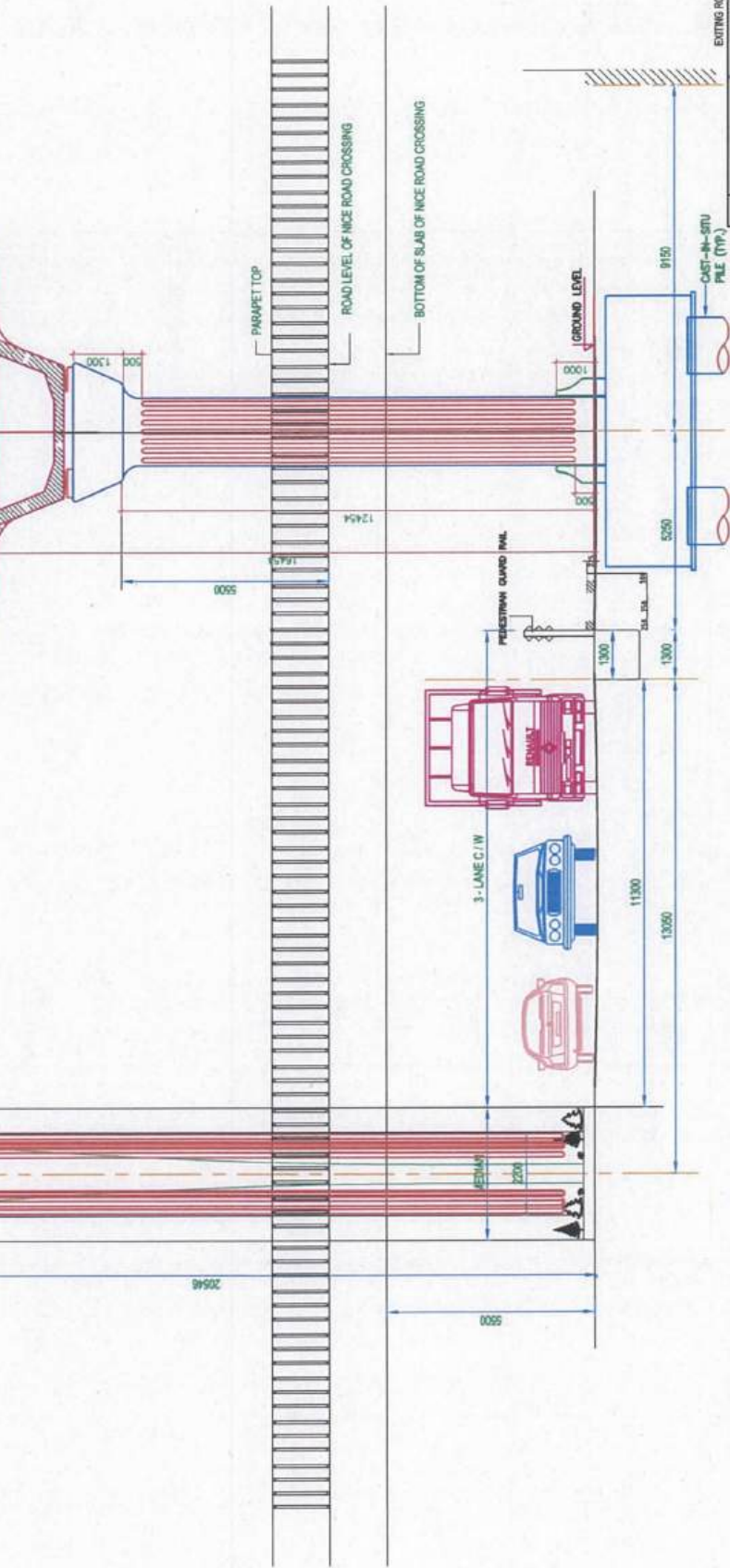
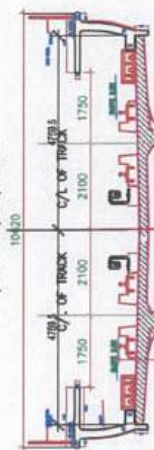
<b>DELHI METRO RAIL CORPORATION LTD.</b> <small>Proposed Schematic Diagram of Elevated Highway and Metro</small>	
<b>Project:</b> Proposed Schematic Diagram of Elevated Highway and Metro <b>Location:</b> Bangalore Metro Rail Echn. In Bommasandra on Hechal Road	
<b>Prepared by:</b> E.E. BHARVA <b>Checked by:</b> S.S. BHARVA <b>Date:</b> 02.08.2011	<b>Scale:</b> NTS <b>Sheet No.:</b> 1/1
<b>Project No.:</b> V-08/2010/HALETT/2011 <b>Sheet No.:</b> 1/1	<b>Date:</b>



ELEVATED HIGHWAY



C/A. OF DECK/PIER/PIER CAP

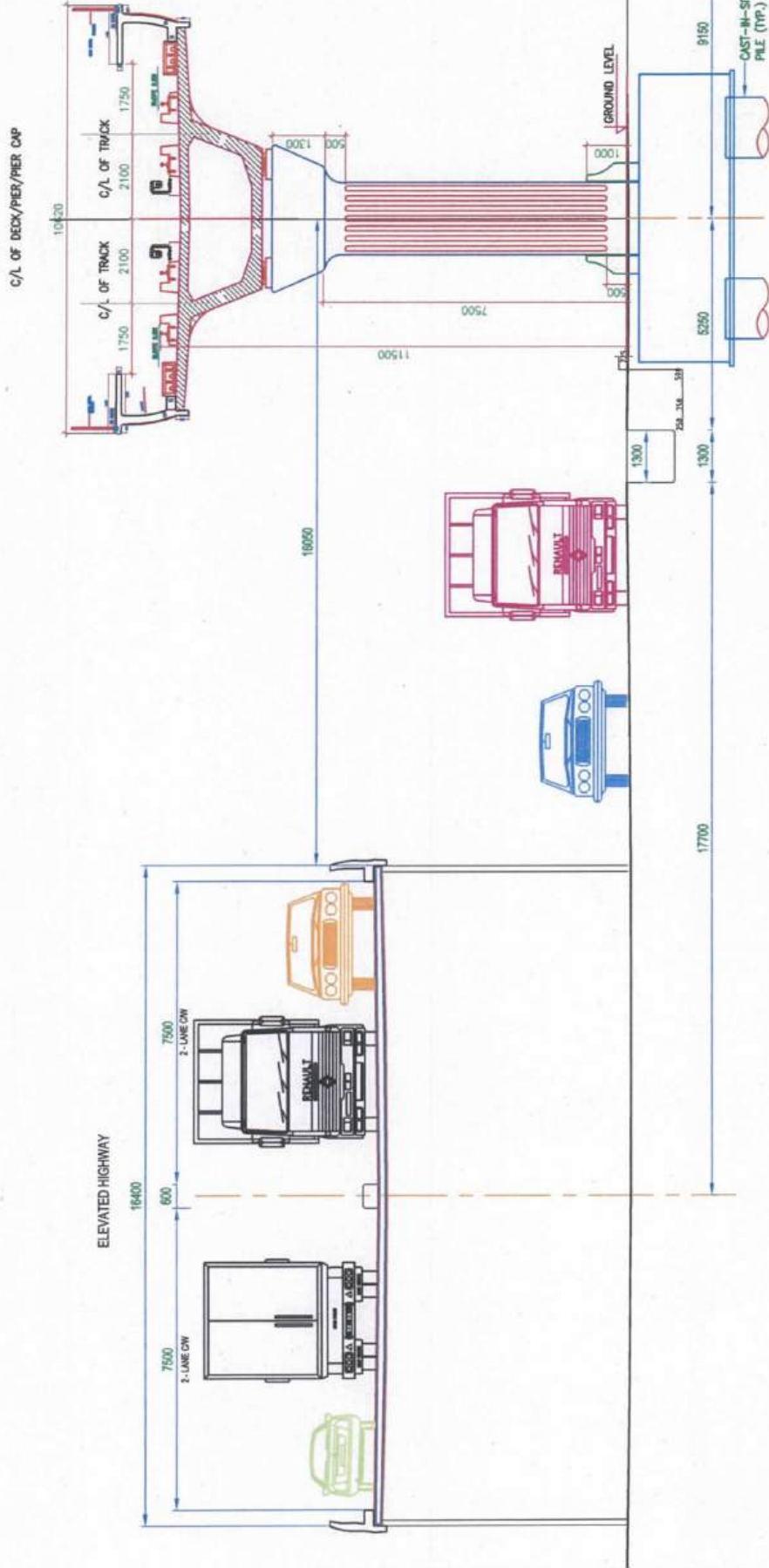


EXITING ROW EXISTING BUILDING LINE

<b>DELHI METRO RAIL CORPORATION LTD.</b> <small>Proposed Schematic Diagram of Elevated Highway and Metro</small>	
<b>Project:</b> Proposed Schematic Diagram of Elevated Highway and Metro <b>Location:</b> Bangalore Metro Rail Extn. to Bommasandra on Hoisar Road	
<b>Author:</b> S.P. SHARMA <b>Scale:</b> 1:1000	<b>Checked:</b> S.S. SHARMA <b>Scale:</b> NTS
<b>Date:</b> 02.05.2011 <b>Project No.:</b> NTS	<b>Sheet No.:</b> 2 <b>Scale:</b> 1:1000

(SECTION D - D)

Cross Section along Nice Road facing Hosur



(SECTION A - A)

*Cross Section at the location of Ramp to Bommasandra*

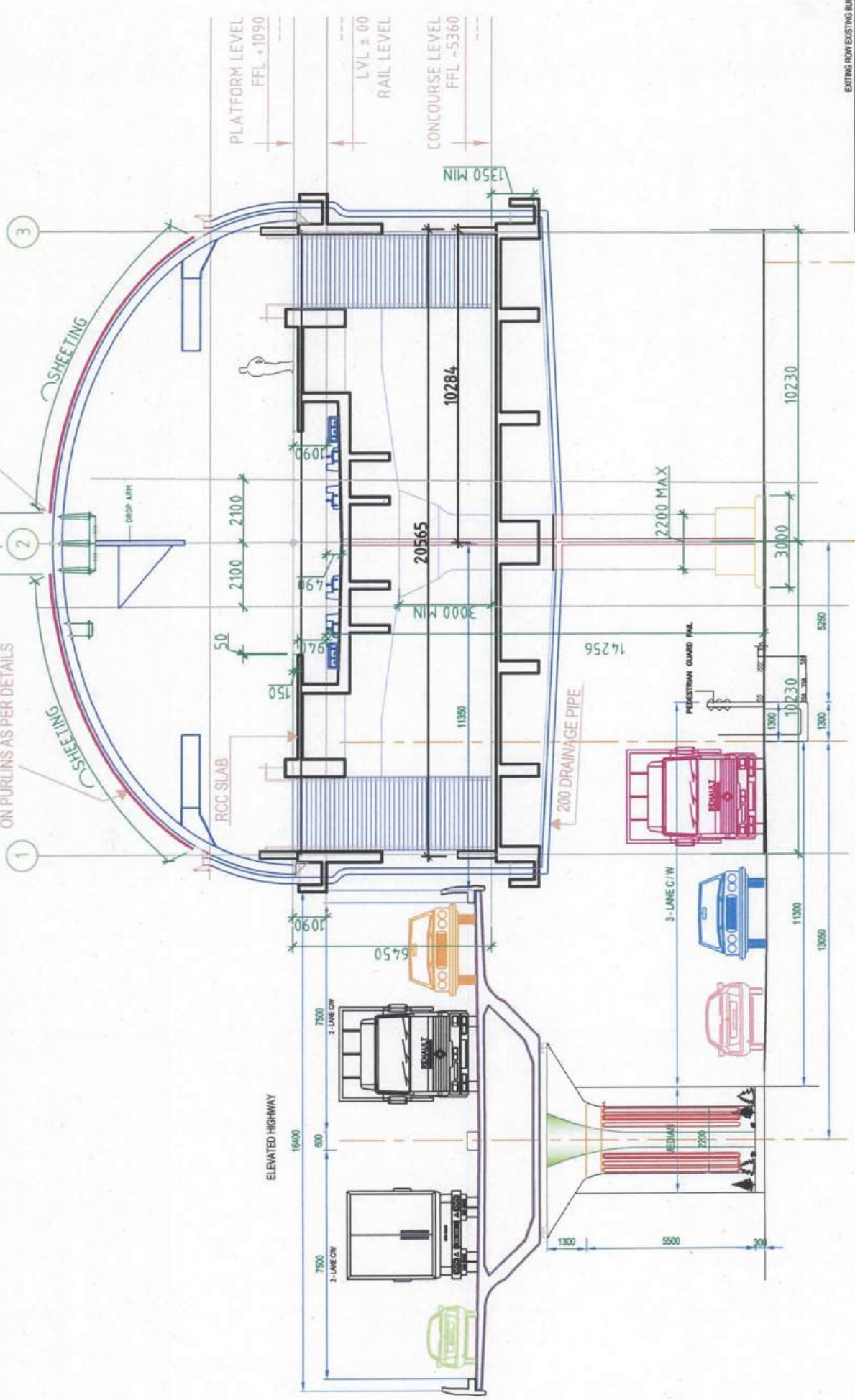
EXISTING ROAD EXISTING BUILDING LINE

<b>DELHI METRO RAIL CORPORATION LTD.</b> Proposed Baramahal Division of Elevated Highway and Metro Corridor Bangalore Metro Rail Estn. to Bommasandra on IIC Road Corridor			
DATE	01.05.2011	SCALE	1:15
DESIGNED BY		CHECKED BY	
DRAWN BY		APPROVED BY	
PROJECT NO. 11/2007		SHEET NO. 3	



MS HOLLOW BUILT UP SECTION  
 PORTAL WITH GALVULUME  
 CORRUGATED SHEETING SUPPORTED  
 ON PURLINS AS PER DETAILS

OPEN TO SKY



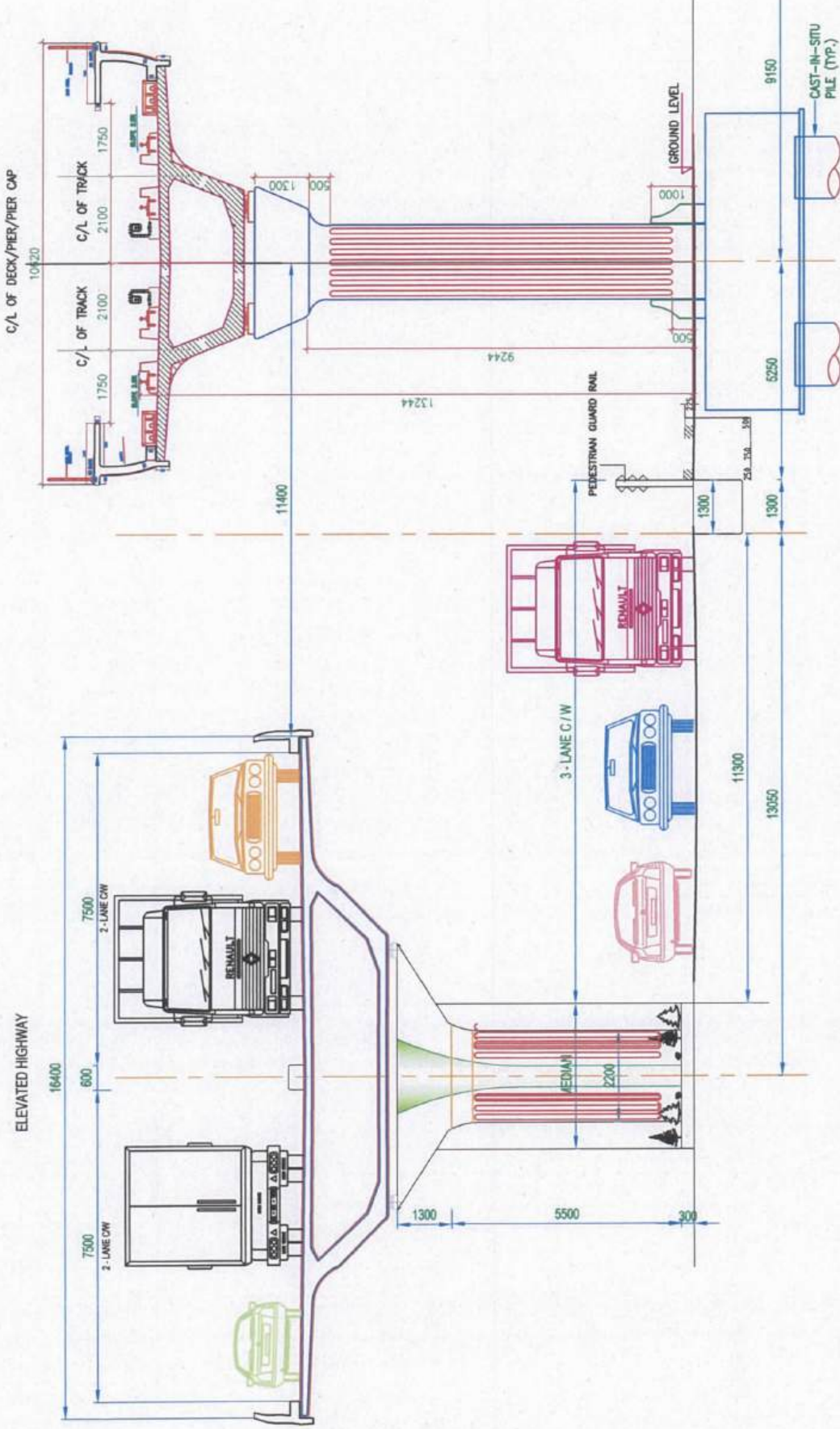
(SECTION B - B)

Cross Section on the Silk Board side Ramp of Elevated Expressway on Housur Road

EXISTING ROW EXISTING BUILDING LINE

<b>DELHI METRO RAIL CORPORATION LTD.</b>	
Proposed Schematic Diagram of Elevated Highway and Metro	
Bangalore Metro Rail Extn. to Bommasandra on Housur Road	
APPROVED BY:	PREPARED BY:
DATE: 02.05.2011	SCALE: 1:50
PROJECT NO: HRS/01/01/01/01/01	SHEET NO: 5



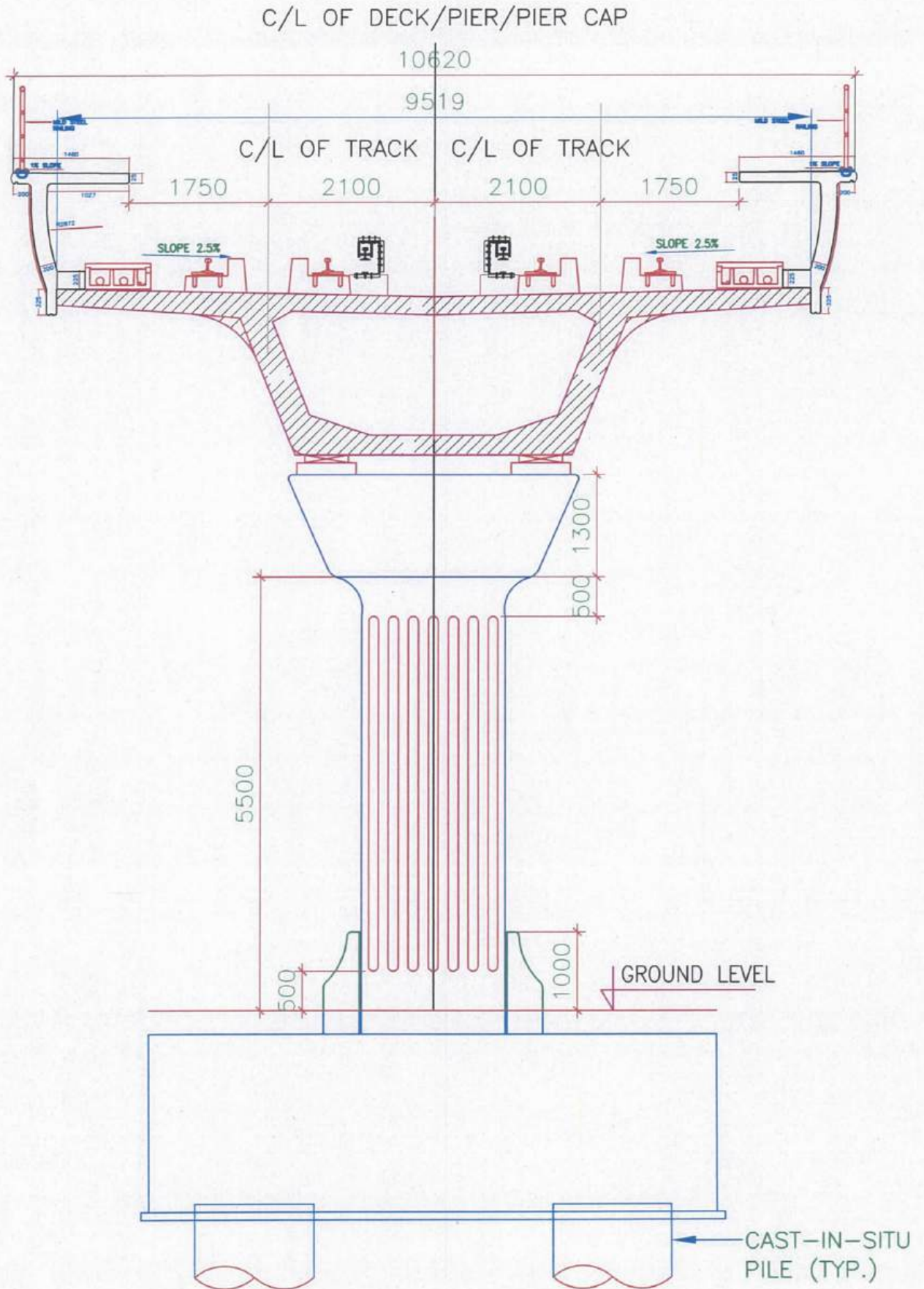


(SECTION C - C)

Cross Section on the Silk Board side Ramp of Elevated Expressway on Housur Road

EXISTING ROW EXISTING BUILDING LINE

<b>DELHI METRO RAIL CORPORATION LTD.</b> <small>Proposed Schematic Diagram of Elevated Highway and Metro</small>	
<b>Project:</b> Bangalore Metro Rail Extn. to Dommasandra on Housur Road	
<b>Contract:</b>	<b>Proposed by:</b>
<b>E.E. DRAWN:</b>	<b>E.O. DRAWN:</b>
<b>DATE:</b> 02.05.2011	<b>SCALE:</b> NTS
<b>DESIGNED BY:</b>	<b>CHECKED BY:</b>
<b>APPROVED BY:</b>	<b>DATE:</b>



TYPICAL CROSS SECTION OF VIADUCT

<b>DELHI METRO RAIL CORPORATION LTD.</b>			
<b>TITLE:</b> TYPICAL CROSS SECTION OF VIADUCT OF Bangalore Metro Rail Extn. to Bommasandra on Hosur Road			
<b>APPROVED BY:</b> S.D. SHARMA	<b>DESIGN BY:</b> S.D. SHARMA	<b>PREPARED BY:</b> SUNIL DUTT	
<b>DATE:</b> 02.06.2011	<b>REV.:</b>	<b>SCALE:</b> NTS	
<b>DRAWING NO.:</b> DMRC/ X-SECTION /BAN EXT./2011	<b>SHEET NO.:</b> 6	<b>SHEET SIZE:</b> A4	



**CHAPTER-5**

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**TRAIN OPERATION PLAN**



## CHAPTER 5

### TRAIN OPERATION PLAN

#### 5.1 Operation Philosophy

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

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

#### 5.2 Stations

List of stations for the RV Road-Electronic City –Bommasandar Corridor of Bangalore Metro are given below:

RV Road-Electronic City –Bommasandar Corridor			
S.No	Name of Stations	Change (in m)	Inter – Station Distance (in km)
	Dead End	(-) 450.00	
1	RV Road Terminal	0.00	450
2	Ragigudda Temple	1255.5	1255.5
3	Jayadev Hospital Compound	2454.3	1128.4
4	BTM Layout	3582.7	960.4
5	Silk Board Junction	4543.1	1217.9
6	HSR Layout	5761.0	1199.8
7	Oxford College	6960.8	897.4
8	Muneshwara Nagar	7858.2	897.4
9	Chikka Begur	9257.5	1399.3
10	Basapur Road	11053.5	1796
11	Hosa Road	11998.3	944.8
12	Electronic City I	12990.1	991.8

RV Road-Electronic City –Bommasandar Corridor			
S.No	Name of Stations	Change (in m)	Inter – Station Distance (in km)
13	Electronic City	13987.2	997.1
14	Huskur Road	15460.2	1473
15	Hebbagodi	16848.3	1388.1
16	Bommasandra	17961.4	1113.1
	Dead End	18366.4	405

### 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 RV Road-Electronic City –Bommasandra Corridor has been assumed as 34 kmph.

#### 5.3.2 Traffic Demand

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

#### 5.3.3 Train formation

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

The basic unit of 6-car train comprising of DMC + TC + MC + MC + TC + DMC configuration is selected for the Bangalore Metro Corridors for the year 2016, 2021, 2031 and 2041.



### Composition

DMC : Driving Trailer Car

MC : Motor Car

TC : Trailer Car

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

### Capacity @ 6 persons per sqm of standee area:

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

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

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

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

DMC : 322 Passengers (Sitting-43, Crush Standing-279)

TC/MC : 356 Passengers (Sitting-50, Crush Standing-306)

6 Car Train : 2068 Passengers (Sitting-286, Crush Standing-1782)

#### 5.3.4 Train Operation Plan

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

Train operation plan with train carrying **capacity @ 6 persons per square meter of standee area** on Bangalore Metro Corridors is given below:

##### i) Year 2016 (Refer Attachment I/A)

- 8 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 12195 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 15510 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 13078 is in the Section between Jayadev Hospital Compound and BTM and the PHPDT demand in the section between BTM and Silk Board is 12973, demand in the remaining sections is in the range of 10720 to 1086 only. The planned capacity of 12195 (15510 under dense loading) is less than the PHPDT demand in two (zero, with dense loading capacity) sections out of fifteen sections.

With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2016 is tabulated and represented on a chart enclosed as Attachment I/A.

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

- 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 17275 is in the Section between Jayadev Hopsital Compound and BTM and the PHPDT demand in the section between BTM and Silk Board is 17212, demand in the remaining sections is in the range of 15646 to 1906 only. The planned capacity of 16260 (20680 under dense loading) is less than the PHPDT demand in two (zero, with dense loading capacity) sections out of fifteen sections.

With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2021 is tabulated and represented on a chart enclosed as Attachment I/B.

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

- 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 21274 is in the Section between Jayadev Hospital Compound and BTM and the PHPDT demand in the section between BTM and Silk Board is 21193, demand in the remaining sections is in the range of 19176 to 2379 only. The planned capacity of 19512 (24816 under dense loading) is less than the PHPDT demand in two (zero, with dense loading capacity) sections out of fifteen sections.

With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2031 is tabulated and represented on a chart enclosed as Attachment I/C.

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

- 4.5 min Headway with 6-car train.
- Available Peak Hour Peak Direction Capacity of 21680 @ 6 persons per square meter of standee area
- Available Peak Hour Peak Direction Capacity of 27573 @ 8 persons per square meter of standee area under dense loading conditions.
- The maximum PHPDT demand of 23442 is in the Section between Jayadev Hospital Compound and BTM and the PHPDT demand in the section between BTM and Silk Board is 23352, demand in the remaining sections is in the range of 21130 to 2622 only. The planned capacity of 21680 (27573 under dense loading) is less than the PHPDT demand in two (zero, with dense loading capacity) sections out of fifteen sections.

With this planned PHPDT capacity, optimum utilization of Rolling Stock will be achieved and empty running of trains will be considerably reduced. However, the Rolling Stock is designed for carrying higher density loading @ 8 standee passengers per square meter and in the sections in which PHPDT capacity exceeds the planned capacity, overloading during these periods will help in

reducing the demand for increased deployment of Rolling Stock. Traffic demand and train capacity for this corridor in the year 2041 is tabulated and represented on a chart enclosed as Attachment I/D.

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 three sections in different years of operation is tabulated below:

**Capacity Provided for RV Road-Electronic City –Bommasandara Corridor**

Bangalore Metro	YEAR			
	2016	2021	2031	2041
RV Road-Electronic City – Bommasandar Corridor				
Cars/trains	6	6	6	6
Head way (Minutes)	8	6	5	4.5
Max. PHPDT Demand	13078	17275	21274	23442
PHPDT Capacity Available	12195 (15510*)	16260 (20680*)	19512 (24816*)	21680 (27573*)

\* @ 8 persons per square meter of standee area

**5.3.5 Train frequency**

The train operation of RV Road-Electronic City –Bommasandra Corridor of Bangalore Metro provides for the following train frequency:

Name of Corridor	2016		2021		2031		2041	
	Peak Hour h/w	Lean Hour h/w	Peak Hour h/w	Lean Hour h/w	Peak Hour h/w	Lean Hour h/w	Peak Hour h/w	Lean Hour h/w
RV Road - Electronic City- Bommasandar Corridor	8 min	12 to 30min	6 min	8 to 15min	5 min	8 to 15min	4.5 min	6 to 15min

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 train operation plan is presented in **Table 1.1, 1.2, 1.3 & 1.4** for years 2016, 2021, 2031 and 2041 for Bangalore Metro Corridor and enclosed as Attachment II. Number of train trips per direction per day for RV Road - Electronic City-Bommasandra Corridor of Bangalore Metro is worked out as 89 in the year 2016, 138 in the year 2021, 150 in the year 2031 and 169 in the year 2041 respectively. The directional splits for RV Road - Electronic City-Bommasandra Corridor are presented in **Table 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 Bangalore Metro is given in **Table 3** enclosed as Attachment IV.



## 5.4 Year wise rake Requirement

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

Corridor	Year	Headway (min)	No. of Rakes	Rake Consist	No. of Coaches
RV Road - Electronic City- Bommasandra Corridor	2016	8	11	6 car	66
	2021	6	15	6 car	90
	2031	5	17	6 car	102
	2041	4.5	19	6 car	114

Requirements of coaches is calculated based on following assumptions-

### Assumptions -

- (i) Train Composition planned as under  
6 car Train Composition: DMC + TC + MC + MC + TC+ DMC  
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 train per section to cater to failure of train on line and to make up for operational time lost.
- (iv) Repair and maintenance reserve has been estimated as 8 % of total requirement (Bare +Traffic Reserve).
- (v) The calculated number of rakes in fraction is rounded off to next higher number.
- (vi) Schedule speed is taken as 34 kmph
- (vii) Total Turn round time is taken as 6 min at terminal station

## 5.5 Rolling Stock

### 5.5.1 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.

### 5.5.2 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 5.1.

**Table 5.1 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

**5.5.3 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.

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

Table 5.2 and 5.3 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 5.2  
Carrying Capacity of Mass Rail Vehicles (Crush@6 Person/sqm of standee area)**

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
<b>Seated</b>	43	43	50	50	286	286
<b>Standing</b>	105	210	115	230	670	1340
<b>Total</b>	148	253	165	280	956	1626

NORMAL-3 Person/sqm of standee area

CRUSH -6 Person/sqm of standee area

**Table 5.3**  
**Carrying Capacity of Mass Rail Vehicles (Crush@8 Person/sqm of standee area)**

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
<b>Seated</b>	43	43	50	50	286	286
<b>Standing</b>	105	279	115	306	670	1782
<b>Total</b>	148	322	165	356	956	2068

NORMAL-3 Person/sqm of standee area

CRUSH -8 Person/sqm of standee area

#### 5.5.4 WEIGHT

The weights of motorcar and trailer cars have been estimated as in Table 5.4, referring to the experiences in Delhi Metro. The average passenger weight has been taken as 65 kg.

**Table 5.4 Weight of Mass Rail Vehicles (TONNES)**

	DMC	TC	MC	6 Car train
<b>TARE (maximum)</b>	36	32	34	240
<b>Passenger</b>				
(Normal)	9.62	10.73	10.73	62.14
(Crush @6p/sqm)	16.44	18.20	18.20	105.69
(Crush @8p/sqm)	20.93	23.14	23.14	134.72
<b>Gross</b>				
(Normal)	45.62	42.73	44.73	266.14
(Crush @6p/sqm)	52.44	50.20	52.20	309.69
(Crush @8p/sqm)	56.93	55.14	57.14	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**.

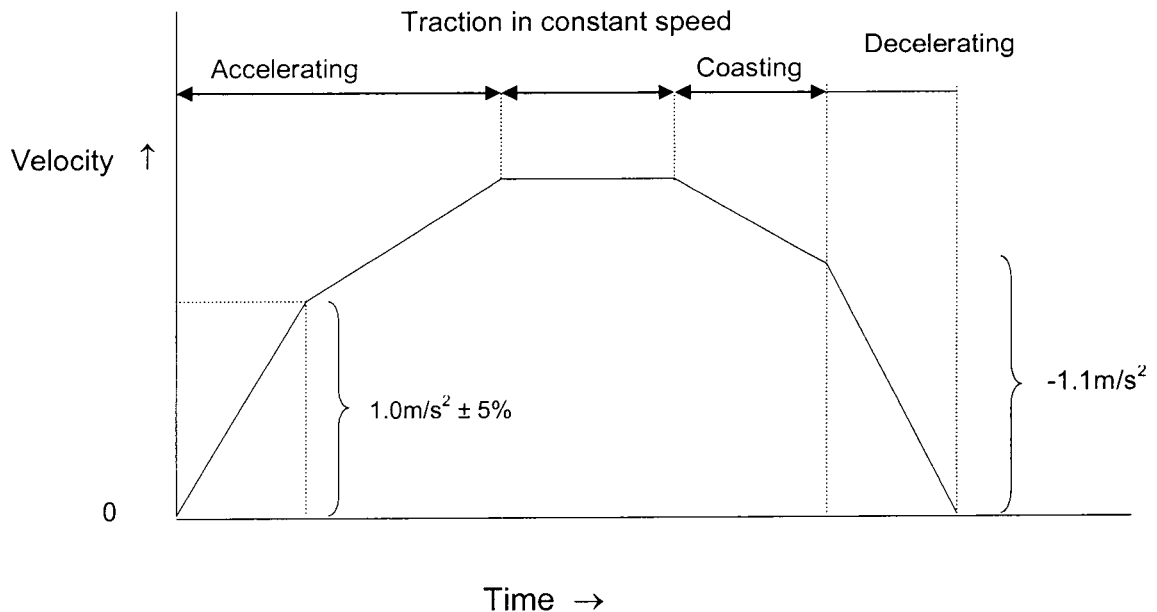
#### 5.5.5 Performance Parameters

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  $1.1 \text{ m/s}^2$  (Normal brake)  
 More than  $1.3 \text{ m/s}^2$  (Emergency brake)



### 5.5.6 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.

### 5.5.7 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-

### 5.5.8 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 carbody.

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.

#### **5.5.9 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.

#### **5.5.10 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.

#### **5.5.11 Propulsion System Technology**

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



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

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

The 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.

### 5.5.12 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



### 5.5.13 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



### 5.5.14 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.

### 5.5.15 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.

#### 5.5.16 Communication

The driving cab of the cars are provided with continuous communication with base Operational Control Center and station control for easy monitoring of the individual train in all sections at all the time .

Public Address and Passenger Information Display System is provided in the car so that passengers are continuously advised of the next stoppage station, final destination station, interchange station, emergency situations if any, and other messages. 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.

#### 5.5.17 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.

### 5.5.18 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



**PHPDT Demand and Capacity Chart**  
Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor

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) 8

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	RV Road Terminal	Ragigudda Temple	9684	12195	15510
2	Ragigudda Temple	Jayadev Hospital Compound	10720	12195	15510
3	Jayadev Hospital Compound	BTM Layout	<b>13078</b>	12195	15510
4	BTM Layout	Silk Board Junction	12973	12195	15510
5	Silk Board Junction	HSR Layout	10476	12195	15510
6	HSR Layout	Oxford College	10391	12195	15510
7	Oxford College	Muneshwara Nagar	10037	12195	15510
8	Muneshwara Nagar	Chikka Begur	9283	12195	15510
9	Chikka Begur	Basapur Road	8801	12195	15510
10	Basapur Road	Hosa Road	8224	12195	15510
11	Hosa Road	Electronic City I	7170	12195	15510
12	Electronic City I	Electronic City	5184	12195	15510
13	Electronic City	Huskur Road	4534	12195	15510
14	Huskur Road	Hebbagodi	2724	12195	15510
15	Hebbagodi	Bommasandra	1086	12195	15510

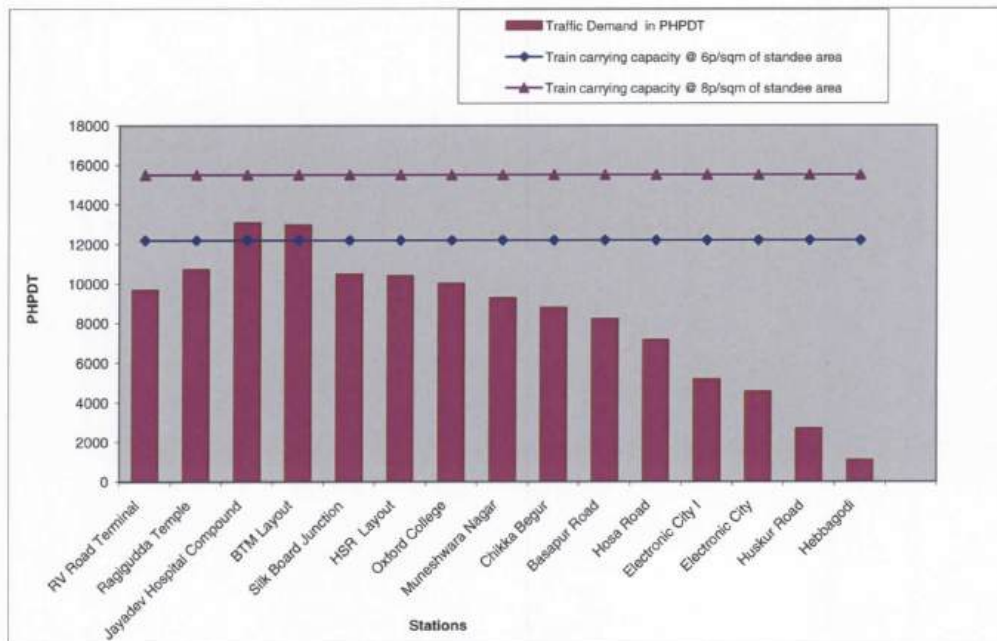


Fig 1.1



**PHPDT Demand and Capacity Chart**

Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor

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) 6

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	RV Road Terminal	Ragigudda Temple	14358	16260	20680
2	Ragigudda Temple	Jayadev Hospital Compound	15646	16260	20680
3	Jayadev Hospital Compound	BTM Layout	17275	16260	20680
4	BTM Layout	Silk Board Junction	17212	16260	20680
5	Silk Board Junction	HSR Layout	14322	16260	20680
6	HSR Layout	Oxford College	13970	16260	20680
7	Oxford College	Muneshwara Nagar	13648	16260	20680
8	Muneshwara Nagar	Chikka Begur	12472	16260	20680
9	Chikka Begur	Basapur Road	11892	16260	20680
10	Basapur Road	Hosa Road	11142	16260	20680
11	Hosa Road	Electronic City I	9735	16260	20680
12	Electronic City I	Electronic City	7016	16260	20680
13	Electronic City	Huskur Road	6248	16260	20680
14	Huskur Road	Hebbagodi	3753	16260	20680
15	Hebbagodi	Bommasandra	1906	16260	20680

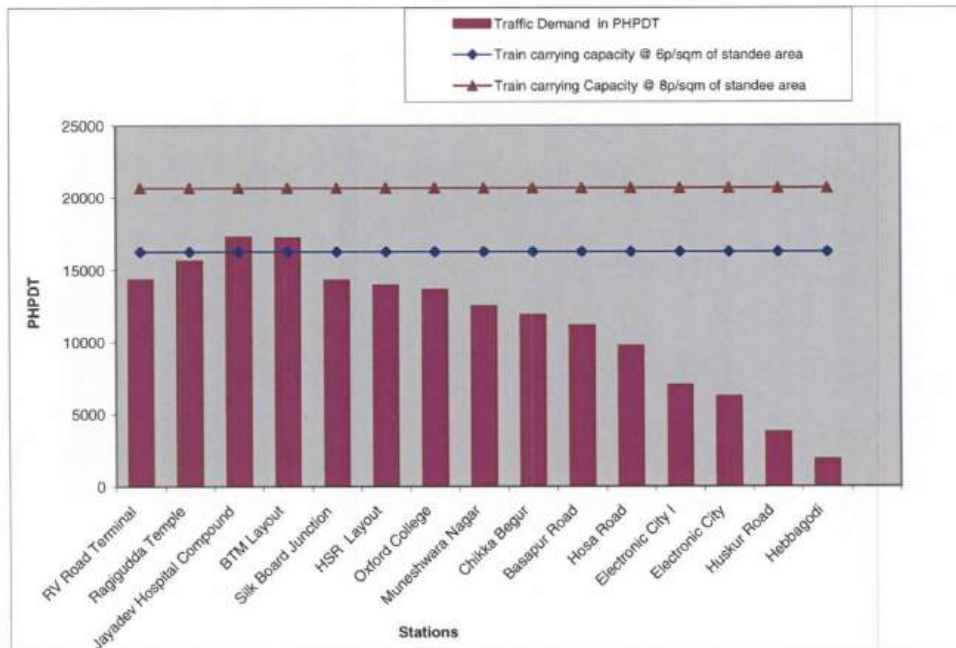


Fig 1.2

**PHPDT Demand and Capacity Chart**

Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor

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) 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	RV Road Terminal	Ragigudda Temple	17597	19512	24816
2	Ragigudda Temple	Jayadev Hospital Compound	19176	19512	24816
3	Jayadev Hospital Compound	BTM Layout	21274	19512	24816
4	BTM Layout	Silk Board Junction	21193	19512	24816
5	Silk Board Junction	HSR Layout	17586	19512	24816
6	HSR Layout	Oxford College	17174	19512	24816
7	Oxford College	Muneshwara Nagar	16923	19512	24816
8	Muneshwara Nagar	Chikka Begur	15523	19512	24816
9	Chikka Begur	Basapur Road	14837	19512	24816
10	Basapur Road	Hosa Road	13930	19512	24816
11	Hosa Road	Electronic City I	12186	19512	24816
12	Electronic City I	Electronic City	8797	19512	24816
13	Electronic City	Huskur Road	7844	19512	24816
14	Huskur Road	Hebbagodi	4713	19512	24816
15	Hebbagodi	Bommasandra	2379	19512	24816

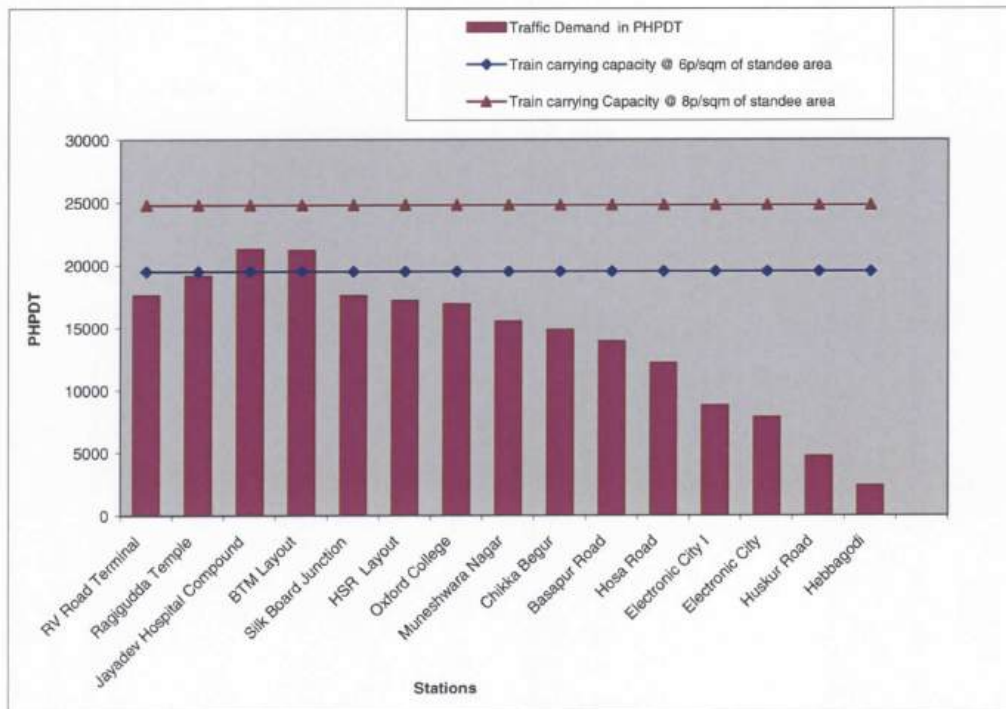


Fig 1.3

**PHPDT Demand and Capacity Chart**

Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor

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) 4.5

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	RV Road Terminal	Ragigudda Temple	19390	21680	27573
2	Ragigudda Temple	Jayadev Hospital Compound	21130	21680	27573
3	Jayadev Hospital Compound	BTM Layout	<b>23442</b>	21680	27573
4	BTM Layout	Silk Board Junction	23352	21680	27573
5	Silk Board Junction	HSR Layout	19451	21680	27573
6	HSR Layout	Oxford College	18924	21680	27573
7	Oxford College	Muneshwara Nagar	18647	21680	27573
8	Muneshwara Nagar	Chikka Begur	17105	21680	27573
9	Chikka Begur	Basapur Road	16349	21680	27573
10	Basapur Road	Hosa Road	15350	21680	27573
11	Hosa Road	Electronic City I	13429	21680	27573
12	Electronic City I	Electronic City	9694	21680	27573
13	Electronic City	Huskur Road	8643	21680	27573
14	Huskur Road	Hebbagodi	5193	21680	27573
15	Hebbagodi	Bommasandra	2622	21680	27573

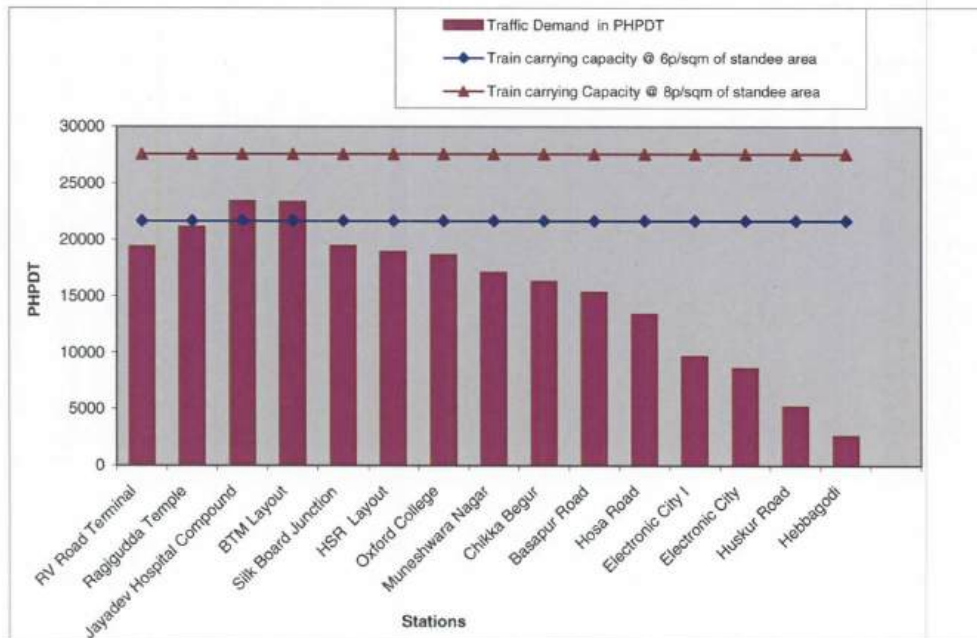


Fig 1.4



**TABLE 1.1**  
**Hourly Train Operation Plan for Bangalore Metro : R V Road - Electronic City-  
Bommasandra Corridor**

Year: 2016

Configuration: 6 Car

Headway(min): 8

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	12	5	5
<b>8 to 9</b>	<b>8</b>	<b>7</b>	<b>8</b>
<b>9 to 10</b>	<b>8</b>	<b>8</b>	<b>7</b>
<b>10 to 11</b>	<b>8</b>	<b>7</b>	<b>8</b>
<b>11 to 12</b>	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
<b>17 to 18</b>	<b>8</b>	<b>8</b>	<b>7</b>
<b>18 to 19</b>	<b>8</b>	<b>7</b>	<b>8</b>
<b>19 to 20</b>	<b>8</b>	<b>8</b>	<b>7</b>
20 to 21	12	5	5
21 to 22	20	3	3
22 to 23	24	2	3
23 to 24	30	2	2
<b>Total No. of train trips per direction per day</b>		<b>89</b>	<b>89</b>

**TABLE 1.2**  
**Hourly Train Operation Plan for Bangalore Metro : R V Road - Electronic City-  
Bommasandra Corridor**

Year: 2021

Configuration: 6 Car

Headway(min): 6

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
<b>8 to 9</b>	<b>6</b>	<b>10</b>	<b>10</b>
<b>9 to 10</b>	<b>6</b>	<b>10</b>	<b>10</b>
<b>10 to 11</b>	<b>6</b>	<b>10</b>	<b>10</b>
<b>11 to 12</b>	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
<b>17 to 18</b>	<b>6</b>	<b>10</b>	<b>10</b>
<b>18 to 19</b>	<b>6</b>	<b>10</b>	<b>10</b>
<b>19 to 20</b>	<b>6</b>	<b>10</b>	<b>10</b>
20 to 21	8	7	8
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
<b>Total No. of train trips per direction per day</b>		<b>138</b>	<b>138</b>



**TABLE 1.3**  
**Hourly Train Operation Plan for Bangalore Metro : R V Road - Electronic City-  
Bommasandra Corridor**

Year: 2031

Configuration: 6 Car

Headway(min): 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
<b>8 to 9</b>	<b>5</b>	<b>12</b>	<b>12</b>
<b>9 to 10</b>	<b>5</b>	<b>12</b>	<b>12</b>
<b>10 to 11</b>	<b>5</b>	<b>12</b>	<b>12</b>
<b>11 to 12</b>	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
<b>17 to 18</b>	<b>5</b>	<b>12</b>	<b>12</b>
<b>18 to 19</b>	<b>5</b>	<b>12</b>	<b>12</b>
<b>19 to 20</b>	<b>5</b>	<b>12</b>	<b>12</b>
20 to 21	8	7	8
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
<b>Total No. of train trips per direction per day</b>		<b>150</b>	<b>150</b>

**TABLE 1.4**  
**Hourly Train Operation Plan for Bangalore Metro : R V Road - Electronic City-  
Bommasandra Corridor**

**Year: 2041**  
**Configuration: 6 Car**  
**Headway(min): 4.5**

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
<b>8 to 9</b>	<b>4.5</b>	<b>13</b>	<b>14</b>
<b>9 to 10</b>	<b>4.5</b>	<b>14</b>	<b>13</b>
<b>10 to 11</b>	<b>4.5</b>	<b>13</b>	<b>14</b>
<b>11 to 12</b>	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
<b>17 to 18</b>	<b>4.5</b>	<b>14</b>	<b>13</b>
<b>18 to 19</b>	<b>4.5</b>	<b>13</b>	<b>14</b>
<b>19 to 20</b>	<b>4.5</b>	<b>14</b>	<b>13</b>
20 to 21	6	10	10
21 to 22	10	6	6
22 to 23	12	5	5
23 to 24	15	4	4
<b>Total No. of train trips per direction per day</b>		<b>169</b>	<b>169</b>

**TABLE 2**  
**Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor**  
**PHPDT for the Year 2016**

S.No	From Station	To Station	Maximum PHPDT	Directional Split to Bommasandra	Directional Split to RV Road Terminal
1	RV Road Terminal	Ragigudda Temple	9684	50%	50%
2	Ragigudda Temple	Jayadev Hospital Compound	10720	50%	50%
3	Jayadev Hospital Compound	BTM Layout	13078	50%	50%
4	BTM Layout	Silk Board Junction	12973	50%	50%
5	Silk Board Junction	HSR Layout	10476	50%	50%
6	HSR Layout	Oxford College	10391	50%	50%
7	Oxford College	Muneshwara Nagar	10037	50%	50%
8	Muneshwara Nagar	Chikka Begur	9283	50%	50%
9	Chikka Begur	Basapur Road	8801	50%	50%
10	Basapur Road	Hosa Road	8224	50%	50%
11	Hosa Road	Electronic City I	7170	50%	50%
12	Electronic City I	Electronic City	5184	50%	50%
13	Electronic City	Huskur Road	4534	50%	50%
14	Huskur Road	Hebbagodi	2724	50%	50%
15	Hebbagodi	Bommasandra	1086	50%	50%

**TABLE 3**  
**Vehicle Kilometer**  
**Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor**

Year	2016	2021	2031	2041
Section Length	17.96	17.96	17.96	17.96
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	89	138	150	169
Daily Train -KM	3197	4957	5388	6071
Annual Train - KM (10 <sup>5</sup> )	10.87	16.85	18.32	20.64
Annual Vehicle - KM (10 <sup>5</sup> )	65.22	101.13	109.92	123.85

**Rake Requirement**

**Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor, Year : 2016**  
**Schedule Speed in Kmph= 34**  
**Passenger Capacity @ 6 Persons/sqm in 6 Car Train: 1626**

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor	17.96	34.0	13078	12195	8	9	1	1	11	6	66
Total Turn Round Time(min)											6

**Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor, Year : 2021**  
**Schedule Speed in Kmph= 34**  
**Passenger Capacity @ 6 Persons/sqm in 6 Car Train: 1626**

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor	17.96	34.0	17275	16260	6	12	1	2	15	6	90
Total Turn Round Time(min)											6



Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor, Year : 2031  
 Passenger Capacity @ 6 Persons/sqm in 6 Car Train: 1626  
 Schedule Speed in Kmph= 34

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor	17.96	34.0	21274	19512	5	14	1	2	17	6	102
Total Turn Round Time(min) 6											

Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor, Year : 2041  
 Passenger Capacity @ 6 Persons/sqm in 6 Car Train: 1626  
 Schedule Speed in Kmph= 34

Section	Distance (kms)	Schedule Speed in kmph	Projected PHPDT Demand	Max. PHPDT Capacity Available	Headway (min)	Rake Requirement			Total No of Rakes	No. of Cars per rake	No. of Cars
						Bare	Traffic Reserve	R&M			
Bangalore Metro : R V Road - Electronic City- Bommasandra Corridor	17.96	34.0	23442	21680	4.5	16	1	2	19	6	114
Total Turn Round Time(min) 6											



## CHAPTER 6

### POWER SUPPLY

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

##### 6.1 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.

##### 6.1.1 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 for 750V DC traction – 20%
- (iii) Elevated/at –grade station load – initially 200KW, which will increase to 500 KW in the year 2041
- (iv) Underground station load - initially 2000KW, which will increase to 2500 KW in the year 2041.
- (v) Depot auxiliary load – initially 1000 KW in the year 2016, which will increase to 1750 KW in the year 2041.

Keeping in view of the Train Operation Plan and demand of auxiliary and traction power, power requirement for RV Road to Bommasandra has been worked out for the year 2016, 2021, 2031 and 2041 which is summarized in Table 6.1:

**Table 6.1 Power Demand Estimation (MVA)**

Corridor		Year			
		2016	2021	2031	2041
RV Road to Bommasandra	Traction	6.8	9.1	11	12.3
	Auxiliary	5.2	6.5	7.8	12.0
	Total	12.0	15.6	18.8	24.4

The detailed calculations of Power Requirements are given at Annexure 6.1.

### 6.1.2 Need for High Reliability of Power Supply

The proposed extension of North-South Corridor of Bangalore metro system to Bommasandra is being designed to handle about 24000 passengers per direction during peak hours when trains are expected to run at about 4.5 minutes 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. 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 good quality of power supply. To ensure reliability of power supply, it is essential that both the sources of supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. Therefore, it is desirable to obtain power supply at high grid voltage of 220kV or 66kV from stable grid sub-stations and further transmission & distribution is done by the Metro Authority itself.

### 6.1.3 Source of power Supply

The high voltage power supply network of Bangalore city was studied in brief. The city has got 220kV and 66kV 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. Based on the discussions with KPTCL, it is proposed to avail power supply for traction as well as auxiliary services from the Nagnathapura sub-station at 66kV voltage levels through single circuit cable feeder.

Electric Power requirement for this extension of Corridor – 1 is likely to be 12 MVA approximately in year 2016 and which is likely to increase to 25 MVA by the year 2041. Under normal conditions, this power will be supplied by the RSS at Basapura Road. The capacity of transformers may be reviewed considering the load requirement/distribution of the corridor at the time of detailed design and for the purpose of ease of replacability and for reducing the requirement of spares, similar capacity of transformers (as being provided at other RSS) may be preferred. While in

case of failure of power supply from this RSS, power requirement will be provided by RSS at Khoday. The transformers capacity of 20/25 MVA at Khoday RSS (under construction) may be reviewed accordingly or space for adding one transformer of 33 kV may be carved out in the RSS layout) for future requirement.

**TABLE 6.2**  
**Sources of Power Supply**

Corridor	Grid sub-station (Input source)	Location of RSS of Metro Authority	Approx. length of 66kV cables
RV Road to Bommasandra	NagnathaPura sub-station (220/66kV)	Basapura Road	2 km. (single circuit)

KPTCL has confirmed availability of requisite power at their above sub-station vide letter No CEE(P&C)/KCO-95/17561/2009-10 dated:- 06.07.2009 (**Annexure – 6.2**). KPTCL has been requested to examine the possibility of another power supply / source either upgrading Nimhene – Jaidev Hospital or from future substation at “Khoday”. The summary of expected power demand from receiving sub-stations is given in Table 6.3:

**TABLE 6.3 Power Demand**

Corridor	RSS	Peak demand – Normal (MVA)		Peak demand* – Emergency (MVA)	
		Year (2016)	Year (2041)	Year (2016)	Year (2041)
RV Road to Bommasandra	RSS at Basapur Road	6.5	12.7	12.0	24.4
	RSS at Khoday or Jaidav Park	5.5	11.7	12.0	24.4

\*Considering Khoday or Jaidev RSS at the failure of Basapur RSS. The power from Jaidev hospital/Khoday Road not yet confirmed by KPTCL. However for extension of N-S corridor to south up-to Anjanapura Township has been confirmed from khode grid sub-station. In case KPTCL has issues in provide power for Jaidev hospital, it can be availed from khoday by adding one more bay, alternately possibility of standby supply can be explored from RV Road.

The 66kV power supply will be stepped down to 33kV level at the above RSSs of metro authority. The 33kV power supply drawn from the RSS will be distributed along the alignment through 33kV Ring main cable network for feeding to traction as well as auxiliary loads. These cables will be laid in dedicated ducts along the viaduct. Interconnection of 33kV power supply between the corridors has been planned at

interchange station as shown in the schematic drawings, which can be used for transfer of power from one corridor to other in emergency situation. However, in case of total grid failure, trains will come to stop but station lighting, ventilation & other essential services can be catered to by stand-by DG sets. Therefore, the proposed scheme is expected to ensure adequate reliability and cater to emergency situations as well.

The 66kV cables will be single core XLPE insulated with 630sq.mm Al conductor. The cables shall be laid through public pathways to RSSs of Metro Authority. One RSS 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. The other RSS of each corridor will be provided with only single 66/33kV transformer with a provision of adding 66kV bay and transformer in future when traffic builds up.

Conventional outdoor type 66kV switchgear is proposed for RSS to be located in approx. 60m x 80m (4800 sqm) land plot. Gas Insulated Switchgear (GIS), though requires less space (approximately half) & less maintenance, is not proposed because of high capital cost. The typical RSS layout as being used in phase-1 may be followed.

**NOTE BY BMRCL:**

- A) KPTCL has reviewed the original proposal and has informed that they would provide one circuit from Yerandahalli 220KV station and one circuit from Naganathapura 220 KV station to Basapura RSS**
- B) KPTCL has also suggested a second 66 KV source from Khoday's station to R V Road Terminal RSS. However the final design would be finalized after system study and detailed design.**

## **6.2 SELECTION OF TRACTION SYSTEM**

The traction system for Bangalore Metro is already selected as 750V dc third rail bottom current collection system. This corridor is an extension of existing corridor. Therefore for this extension of North South corridor from R.V. Road to Bommasandra, the same traction system i.e. 750V dc third rail bottom current collection system is proposed.

### **6.2.1 Design Criteria for Power Supply and Traction System:**

Train Operation Plan envisages running of trains is 6 cars with 8 to 4.5 minutes headway for year 2016 to year 2041. However, initially equipment will be installed to cater the expected power requirements during initial years of operations. As and when the traffic builds up in year 2016 & 2041, the power supply system will need slight



augmentation by way of adding main power transformers & traction transformer-rectifier sets.

### 6.2.2 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 requirement comes to 8 TSS for proposed line as shown in the power supply schematic drawings. The TSS along with Auxiliary Sub-Stations (ASS) will be located at station building itself at mezzanine or platform level inside a room. Self-cooled, cast resin dry type rectifier-transformer is proposed, which is suitable for indoor application. Initially, 1x 2.8 MW transformer-rectifier set shall be provided in each TSS with space provisions for an additional set to be accommodated in future. From the traction sub-stations, 750V dc cables will be laid upto third rail and return current cables will be connected to running rails.

### 6.2.3 Rating of Major Equipment

Based on emergency demand expected at each RSS as shown in Table 6.3, 2 nos. 66/33kV main receiving transformers of 20/25 MVA capacity shall be provided, at Basapur Road RSS, one to be in service and second one to serve as standby. The RSS to be located at Mysore Road and R.V. Road terminal will be provided with only one 66/33KV power transformer of 20/25 MVA. The 66kV cable shall be 3-phase single core XLPE insulated with 630mm<sup>2</sup> Al conductor to meet the normal & emergency loading requirements and fault level of the 66kV supply.

Traction transformer-rectifier set (33kV/750V dc) shall be of 2.8 MW 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 mm<sup>2</sup> copper from RSS to 33kV cable network
- \_ 3 core x 300 mm<sup>2</sup> copper for 33kV ring main cable network.

Entire 33kV cables shall be 3 phase, XLPE insulated with copper conductors. Cables to be located inside the tunnel shall be with Fire Retardant Low Smoke Zero Halogen (FRLSOH) properties, while those on outdoor may be with ordinary PVC sheath.

Adequate no. of cables are required for transfer of power from TSS to third rail. Single phase XLPE insulated cables with 400mm<sup>2</sup> copper conductor are proposed for 750V dc as well as return current circuit. Based on current requirements, 3 cables are required for each of the four circuits 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.

### **6.3 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, accordingly two dry type cast resin transformers (33/0.415kV) of 500 kVA for elevated / at grade stations (with one transformer as standby) are proposed to be installed. The Depot ASSs will also be provided with 2 x 2000 kVA auxiliary transformers.

### **6.4 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 KVA capacity at elevated/at-grade stations to cater the following essential services:

- (i) Lift operation
- (ii) Essential lighting
- (iii) Ventilation requirements of stations
- (iv) Signaling & telecommunications
- (v) Fire fighting system.

Silent type of DG sets are proposed which have low noise levels and do not require separate room for installation.

### **6.5 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 fibre 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, intertripping 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.

## 6.6 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.

## 6.7 STRAY CURRENT CORROSION PROTECTION MEASURES

### 6.7.1 Concept of dc Stray Current Corrosion

In dc traction systems, bulk of return current finds its path back to the traction sub-station via the return circuit i.e. running rails. The running rails are normally insulated to minimize leakage of currents to the track bed. However, due to leaky conditions, some current leakage takes place, which is known as 'stray current'. The current follows the path of least resistance. Return current deviates from its intended path if the resistance of the unintended path is lower than that of intended path. The stray current may flow through the unintended path of metallic reinforcements of the structure back to the substation.

It is also possible that part of the stray current may also flow into soil, where it may be picked up by metallic utilities and discharged back to soil and then to near the sub-station.

The dc stray currents cause metal detraction in watery 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  
 $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$  ( $\text{Fe}^{2+}$  ions migrate away from the metal)

That is how, dc stray currents cause corrosion of metallic structure where it leaves the metal. Pitting and general form of corrosion are most often encountered on dc electrified railways.

### 6.7.2 Effect of Corrosion

Detraction rate of metals can be calculated by Faraday's First Law:

$$m = c.i.t$$

Where m = mass (kg)

c = Coefficient of detraction (kg/Amp.year)

i = Current (Amp)

t = time (year)

c = 2.90 for Aluminium

= 33.80 for Lead

= 9.13 for Iron

= 10.4 for Copper

That means dc stray current of 1 – ampere flowing continuously can eat away approx. 9 kg of steel in a year. If 5000 amperes of current flows for one year to power the trains on a transit system, and that 2 percent of this current (100 amperes) leaks as stray current, the amount of steel metal loss is 0.9 ton per year. Therefore, the safety implications are considerable for structural reinforcements. In addition, corrosion may also affect neighboring infrastructure components such as buried pipelines and cables.

### 6.7.3 Measures for Protection against Stray Current Corrosion

Earthing & bonding and protection against stray current corrosion are interrelated and conflicting issues. Therefore, suitable measures are required to suppress the stray currents as well as the presence of high touch potentials. Safety of personnel is given preference even at a cost of slightly increased stray currents.

Following measures are required to restrict the stay current:-

- (i) Decreasing the resistance of rail-return circuit
- (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 Worldover for protection against stray current corrosion. Traditionally, Earthed system was used by old metros. Hybrid earthing system is being tried on experimental basis on few new metros. Floating

system has been extensively used by recent metros. As per the trends World over, floating system (i.e. traction system with floating negative) is proposed which reduces the dc stray current to considerable level. The arrangement shall comply with following latest CENELEC standards:-

- EN 50122-1:- Railway Applications (fixed installations) 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 are as under:-  
Elevated section :- 0.5 Siemens/Km  
Tunnel section :- 0.1 Siemens/Km.
- ii) Stray Current Collector Cables {commonly known as structural earth (SE) cable} (2x200 mm<sup>2</sup> 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.

#### 6.7.4 Special Arrangements in Depot

A separate traction sub-station (TSS) shall be provided for depot so as to facilitate isolation of depot traction supply from mainlines in order to prevent the leakage of return currents to depot area. Tracks of Depot area shall also be isolated from mainline through insulated rail joints (IRJ). Remote operated 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 shall be developed during the design stage.

## **6.8 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.

The rectifier-transformer used in dc traction system produces harmonic voltages, which may cause interference to telecommunications and train control/protection systems. The rectifier-transformer shall be designed with the recommended limits of harmonic voltages, particularly the third and fifth harmonics. The proposed 12-pulse rectifier-transformer reduces the harmonics level considerably. Detailed specification of equipment e.g. power cables, rectifiers, transformer, E&M equipment etc shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signaling & telecomm, traction power supply, E&M system etc) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMC plan will require to be developed during project implementation stage.

## **6.9 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-roomless type lifts with gearless drive have 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.

#### 6.10 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 is assessed to be about 37 million units in initial years (2016), which will 75 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. 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.

## Extension of N-S Corridor

POWER REQUIREMENTS	RV Road -Electronic City- Bommasandra Extension							
Traction power requirements	Year 2016		Year 2021		Year 2031		Year 2041	
No of cars	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)
Tare weight of train	204	T	204	T	204	T	204	T
Passenger weight	124	T	124	T	124	T	124	T
Total Train weight	328	T	328	T	328	T	328	T
Section length	18.36	KM	18.36	KM	18.36	KM	18.36	KM
Headway	8	mts	6	mts	5	mts	4.5	mts
Specific Energy consumption	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM	75	KWhr/1000 GTKM
No. of trains/hr in both directions	15		20		24		27	
Peak traction power requirement	6.8	MW	9.0	MW	10.8	MW	12.0	MW
Less Regeneration @20%	1.4	MW	1.8	MW	2.2	MW	2.4	MW
Depot Power requirement	0.8	MW	1.0	MW	1.3	MW	1.5	MW
Net traction power requirement	6.2	MW	8.2	MW	9.9	MW	11.1	MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	6.8	MVA	9.1	MVA	11.0	MVA	12.3	MVA
<b>Station aux power requirement</b>								
Elevated/at-grade station	0.20	MW	0.25	MW	0.30	MW	0.50	MW
Underground stations	2.00	MW	2.25	MW	2.25	MW	2.50	MW
No. of elevated/at-grade stations	16		16		16		16	
No. of Underground stations	0		0		0		0	
Total Station Aux Power requirement	3.2	MW	4.0	MW	4.8	MW	8.0	MW
Depot Aux power requirement	1.0	MW	1.25	MW	1.5	MW	1.75	MW
Total Aux Power requirement	4.2	MW	5.3	MW	6.3	MW	9.8	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	5.2	MVA	6.5	MVA	7.8	MVA	12.0	MVA
Total traction & aux power requirement (MW)	10.37	MW	13.48	MW	16.22	MW	20.89	MW
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	12.0	MVA	15.6	MVA	18.8	MVA	24.4	MVA

**Note:-**

The requirement of PD load is not considering in estimation of power calculation.

## Energy Consumption

Extension of N-S Corridor from R.V. Road - Electronic City-Bommasandra								
Year	Year 2016		Year 2021		Year 2031		Year 2041	
No of cars	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)
LENGTH (KM)	18.36	KM	18.36	KM	18.36	KM	18.36	KM
No. of trains per direction in a day*	89		138		150		169	
WEIGHT OF TRAIN & PASSENGER	328	T	328	T	328	T	328	T
SFC (NET ) with 20% regen	60	KWH/1000 GTKM	60	KWH/1000 GTKM	60	KWH/1000 GTKM	60	KWH/1000 GTKM
Yearly Traction Energy consumption with 365 days working with 20% regen	23.48	million units	36.41	million units	39.58	million units	44.59	million units
<b>Station aux power requirement</b>								
Elevated/at-grade station	0.20	MW	0.25	MW	0.30	MW	0.50	MW
U/G station	2.00	MW	2.25	MW	2.25	MW	2.50	MW
no. of elevated/at-grade stations	16		16		16		16	
no. of U/G stations	0		0		0		0	
Depot Aux power requirement	1.0	MW	1.25	MW	1.5	MW	1.75	MW
Total Aux Power requirement	4.2	MW	5.3	MW	6.3	MW	9.8	MW
Total Aux power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	5.2	MVA	6.5	MVA	7.8	MVA	12.0	MVA
Diversity factor of aux loads	0.4		0.4		0.4		0.4	
Yearly Aux Energy consumption 20 hrs/day and 365 days working (million units)	12.88	million units	16.10	million units	19.32	million units	29.89	million units
<b>Net Annual Energy Consumption (Traction &amp; Aux)</b>	<b>36.4</b>	<b>million units</b>	<b>52.5</b>	<b>million units</b>	<b>58.9</b>	<b>million units</b>	<b>74.5</b>	<b>million units</b>

**KARNATAKA POWER TRANSMISSION CORPORATION LIMITED**

Superintending Engineer (Elec) Planning 2<sup>nd</sup> Floor, Kaveri Bhavan, Bangalore - 560 009.



Ref No. No. CEE (P & C)/KCO-95/17561/2009-10/

Date: 06-07-2009.

To:

The Executive Director,  
Delhi Metro Rail Corporation  
Kaveri Bhavan, Fire Brigade Line  
Barakhamba Road,  
NEW DELHI-110001.



Sir,

**Sub: Extension of North-South Corridor of Bangalore Metro between RV Road to Electronic city.**

**Ref: 1) Letter No. DMRC/Elect/BM/Part-III /29707. Dated: 22-06-09 of M/s. Delhi Metro Rail Corporation Ltd. Delhi addressed to D (T), KPTCL.**

**2) Proceedings of the joint meeting held on 24.09.2007**

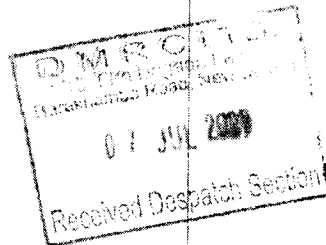
**3) T.O. Note No. CEE (P & C)/KCO-95/17561/2009-10/ Note-15. Dated: 12-09-09.**

With reference to the above subject, I am directed to communicate approval for allotting one 66 kV bay at 220 kV Maganathapura Sub-station under DCW for drawing 66 kV OH/UG line to the proposed 66 kV Metro stations between RV Road to Electronic city.

You are requested to contact To Chief Engineer (Ele), Bangalore Transmission zone KPTCL, Ananda Rao Circle, Bangalore for estimate and further needful.

Yours faithfully,

Convenor, T.C. Committee &  
Superintending Engineer Electy., Planning.



Copy to The Chief Engineer, Electy., Bangalore Transmission Zone, KPTCL, Ananda Rao Circle, BANGALORE-560009 for information and further needful action.

Name of the (KPTCL) /Date

TO: /

TEL: /

50-91 50-50-101



**CHAPTER-7**

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**TRAIN MAINTENANCE DEPOT**



## CHAPTER 7

### MAINTENANCE DEPOTS

7.1	<u>Extension Line</u>	<u>Gauge (mm)</u>	<u>Route Length (KMs)</u>
	R.V.Road – Bommasandra	1435	18.82

- For establishment of train maintenance facilities for the trains of the above section of north-south corridor, following assumption are made:

- (i) All major overhauls and repairs of equipments of the trains of Extension line shall be carried out at existing Depot-cum-workshop at Peenya village and augmentation to existing infrastructure corresponding to major inspection (IOH/POH) & repair workload of Extension-line trains shall be made at the existing Depot-cum-workshop at Peenya village.
- (ii) Minor inspections, repairs and component replacements arising on trains in this Extension line are done at Hebbagodi in a satellite depot to be set up there.
- (iii) Trains plying on the Extension line can be transferred to Peenya depot because suitable link will be provided at R.V. terminal i.e. passenger interchange station.
- (iv) The operation of trains on the Extension line is confined between R.V.Road and Bommasandra stations.
- (v) Sufficient land is available at Hebbagodi for establishment of a Satellite depot.
- (vi) All lines (SBLs, IBLs and WSLs) are planned for 6-Car trains.

- 7.2 In broad terms this chapter covers conceptual design of a satellite depot a Hebbagodi and Augmentation in existing infrastructure at Peenya village on following aspects and will work as a guide for detailed design later:

- Layout of Stabling-shed, Inspection-shed, heavy repair, minor repairs, maintenance workshop and cleaning of Rolling Stock.

- Operational and functional safety requirements.
- Ancillary buildings for other maintenance facilities.
- Electrical & Mechanical Services, power supply and distribution system.
- Water Supplies, Drainage & Sewerage.

### 7.3 MAINTENANCE NEEDS TO ROLLING STOCK

- Monitoring of the performance of equipment by condition monitoring of key parameters. The concept is to evolve the need based maintenance regime, which can be suitably configured in the form of schedules like daily check, “A” checks, “B” type checks, “IOH” and “POH”.
- Labor intensive procedures are kept to the minimum. Automation with state of the art machinery to ensure quality with reliability.
- Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.
- Energy conservation is given due attention.

### 7.4 ROLLING STOCK MAINTENANCE NEEDS

#### 7.4.1 Maintenance Schedule

The following maintenance schedule has been envisaged for conceptual design of depots assuming 500 kms for both lines running per train per day, taking in consideration the passenger load of 2014/15, 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.	Workshop

		Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	
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

#### 7.4.2 Washing Needs of Rolling Stock

Cleanliness of the trains is essential. Following schedules are recommended for environment of Bangalore:

S.N.	Kind Inspection	Maint. Cycle	Time	Maintenance Place
1.	Outside cleaning (wet washing on automatic washing plant)	3 Days	10 mins.	Single Pass through Automatic washing plant of Depot
2.	Outside heavy Cleaning (wet washing on automatic washing plant and Front Face, Vestibule/Buffer area. Floor, walls inside/outside of cars and roof. Manually)	30 days	2 – 3 hrs.	(Automatic washing plant & cleaning & washing shed)

- 7.5 (i) Year-wise planning of maintenance facility setup at depot-cum- workshop at Peenya village is tabulated below as per TOP:

Year	Head way in minutes	No. of trains	No. of Coaches
2014/2015	8.0	11 (3-Car)	66
2021	6.0	15 (3-Car)	90
2031	5.0	17 (6-Car)	102
2041	4.5	19 (6-Car)	114

(ii) Average earning/day/rake (19 hrs working)

Year	6-Cars trains		Remarks
	Earning/ day/train (Kms)	Total trains	
2014/15	530	11	i) 'A' inspection frequency after every 10 days
2021	519	15	
2031	532	17	ii) 'B' inspection frequency after every 30 days
2041	544	19	

(iii) Requirement of Stabling and inspection lines and IBLs:

Year	Requirement
2014/2015	11 lines X 6-Cars
2021	15 lines X 6-Cars
2031	17 lines X 6-Cars
2041	19 lines X 6-Cars

(iv) Distribution of Stabling and Inspection Lines at R.V Road & Bommasandra.

Year	Stabling lines at R.V.Road and Bommasandra terminals	Depot at Hebbagodi		Total
		IBL	SBL	
2014/ 2015	2 lines X 6-Cars each	3 lines X 6- Cars	5 lines X 6-Cars	12 lines X 6-Cars
2021	- do -	-do-	9 lines X 6-Cars	16 lines X 6-Cars
2031	- do -	-do-	11 lines X 6-Cars	18 lines X 6-Cars
2041	- do -	-do-	13* lines X 6-Cars	20 lines X 6-Cars

'\*' space will have to be earmarked for maximum of 13 SBLs in the depot.

7.6 Requirement of inspection lines at Hebbagodi Depot:

Schedule	Maintenance Requirement (No. of Cars)	Lines Needed
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<b>i) Year 2014/2015 - Maximum no. of rake holding is (11X 6) Cars = 66 Cars</b>		
'A' Checks (5000 km) 10 days	(11 X 6) Cars = 66 Cars	1 Line x 6* cars (with Sunken Floor)
'B' Checks (15000 km) 30 days	(11 X 6) Cars = 66 Cars	1 Line x 6* cars (with Sunken Floor)
Unscheduled line	For minor repairs, testing and after IOH/POH	1 Line x 6* cars (with sunken Floor)
Total requirement for expansion		1 bays of 3 lines
<b>ii) Year 2021 - Maximum no. of rake holding is (15 X 6) Cars = 90 Cars</b>		
'A' Checks (5000 km) 10 days	(15 X 6) Cars = 90 Cars	1 Line X 6* Cars (with sunken floor)
'B' Checks (15000 km) 30 days	(15 X 6) Cars= 90 Cars	1 Line X 6* Cars (with sunken floor)
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6* Cars (with sunken floor)
Requirement: Same as above		1 Bay of 3 lines
<b>iii) Year 2031 (Maximum no. of rake holding is (17X6) Cars = 102 Cars</b>		
'A' Checks (5000 km) 10 days	(17 X 6) Cars = 102 Cars	1 Line X 6* Cars (with sunken floor)
'B' Checks (15000 km) 30 days	(17 X 6) Cars = 102 Cars	1 Line X 6* Cars (with sunken floor)
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6* Cars (with sunken floor)
Requirement: Same as above		1 Bay of 3 lines
<b>iv) Year 2041 (Maximum no. of rake holding is (19X6) Cars = 114 Cars</b>		
'A' Checks (5000 km) 10 days	(19 X 6) Cars = 114 Cars	1 Line X 6* Cars (with sunken floor)
'B' Checks (15000 km) 30 days	(19 X 6) Cars = 114 Cars	1 Line X 6* Cars (with sunken floor)
Unscheduled line	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X 6* Cars (with sunken floor)

ii) Facilities shall be provided to carry out the inspection of the following sub-systems/equipments:

- Electronics; PAPIIS

- Mechanical components, couplers etc
- Batteries
- Air conditioner
- Brake modules
- Bogie
- Traction Motor
- Vehicle doors, windows and internal fittings
- Power system including converter, circuit breaker etc.

These activities shall be grouped into “A” checks. The minor scheduled inspections (“A” checks) shall be carried out during the day off peak and night. Since “B” checks take longer time, these cannot be completed in the off peak times. One inspection line will be nominated for “A” checks. For “B” checks, separate line will be nominated where the rakes may be kept for long time. One dedicated line in Depots will be used for the adjustment and testing after integration of IOH/POH equipment on Coaches.

## 7.7 DESIGN OF DEPOT FACILITIES

### 7.7.1 Stabling Lines at Depot at Hebbagodi and terminal station at R.V.Road:

i)

S.No.	6-Car
1	Length of rake=130 mts.
2	Minimum length of SBL=130m (rake length) + 20m (for cross pathway, Signal and friction buffers).

ii) Stabling lines are designed for 150 m length to cater for safe gap from the friction buffer stops and the signaling interlocking needs. Looking to the car width of 2880 on SG, 5.0m “Track Centre” is proposed for all the stabling lines. Thus, space between stabling shall be sufficient to include 800mm wide paved pathway to be constructed between tracks to provide access for internal train cleaning and undercarriage inspection with provision of following facilities:

- (a) Each stabling line to have water connection facility so that local cleaning, if required, is facilitated.
- (b) Platforms at suitable points at each end of stabling lines to enable train operators to board or de-board conveniently.

### 7.7.2 Inspection Sheds at Hebbagodi

All IBLs are computed for 6 – Car trains

Length = [Cross path at end + space for friction buffer stop + Length of Rake + Cross path at end which keeps Gap from gate] .

Length = 10.0m + 130.0m + 10m = 150m

There shall be one inspection bays of 150 X 20 m size with three inspection lines having sunken floor and overhead roof inspection platforms at Hebbagodi. The floor will be sunken by 1100mm. The track spacing between the adjacent IBLs shall be 6.25 m/s These bays of 150 X 20m covering three lines are planned for inspection load of 20 6-Car train sets during the years 2015 to 2041.

Roof Inspection platforms and walk-ways for roof inspection supported on the columns shall be provided. There would be lighting below the rail level to facilitate the under frame inspection. Ramps of 1:8 slopes, 3 meter wide have been provided with sunken floor system for movement of material for the cars. Further, 5m cross pathways are left at each end for movement of material by fork lifter/Leister/Hand trolley. 415V 3 phase 50 Hz, 230V 1 phase 50 Hz AC supply and Pneumatic supply shall also be made available on each inspection shed columns. Air-circulators shall be provided on each column. Each inspection line shall be provided with EOT crane of 1.5 T to facilitate lifting of equipment.

Roof and walls shall be of such design that optimum natural air ventilation occurs all the time and sufficient natural light is also available.

- There shall be arrangement for cleaning of HVAC filters with high pressure water jet adjacent to Inspection bays.

### 7.8 Requirement of lifting/repair lines at Hebbagodi Depot:

Year	Wheel Bogie storage	Unschedule repairs	Total
2014 / 2015	1	1	2
2021	1	1	2
2031	1	1	2
2041	1	1	2
Remarks	<ul style="list-style-type: none"> <li>• There shall be one bay of size 150 X 32 mts. With two embedded lines spanned with 15T / 3T over head cranes. One of the embedded lines is provided with Pit-jacks for lifting of a unit of 2-Cars simultaneously. This line may have two pits of one coach length for facilitating undercarriage inspection. The other embedded line shall be used for stocking of wheels &amp; Bogies etc. These two lines will occupy a space of 150 X 21 meters with 10.5 meters track centers apart, rest of the space shall be available for stocking / repairs of traction and ancillary equipment.</li> </ul>		

	<ul style="list-style-type: none"> <li>• Repair-shop shall have an array of service rooms along the length. The can be made of column and beam structure with architectures of brick works. These rooms shall cater as Service, Overhauling, Stores, Locker and office rooms.</li> <li>• There shall be washing and cleaning equipments on the repairs shop floor. Air circulators, Power supply points and Compressor air pipe lines shall be provided at every column. Battery maintenance cell with arrangement of fumes that are exhausted by suitable exhaust system.</li> <li>• Repair-shed lines shall be interconnected with Turn-table to facilitate transfer of equipments.</li> <li>• Repair and staking of heavy equipments such as air conditioner shall be so located that it does not effect movement inside the repair-shop.</li> <li>• Suitable arrangement for Repair of unit, equipments and their testing facilities should be available.</li> </ul>
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### 7.9 Augmentation-Workshop lines at depot-cum-workshop at Peenya Village

Year	IOH	POH	Heavy Lifting / Unschedule lifting	Wheel & Bogie Storage	Total	Remarks
2014 / 2015	1	1	1	1	4	<ul style="list-style-type: none"> <li>• Two bays of 2 WSL each with provision for expansion by one bay of 2 lines for future i.e. 2021-31.</li> <li>• All POH/IOH, heavy repairs of all the trains of extension of the corridor are also done here.</li> </ul>
2021	1	1	1	1	4	
2031	2	1	1	2	6	
2041	2	1	1	2	6	
<b>Remarks</b>	<ul style="list-style-type: none"> <li>• Keeping in view the combined train load of existing lines and extension line from the years 2021-2031 the workshop will have to handle about 45 6- Cars trains for carrying out IOH/POH. Provision of future expansion by one bay of 2 lines (150X21 meters) in the existing 2-bay workshop of 154X42 meters has been advised vide DMRC letter no. Dy.CEE–RSW/2007 dt. 18.09.2007. This bay shall be made operational by the year 2021.</li> <li>• Other major requirements of machinery and plants have been indicated in DMRC letter no.Dy.CEE – RSW/2007 dt. 18.09.2007.</li> </ul>					

### 7.10 Operational Features at Hebbagodi Depot:

The rake induction and withdrawal to main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to main line from Inspection Shed / Repair-shop area. Movement from depot to the main line is so planned that the headway of main line is not affected. Simultaneous receipt and dispatch of trains from depot to main line is feasible in the present site scenario. Both of these activities will be done effectively without effecting the train operation on the main line. The stabling lines would be interlocked with the main line thereby induction of train from the stabling would be safe and without loss of time. The proposition for a transfer track on the incoming line as well as on the outgoing line to facilitate the movement of rake in the depot by Operation Control Centre (OCC) even though the further path inside the depot is not clear shall be explored in the detailed design stage depending on the actual availability of land.

An emergency line is also provided from which an emergency rescue vehicle may be dispatched to main line in the event of emergency if necessary.

## 7.11 Infrastructure Facilities

### I. Inspection Sheds

As indicated in paras 7.5 (iv) and 7.6 (i)

### II. Stabling Lines in Depots

- a) The requirement of lines shall be in accordance with the table indicated at paras 7.5(iv) & 7.7.1. A part of stabling siding in the depot shall be covered with a roof in order to facilitate testing of air-conditioning of trains and their pre-cooling under controlled condition of temperature.
- b) Separate toilets adjacent to stabling lines shall be provided with small room for keeping cleaning aids and for utilization by the contractor's staff.

### A) Other facilities at Hebbagodi depot :

#### I. 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.

#### II. 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.

### **III. Test Track at Hebbagodi depot**

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.

### **IV. 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.

### **V. 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.

### **VI. 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.

### **VII. 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.

#### **VIII. 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.

#### **IX. Watch Towers**

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

#### **X. 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.

#### **XI. 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, 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.

## **XII. 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.

## **XIII. 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.

### **B) Requirement of buildings and major plants and machinery, is given at Annexure I and II for Hebbagodi:**

Following Safety features should be incorporated in the design of all the Maintenance Depots

- a) Access to the under-carriages should be interlocked with 3<sup>rd</sup> 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 3<sup>rd</sup> 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 Hebbagodi**

S.No.	Name of Building	Size	Brief Function
1.	Inspection Shed	150 x 20 m	Servicing of Cars for 10 days & 30 days inspection.
	Running repair shed	150 x 42m	Lifting of cars for unit replacement of repaired bogies, wheels, under hung electric and mechanical equipments.
	Associated sections	150 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 25m	<ul style="list-style-type: none"> <li>i. Stocking of spares for regular &amp; emergency requirement including consumable items.</li> <li>ii. This store caters for the requirement of depot for rolling stock &amp; other disciplines.</li> <li>iii. To be provided with computerized inventory control.</li> <li>iv. Loading/unloading of material received by road.</li> </ul>
3.	Elect. Sub-station DG set room	80 x 20m	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 20m	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	80 x 6 m 40 x 6 m 40 x 10 m	<ul style="list-style-type: none"> <li>i. Close to the depot entry.</li> <li>ii. Close to the stabling lines.</li> <li>iii. Close to the repair bay.</li> </ul>

6.	(i) Auto coach washing plant (ii) Space for AWP machine room	40 x 10m 20 x 10	For automatic washing of coaches. Washing apron is for collection of dripping water and its proper drainage.
7.	Washing apron for Interior cleaning	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	150 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	



## Annexure-II

## List of Plants &amp; Equipments at Hebbagodi

S.No.	Equipment	Qty	Unit	Imp. / Ind.
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	1	Nos.	Imp
2	Mobile jacks 15T for lifting cars	8	Nos.	Imp
3	Pit jacks (complete set on one line)	1	Set	Imp
4	Re-railing equipment consisting of rail cum road vehicle and associated jack system etc.	1	Set	Imp
5	Run through type Automatic Washing plant for Metro cars.	1	Nos.	Imp
6	Work lift platform	2	Nos.	Imp
7	Electric bogie tractor for pulling cars and bogies inside workshop	1	Nos.	Imp
8	Chemical cleaning tanks, ultrasonic cleaning tanks, etc	1	Set	Imp
9	Compressor for Inspection shed & shop air supply	2	Nos.	Ind
10	Travelling O/H crane Repair-shop 15 T:- 2 Nos; 3 T :- 2 Nos	2+2	Nos.	Ind
11	Mobile jib crane	2	Nos.	Ind
12	Mobile lifting table	2	Nos.	Ind
13	Carbody stands	16	Nos.	Ind
14	Bogie turn tables	2	Nos.	Ind
15	Underframe & Bogie blowing plant	1		Ind
16	AC filter cleaning machine	1	Nos.	Ind
17	Portable cleaning plant for rolling stock	1	Nos.	Ind
18	High-pressure washing pump for front and rear end cleaning of car	1	Nos.	Ind
19	Shot blast cleaner	1	Set	Ind
20	Axle shaft inspection station	1	Set	Ind
21	Industrial furniture	1	L.s.	Ind
22	Minor equipment and collective tools	-	Set	Ind
23	Induction heater	1	No.	Ind
24	Oven for the motors	1	No.	Ind
25	EMU battery charger	3	Nos.	Ind
26	Welding equipments (Mobile welding, oxyacetylene, fixed arc welding)	2	Set	Ind
27	Electric and pneumatic tools	-	Set	Ind
28	Measuring and testing equipment	-	Set	Ind
29	Tool kits	-	Nos.	Ind
30	Mobile safety steps	6	Nos.	Ind
31	Fork lift tractor	2	Nos.	Ind

32	Pallet trucks	2	Nos.	Ind
33	Diesel/battery Shunting Locomotive	1	Nos.	Ind
34	Road vehicles (pickup van/ truck)	1	Set	Ind
35	Miscellaneous office equipments	-	Nos.	Ind
36	Special jigs and fixtures and test benches for Rolling Stock			Ind
37	Battery operated rail-cum-road shunter with suitable coupler	2	Nos	Ind



**CHAPTER-8**

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**ENVIORNMENT & SOCIAL  
IMPACT ASSESSMENT**





## CHAPTER 8

# ENVIRONMENTAL IMPACT ASSESSMENT

### 8.1 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 people 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 for a ridge in the middle of the city 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 rainfall during June to September and November to December and about 54.18% of rainfall occurs due to southwestern monsoon and about 26.53% due to northeastern monsoon.

With the advent of IT industries and educational institutions at Electronic City, people have occupied the intermediary spaces largely between the North and South of the City. Environmental Impact Assessment (EIA) was carried out to assess the Metro Rail Alignment from RV Road Terminal - Electronic City - Bommasandra Industrial Area with provision for future extension beyond Bommasandra Industrial Area.

#### 8.1.1 Objective of EIA Study

Ministry of Environment and Forests (MoEF), New Delhi has issued various notifications on Environmental Impact Assessment since 1994 the latest being in 2009. According to the notification, 32 types of projects under Schedule-I require environmental clearance from MoEF. Rail projects are exempted from this schedule. This clearly indicated that the proposed project does not require Environmental Clearance. However, Environment Impact Assessment is necessary to assess the impacts and hence, the present study will fulfill this requirement.

The objective of the study is to assess the condition of existing environment, such as air, noise, water, soil, biological and socio economic conditions to identify negative and positive impacts due to the proposed project. Environment Management Plan (EMP)

and monitoring programme will be suggested to control any adverse environmental impacts arising from the proposed project.

### 8.1.2 Project Description

Mass Rapid Transport System (MRTS) is a public transportation system which facilitates commuters to reach any part of the city within short duration. The proposed alignment is North-South Corridor of Bangalore Metro Phase II and this has a lower capacity and lower speed compared to other rail systems and is considered as the best alternate mode of transport in populated area. It starts from RV Road Terminal and terminates at Bommasandra Industrial Area covering a length of 18.82 km. The proposed Metro Rail interweaves through the commercial and residential areas of the city and covers some localities of Jayanagar, East End, JP nagar, Jayadeva Flyover, BTM layout, HSR layout, Central Silk Board Junction, Someshwara Colony, Singasandra, and Electronic City, Hebbagodi and Bommasandra Industrial Area. There are 16 stations in this alignment of which 4 stations are from RV Road terminal to Silk Board Junction and 12 stations from Silk Board Junction to Bommasandra Industrial Area. The salient features of the proposed alignment and stations and the proposed extension of the alignment is given in Table 8.1 and Table 8.2.

**TABLE 8.1: IMPORTANT SALIENT FEATURES OF THE PROPOSED ALIGNMENT**

Salient Features	RV Road Terminal to Electronic City	Electronic City to Bommasandra Industrial Area
Proposed alignment	North-South Corridor	North-South Corridor extension
Length of the alignment	14.84 km	3.24 km
Connecting areas	RV Road Terminal to <b>Electronic City connecting</b> Jayanagar, East End, JP nagar, Jayadeva Flyover, BTM layout, HSR layout, Central Silk Board Junction, Someshwara Colony and Singasandra.	<b>Electronic City</b> to Bommasandra Industrial Area connecting Veerasandra, Huskur Gate and Hebbagodi.
Number of stations	13 (Elevated -12, Surface - 0 & Underground – 0)	3 (Elevated - 3, Surface - 0 & Underground - 0)
Right of Way	20 m	
Project implementation	Start Date: 2012 and Completion Date: 2016	
Rail capacity	1500 passenger/trip (6 coach)	
Frequency	1 train for every 4 minutes (Peak hours)	
Industry/Companies along the proposed alignment	Nace Software, Valumart Infotech, Flint Solutions, Nival Tech, Nulyne, TES Electronic Solutions, Hinduja Global Solution, Wipro, Infosys etc	HCL, Novozymes, Biocon, SKF Industries etc.
Educational Institutions along the proposed alignment	NBK Memorial Educational Society, Planet Kids School, Image College of Arts, Animation & Technology, Oxford	Center for Development and Telematics



	Dental College and Hospital, Venkateshwara Institute of Nursing, Government School, Center for Development and Telematics	
Hospitals along the proposed alignment	Sri Krishna Sevashram Hospital, Manipal Hospital, Jayadeva Hospital, ESI Dispensary and Garden View Hospital	--
Flyover along the alignment	Silk Board Flyover, Express toll way is running parallel to alignment on Hosur Road	Express toll way is running parallel to alignment on Hosur Road
Major road approach joining the alignment	RV Road, East End Main Road, Bannerghatta Road, Hosur Road, NICE Corridor	Hosur road

TABLE 8.2: STATIONS IN THE PROPOSED ALIGNMENT

S.No.	Station Name	Chainage (m)	Type
<b>RV Road Terminal to Electronic City - Bommasandra Industrial Area</b>			
1	RV Road	0.00	Elevated
2	Ragigudda	1255.5	Elevated
3	Jayadeva Hospital	2454.3	Elevated
4	BTM Layout	3582.7	Elevated
5	Silk Board	4543.1	Elevated
6	HSR Layout	5761.0	Elevated
7	Oxford College	6960.8	Elevated
8	Muneshwara Nagar	7858.2	Elevated
9	Chikka Begur	9257.5	Elevated
10	Basapur Road	11053.5	Elevated
11	Hosa Road	11998.3	Elevated
12	Electronic City-I	12990.1	Elevated
13	Electronic City	13987.2	Elevated
14	Huskur Road	15560.2	Elevated
15	Hebbagodi	16848.3	Elevated
16	Bommasandra Industrial Area	17961.4	Elevated

### 8.1.3 Project Benefits

Electronic City has a conglomeration of various largest IT companies of the country such as Hewlett Packard, Infosys, Siemens, Wipro etc., and it is the promising areas in Bangalore South. Hosur Road is the only access road which connects the people from other parts of the city to Electronic City and Bommasandra Industrial Area Industrial Area. The main objective of the proposed alignment is to ease the traffic congestion by facilitating commuters to use public transport in minimal travel time and to reduce air pollution from private vehicles. 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

## 8.2 ENVIRONMENTAL BASELINE STUDIES

### 8.2.1 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 speed was in the range of 2-6 km/hr during the morning observation predominantly in the east-west direction while, the speed in the evening was slightly higher, ranging from 4-8 km/hr.

### 8.2.2 Ambient Air Quality

The existing levels of ambient air quality parameters were assessed at three representative locations along the proposed alignment for Suspended Particulate Matter (SPM), Respirable Particulate Matter (RPM), Sulphur dioxide (SO<sub>2</sub>), Oxides of Nitrogen (NO<sub>x</sub>), Carbon Monoxide (CO) and Hydrocarbons (HC).

Respirable Dust Sampler 460 BL was deployed to monitor RPM, SPM, SO<sub>2</sub> and NO<sub>x</sub>. The sampler was placed to obtain 8 hourly average values of the above said parameters in the month of June 2009. The parameters were monitored and analyzed as per CPCB and NAQM standards.

One grab sample was collected at each ambient air quality monitoring station for analyzing CO and HC. The spot concentration of CO was recorded using Indicator Tube Technique while HC was recorded by Electrochemical Sensor Technique. The ambient air quality results are represented in Table 8.3

**TABLE 8.3: AIR QUALITY PARAMETERS ALONG THE PROPOSED ALIGNMENT**

Monitoring Locations	Parameters Concentration ( $\mu\text{g}/\text{m}^3$ )				
	RPM	SPM	SO <sub>2</sub>	NO <sub>x</sub>	CO
Near Indian Bharat Petroleum, Near Silk Board Junction	462.36	824.90	7.4	64.15	2186

Near Electronic City Bus Stop	312.08	480.12	5.3	62.72	1821	
Near Bommasandra Industrial Area Bus Stop	294.51	386.71	6.5	53.65	-	-
National Ambient Air Quality Standard	<b>100</b>	<b>200</b>	<b>80</b>	<b>80</b>	<b>2000</b>	-

RPM and SPM was found to exceed the National Ambient Air Quality Standard (NAAQ). This increase in RPM and SPM was due to vehicular pollution which is increasing exponentially along the proposed alignment. The results of SO<sub>2</sub> and NO<sub>x</sub> indicated that the values were well within the NAAQ standards. The concentration of CO was slightly higher near Silk Board Junction when compared to CPCB Standards.

### 8.2.3 Noise Quality

The ambient noise levels were recorded at three 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<sub>day</sub> and L<sub>night</sub> of the study area. L<sub>day</sub> is defined noise level measured over a period of 16 hours during day (6 am to 10 pm). L<sub>night</sub> is defined as noise level measured over a period of 8 hours during night (10 pm to 6 am) in the month of June 2009. The noise levels measured are given in Table 8.4

**TABLE 8.4: MEASURED NOISE LEVELS ALONG THE PROPOSED ALIGNMENT**

Monitoring Locations	Noise level dB (A) Leq	
	Day (Leq)	Night (Leq)
Near Indian Bharat Petroleum, Near Silk Board Junction	79.5	70.8
Near Electronic City Bus Stop	77.3	71.5
Near Bommasandra Industrial Area Bus Stop	72.5	68.9
Ambient Noise Standards		
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	50	40

It is observed that noise equivalent levels along the proposed alignment varied in the range 72.5 – 79.5 dB (A) in the day time and 68.9 – 71.5 dB (A) in the night time. These ranges recorded were higher than the permissible limits of CPCB. The source of noise levels in the study area is mainly due to the commercial activities and vehicular movement during the peak hours of the day. Since the Hosur National Highway (NH-7)

is running parallel to the alignment, vehicle movement is observed to be slightly more during night time. There are no major industries which generate noise along the alignment.

#### 8.2.4 Traffic Survey

Identification of traffic volume is most important component in the proposed project. Classified traffic volume count survey has been conducted at the selected locations by trained enumerators for 12 hours from morning 08.00 am to 08.00 pm on working days. The vehicle data has been collected in 15 minute time interval as per the vehicle classification mentioned by Indian Road Congress (IRC). The traffic volume survey was conducted at four locations in the month of June 2009. The first location was near Jayanagar 5th Block signal after Woodys Hotel, the second was near Silk Board Junction, the third location was at Electronic City Junction and the fourth location was near Bommasandra Industrial Area. The locations were identified based on the reconnaissance survey of the proposed metro alignments. The traffic details for the locations are presented in Table 8.5.

**TABLE 8.5: PEAK HOUR TRAFFIC MOVEMENT ALONG THE PROPOSED ALIGNMENT**

Vehicle Type	VC-1		VC-2		VC-3		VC-4	
	NOs	%	NOs	%	NOs	%	NOs	
Two Wheeler	4892	59.15	5089	54.32	2059	44.13	1106	35.16
Auto Rickshaw	910	10.66	681	7.27	170	3.64	117	3.72
Car/Jeep/Van/Taxi	1698	20.53	2567	27.40	1557	33.37	1193	37.92
Mini-Bus	233	2.73	142	1.52	149	3.19	63	2.0
Bus	330	3.99	450	4.80	307	6.58	159	5.05
LCV	108	1.26	141	1.51	178	3.81	215	6.83
2 - Axle Trucks	44	0.53	152	1.62	168	3.60	216	6.87
3 - Axle Trucks	16	0.19	13	0.14	36	0.77	61	1.94
Tractor with/without Trailor	0	0	2	0.02	5	0.11	8	0.25
Bicycles	39	0.47	131	1.40	37	0.79	8	0.25
Total Vehicles	<b>8270</b>	<b>100</b>	<b>9368</b>	<b>100</b>	<b>4666</b>	<b>100</b>	<b>3146</b>	<b>100</b>
Total PCU	<b>8538</b>	-	<b>8138</b>	-	<b>4823</b>	-	<b>3647</b>	-

VC-1: Jayanagar 5<sup>th</sup> Block; VC-2: Near Silk Board Junction

VC-3: Electronic City Junction; VC-4: Near Bommasandra Industrial Area

It is observed that, the two wheelers density ranges from 35 % to 59 % and is found to be dominated compared to other vehicles on road. The variation in traffic is observed in the roads and this depends on various factors such as human behavior, importance of the area and deviations of traffic towards adjoining areas based on their importance of activities. The Congestion Index (CI) was worked out for the proposed alignment and presented in Table 8.6.

**TABLE 8.6: CONGESTION INDEX FOR THE PROPOSED ALIGNMENT**

Sl. No.	Location ID	Peak Hour Traffic Volume in PCU	Designed Service Volume PCU	Maximum Capacity PCU	Congestion Index (CI) Based on	
					Design Service Volume	Maximum Capacity
1	VC-1	8538	3600	5143	2.37	1.66
2	VC-2	8138	5400	7714	1.51	1.05
3	VC-3	4823	5400	7714	0.89	0.63
4	VC-4	3647	5400	7714	0.66	0.47

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. The Congestion Index has exceeded the limit in VC-1 and VC-2. However, the slightly lesser CI is observed in VC-3 and VC-4, this is due to recent widening of Hosur road (NH7) from four lane to six lane resulting in enhancement of Designed Service Volume and Maximum Capacity of the road.

The total vehicle plying from Electronic City to Bommasandra Industrial Area is low compare to RV Road Terminal to Electronic City because Bommasandra Industrial Area and 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.

### 8.2.5 Water and Soil Quality

The Ground water samples were collected from bore wells at 5 locations along the proposed alignment for analysis of Physico-chemical characteristics. The collected samples were analysed as per the CPCB drinking water standards. The physicochemical characteristics of ground water samples collected are summarized in Table 8.7

**TABLE 8.7: PHYSICO-CHEMICAL CHARACTERISTICS OF WATER ALONG THE PROPOSED ALIGNMENT**

Sl. No	Parameters	Observed range	CPCB Limits (Drinking water)
1	pH	6.71 - 7.16	6.5-8.5
2	Total Chlorides (mg/l)	31.99 – 259.92	250
3	Total Hardness (mg/l)	90.5 – 325.37	300
4	Calcium as Ca (mg/l)	21.5 – 80.52	75
5	Magnesium as Mg (mg/l)	12.55 – 28.65	30
6	Sulphate as SO <sub>4</sub> (mg/l)	6.25 – 38.50	200
7	Nitrate as NO <sub>3</sub> (mg/l)	5.85 – 28.74	45
8	Total Dissolved Solids (mg/l)	320 – 742	500



The ground water sample collected showed that most of the parameters were generally well within the permissible limits as specified by CPCB. However, the total chlorides and total hardness are slightly higher in compared to standards. In few places, the total dissolved solids exceed the standards. Similarly the surface water sample was also collected from Madiwala Lake located along the proposed alignment for analysis of Biological Oxygen Demand (BOD). It was observed that the BOD of the lake was 12.0 mg/l, while the permissible limit for BOD according to BIS is 3 mg/l.

Similarly representative surface soil samples from a depth of 0 - 20 cm were collected from different locations and were analysed for soil physico-chemical properties. The bulk density of soils ranged from 1.21 - 1.52 g/cm<sup>3</sup>. Thus, the porosity and water holding capacity also varied largely and found in the range of 42.3 - 52.2 % and 42.2 - 55.5 % respectively. 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 0.21 - 0.45 per cent. The soil organic carbon contents of the study area varied to a great extent depending on the land use.

## **8.2.6 Green Cover Assessment**

Bangalore city has the dubious distinction of being one of the fastest growing Metropolitan city in Asia. Despite this fast growth, it 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's 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.

### **8.2.6.1 Methodology**

Green cover assessment study has been carried out to record the plant species existing all along the proposed Metro rail corridor from RV Road terminal to Electronic City - Bommasandra Industrial Area and further extension to Bommasandra Industrial Area. Botanist have identified and recorded various species on the rail alignment with the available field guides for Bangalore city.

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 stations. 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.

### 8.2.6.2 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 8.8. Trees to be cut and trimmed at stations, curves and alignment were studied as per the maps provided by DMRC.

**TABLE 8.8: TREE POPULATION ALONG THE PROPOSED ALIGNMENT**

Sl. No.	Metro Alignment	Trees found along the alignment			
		0-5m		5-10m	
		Left	Right	Left	Right
1	RV Road terminal to Electronic City Junction	7	35	112	137
2	Electronic City to Bommasandra Industrial Area	0	0	0	22
<b>Total</b>		<b>7</b>	<b>35</b>	<b>112</b>	<b>159</b>

A total of 291 trees were recorded in the proposed alignment of which 42 trees were recorded at 0-5 m alignment and 249 at 5-10 m respectively. In the proposed Electronic City – Bommasandra Industrial Area length there were no trees found within the 0-5 m while 22 trees were observed in 5-10 m along the right side of the alignment. It is observed that there are more number of trees in the right side of the alignment. 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*.

### 8.2.6.3 Affected Tree Population

A total of 118 trees will have to be cut and 289 trees will have to be pruned from RV Road Terminal to Electronic City. The 289 trees being trim attributes to loss of 2405 m<sup>2</sup> canopy area. It is observed that slightly more trees are going to be cut for construction of stations from R V road terminal to Silk Board Junction; however few trees are found to be affected from Silk Board Junction to Electronic City because the alignment runs in service road and has single sided stations. The details of affected tree population are given in Table 8.9.

**TABLE 8.9: OVERALL AFFECTED TREES ALONG THE PROPOSED ALIGNMENT**

Sl. No	Locations	No. of trees to be cut	No. of trees to be trimmed	Canopy area loss (m <sup>2</sup> )
<b>RV Road Terminal to Electronic City - Bommasandra Industrial Area</b>				
1	Stations	84	39	131
2	Curves	19	5	32
3	Road median	2	0	0
4	Alignment	21	271	2316
<b>Total</b>		<b>126</b>	<b>315</b>	<b>2479</b>

It is estimated that out of 126 trees to be cut along corridor, 57 trees are big canopy trees followed by medium canopy of 41 and small canopy trees of 28 respectively. The majority of the smaller canopy trees belong to Ashoka trees planted along the proposed alignment.

The affected tree canopy is depicted in Table 8.10.

**TABLE 8.10: AFFECTED TREE CANOPY ALONG THE PROPOSED ALIGNMENT**

Sl. No	Tree canopy	Alignment, Curves & Median		Stations	
		Number	Biomass (t)	Number	Biomass (t)
<b>RV Road Terminal to Electronic City - Bommasandra Industrial Area</b>					
1	Big canopy trees with girth >70cm at GBH	8	15.06	42	162.24
2	Medium canopy trees with girth 40 to 70 cm at GBH	10	1.59	30	8.04
3	Small canopy trees and shrubs with girth <40 cm	24	0.27	04	0.44
<b>Total</b>		<b>42</b>	<b>16.92</b>	<b>84</b>	<b>170.72</b>

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. Very few trees to be cut in median i.e. at R V Road Terminal and 19 trees will be cut in curves.

### 7.2.7 Socio Economic Assessment

Socio Economic Survey was conducted through questionnaires 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 the Right of Way (ROW). Many questions were posed to the public and their perception regarding Metro Rail was collected. In addition, the people participatory appraisal has been conducted for the Project Affected People (PAPs). The result of the survey has been explained in the following paragraphs.

According to the inception conducted in the proposed alignment few commercial structures, educational institutions and few residential structures are partially affected. The alignment is designed such that most of the open land has been utilized rather than structures.

#### 8.2.7.1 Features Identified along the Alignment

##### ➤ RV Road Terminal to Electronic City

- **From RV Road Terminal to Ragigudda:** The rail track is at the centre of the existing road, hence shoulder area of the road will be acquired. At RV Road Terminal only 2 small shops and Hopcoms are within the ROW. Other than these, no displacement is likely to be take place. However, these shops were covered under social survey in order to know their socio-economic status.

- **From Ragigudda to Jayadeva Hospital:** At a distance of 770 m away from Ragigudda the alignment gradually moves to the left end of the existing road. This is due to presence of Jayadeva Flyover. There are a few shops along the left side of the existing road which are likely to be affected due to the change in the alignment. There is existence of High Tension Line of about 946.176 m distance away from Ragigudda.
- **From Jayadeva Hospital to BTM Layout:** The alignment from the left end of the road moves gradually to the centre at the location where Jayadeva Flyover ends. There are a few shops which are likely to be affected due to the change in the alignment.
- **From BTM Layout to Silk Board:** The alignment is at the centre of the existing road hence there will not be any property loss.
- **From Silk Board to Electronic City - Bommasandra Industrial Area:** The alignment runs over the existing service road up to the Electronic City. All along the right side of the alignment there is land requirement and property loss is minimum except at stations.

#### 8.2.7.2 Features Identified along the Stations

Stations are proposed based on the availability of open land. Out of the 12 stations only 3 stations i.e. HSR Layout, Muneshwara Nagar and Electronic City have structures within the proposed station area while the rest of the 9 stations have open land.

There are 3 stations in the proposed extension from Electronic City to Bommasandra Industrial Area. All the stations are planned on service road and open land.

8.2.7.3 The number of properties affected by this extension are given in the table below.

Alignment / Station	DETAILS OF PROPERTY				
	RESIDENTIAL	COMMERCIAL	RELIGIOUS	OTHERS	TOTAL
Viaduct	05	143	04	17	169
Stations	07	25	02	08	42
<b>TOTAL</b>	<b>12</b>	<b>168</b>	<b>06</b>	<b>25</b>	<b>211</b>

#### 8.2.7.4 Socio Economic Profile of the PAPs

It is observed from the survey that most of the project affected structures have individual type of business. Almost all the buildings along the alignment are pucca houses and have been constructed with brick-mortar. There are few semipucca houses from Silk Board Junction to Electronic City. Most of the buildings which are likely to be affected are ground floor followed by 1st floor, only few buildings were 2nd floor. Majority of people being interviewed are carrying on commercial activities from 5-10 years and are licensed.

It is observed from the survey that maximum number of people who are in age group of 18-35 years are likely to be affected. The analysis of data reveals that the majority of the people belong to Hindu religion. The caste distribution of Project affected Families (PAFs) shows that majority of the people are general category. There was no Schedule Tribes found along the alignment, however, only 3 house holds belong to Schedule Caste were observed. It is noted that majority of people being affected due to the proposed alignment have their annual income is  $\geq 2$  lakhs and whose main source of income is through business, rent and job.

#### 7.2.7.5 Perception of PAPs (Rehabilitation and 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 alignment. 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 and wide range of benefits to the surrounding community.

### 8.3 NEGATIVE ENVIRONMENTAL IMPACTS

#### 8.3.1 Impacts due to Project Location

##### 8.3.1.1 Land Acquisition

Land area to be acquired for this line has been given in Civil Engineering chapter.

##### 8.3.1.2 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 existing 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 441 trees during construction from RV Road Terminal to Electronic City. Out of these, 126 trees will be cut in areas of proposed alignment, stations, curves and median and rest 315 trees will be pruned all along the proposed alignment, stations and curves. The 289 trees canopy loss constitute to about 2479 m<sup>2</sup> of which major portion coming in RV Road Terminal to Silk Board Junction. The 126 trees to be cut in the proposed corridor constitute about 187.64 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.

### 8.3.1.3 Utility/Drainage Problems

The proposed alignment runs on existing road and elevated all along the stretch. The utility services viz., lamp post, bus stop, manhole, drain, power line and telephone cables will be affecting partially, thus some of the utilities will have to be maintained in working condition during construction stage itself. These utilities are essential for the people living in the vicinity, hence temporary/permanent diversion of the necessary utilities have to be considered to minimize the inconvenience caused due to the project. The utilities/drainage which are likely to be affected due to stations and alignments are listed in Table 8.11.

**TABLE 8.11: LIST OF PUBLIC UTILITIES TO BE SHIFTED ALONG THE PROPOSED ALIGNMENT**

Location	Utilities (Numbers)					
	Lamp Post	Bus Stop	Manhole	Telephone cable	Power line	Drain
RV Road Terminal to Electronic City						
Stations	21	2	6	8	--	13
Alignment	94	1	2	4	1	--
<b>Total</b>	<b>115</b>	<b>3</b>	<b>8</b>	<b>12</b>	<b>1</b>	<b>13</b>

It is observed that, Station 4, Station 5, Station 6 and Station 12 will adversely affect the drainage. Around 13 drains with width ranging from 4.33 to 13.78 m and length ranging from 120.23 to 190.147 m will have to be diverted. In addition to these utilities about 115 lamp posts, 12 telephone cables and one high tension line (4.01 m width) will be affected. There is only one drain running parallel to the left side of the alignment from Silk Board Junction to Electronic City. There is no major utilities loss noticed from Electronic City to Bommasandra Industrial Area.

## 8.3.2 Impacts due to Project Construction

### 8.3.2.1 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 movement of more than 100 vehicles per day. 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.

### 8.3.2.2 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.

### 8.3.2.3 Soil Erosion and Health Risk at Construction Site

Land leveling and excavation leads to soil erosion. From the estimations made on the basis of preliminary drawings, it is estimated that the total quantum of excavated soil from the twin corridors will be approximately of about 5.50 lakh cubic meters and a portion of this can be used for backfilling.

Health is usually affected due to lack of sanitation facilities (water supply and human waste disposal) and insect vector disease hazards of local workers. Problems could arise due to difference in cultural habits of imported workers and local residents.

Dumping of construction spoils like concrete, bricks, waste material from camps etc cause surface and ground water pollution. Movement of vehicles carrying construction materials/spoils will also cause dust to accumulate in air causing air pollution.

### 8.3.2.4 Traffic Diversion

Temporary traffic diversion is essential for smooth flow during construction hence this will result in 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 thus increase air and noise pollution. This impact is however only temporary in nature, as the diversion will last only till the construction phase is completed.

### 8.3.2.5 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 water requirement during various construction activities such as concrete mixing, curing, washing, dust suppression etc. will need significant amount of water. The water demand estimated for the proposed project is approximately about 500 m<sup>3</sup>. 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.

### **8.3.2.6 Natural Disaster**

The 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.

### **8.3.2.7 Loss of Historical and Cultural Monuments**

The proposed alignment does not involve any loss of historical/cultural monuments and it is beyond sensitive areas.

## **8.3.3 Impacts due to Project Operation**

### **8.3.3.1 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.

### **8.3.3.2 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.

### **8.3.3.3 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 12 stations is 27000 liters/day and 6750 liters/day for the future extension. In addition, water demand at stations for cleaning, sanitation, fire fighting and washing purpose will be about 450 m<sup>3</sup>/day. Municipal water or ground water supply will be tapped for drinking purposes. The sewage treatment plant at the K&C (Koramangala and Chalaghatta) Valley is proposed for toilets cleaning, washing etc. As per the waste water discharge about 0.4 MLD sewage treatment plant has been proposed.

Water pollution may be due to spilling of oil, grease, fuel and paint in the equipment yards. However, since the Metro rail runs through electricity the quantities of such spills are very negligible.

#### 8.3.3.4 Solid Waste Generation

The waste generated from stations and rail includes garbage, rubbish from wrappers, discarded boxes, rags etc are the solid waste sources. Based on the data generated, it is estimated that about 6g of refuse will be generated per person per day at Indian Railway Stations. There is no shop or cafes at these stations hence there is no much generation of garbage. Due to unavailability of solid waste data, it is assumed about 3g/ person/ day of refuse generation at proposed Metro stations. Thus, it is estimated that about 1.00 tonne of solid waste is likely to be generated from RV Road Terminal to Electronic City and about 0.25 tonne from Electronic City to Bommasandra Industrial Area. 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.

### 8.4 POSITIVE ENVIRONMENTAL IMPACTS

#### 8.4.1 Employment Opportunities

The proposed alignment is expected to commence during 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 to employment. It is estimated that, about 2000 people per day are expected to be deployed during the peak period of construction activity for the project. On an average 2.4 lakh man days are required annually. During operational phase, there will be employment generation for about 650 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.

#### 8.4.2 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. Invest in surrounding companies or industries are anticipated. In addition to this factor socio-economic conditions of people along the corridor will also be benefited. The reduction in number vehicles directly reduces fuel consumption and pollutants. The proposed alignment will facilitate people to move quickly towards other parts of city. This will encourage people to be involved in trade and commerce and other services. 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.

### 8.4.3 Reduction in Number of Vehicles on Road

The existing road network is extensively used by pedestrians, cyclists, motorists, buses and trucks etc, this has caused traffic congestion. According to the survey carried out on the proposed alignment from RV Road Terminal to Electronic City, the vehicle movement of two wheelers ranges from 2059 to 5089, three wheelers ranges from 170 to 910, four wheelers ranges from 1557 to 2567 and buses ranges from 142 to 450 during peak hours. Similarly the survey carried out in the stretch from Electronic City to Bommasandra Industrial Area indicated 1106 two wheelers, 117 three wheelers, 1193 four wheelers and 222 buses traveling 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 peak hour traffic data collected during traffic survey conducted along the proposed alignment has been projected upto 2016 (Metro fully operational) with an annual growth rate of 5%. The details of the projected traffic by 2016 are summarized in Table 8.12.

**Table 8.12: Projected peak hours traffic volume**

Vehicle Type	Vehicles/ day							
	2009				2016			
	VC-1	VC-2	VC-3	VC-4	VC-1	VC-2	VC-3	VC-4
Two Wheeler	4892	5089	2059	1106	6884	7161	2897	1556
Auto Rickshaw	910	681	170	117	1280	958	239	165
Car/Jeep/Van/Taxi	1698	2567	1557	1193	2389	3612	2191	1679
Mini-Bus	233	142	149	63	328	200	210	89
Bus	330	450	307	159	464	633	432	224
Other Four Wheelers	168	308	387	500	236	433	545	704
Total Vehicles*	<b>8231</b>	<b>9237</b>	<b>4629</b>	<b>3138</b>	<b>11582</b>	<b>12997</b>	<b>6513</b>	<b>4417</b>

Note: Annual 5% traffic growth is considered as per norms of Planning Commission

\* Bicycles excluded

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.



**Table 8.13: Expected reduction of vehicles on road due to the proposed alignment**

Category of vehicles	No. of Vehicles without Metro 2016				No. of Vehicles with Metro 2016				% Shift to Metro
	VC-1	VC-2	VC-3	VC-4	VC-1	VC-2	VC-3	VC-4	
Two wheelers	6884	7161	2897	1556	4474	4654	1883	1011	35
Three Wheelers	1280	958	239	165	1024	767	191	132	20
Four Wheelers	2389	3612	2191	1679	1792	2709	1643	1259	25
Mini-Bus	328	200	210	89	311	190	199	85	5
Bus	464	633	432	224	371	507	346	179	20
Other Four Wheelers	236	433	545	704	236	433	545	704	0
<b>Total</b>	<b>11582</b>	<b>12997</b>	<b>6513</b>	<b>4417</b>	<b>8210</b>	<b>9260</b>	<b>4807</b>	<b>3370</b>	<b>-</b>

#### 8.4.4 Less Fuel Consumption

The main fuels consumed by 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 and depicted in Table 4.3 and Table 4.4. The projected vehicles in the proposed alignment from RV Road Terminal to Electronic City will save 2122 liters / day of petrol and 595 liters/ day of diesel after initiation of Metro rail. Similarly, the projected vehicles in the future proposed alignment from Electronic City to Bommasandra Industrial Area will save 234 liters / day of petrol and 89 liters/ day of diesel.

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. 4.03 crores from petrol and Rs. 0.80 crores from diesel can be saved per year from RV Road Terminal to Electronic City (Table 4.3). Similarly, Rs. 0.44 crores from petrol and Rs. 0.12 crores from diesel can be saved per year from Electronic City to Bommasandra Industrial Area. Thus, we can save fuel cost nearly Rs. 4.83 crores from RV Road Terminal to Electronic City and Rs. 0.56 crores from Electronic City to Bommasandra Industrial Area per year. Hence, the overall fuel cost savings is about Rs. 5.39 crores / year from RV Road Terminal to Bommasandra Industrial Area. 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.

**Table 8.14: Expected fuel consumption per day along the proposed alignment**

Mode of Transport	No. of vehicles (Peak hours)				Total km vehicle traveled / day*				Mileage (km/l)	Total fuel consumption / day (in liters)				
	VC-1	VC-2	VC-3	VC-4	VC-1	VC-2	VC-3	VC-4		VC-1	VC-2	VC-3	VC-4	Total
<b>Without Metro (2016)</b>														
Two Wheelers	6884	7161	2897	1556	34418	37236	12458	5602	40	860	931	311	140	2243
Three Wheelers	1280	958	239	165	6402	4983	1029	594	22	291	226	47	27	591
Four Wheelers	2389	3612	2191	1679	11946	18783	9421	6044	11	1086	1708	856	549	4199
<b>Total Petrol required / day</b>										<b>2237</b>	<b>2865</b>	<b>1215</b>	<b>717</b>	<b>7034</b>
Mini-Bus	328	200	210	89	1639	1039	902	320	7	234	148	129	46	557
Bus	464	633	432	224	2322	3293	1858	806	4.6	505	716	404	175	1800
Other Four Wheelers	236	433	545	704	1182	2254	2342	2534	4.5	263	501	520	563	1847
<b>Total Diesel required / day</b>										<b>1002</b>	<b>1365</b>	<b>1053</b>	<b>784</b>	<b>4204</b>
<b>With Metro (2016)</b>														
Two Wheelers	4474	4654	1883	1011	22371	24203	8098	3641	43	520	563	188	85	1356
Three Wheelers	1024	767	191	132	5122	3986	823	475	24	213	166	34	20	434
Four Wheelers	1792	2709	1643	1259	8960	14087	7066	4533	12	747	1174	589	378	2887
<b>Total Petrol required / day</b>										<b>1480</b>	<b>1903</b>	<b>811</b>	<b>482</b>	<b>4677</b>
Mini-Bus	311	190	199	85	1557	987	856	304	8	195	123	107	38	463
Bus	371	507	346	179	1857	2634	1486	645	5	371	527	297	129	1325
Other Four Wheelers	236	433	545	704	1182	2254	2342	2534	4.8	246	470	488	528	1732
<b>Total Diesel required / day</b>										<b>812</b>	<b>1120</b>	<b>892</b>	<b>695</b>	<b>3519</b>

\* As per the alignment distance (VC-1 = 5 km, VC-2 = 5.2 km, VC-3 = 4.3 km and VC-4 = 3.6 km)

**Table 8.15: Expected fuel and their cost savings from the proposed alignment**

Savings	VC-1	VC-2	VC-3	VC-4	Total
Total Petrol (Liters) saved / day	757	962	403	234	2357
Total Diesel (Liters) saved / day	189	245	161	89	685
Total Petrol Cost (Rs.) saved / day	39372	50025	20968	12183	122548
Total Diesel Cost (Rs.) saved / day	7000	9077	5952	3301	25329
Total Petrol Cost (crores) saved / year	4.03			0.44	4.47
Total Diesel Cost (crores) saved / year	0.80			0.12	0.92
Total Fuel Cost (crores) savings / year	4.83			0.56	5.39

#### 8.4.5 Reduction in Air Pollution

The urban air pollution generally means unacceptable levels of pollutants emitted from vehicles such as Carbon Monoxide (CO), Hydro Carbons (HC), Nitrogen oxides (NOx), Sulphur Dioxide (SO<sub>2</sub>) and particulates in the atmosphere. The environmental study conducted by CPCB/KSPCB indicates that the high level of air pollution in the Bangalore City is mainly due to urban transportation. The baseline environmental study carried out in the present study supports this statement. The survey conducted clearly indicates that two and three wheelers are seen predominantly on the proposed alignment. With the operation of both Phase-I and Phase-II corridors of Metro, many commuters are expected to shift from the private/public transportation to Metro rail. This shift will considerably reduce the usage of personalized vehicles, which is eventually reduce the air and noise pollution at source itself. Currently, the emission of CO, NOx and HC of vehicles plying on road is within the CPCB standard while particulate matter found to be exceeded the permissible limit. An attempt has been made to estimate the pollution load by colligating exhaust emission factor and the petrol consumption. The reduction in air pollution after commissioning of Metro is depicted in Table 8.16. It is observed that the proposed project will reduce nearly 1.0 tonne of pollutants per day.

**Table 8.16: 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 kg)				
		VC-1	VC-2	VC-3	VC-4	Total
Carbon Monoxide	391	296.05	376.15	157.66	69.36	899.22
Hydrocarbons	34	25.74	24.77	9.99	2.34	62.84
Oxides of Nitrogen	19.2	14.54	13.99	5.64	1.32	35.48
Oxides of sulphur	1.5	1.14	1.09	0.44	0.10	2.77
Particulate matter	1.9	1.44	1.38	0.56	0.13	3.51
<b>Total</b>		<b>338.91</b>	<b>417.38</b>	<b>174.29</b>	<b>73.25</b>	<b>1003.83</b>

\* Exhaust emission factor as per H.B. Mathur, 1984.

#### 8.4.6 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 per trip. 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 non peak hours i.e. 11.00 am to 4:00 pm and 8.00 pm to 12.00 am (9 hours) accounts to 67 trips. Since the Metro is in urban area passengers will be more during day while hardly few passengers can be expected to travel at night.

Considering the average train movement, around 3.25 lakhs passenger/day is expected. The existing transportation system on the city roads takes 1.5 to 2.0 hours to reach Electronic City from City Bus Station, while the estimated travel time using Metro rail takes < 1 hour to cover the same distance. 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 162500 man hours.

#### 8.4.7 Reduction in Accidents

Since Hosur Road is a National Highway, the LMV and HMV plying on the road move at a fast pace. As per the Bangalore traffic police data, about 120 deaths and 1500 accidents occurred during 2008 on Hosur road and the stretch from Madiwala to Electronic City is dangerous as compare to other city roads. There are several villages on either sides of Hosur road, pedestrian movement is high. The construction of flyover has not much reduced the accidents so far. 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.

#### 8.4.8 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.

### 8.5 ENVIRONMENTAL ASSESSMENT

#### 8.5.1 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 8.17.

**Table 8.17: 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	<b>Impacts due to Project Construction</b>				
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	<b>Impacts due to Project Operation</b>				
3.1	Oil Pollution		*		Waste management plan will be adapted
3.2	Noise Pollution		*		Not much envisaged
3.3	Water Supply and Sanitation at Stations		*		Water and waste management plan will be adapted
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

### 8.5.2 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.

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

- s EIU = Environmental Impact Unit  
 EQ<sub>ij</sub> = Environmental Quality Relative Scale value for i<sup>th</sup> factor of j<sup>th</sup> alternative  
 PIU<sub>i</sub> = Parameter Importance Unit for i<sup>th</sup> 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 8.18.

**TABLE 8.18: 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				
a) Air Quality	345	185	245	+60
b) Water Table/ Quality	114	112	113	+1
c) Land	65	63	61	- 2
II. BIOLOGICAL				
a) Terrestrial Ecosystem	205	185	200	+ 15
b) Aquatic Ecosystem	22	21	22	+ 1
III. SOCIO ECONOMIC (Traffic Congestion, Fossil Fuels, Quality of life, Comforts etc)	249	45	225	+180
Total	1000	611	866	+255

It is observed that the initiation of the Metro rail system from RV Road Terminal to Bommasandra Industrial Area would be beneficial against an ideal of 1000 units. The EIU stands at 611 units at present with the absence of Metro; an increase up to 866 units following the introduction of Metro rail is accompanied by the implementation of a comprehensive Environmental Management Plan. Therefore, a net gain of 255 EIU units (42 % gain) with respect to baseline (2009) is observed which demonstrates a positive benefit to the surrounding community.

Incidentally, the prevailing baseline EIU value of 611 (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 611. The overall benefit in EIU due to Metro will be =  $866 - 535 = 331$  with reference to predicted EIU value of 535 after 7 years, i.e. the improvement of 62 %.

## 8.6 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.

## 8.6.1 Mitigation Measures

### 8.6.1.1 Compensation for Loss of Land

As discussed in the Chapter 4, the land to be acquired for the proposed alignment is 21.25 ha. Out of which 14.60 Ha land is Government. According to Land Acquisition Act, 1894 a suitable compensation should be provided for land owners. The compensation to be provided to the land owners has been worked out at an average of Rs. 2500/ sq ft with reference to the Bangalore Development Authority (BDA) Gazetteer, 2007. Therefore, the total Private land acquisition from RV Road Terminal to Bommasandra Industrial Area is about 6.65 ha and the total compensatory cost is Rs. 166.25 crores. Individual beneficiaries will be identified and their compensation will be taken care without any misuse.

### 8.6.1.2 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 126 trees are likely to be lost due to the proposed alignment from RV Road Terminal to Electronic City and the total value of these trees lost is Rs. 100400. According to the MoEF guidelines for compensatory afforestation, ten trees have to be planted for each tree cut. Hence, 1260 trees will be planted along the corridor. These trees would have occupied about 1.26 ha area @ Rs. 10 Sq. m per tree. The cost includes saplings, tree guard, watering, control of pest and weed, thinning and maintenance for 5 years excluding the land cost. The Compensatory reforestation cost from RV Road Terminal to Electronic City will be 11.8 lakhs and from Electronic City to Bommasandra Industrial Area is about 0.8 lakhs which includes road side plantation.

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 1260 trees in 3.11 acres of land under compensatory afforestation can sequester 311 metric tonnes of carbon in 50 years, thus the proposed project can sequester 6.22 metric tones of carbon in a year.

### 8.6.1.3 Green Belt Development

In addition to the compensatory afforestation (plantation), green belt area can be developed for the total 18 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 8.19.**

- a. One row of small trees at three meter intervals in the central ribbon @ Rs. 125/sapling for 333 saplings (for 1 km elevated length) = **Rs. 41600.00**
- b. Small shrubs on both sides of central ribbon to cover 0.75 m width @ Rs. 50/sapling or 1333 saplings for two sides = 2666 seedlings  
Rs. 50 x 2000= **Rs. 133300.00**
- c. Grasses and perennial herbs on both the sides of 1000 m @ Rs. 50/m<sup>2</sup> to cover balance 0.75 m width  
Rs. 50 x 0.75 m<sup>2</sup> x 2000 m = **Rs. 75000.00**

**Table 8.19: Cost Estimate for Green Belt Development along the proposed alignment**

Green belt type	Establishment cost for 1 km	RV Road to Electronic City (14.5 km)
Small trees	41600	603200
Shrubs	133300	1932850
Grass/herbs	75000	1087500
<b>Total</b>	<b>2,49,900</b>	<b>36,23,550</b>

The total cost for green belt development under the elevated track is from RV Road Terminal to Electronic City the cost is about Rs. 36.23 lakhs.

#### 8.6.1.4 Translocation of trees

Among the 126 trees to be cut, about 22 trees can be translocated to nearby park, which are having shallow root systems. This requires Rs. 5,000 tree towards translocation expense resulting a total Rs.110000.00 is required to translocate 22 trees without any damage.

**NOTE BY BMRCL:**

***Translocation of trees is found to be not successful as the rate of survival of translocated trees is about 10% and the cost of translocation of each tree comes to Rs.1.00 lakh. So instead of translocating the trees, saplings will be planted at the rate of 10 trees for every tree that will be cut***

#### 8.6.1.5 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. The proposed project involves displacement of 14 residential of about 433.32 sq m of land and 85 commercial sectors comprising of shops and companies of about 6235.699 Sq m. According to the survey majority houses affected are from Silk Board Junction to Electronic City. The future extension from Electronic City to Bommasandra Industrial Area area affects one commercial area while the rest of the area is open land belonging to private sector.

Compensatory land records for each person have been updated to give compensation to the right persons and to avoid misuse of any property. The compensation for loss land in the proposed alignment from RV Road Terminal to Electronic City is Rs. 152.25 crores and Rs. 24.37 from Electronic City to Bommasandra Industrial Area. Therefore, about Rs. 176.57 crores will be paid a compensation for property loss due to the proposed project. As per the BDA Gazetteer 2007, the land cost has been worked out at Rs. 2500/ sq ft from RV Road Terminal to Electronic City area and Rs. 1000/ sq ft from Electronic City to Bommasandra Industrial Area area.

About 500 workers per day will be employed for the construction work and during peak working days it may reach 2000. Provisions will be made to enhance the female employment opportunities by encouraging female workers to participate even in the construction activities. To prevent possible traffic congestion, temporary access roads will be used during construction phase for transportation of personnel/ materials /equipment. However, the traffic congestion is less likely to be observed as the proposed construction activity is in service road.

#### 8.6.1.6 Water Supply and Sanitation

The water demand for the proposed project is expected to be around 500 m<sup>3</sup> and 450 m<sup>3</sup> during construction and operation phases respectively. Much of the water



required for construction would be met by treated water from nearest BWSSB and the additional water would be procured from private water supplier chain.

Runoff from the construction site can be a source of water pollution. Cement based products/ dust carried by the runoff from the land surface can pollute surface water bodies. Surface covers are proposed to be spread on the land to prevent dust settlement on the land surface. Proper sanitary facility will be made available for the construction workers. The construction workers drinking water demand will be fulfilled only through ground water. Efforts shall be made to reduce the wastage of water during construction by encouraging water recycling techniques. During the operation phase, adequate water supply and sanitation facilities would be made available at all the stations.

#### **8.6.1.7 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.

#### **8.6.1.8 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 muffers, sound barriers etc. Vehicles used for transportation of construction materials would be equipped with proper silencers. Careful planning has been made to operate the construction equipments to have minimal disturbances. The construction equipments would be run only during the daytime and their noise would be monitored as per CPCB standards. Establishment of tree cover all along the corridor will further reduce the noise levels during operation phase. In addition, an appropriate chronological land use planning would be made available to prevent and minimize noise and vibration impacts.

#### **8.6.1.9 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.

**8.6.1.10 Soil Disposal**

The construction activities will generate approximately 5.50 lakhs m<sup>3</sup> of soil/debris causing soil erosion during excavation. This can be mitigated by utilizing around 40 % of excavated soil for land filling purposes and rest will be transported to the sites as suggested by Bangalore Development Authority (BDA) or other municipal agencies. 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.

**8.6.1.11 Rain Water Harvesting**

Roof top rain water harvesting can be carried out at stations. The rooftop of the stations will act as 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 30000 sqm of the station area can harvest approximately 17.85 million liters of rainwater annually in the proposed alignment from RV Road to Electronic City. Similarly, around 8000 sqm of the station area will harvest 4.76 million liters of rainwater annually in the line from Electronic City to Bommasandra Industrial Area.

**TABLE 8.20: RAIN WATER HARVESTING POTENTIAL ALONG THE PROPOSED ALIGNMENT**

Items	RV Road to Electronic City
Stations Roof area (sq m)	30000
Total rain water available for harvest (Million liters)	17.85
Total	<b>22.61 million liters</b>

Note: Avg. annual rainfall - 850 mm; Rainfall availability for harvest – 70 %

**8.6.1.12 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 and these DG sets will be monitored as per CPCB guidelines.

Some of the effective species which absorb air pollutants are *Azadirachta indica*, *Terminalia chebula*, *Dalbergia sissoo*, *Albizia amara* and *Mangifera indica* are proposed along the road sides.

#### **8.6.1.13 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.

#### **8.6.1.14 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. Hazards have 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.

## **8.7 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.

## **8.8 ENVIRONMENTAL COSTS**

All costs involved in Environmental Management and monitoring are likely to be 2.75 crores which has been taken into account in the cost chapter.

**CHAPTER-9**

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**COST ESTIMATES**



## CHAPTER 9

### COST ESTIMATES

#### 9.1 INTRODUCTION

9.1.1 Detailed cost estimates for R V Road – Electronic City – Bommasandra Ind Area line have been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, etc. considering 750v DC Traction at January 2011 price level.

9.1.2 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.

**NOTE BY BMRCL:**

*These observations are noted and wherever differences have arisen they have been noted in the paras concerned.*

9.1.3 In order to arrive at realistic cost of various items, costs have been assessed on the basis of accepted rates in various contracts of DMRC Ph-III works. For some of the items, tenders have been finalized recently and most of these tenders are with fixed price rates (i.e. no escalation is payable during contract period). Such rates have been adopted, as they are. 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 estimates of some items have been revised based on Bangalore Metro phase-1 rates**

9.1.4 The overall capital cost for R V Road – Electronic City – Bommasandra Ind Area, at January 2011 price level, works out to Rs. 3223.2 crores, 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 9.1

**NOTE BY BMRCL: BMRCL estimate is Rs.4188.56 crores**

**TABLE 9.1**

**(Rs In Crores)**

**Abstract Cost Estimate of R V Road - Elec City - Bommasandra line (BM Ph-II)**  
**Total length = 18.82 km, ( Completely Elevated)**  
**Total Station = 16nos ( all elevated)**

**January 2011 price level (Cost without Taxes & Duties)**

S. No.	Item	Unit	As per DPR			As per BMRCL		
			Rate	Qty.	Amount (Rs in Cr.)	Rate	Qty.	Amount (Rs in Cr.)
<b>1.0</b>	<b>Land</b>							
1.1	Private land	Hect.	29.56	6.650	196.57	30.00	21.25	637.50
1.2	Govt.Land	Hect.	5.00	14.600	73.00	0.00	14.60	0.00
1.3	Railway Land	Hect.	17.70	0.000	0.00	0.00	0.00	0.00
1.4	Temporary land for casting yard, working spaces etc.	Hect.	1.20	8.000	9.60	1.20	8.00	9.60
1.5	Miscellaneous works like Boundary wall etc.	km	0.70	0.000	0.00	0.00	0.00	0.00
1.6	Cost of land for rehabilitation ( to be identified)	LS			40.00			40.00
	<b>Sub Total (1)</b>				<b>319.17</b>			<b>687.10</b>
<b>2.0</b>	<b>Alignment and Formation</b>							
2.1	Underground section by Cut & Cover excluding Station length	R. km.	101.16	0.000	0.00	0.00	0.00	0.00
2.2	Tunneling by TBM	R. km.	144.31	0.000	0.00	0.00	0.00	0.00
2.1	Elevated viaduct section	R. km.	29.87	19.320	577.14	31.50	19.320	608.58
2.1.1	Special Spans	R. km.	41.90	0.500	20.95	41.90	05.00	20.95

3	<b>Station Buildings</b>							
4.1	Underground Station	Each	120.75	0.000	0.00	0.00	0.00	0.00
3.1	Elevated stations (including finishes)							
a	Type (A) way side	Each	20.59	12.000	247.09	30.60	12.000	367.20
b	Type (B) Way side with signaling	Each	22.02	2.000	44.04	32.40	2.000	64.80
c	Type (C), Terminal station	Each	23.44	2.000	46.87	34.20	2.000	68.40
3.2	Interchange facilities at interchange stations	Each	5.25	1.000	5.25	5.25	1.000	5.25
3.3	Subways for stations	Each	10.00	12.000	120.00	12.00	12.000	120.00
	<b>Sub total (3)</b>				<b>463.25</b>			<b>625.65</b>
4	<b>E&amp;M Works</b>							
5.1	Underground station (E&M ,Lifts ,Escalators, DG sets, UPS, TVS, ECS etc.)	Each	51.53	0.000	0.00	0.00	0.00	0.00
4.1	Elevated station (E&M, Lifts Escalators, DG sets etc.)	Each	6.53	16.000	104.50	6.47	16.00	103.52
	<b>Sub total (4)</b>				<b>104.50</b>			<b>103.52</b>
5.0	<b>Depot</b>							
5.1	Depot at Hebbagodi ( i/c Civil works, E & M,P&M, Track work, OHE etc.)	LS			150.00			Civil E&M 120.00 Track 28.00 M & P 90.00 <u>238.00</u>
	<b>Sub total (5)</b>				<b>150.00</b>			<b>238.00</b>
6.0	<b>Permanent Way</b>							
6.1	Ballastless track for elevated and at grade alignment	R. km.	6.48	19.320	125.16	6.42	19.320	124.03
	<b>Sub total (6)</b>				<b>125.16</b>			<b>124.03</b>
7	<b>Traction &amp; power</b>							
7.1	<b>Traction &amp; power supply incl. OHE, ASS etc.</b>							
7.1.1	Elevated & at grade section	R. km.	9.36	18.820	176.16	15.62	18.820	293.97
	<b>Sub total (7)</b>				<b>176.16</b>			<b>293.97</b>
8.0	<b>Signalling and Telecom.</b>							
8.1	Signalling	R. km.	9.73	18.820	183.12	11.37	18.820	213.98

8.2	Telecom	Each Stn.	4.36	16.000	69.76	5.04	16.00	80.64
8.3	Automatic fare collection							
9.3.1	Underground stations	Each	2.96	0.000	0.00	0.00	0.00	0.00
8.3.2	Elevated stations	Each	2.96	16.000	47.38	2.50	16.00	40.00
9.4	PSD at various stations	LS			0.00			0.00
	<b>Sub Total (8)</b>				<b>300.26</b>			<b>334.62</b>
9.0	R & R incl. Hutments and road restoration etc.	LS			59.28			59.28
	<b>Sub Total (9)</b>				<b>59.28</b>			<b>59.28</b>
10.1	Misc. Utilities, other civil works such as median, road signages etc.	R. km.	3.15	18.820	59.28	3.12	18.820	58.72
10.2	Electrical Utilities	LS			49.40			49.40
10.3	Telecom Utilities	LS			9.88			9.88
	<b>Sub Total (10)</b>				<b>118.56</b>			<b>118.00</b>
11	Rolling Stock (SG)	Each	8.40	66.000	554.40	66.00	9.50	627.00
	<b>Sub Total (11)</b>				<b>554.40</b>			<b>627.00</b>
12.1	Barracks for CISF including security equipments	LS			4.94			4.94
12.2	Staff Quarters for O&M	LS			21.74			60.00
	<b>Sub Total (12)</b>				<b>26.68</b>			<b>64.94</b>
13	Total of all items except Land				<b>2676.34</b>			<b>3218.54</b>
14	General Charges incl. Design charge @ 5% on all items except land				133.82			160.93
15	Total of all items including General charges				<b>2810.16</b>			<b>3379.47</b>
16	Total of cost inclusive land cost				<b>3129.33</b>			<b>4066.57</b>
17	Contingencies @ 3 %				93.88			122.00
18	Gross Total				<b>3223.21</b>			<b>4188.56</b>

## 9.2 CIVIL ENGINEERING WORKS

### 9.2.1 Land

- i) Land requirements have been kept to the barest minimum & worked out on area basis. For elevated alignment in the middle of NH-4, no land is proposed to be acquired permanently, except small areas for locating entry/exit structures, traffic integration, etc. at stations. However for the

portion of the elevated alignment on Eastern side of NH-4 (due to planned elevated road in the middle of NH-4 by NHAI) some land for alignment as well as for stations required to be acquired.

- ii) Total land requirements have been worked out to 21.25Ha out of which 14.60 Ha is govt. land and 6.65 Ha is private land.
- iii) It is proposed to reserve **12.0 Ha.** of the land near Hebbagodi station for Car maintenance Depot. Also **8.0 Ha** of Govt land is reserved for Construction depot and casting yard during construction on temporary acquisition basis

**NOTE BY BMRCL:**

*The rate proposed in the DPR for private land is Rs.29.56 crores and Rs.5.00 crores for Govt. land. As per DPR the land identified for location of Depot is 14.60 hectares situated in Hebbagodi village of Anekal Taluk. This is shown as Govt. land. But on verification of records it is found to be private land. So the rate of this land can not be Rs.5.00 crores per hectare. The rate of this land is taken as Rs.30.00crores per hectare as recommended in DPR for private land. The revised cost of this land comes to Rs.438.00crores. As a result of this, the cost of land has gone up to Rs.687.10 crores from Rs.319.17 crores, thus resulting in an increase of Rs.367.93 crores.*

The summary of the land details is placed at Table 9.2

**9.2.2 Alignment**

- i) **Elevated Section:** Rates are based on rates of Delhi Metro Ph-III works. 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 works.*

**9.2.3 Station Buildings**

- ii) **Elevated Stations:** Estimated rate is based on rates of Delhi Metro Ph-III works. 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. Provision for 12 number of subways for the station located on one side of the road (NH and also ring road) is also made.

**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. Hence the cost estimate of station buildings proposed in DPR is not realistic and as such can not be adopted. So the cost estimate as proposed by BMRCL may be accepted.**

- 9.2.4 Permanent Way** - For elevated sections, ballast less track has been planned. Rates adopted are based on rates of Delhi Metro Ph-III works, for ballast less tracks.

**Note By BMRCL:**

**The rate for permanent way is Rs.6.42 crores per km. and this is based on Bangalore Metro Phase-I works.**

**9.3 UTILITY DIVERSIONS**

- 9.3.1 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.

**9.4 ENVIRONMENTAL IMPACT ASSESSMENT**

- 9.4.1 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.

**9.5 REHABILITATION & RESETTLEMENT**

- 9.5.1 **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.

**9.6 TRACTION & POWER SUPPLY**

- 9.6.1 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.

9.6.2 The rates adopted for various items are based on the rates for similar works being done for Delhi Metro Ph-III works.

**NOTE BY BMRCL:**

***The cost estimate for traction and power supply is Rs.15.62 crores per km. This cost variation is mainly due to the extra distance from where the KPTCL is supplying power.***

**9.7 ELECTRICAL SERVICES AT STATIONS**

9.7.1 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, are therefore 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.

**9.8 SIGNALLING & TELECOMMUNICATION WORKS**

9.8.1 The rates adopted are based on rates of elevated corridors of Delhi Metro Ph-III works. 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. Moreover it may be noted that the signaling and telecommunication involves CBTS and the rate for signaling is Rs.11.37 crores per km and for telecom it is Rs. 5.04 crores for each station.***

**9.9 AUTOMATIC FARE COLLECTION**

9.9.1 Adopted rates are based on rates of Delhi Metro Ph-III works. These rates include escalation during the period of equipment manufacture and their supply, including installation.

**9.10 ROLLING STOCK**

9.10.1 The base cost is taken on the basis of rates of Delhi Metro Ph-III works.



**Note by BMRCL:**

**The cost of the Rolling Stock as per the last procurement and adding the cost escalation comes to RS.9.50 crores per coach.**

**9.11 TAXES AND DUTIES**

Estimate for taxes and duties are given in **Table 9.3**. It is estimated that the taxes and duties will amount to Rs **496 crore** and the total cost inclusive of taxes and duties is Rs. **3719.21crores**.

**Table 9.2**  
**LAND REQUIREMENT for RV Road - Electronic City – Bommasandra Ind Area**

DETAILS OF LAND PERMANENTLY REQUIRED FOR RUNNING SECTION					LAND REQUIRED FOR STATIONS			
S. NO.	PLOT NO.	LOCATION	AREA(m <sup>2</sup> )	OWNERSHIP	S. NO.	PLOT NO.	AREA(m <sup>2</sup> )	OWNER SHIP
1	RS 1	R.V.Road Terminal to Ragigudda	402.06	Private	1	RV-1	3669.7	Govt.
2	RS 2	Ragigudda to Jayadeva Hospital	1.23	Private	2	RV-2	312.4	Govt.
3	RS 3	Ragigudda to Jayadeva Hospital	114.93	Private	3	RV-3	760.1	Govt.
4	RS 4	Ragigudda to Jayadeva Hospital	190.02	Private	4	RAG-1	3587.9	Govt.
5	RS 5	Ragigudda to Jayadeva Hospital	48.06	Private	5	RAG-2	229.2	Govt.
6	RS 6	Ragigudda to Jayadeva Hospital	111.13	Private	6	RAG-3	518	Govt.
7	RS 7	Ragigudda to Jayadeva Hospitalr	137.08	Private	7	RAG-4	2477.4	Pvt.
8	RS 8	Jayadeva Hospital to BTM Layout	269.86	Private	8	JAY-1	239.2	Pvt.
9	RS 9	Jayadeva Hospital to BTM Layout	207.16	Private	9	JAY-2	289.7	Pvt.
10	RS 10	Jayadeva Hospital to BTM Layout	186.25	Private	10	JAY-3	504.7	Govt.
11	RS 11	Jayadeva Hospital to BTM Layout	200.03	Private	11	JAY-4	144.5	Govt.
12	RS 12	Jayadeva Hospital to BTM Layout	87.1	Private	12	JAY-5	2293.1	Pvt.
13	RS 13	Jayadeva Hospital to BTM Layout	189.81	Private	13	JAY-6	460.5	Govt.
14	RS 14	Jayadeva Hospital to BTM Layout	21.26	Private	14	JAY-7	910.4	Govt.
15	RS 15	Jayadeva Hospital to BTM Layout	86.47	Private	15	JAY-8	594.1	Govt.
16	RS 16	Jayadeva Hospital to BTM Layout	190.07	Private	16	BTM-1	59.5	Govt.
17	RS 17	Jayadeva Hospital to BTM Layout	84.56	Private	17	BTM-2	1084.5	Govt.
18	RS 18	Jayadeva Hospital to BTM Layout	156.06	Private	18	BTM-3	468	Govt.
19	RS 19	Jayadeva Hospital to BTM Layout	27.36	Private	19	BTM-4	383.9	Pvt.
20	RS 20	Silk Board Junction to HSR Layout	151.94	Private	20	BTM-5	824.9	Govt.
21	RS 21	Silk Board Junction to HSR Layout	459.3	Private	21	BTM-6	2027.9	Govt.
22	RS 22	Silk Board Junction to HSR Layout	26.73	Private	22	SBJ-1	84.8	Govt.
23	RS 23	Silk Board Junction to HSR Layout	2.95	Private	23	SBJ-2	397.4	Pvt.
24	RS 24	Silk Board Junction to HSR Layout	0.76	Private	24	SBJ-3	339.3	Govt.
25	RS 25	Silk Board Junction to HSR Layout	34.19	Private	25	SBJ-4	849.5	Govt.
26	RS 26	Silk Board Junction to HSR Layout	22.98	Private	26	SBJ-5	82.1	Govt.

27	RS 27	Silk Board Junction to HSR Layout	18.5	Private	27	SBJ-6	425.3	Pvt.
28	RS 28	HSR Layout to Oxford College	0.34	Private	28	SBJ-7	168.1	Pvt.
29	RS 29	HSR Layout to Oxford College	16.78	Private	29	HSR-1	1976.1	Pvt.
30	RS 30	HSR Layout to Oxford College	9.02	Private	30	HSR-2	468	Pvt.
31	RS 31	HSR Layout to Oxford College	1.68	Private	31	OXF-1	194.7	Pvt.
32	RS 32	HSR Layout to Oxford College	3.87	Private	32	OXF-2	457.3	Govt.
33	RS 33	HSR Layout to Oxford College	36.11	Private	33	OXF-3	360.5	Pvt.
34	RS 34	HSR Layout to Oxford College	10.12	Private	34	OXF-4	433.3	Govt.
35	RS 35	HSR Layout to Oxford College	3.98	Private	35	OXF-5	1586.1	Pvt.
36	RS 36	HSR Layout to Oxford College	5.73	Private	36	OXF-6	2116.2	Govt.
37	RS 37	HSR Layout to Oxford College	9.82	Private	37	MN-1	322.2	Pvt.
38	RS 38	HSR Layout to Oxford College	3.43	Private	38	MN-2	1013.8	Pvt.
39	RS 39	HSR Layout to Oxford College	2.73	Private	39	MN-3	601	Pvt.
40	RS 40	HSR Layout to Oxford College	2.8	Private	40	MN-4	220.9	Pvt.
41	RS 41	HSR Layout to Oxford College	5.5	Private	41	CB-1	1665.3	Pvt.
42	RS 42	Oxford College to Muneshwara Nagar	7.3	Private	42	CB-2	468	Pvt.
43	RS 43	Oxford College to Muneshwara Nagar	5.08	Private	43	CB-3	11808.4	Pvt.
44	RS 44	Oxford College to Muneshwara Nagar	2.09	Private	44	BR-1	872.8	Govt.
45	RS 45	Muneshwara Nagar to Chikka Begur	27.82	Private	45	BR-2	717.4	Pvt.
46	RS 46	Muneshwara Nagar to Chikka Begur	17.93	Private	46	BR-3	468	Govt.
47	RS 47	Muneshwara Nagar to Chikka Begur	7.41	Private	47	BR-4	726.5	Govt.
48	RS 48	Muneshwara Nagar to Chikka Begur	25.48	Private	48	HR-1	326.3	Pvt.
49	RS 49	Muneshwara Nagar to Chikka Begur	23.8	Private	49	HR-2	2459	Pvt.
50	RS 50	Muneshwara Nagar to Chikka Begur	80.94	Private	50	HR-3	468	Pvt.
51	RS 51	Muneshwara Nagar to Chikka Begur	16.23	Private	51	HR-4	725.6	Pvt.
52	RS 52	Muneshwara Nagar to Chikka Begur	47.16	Private	52	EC1-1	2021.3	Pvt.
53	RS 53	Muneshwara Nagar to Chikka Begur	5.3	Private	53	EC1-2	468	Pvt.
54	RS 54	Muneshwara Nagar to Chikka Begur	23.36	Private	54	EC1-3	409.1	Govt.
55	RS 55	Muneshwara Nagar to Chikka Begur	3.59	Private	55	EC1-4	6145.1	Pvt.
56	RS 56	Muneshwara Nagar to Chikka Begur	5.59	Private	56	EC-1	480.3	Pvt.
57	RS 57	Muneshwara Nagar to Chikka Begur	1.46	Private	57	EC-2	468	Pvt.
58	RS 58	Muneshwara Nagar to Chikka Begur	2.33	Private	58	EC-3	91.3	Pvt.
59	RS 59	Muneshwara Nagar to Chikka Begur	18.97	Private	59	EC-4	156	Pvt.
60	RS 60	Muneshwara Nagar to Chikka Begur	1.83	Private	60	EC-5	612.1	Pvt.
61	RS 61	Muneshwara Nagar to Chikka Begur	33.54	Private	61	HUR-1	374.6	Govt.
62	RS 62	Muneshwara Nagar to Chikka Begur	49.53	Private	62	HUR-2	688.6	Pvt.
63	RS 63	Muneshwara Nagar to Chikka Begur	2.2	Private	63	HUR-3	468	Pvt.
64	RS 64	Muneshwara Nagar to Chikka Begur	2.5	Private	64	HUR-4	280.3	Govt.
65	RS 65	Muneshwara Nagar to Chikka Begur	10.36	Private	65	HUR-5	16.9	Pvt.
66	RS 66	Muneshwara Nagar to Chikka Begur	1.36	Private	66	HEB-1	1594.2	Govt.
67	RS 67	Chikka Begur to Basapur Road	32.17	Private	67	HEB-2	1274.9	Pvt.

68	RS 68	Chikka Begur to Basapur Road	12.03	Private	68	BOM-1	16309.1	Pvt.
69	RS 69	Chikka Begur to Basapur Road	50.08	Private	69	BOM-2	412.8	Pvt.
70	RS 70	Chikka Begur to Basapur Road	3.09	Private	70	BOM-3	468	Pvt.
71	RS 71	Chikka Begur to Basapur Road	5.91	Private	71	BOM-4	790.4	Govt.
72	RS 72	Chikka Begur to Basapur Road	39.62	Private	<b>Total</b>		<b>87410.4</b>	

73	RS 73	Chikka Begur to Basapur Road	0.03	Private
74	RS 74	Electronic City - I to Electronic City	1.56	Private
75	RS 75	Electronic City - I to Electronic City	1.35	Private
76	RS 76	Electronic City - I to Electronic City	2.41	Private
77	RS 77	Electronic City - I to Electronic City	4.22	Private
78	RS 78	Electronic City - I to Electronic City	1.88	Private
79	RS 79	Electronic City - I to Electronic City	5.83	Private
80	RS 80	Electronic City - I to Electronic City	14.36	Private
81	RS 81	Electronic City - I to Electronic City	30.12	Private
82	RS 82	Electronic City - I to Electronic City	0.73	Private
83	RS 83	Electronic City - I to Electronic City	8.46	Private
84	RS 84	Electronic City - I to Electronic City	17.07	Private
85	RS 85	Electronic City - I to Electronic City	0.54	Private
86	RS 86	Electronic City - I to Electronic City	4.86	Private
87	RS 87	Electronic City - I to Electronic City	3.15	Private
88	RS 88	Electronic City to Huskur Road	47.79	Private
89	RS 89	Electronic City to Huskur Road	79.43	Private
90	RS 90	Electronic City to Huskur Road	8.1	Private
91	RS 91	Huskur Road to Hebbagodi	2.29	Private
92	RS 92	Huskur Road to Hebbagodi	3.55	Private
93	RS 93	Huskur Road to Hebbagodi	5.55	Private
94	RS 94	Hebbagodi to Bommasandra	36.92	Private
95	RS 95	Hebbagodi to Bommasandra	322.7	Private
96	RS 96	Hebbagodi to Bommasandra	11.54	Private
97	RS 97	Hebbagodi to Bommasandra	36.1	Private
98	RS 98	Hebbagodi to Bommasandra	71.9	Private
99	RS 99	Hebbagodi to Bommasandra	35.8	Private
100	RS 100	Hebbagodi to Bommasandra	7.02	Private
101	RS 101	Hebbagodi to Bommasandra	270.79	Private
<b>Total</b>			<b>5141.87</b>	

Table 9.3

## R V Road - Elec City - Bommasandra line (BM Ph-II) – As per DPR

Details of Taxes and Duties						
S. No.	Description	Total cost without Taxes & duties (Cr.)	Taxes and duties			Total taxes & duties (Cr.)
			customs duty (Cr.)	excise duty (Cr.)	VAT (Cr.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground	0.00	0.00	0.00	0.00	<b>0.00</b>
	Elevated, at grade & entry to Depot	598.09		43.12	57.72	<b>100.85</b>
<b>3</b>	<b>Station Buildings</b>					
	a) Underground station-civil works	0.00	0.00	0.00	0.00	<b>0.00</b>
	b) Underground station-EM works	0.00	0.00	0.00	0.00	<b>0.00</b>
	c) Elevated station - civil works	463.25		33.40	44.71	<b>78.11</b>
	d) Elevated station-EM works	104.50	4.38	7.32	9.80	<b>21.49</b>
<b>5</b>	<b>Depot</b>					
	Civil works	60.00	3.77	3.03	4.05	<b>10.85</b>
	EM works	90.00	3.77	6.30	8.44	<b>18.51</b>
<b>6</b>	<b>P-Way</b>	125.16	20.97	2.19	2.93	<b>26.10</b>
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	176.16	14.76	9.25	12.39	<b>36.40</b>
<b>8</b>	<b>S and T Works</b>					
	S & T	252.88	42.38	5.21	6.97	<b>54.56</b>
	AFC	47.38	7.44	1.22	1.63	<b>10.30</b>
<b>9</b>	<b>R &amp; R hutments</b>	59.28			3.71	<b>3.71</b>
<b>10</b>	<b>Misc.</b>					
	Civil works	59.28		4.27	5.72	<b>10.00</b>
	EM works	59.28		5.19	6.95	<b>12.14</b>
<b>11</b>	<b>Rolling stock</b>	554.40	102.19	4.45	5.96	<b>112.61</b>
	<b>Total</b>	<b>2649.67</b>	<b>199.66</b>	<b>124.97</b>	<b>170.98</b>	<b>495.61</b>
	<b>Total taxes &amp; Duties</b>					<b>496</b>

**R V Road - Elec City - Bommasandra line (BM Ph-II) – 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.)	
<b>2</b>	<b>Alignment &amp; Formation</b>					
	Underground		0.00	0.00	0.00	0.00
	Elevated, at grade & entry to Depot	629.53		45.39	60.76	106.15
<b>3</b>	<b>Station Buildings</b>					
	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	625.65		45.11	60.38	105.49
	d) Elevated station-EM works	103.52	4.34	7.25	9.71	21.29
<b>5</b>	<b>Depot</b>					
	Civil works	148.00	9.30	7.47	10.00	26.77
	EM works	90.00	3.77	6.30	8.44	18.51
<b>6</b>	<b>P-Way</b>	124.03	20.78	2.17	2.91	25.86
<b>7</b>	<b>Traction &amp; power supply</b>					
	Traction and power supply	293.97	24.63	15.44	20.67	60.74
<b>8</b>	<b>S and T Works</b>					
	S & T	294.62	49.37	6.07	8.12	63.56
	AFC	40.00	6.28	1.03	1.38	8.69
<b>9</b>	<b>R &amp; R hutments</b>	59.28			3.71	3.71
<b>10</b>	<b>Misc.</b>					
	Civil works	58.72		4.23	5.67	9.90
	EM works	59.28		5.19	6.95	12.14
<b>11</b>	<b>Rolling stock</b>	627.00	115.57	5.04	6.74	127.35
	<b>Total</b>	<b>3153.60</b>	<b>234.05</b>	<b>150.70</b>	<b>205.43</b>	<b>590.17</b>
	<b>Total taxes &amp; Duties</b>					<b>590</b>

**CHAPTER-10**

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**FINANCIAL VIABILITY, FARE  
STRUCTURE & FINANCING OPTIONS**





## CHAPTER 10

# FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

### 10.1 INTRODUCTION

The R. V. Road Bommasandra Corridor of Bangaluru Metro is proposed to be constructed with an estimated cost of Rs 3223 Crore at January 2011 price level without taxes but including land cost of Rs. 329 crore. The estimated cost with central taxes is Rs. 3548 crore.

The estimated cost at January-2011 price level includes an amount of Rs.4.94 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.

### 10.2 Costs

#### 10.2.1 Investment Cost

10.2.1.1 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 10.1 have been taken as the initial investment. The cash flow of investments separately is placed in Table –10.1 as below.

**Table 10.1 Corridor-wise & Year wise Investment-With Central Taxes – As per DPR**

Financial Year	Estimated Cost	Figs in Rs. Cr.
		Completion Cost



2012-13	487.00	511.00
2013-14	808.00	893.00
2014-15	805.00	955.00
2015-16	644.00	802.00
2016-17	322.00	421.00
2017-18	322.00	442.00
2018-19	160.00	231.00
<b>Total</b>	<b>3548.00</b>	<b>4255.00</b>

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

Figs in Rs. Cr.

Financial Year	Estimated Cost	Completion Cost
2012-13	617.40	671.12
2013-14	1034.50	1190.54
2014-15	1043.63	1300.23
2015-16	835.08	1092.41
2016-17	417.68	572.34
2017-18	417.08	601.61
2018-19	208.54	315.84
<b>Total</b>	<b>4573.31</b>	<b>5744.09</b>

10.2.1.2 Although the construction is expected to get over by 31<sup>st</sup> 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.

10.2.1.3 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.

10.2.1.4 The escalation factor used is 5% p.a.

**10.2.2 Additional Investment**

Total investment provided in the FIRR calculation towards requirement of additional rolling stock duly escalated @5% PA is placed in table 10.2 as under: -

**Table 10.2 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
24	396.00	12	321.00	12	523.00

**10.2.3 Operation & Maintenance (O&M) Costs**

10.2.3.1 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 Bangaluru 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.

10.2.3.2 The total O&M cost of both the corridors have been tabulated in Table 10.3 as below:

**Table 10.3 Operation and Maintenance Costs**

Figs in Rs. Cr.

YEAR			Staff	Maintenan ce Expenses	Energy	Total
2016	-	2017	75.26	18.82	18.58	112.66
2017	-	2018	82.03	19.76	19.51	121.30
2018	-	2019	89.41	20.75	20.49	130.65
2019	-	2020	97.46	21.79	21.51	140.76
2020	-	2021	106.23	22.88	22.59	151.70
2021	-	2022	115.79	24.02	34.21	174.02
2022	-	2023	126.22	25.22	35.92	187.35
2023	-	2024	137.57	26.48	37.71	201.77
2024	-	2025	149.96	27.81	39.60	217.36
2025	-	2026	163.45	29.20	41.58	234.23
2026	-	2027	178.16	30.66	43.66	252.48
2027	-	2028	194.20	32.19	45.84	272.23
2028	-	2029	211.68	33.80	48.13	293.61
2029	-	2030	230.73	35.49	50.54	316.75
2030	-	2031	251.49	37.26	53.07	341.82



2031	-	2032	274.13	39.13	62.51	375.76
2032	-	2033	298.80	41.08	65.64	405.52
2033	-	2034	325.69	43.14	68.92	437.74
2034	-	2035	355.00	45.29	72.37	472.66
2035	-	2036	386.95	47.56	75.98	510.49
2036	-	2037	421.78	49.94	79.78	551.49
2037	-	2038	459.74	52.43	83.77	595.94
2038	-	2039	501.11	55.05	87.96	644.13
2039	-	2040	546.21	57.81	92.36	696.38
2040	-	2041	595.37	60.70	96.98	753.04
2041	-	2042	648.96	63.73	128.79	841.48
2042	-	2043	707.36	66.92	135.23	909.51
2043	-	2044	771.02	70.26	142.00	983.28
2044	-	2045	840.42	73.78	149.10	1063.29
2045	-	2046	916.05	77.47	156.55	1150.07

#### 10.2.4 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.

#### 10.2.5 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.

### 10.3 Revenues

The Revenue of Bangalore metro mainly consists of fare box collection and other incomes from property development, advertisement, parking etc.

#### 10.3.1 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.

#### 10.3.2 Traffic

10.3.2.1 a. The projected ridership figures years are as indicated in table 10.4 as below: -

**Table 10.4 Projected Ridership**

Year	Trips per day (lakhs)
2016-17	2.40
2021-22	3.70
2031-32	4.55
2041-42	5.02

10.3.1.1 b. The growth rate for traffic is assumed at 11% Per Annum upto 2021-22 and @ 2% upto 2031-32 and thereafter @ 1% per annum..

### 10.3.2.2 Trip Distribution

The trip distribution has been worked out by considering average lead of 8.275 KM, which is placed in Table 10.5 below: -

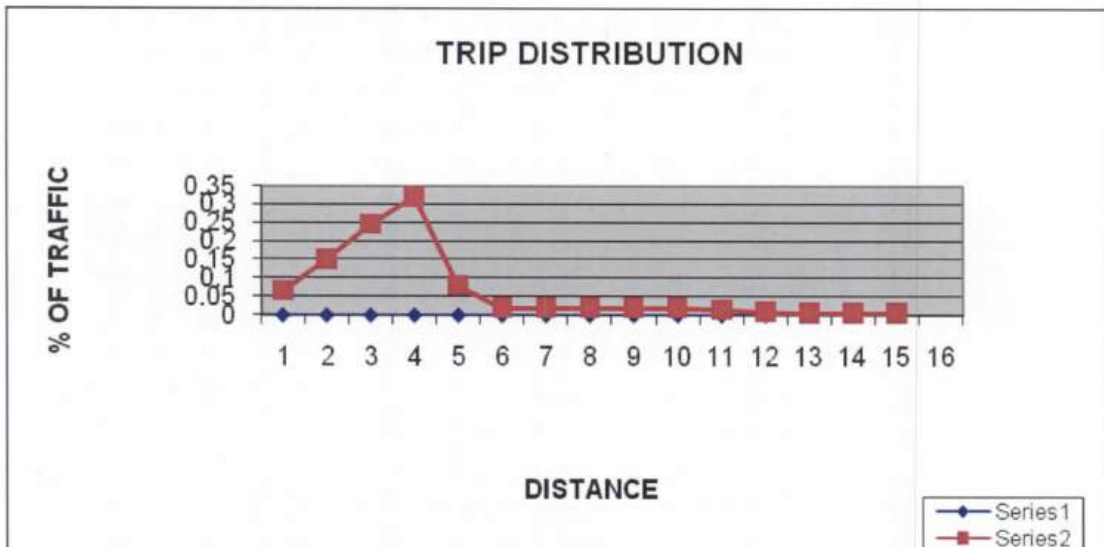
**Table 10.5 Trip Distribution**

Distance in kms.	Percent distribution
0-2	7.00%
2-4	15.00%
4-6	24.50%
6-9	32.00%
9-12	8.00%
12-15	2.00%
15-18	2.00%
18-21	2.00%
21-24	2.00%
24-27	2.00%
27-31	1.50%
31-35	0.50%
35-39	0.50%
39-44	0.50%
>44	0.50%
Total	100.00%

The graphic presentation of the same is placed below in Figure-10.1.



Figure 10.1 –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 10.6.

Table 10.6 Fare Structure in 2015-16

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 of BMRCL:

*The fares fixed by BMRCL are as shown below.*





<i>Dist km</i>	<i>Fare</i>
1	10.00
2	10.00
3	12.00
4	12.00
5	14.00
6	14.00
7	15.00
8	17.00
9	17.00
10	19.00
11	19.00
12	21.00
13	21.00
14	23.00
15	23.00
16	25.00
17	26.00
18	27.00
19	28.00
20	29.00
21	30.00
22	31.00
23	32.00
24	33.00
25	34.00

### 10.3.3 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 if additional residual rental income as detailed in the table 10.7 accrue from Property Development is not considered. Therefore, the State Government should provide sufficient land for PD activity to the Bengaluru Metro as detailed below: -

Bengaluru Metro has 20 hectares of lands for the proposed corridor, which can be exploited for Real Estate Development with the involvement of established Developers. The property development models can be designed in a way that



not only the upfront receipts but also the regular receipts in the development of lease rentals can be ensured to supplement the fare box collection and reduce the fare structure.

The SPV i.e., BMRC will give the land free of cost to the developer or develop the same on its own. The developer will bring equity to the extent of Rs.361 crore and the balance amount towards construction and upfront money to be given to JMRC as 12% Market Debt. The estimated development cost will be Rs.1444 crore. It is assumed that the rental revenue (assumed @ Rs. 70/Sq. ft.) will accrue to the developer from the FY 2017-18 which has been escalated @2.5% every year. Out of the estimated rental income, apart from meeting maintenance expenditure, the developer will repay the loan and interest. After meeting these obligations and retaining 14% return on his equity with an escalation @5% every year, the residual rental earnings will accrue to JMRC, which has been taken into account in the FIRR calculations.

The details of PD income accrue to JMRC is tabulated as under; -

**Table 10.7 Estimated generation of Rental Income from PD  
(Rs/Crore)**

Year	Const ruction cost	Upfro nt	Rental Income	Maint enanc e Expe nditur e	Loan	IDC	Loan repay ment	Bal Loan Amoun t	Intere st on Loan @15 %	Return @14% to the develo per	Resid ual rental incom e to LMRC
2012 - 2013	0	0			0	0		0		-180.5	
2013 - 2014	0	0			0	0		0		-180.5	
2014 - 2015	458	0			278	17		295			
2015 - 2016	481	0			578	53		631			
2016 - 2017	505	0			1083	108		1191			0
2017 - 2018			52	5			0	1191	143	36	-132
2018 - 2019			105	11			0	1191	143	38	-87
2019 - 2020			165	17			79	1112	143	40	-114
2020 - 2021			225	45			79	1033	133	42	-74
2021 - 2022			288	58			79	954	124	44	-17
2022 - 2023			296	59			79	875	114	46	-2
2023 - 2024			364	73			79	796	105	48	59
2024 - 2025			435	87			79	717	96	50	123
2025 - 2026			509	102			79	638	86	53	189
2026 - 2027			588	118			79	559	77	56	258
2027 - 2028			669	134			79	480	67	59	330
2028 - 2029			686	137			79	401	58	62	350
2029 - 2030			703	141			79	322	48	65	370
2030 - 2031			721	144			79	243	39	68	391
2031 - 2032			739	148			79	164	29	71	412
2032 - 2033			757	151			79	85		75	452
2033 - 2034			776	155			85	0		79	457



Year			Const ructio n cost	Upfro nt	Rental Income	Maint enanc e Expe nditur e	Loan	IDC	Loan repay ment	Bal Loan Amou nt	Intere st on Loan @15 %	Return @14% to the develo per	Resid ual rental incom e to LMRC
2034	-	2035			795	159						83	553
2035	-	2036			815	163						87	565
2036	-	2037			836	167						91	578
2037	-	2038			857	171						96	590
2038	-	2039			878	176						101	601
2039	-	2040			900	180						106	614
2040	-	2041			922	184						111	627
2041	-	2042			945	189						117	639
<b>Total</b>			<b>1444</b>	<b>0</b>	<b>15026</b>	<b>2974</b>	<b>1939</b>	<b>178</b>	<b>1191</b>		<b>1405</b>	<b>1724</b>	<b>7732</b>

### 12.4 Financial Internal Rate of Return (FIRR)

The FIRR with Central taxes only is produced in Table 10.8.

**Table 10.8 FIRR:**

Particulars	Completion Cost With Central Taxes only
<b>FIRR (%)</b>	<b>0.83%</b>

10.4.1 The Financial Internal Rate of Return (FIRR) obtained with the above revenues and costs for 30 years are placed in table 10.9: -

**Table 10.9 –FIRR (with Central taxes)**

**Figs in cr. (Rs.)**

Year			Outflow				Inflow			Net Cash Flow	
			Completion Cost	Additional Cost	Running Expense s	Replac e-ment costs	Total Costs	Fare Box Revenue	PD & ADVT	Total Revenu e	IRR
2012	-	2013	511		0		511	0	0	0	-511
2013	-	2014	893		0		893			0	-893
2014	-	2015	955		0		955			0	-955
2015	-	2016	802		0		802			0	-802
2016	-	2017	421		112.66		534	143.71	14	158	-376
2017	-	2018	442		121.30		563	159.52	-116	43	-520
2018	-	2019	231		130.65		362	187.74	-68	120	-242
2019	-	2020	0	0	140.76		141	208.39	-93	115	-26
2020	-	2021	0	0	151.70		152	244.69	-50	195	43
2021	-	2022	0	396	174.02		570	248.49	8	256	-314
2022	-	2023	0	0	187.35		187	267.34	25	292	105
2023	-	2024	0	0	201.77		202	272.68	86	359	157
2024	-	2025	0	0	217.36		217	292.88	152	445	228
2025	-	2026	0	0	234.23		234	298.74	219	518	283
2026	-	2027	0	0	252.48		252	320.08	290	610	358



2027	-	2028	0	0	272.23		272	326.49	363	689	417
2028	-	2029	0	0	293.61		294	349.34	385	734	441
2029	-	2030	0	0	316.75		317	356.32	406	762	445
2030	-	2031	0	0	341.82		342	380.78	429	810	468
2031	-	2032	0	321	375.76		697	391.82	451	843	146
2032	-	2033	0	0	405.52		406	413.78	493	907	502
2033	-	2034	0	0	437.74		438	417.92	499	917	479
2034	-	2035	0	0	472.66		473	441.06	597	1038	566
2035	-	2036	0	0	510.49		510	445.47	610	1055	545
2036	-	2037	0	0	551.49	1113	1664	469.74	625	1095	-570
2037	-	2038	0	0	595.94	1168	1764	474.44	637	1112	-652
2038	-	2039	0	0	644.13		644	499.62	651	1151	506
2039	-	2040	0	0	696.38		696	504.61	664	1169	473
2040	-	2041	0	0	753.04		753	532.27	680	1213	459
2041	-	2042	0	523	841.48		1364	536.95	693	1230	-135
Total			4255	1240	9433.32	2281	17209	9185	8650	17836	0.83%

The various sensitivities with regard to increase/decrease in capital costs, O&M costs and revenues are placed in Table 10.10 below :-

**Table 10.10 –FIRR Sensitivity**

<b>CAPITAL COSTS with Central Taxes</b>			
10% increase in capital cost	20% increase in capital cost	10% decrease in capital cost	20% decrease in capital cost
0.24%	-0.29%	1.49%	2.23%
<b>REVENUE</b>			
20% decrease in Fare Box revenue	10% decrease in Fare Box revenue	10% increase in Fare Box revenue	20% increase in Fare Box revenue
Negative	-2.85%	3.16%	4.94%
<b>O&amp;M COSTS</b>			
10% increase in O&M cost		10% decrease in O&M cost	
-0.47%		1.89%	

These sensitivities have been carried out independently for each factor.

### 10.5 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.

### 10.5.1 ALTERNATIVE MODELS OF FINANCING

10.5.2 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.329.00



Crede 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. 1742 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 also funds the full loan requirement after obtaining their Board and EC approval. 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.

13.5.1 The funding pattern assumed under this model (SPV) is placed in table 10.11 as under: -

**Table 10.11 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%	851.50	20%	851.50	40%	1703.00
SD for land cost by GO Karnataka	0%	0.00	8%	329.00	8%	329.00
Additional SD for Central Taxes by GOI (80%) & GO Karnataka (20%)	7%	312.00	3%	78.00	9%	390.00
JICA Loan @ 1.40% PA/Market Borrowing @12% PA	43%	1833.00	0%	0.00	43%	1833.00
<b>Total</b>	<b>70.00%</b>	<b>2996.50</b>	<b>31.00%</b>	<b>1258.50</b>	<b>100.00%</b>	<b>4255.00</b>

**10.5.4 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-



**10.5.5 BOT Model:** - In this model, the private firm will be responsible for financing, designing, building, operating and maintaining of the entire project. The contribution of Government of Karnataka will be limited to cost of land only. Such a project become eligible for Viability Gap Funding (VGF) upto 20% from the Central Government provided the state government also contribute same or more amount towards the project. The metro being a social sector project not much private parties are available to bid for such a project. Besides quite expectedly the private operator may demand assured rate of return in the range of 16% to 18% or a comfort of guaranteed ridership.

**10.5.6** The funding pattern assumed under this model including the cost of land to ensure 16% post tax return on operators equity i.e. Equity Internal Rate of Return (EIRR) is placed in table 12.12 tabulated as under: -

**Table 10.12 Funding pattern under BOT model  
(With central taxes but excluding state taxes)**

Particulars	% Of contribution	Amount (Rs/Crore)
VGF by GOI	20%	851.00
VGF by Karnataka State Government	61%	2620.00
Land to be provided free of cost by State	8%	329.00
Equity by Concessionaire	4%	152.00
Concessionaire's debt @11% PA	7%	303.00
<b>Total</b>	<b>100%</b>	<b>4255.00</b>

**10.6.1 Recommendations:** - The FIRR of subject metro with taxes is 0.83% & the cumulative cash balance at the end of 30 years (including construction period) is positive to the extent of Rs.25904 crore with JICA loan and with market borrowing @11% per annum is Rs.726 crore after meeting all the operational expenses, interest payment and repayment of loan. Hence, the corridors are recommended for implementation.

**10.6.2** The total contribution of GOI & Government of Karnataka under the SPV model excluding PTA to be repaid latter is Rs.2422 Crore only (excluding state taxes to be exempted of Rs.171 Crore at Jan-2011 level) as against Rs. 3800 crore under BOT model. Since the Bengaluru 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.

**10.6.3** 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 10.13.1, 10.13.2 and 10.13.3. The cash flow of PD is shown in table 10.13.4.

**10.6.4** The funding pattern assumed under DMRC/BMRC/CMRC model is depicted in the pie chart i.e., Figure 10.2 as under.

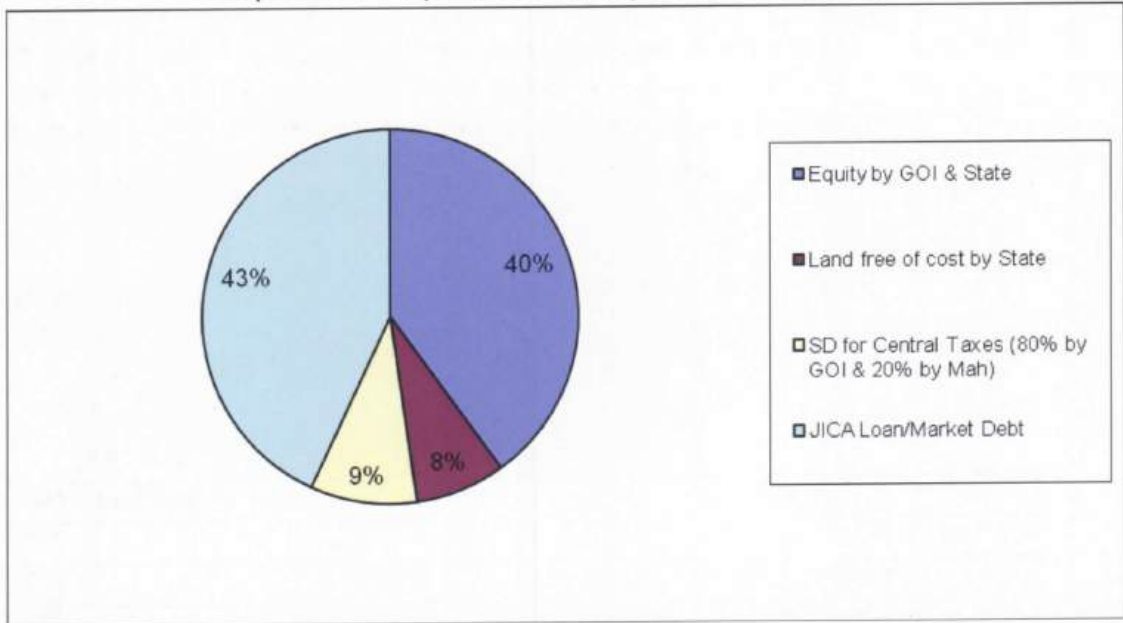


Fig 10.2





Table 10.13.2

Year	CAPITAL COST - CURRENT				WITH CENTRAL TAXES ONLY											11.00%								
	Completion Cost	Additional Capital	Running Expenses	DEPRECIATION	REPLACEMENT COSTS	TOTAL COSTS	FARE BOX REVENUE	PD & ADVT REVENUE	TOTAL REVENUE	NET CASH FLOW FOR IRR	Operation at Subsidy from State Govt.	NET CASH FLOW FOR IRR after Subsidy	Funds other than loan i.e. Equity & SD	Availability of cash	Cumulative cash	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	24	25
2013	511	0	0	0	0	511	0	0	0	511	0	511	701	190	190	0	0	0	0	0	0	23	24	190
2014	893	0	0	0	0	893	0	0	0	893	0	893	700	193	193	0	0	0	0	0	0	0	190	0
2015	865	0	0	0	0	865	0	0	0	865	0	865	341	614	614	0	0	0	0	0	0	0	0	0
2016	42	0	0	0	0	42	0	0	0	42	0	42	339	461	461	0	0	0	0	0	0	0	0	0
2017	42	0	0	0	0	42	143.71	14	158	376	376	376	376	62	1160	1078	617	0	96.99	1209	0	73	45	45
2018	231	0	0	0	0	231	159.52	-116	43	520	43	520	320	442	1602	1602	442	0	137.53	1429	0	-196	-78	-32
2019	0	0	0	0	0	0	121.30	69	120	-242	-242	-242	0	-242	0	0	231	0	181.48	2052	0	368	-250	-282
2020	0	0	0	0	0	0	208.99	-93	115	36	36	36	0	36	0	0	228	0	0	2283	238	-395	505	-282
2021	0	0	0	0	0	0	248.69	-50	195	-43	-43	-43	0	-43	0	0	228	0	0	2055	251	-326	-436	-1222
2022	0	0	0	0	0	0	248.48	8	256	314	314	314	0	314	0	0	228	0	0	2827	226	-262	-768	-1990
2023	0	0	0	0	0	0	267.34	25	292	105	105	105	0	105	0	0	228	0	0	1598	201	-214	-324	-2561
2024	0	0	0	0	0	0	272.68	86	359	228	228	228	0	228	0	0	228	0	0	1371	176	-137	-247	-2561
2025	0	0	0	0	0	0	298.74	215	518	283	283	283	0	283	0	0	228	0	0	1143	151	-41	-151	-2712
2026	0	0	0	0	0	0	326.08	290	510	358	358	358	0	358	0	0	228	0	0	915	126	40	-70	-2782
2027	0	0	0	0	0	0	326.49	363	689	417	417	417	0	417	0	0	228	0	0	687	101	139	29	-2753
2028	0	0	0	0	0	0	349.34	385	734	441	441	441	0	441	0	0	231	0	0	459	76	223	113	-2840
2029	0	0	0	0	0	0	356.32	408	762	445	445	445	0	445	0	0	231	0	0	231	51	272	159	-2062
2030	0	0	0	0	0	0	380.78	429	810	468	468	468	0	468	0	0	228	0	0	25	0	350	420	-1593
2031	0	0	0	0	0	0	391.82	451	843	146	146	146	0	146	0	0	228	0	0	0	0	349	146	-1447
2032	0	0	0	0	0	0	413.78	493	907	502	502	502	0	502	0	0	228	0	0	0	0	384	502	-946
2033	0	0	0	0	0	0	441.06	597	1038	566	566	566	0	566	0	0	228	0	0	0	0	361	479	-467
2034	0	0	0	0	0	0	445.47	610	1055	545	545	545	0	545	0	0	228	0	0	0	0	448	566	39
2035	0	0	0	0	0	0	469.74	625	1095	570	570	570	0	570	0	0	228	0	0	0	0	427	548	644
2036	0	0	0	0	0	0	474.44	637	1112	552	552	552	0	552	0	0	228	0	0	0	0	392	570	74
2037	0	0	0	0	0	0	489.62	651	1151	506	506	506	0	506	0	0	228	0	0	0	0	320	552	-578
2038	0	0	0	0	0	0	504.61	664	1169	473	473	473	0	473	0	0	228	0	0	0	0	320	506	-72
2039	0	0	0	0	0	0	532.27	660	1213	459	459	459	0	459	0	0	228	0	0	0	0	286	473	401
2040	0	0	0	0	0	0	536.95	693	1230	-135	-135	-135	0	-135	0	0	228	0	0	0	0	273	459	860
2041	0	0	0	0	0	0	9165	8651	17836	636	636	636	0	636	0	0	1833	0	0	0	0	202	135	726
2042	4255	1240	9433	3444	2201	17209	0	0	17836	636	636	636	0	636	0	0	1833	2283	450	20200	1873	3086	726	0
<b>Funding Pattern</b>																								
Items																								
Equity by GOI & State	State	Total																						
Land free of cost by State	852	1704																						
SD for Central Taxes	312	328																						
PD	78	78																						
JICA Loan/Market Debt	1833	1259																						
Total	4255	4255																						



CHAPTER 10 - FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

Table 10.13.3

Market Ltd. 11.00%  
for Debt

3800 89%  
BOT (WITH CENTRAL TAX)

Grant 3800 89%

152  
#REF!

455 Concess Equity

Completion Cost (Total)  
CAPITAL COST - COMPLETION (Concess

#REF!

Year	Completion on Cost	Additional on Cost	Running Expenses	Depreciation	Replacement Costs	Total Costs	Fare Box Revenue	PD & ADVT. Metro	Total Revenue	Net Cashflow w/for FIRR	Concess on Equity	Funds Available	govt support	Loan	Cumul Loan	IDC (Concess Loan)	Repayment of Loan	Repayment of Concess Loan	Interest (Concessional)	FBT	Cash Balances	Cumulative cash	Return on Equity - PRE TAX	Tax on Profit @33.99 IRR	Equity IRR					
1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
2012	131.00	0	0	0	0	511	0	0	0	0	38.00	-93	0	0	0	93	0	0	24	26	27	0	29	30	31	-38.00	-38.00	-38.00	0	
2013	133.00	0	0	883	0	883	0	0	0	-893.00	38.00	-188	0	0	95	188	0	0	0	0	0	0	-38.00	0	0	0	-38.00	-38.00	-38.00	0
2014	119.00	0	0	955	0	955	0	0	0	-955.00	38.00	-269	0	0	81	279	0	0	0	0	0	0	-38.00	0	0	0	-38.00	-38.00	-38.00	0
2015	42.00	0	0	802	0	802	0	0	0	0	38.00	-273	0	0	4	304	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0.00	0	113	0	533.660582	143.7076	14.37078	158.08	0	0	0	-273	0	0	0	335	0	0	0	0	0	0	45.42	0	0	45.42	0	0	0	0
2017	0.00	0	121	0	563.303928	159.518658	-116.04843	43.47	0	0	0	0	0	0	0	368	0	0	0	0	0	0	-77.84	0	0	-77.84	0	0	0	0
2018	0.00	0	131	0	361.65037	187.79655	68.226045	119.51	0	0	0	-303	0	0	30	435	0	0	0	0	0	0	-80.62	0	0	-80.62	0	0	0	0
2019	0.00	0	141	0	140.759446	208.39059	-93.18091	115.23	0	0	0	0	0	0	0	406	0	0	0	0	0	0	-102.36	0	0	-102.36	0	0	0	0
2020	0.00	0	152	0	151.6558668	244.686001	-49.5314	195.15	0	0	0	0	0	0	377	0	0	0	0	0	0	0	-30.19	0	0	-30.19	0	0	0	0
2021	0.00	0	152	0	187.352797	267.337458	292.07	104.72	0	0	0	0	0	0	319	0	0	0	0	0	0	0	-383.96	0	0	-383.96	0	0	0	0
2022	0.00	0	187	0	201.76904	272.684248	152.28823	359.95	0	0	0	0	0	0	290	0	0	0	0	0	0	0	37.45	0	0	37.45	0	0	0	0
2023	0.00	0	202	0	217.360468	292.882298	152.28823	445.17	0	0	0	0	0	0	261	0	0	0	0	0	0	0	93.11	0	0	93.11	0	0	0	0
2024	0.00	0	217	0	234.236737	298.739944	152.28823	517.61	0	0	0	0	0	0	232	0	0	0	0	0	0	0	166.92	0	0	166.92	0	0	0	0
2025	0.00	0	234	0	252.476161	320.083855	290.00839	517.61	0	0	0	0	0	0	203	0	0	0	0	0	0	0	303.11	0	0	303.11	0	0	0	0
2026	0.00	0	252	0	272.226844	349.324608	384.93357	689.13	0	0	0	0	0	0	174	0	0	0	0	0	0	0	459.45	0	0	459.45	0	0	0	0
2027	0.00	0	272	0	293.605708	369.332408	405.63224	734.27	0	0	0	0	0	0	145	0	0	0	0	0	0	0	609.54	0	0	609.54	0	0	0	0
2028	0.00	0	294	0	316.753007	395.32408	429.63224	781.95	0	0	0	0	0	0	116	0	0	0	0	0	0	0	726.30	0	0	726.30	0	0	0	0
2029	0.00	0	317	0	341.819701	390.782921	429.63224	809.86	0	0	0	0	0	0	87	0	0	0	0	0	0	0	843.00	0	0	843.00	0	0	0	0
2030	0.00	0	342	0	366.811808	391.819687	451.18191	843.00	0	0	0	0	0	0	58	0	0	0	0	0	0	0	960.42	0	0	960.42	0	0	0	0
2031	0.00	0	321	0	405.515951	413.784805	493.37848	907.19	0	0	0	0	0	0	28	0	0	0	0	0	0	0	1076.30	0	0	1076.30	0	0	0	0
2032	0.00	0	406	0	437.743628	417.922654	498.94727	1034.81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1202.77	0	0	1202.77	0	0	0	0
2033	0.00	0	438	0	472.659357	441.058851	591.10569	1034.81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1329.29	0	0	1329.29	0	0	0	0
2034	0.00	0	473	0	510.461302	446.46544	609.54604	1054.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1455.81	0	0	1455.81	0	0	0	0
2035	0.00	0	510	0	1113.16844939	469.143889	624.97439	1094.72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1581.78	0	0	1581.78	0	0	0	0
2036	0.00	0	551	0	844.126074	474.441327	637.44413	1111.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1708.25	0	0	1708.25	0	0	0	0
2037	0.00	0	596	188	1168.176319364	499.61849	650.96168	1150.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1834.73	0	0	1834.73	0	0	0	0
2038	0.00	0	644	188	848.376875	504.612814	1169.07	1169.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1961.21	0	0	1961.21	0	0	0	0
2039	0.00	0	696	188	0	532.272956	880.27233	1212.51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2088.70	0	0	2088.70	0	0	0	0
2040	0.00	0	753	188	0	1384.93525	936.950934	1265.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2216.19	0	0	2216.19	0	0	0	0
2041	0.00	0	841	188	0	1720.9	918.5	1738.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2370.38	0	0	2370.38	0	0	0	0
2042	0.00	0	943.3	344.4	228.1	1720.9	918.5	1738.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2544.76	0	0	2544.76	0	0	0	0
Total	455	1240	943.3	344.4	228.1	1738.3	918.5	1738.3	1738.3	1738.3	152	0	0.00	303	504.5	131.86	434.9	0	423	4535.6	4023.5	0	17.03%	626	16.06%					





Table 10.13.4  
Ar. PD in Sq. ft. 5,500,000.00  
Rs/Crore 1,375.00  
70  
Rent per SQ FT 200000  
2.75 Construction cost= (@ 0.25 lakhs per Sqm  
For PD say 100% FAR 5,500,000.00  
200000 Meter 0  
200000 Meter 0  
Total Land available for PD 200000

Year	Construction cost of the Developer	Upfront Money to HMRC	Earning of Developer	Maintenance Expenditure	Developer's Equity	Developer's Market Debt Loan	IDC on Loan @12%	Total Loan of the Developer	Loan repayment	Bal Loan Amount	Interest on Loan @12%	Return @14% + 5% escalation pa	Residual rental income to SPV
1 2012 - 2013	0	0	0			0	0	0	0	0		-180.5	
2 2013 - 2014	0	0	0			0	0	0	0	0		-180.5	
3 2014 - 2015	458	0			180.5	278	17	295		295			
4 2015 - 2016	481	0			180.5	578	53	631		631			
5 2016 - 2017	505	0				1083	108	1191		1191			0
6 2017 - 2018			52	5				0	0	1191	143	36	-132
7 2018 - 2019			105	11				0	0	1191	143	38	-87
8 2019 - 2020			165	17				0	0	1112	143	40	-114
9 2020 - 2021			225	45				0	0	1033	133	42	-74
10 2021 - 2022			288	58				0	0	954	124	44	-17
11 2022 - 2023			296	59				0	0	79	875	114	46
12 2023 - 2024			364	73				0	0	79	796	105	48
13 2024 - 2025			435	87				0	0	717	96	50	59
14 2025 - 2026			509	102				0	0	638	86	53	189
15 2026 - 2027			588	118				0	0	559	77	56	258
16 2027 - 2028			669	134				0	0	480	67	59	330
17 2028 - 2029			686	137				0	0	401	58	62	350
18 2029 - 2030			703	141				0	0	322	48	65	370
19 2030 - 2031			721	144				0	0	243	39	68	391
20 2031 - 2032			739	148				0	0	164	29	71	412
21 2032 - 2033			757	151				0	0	85	75	75	452
22 2033 - 2034			776	155				0	0	0	0	79	457
23 2034 - 2035			795	159				0	0	0	0	83	553
24 2035 - 2036			815	163				0	0	0	0	87	565
25 2036 - 2037			836	167				0	0	0	0	91	578
26 2037 - 2038			857	171				0	0	0	0	96	590
27 2038 - 2039			878	176				0	0	0	0	101	601
28 2039 - 2040			900	180				0	0	0	0	106	614
29 2040 - 2041			922	184				0	0	0	0	111	627
30 2041 - 2042			945	189				0	0	0	0	117	639
Total	1444	0	15026	2974	361	1938	178	2116	1191	12875	1405	1363	7752

**CHAPTER-11**

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**ECONOMICAL INTERNAL RATE OF RETURN**



## CHAPTER 11

### ECONOMIC ANALYSIS

#### 11.1 Introduction:

The objective of the cost- benefit analysis is to identify and quantify the economic benefits and costs associated with the project (implementation of 18.82 kms of metro corridor: RV Road - Bommasandra Corridor in Bangalore), in order to select the optimum solution along with the economic viability in terms of its likely investment return potential.

The cost – benefit analysis is carried out by using the Discounted Cash Flow (DCF) technique to obtain the economic internal rate of return (EIRR %) and economic net present value (ENPV) for the proposed investments linked with the project. This is followed by a 'sensitivity analysis' carried out by increasing or decreasing the critical factors affecting the cost and benefit streams of the proposed project, in order to ascertain their effect on the economic feasibility indicators i.e. ENPV, EIRR.

#### 11.2 Economic Analysis Approach

The economic appraisal of the metro system has been carried out within the broad framework of Social Cost –Benefit Analysis Technique. It is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the “with” and “without” project scenario. In the analysis, the cost and benefit streams arising under the above project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate factors. The annual streams of project costs and benefit have been compared over the entire analysis period to estimate the net cost/ benefit and to calculate the economic viability of the project in terms of EIRR.

#### 11.3 Analysis Period

The analysis period of the project is taken as 37 years from the base year 2009 as follows:

Base Year 2009

Construction period – 2012 to 2015 (4 years)

Project opening for traffic – 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.

#### 11.4 Estimation of Costs

The project cost stream comprises capital cost, operation and maintenance cost. Cost components considered for the purpose of this exercise include:

- Capital cost of infrastructure
- Operation and Maintenance cost of the system

The project cost is taken as Rs. 3458 Crores. The Operation & Maintenance Cost (O & M cost) is assumed as 3% of the project cost/annum. This cost has been converted to economic price by applying a factor of 0.85.

The development of metro is proposed in four years. The proposed phasing of construction is explained in Table 11.1.

**Table 11.1: Phasing of Construction**

Year	Phasing	Cost (Rs. In Crores) in Financial price
2012	15%	532
2013	30%	1064
2014	35%	1242
2015	20%	710
Total		3548

#### 11.5 Estimation of Benefits

The proposed metro will yield tangible and non-tangible savings due to equivalent reduction in road traffic and certain socio-economic benefits. Introduction of metro will result in reduction in number of buses, usage of private vehicles, air pollution and increase the speed of road-based vehicles. This, in turn, will result in significant social benefits due to reduction in fuel consumption, vehicle operating cost and travel time of passengers. Reduction in accidents, pollution and road maintenance costs are the other benefits to the society in general.

The benefit stream that has been evaluated and quantified includes:

Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing bus system and private vehicles in case the metro project is not taken up.

Savings in operating costs of all buses and other vehicles due to de-congestion including those that would continue to use the existing transport network even after the metro is introduced.

Savings in time of commuters using the metro over the existing transport modes because of faster speed of metro.

Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.

Savings in fuel consumption on account of less number of vehicles on road and decongestion effect with introduction of metro are included in those of vehicle operating cost.

Quantification of some of the social benefits has not been attempted because universally acceptable norms do not exist to facilitate such an exercise. However, it has been considered appropriate to highlight the same, as given below:

Reduction in accidents and pollution from vehicles

Reduced road stress

Better accessibility to facilities in the influence area

Economic stimulation in the micro region of the infrastructure

Increased business opportunities

Overall increased mobility

Facilitating better planning and up-gradation of influence area.

Improving the image of the city.

## 11.6 Transport Demand on Metro Corridor

At present mostly bus system is meeting the transport demand in the study area. Part of the demand is also met by IPT modes and private modes. As given in traffic chapter, the estimated transport demand on metro is given in Table 11.2.

**Table 11.2 Transport Demand Forecast on the proposed metro corridor**

ITEM	2016	2021	2031
Trips on metro / day (Lakh)	2.40	3.70	4.55

### 11.7 Reduction in Traffic Congestion and Fuel Consumption

The traffic on the metro is expected to shift from buses, auto rickshaw, car, taxi and two wheelers. It has been estimated that the number of buses and other private modes are likely to decrease with the introduction of the metro corridors. This will save Rs. 194 Crores in the year 2016 towards the vehicle operating cost (VoC).

### 11.8 Passenger Time Saving

With the introduction of metro, there will be reduction in traffic congestion on the roads and correspondingly, there will be saving in time of commuters travelling by various modes of road transport. Similarly, metro System itself being faster than conventional road transport modes, will also lead to considerable saving in time of commuters travelling on metro. With the implementation of the project, the annual passenger time savings are estimated at Rs. 257 Crore for the year 2016.

### 11.9 Results of Economic Analysis

The cost and benefit streams for 30-year period in the economic prices have been worked out and presented in Annexure 1. The residual value of the metro facilities in last year has not been taken into account as benefit in these tables.

In the analysis, the 'with project' alternative of providing metro system is compared with the base option of 'without project (Do- nothing scenario)' alternative of using the existing transport facilities. This is to arrive the net economic benefits, which consist of reduction in vehicle operation cost and reduction in travel time. The total cost worked out on the above basis is then subtracted from the total benefits to estimate the net benefit of the project. This flow is then subjected to the process of discounting to work out the EIRR and ENPV on the project, to examine the viability of the Project in Economic terms. The results are given in Table 11.3.

**Table 11.3: Results of Economic Analysis**

Sl. No.	Parameter	Results
1	EIRR (%)	18.1%
2	ENPV (Rs. In crores @ 12% discount rate)	1229.7



The EIRR for the proposed metro project is worked out to be 18.1%.

#### 11.10 Sensitivity Analysis

A sensitivity analysis is carried out for the following scenarios;

Increase in cost by 10%

Decrease in benefits by 10%

Combined scenario of Increase in cost by 10% and Decrease in benefits by 10%

The EIRR under these scenarios are given in Table 11.4. Details are presented in Annexure 11.1.

**Table 11.4 Results of Sensitivity Analysis**

Scenario	EIRR (%)	ENPV (Rs. in crores @ 12% discount rate)
<b>Normal Scenario</b>	<b>18.1%</b>	<b>1229.7</b>
Sensitivity I: 10% increase in cost	16.8%	1035.8
Sensitivity II: 10% reduction in benefits	16.7%	912.9
<b>Sensitivity III: 10% increase in cost and 10% reduction in Benefits</b>	<b>15.5%</b>	<b>719.1</b>

In the sensitivity analysis, the EIRR is found to be at 16%, under the combined scenario of increase in cost by 10% and decrease in benefits by 10%. Hence the project is found to be economically viable.

**Annexure 11.1**

<b>Cost and Benefit Stream : Normal Scenario</b>							
<b>Units: Rs in Crores</b>							
<b>YEAR</b>	<b>CAPITAL</b>	<b>Operation &amp; Maintenance Cost</b>	<b>TOTAL COSTS</b>	<b>SAVINGS FROM</b>		<b>TOTAL SAVINGS</b>	<b>NET CASH FLOW</b>
				<b>TIME</b>	<b>VOC</b>		<b>Rs. IN Cr.</b>
2009	0.00	0.00	0.00	0.00	0.00	0.00	0
2010	0.00	0.00	0.00	0.00	0.00	0.00	0
2011	0.00	0.00	0.00	0.00	0.00	0.00	0
2012	-452.37	0.00	-452.37	0.00	0.00	0.00	-452
2013	-904.74	0.00	-904.74	0.00	0.00	0.00	-905
2014	-1055.53	0.00	-1055.53	0.00	0.00	0.00	-1056
2015	-603.16	0.00	-603.16	0.00	0.00	0.00	-603
2016	0.00	-90.47	-90.47	256.88	194.30	451.19	361
2017	0.00	-90.47	-90.47	306.77	238.45	545.22	455
2018	0.00	-90.47	-90.47	356.66	282.60	639.26	549
2019	0.00	-90.47	-90.47	406.55	326.75	733.30	643
2020	0.00	-90.47	-90.47	456.44	370.90	827.33	737
2021	0.00	-90.47	-90.47	506.33	415.04	921.37	831
2022	0.00	-90.47	-90.47	519.88	426.59	946.47	856
2023	0.00	-90.47	-90.47	533.43	438.13	971.56	881
2024	0.00	-90.47	-90.47	546.98	449.68	996.66	906
2025	0.00	-90.47	-90.47	560.53	461.22	1021.75	931
2026	0.00	-90.47	-90.47	574.08	472.76	1046.84	956
2027	0.00	-90.47	-90.47	587.63	484.31	1071.94	981
2028	0.00	-90.47	-90.47	601.18	495.85	1097.03	1007
2029	0.00	-90.47	-90.47	614.73	507.40	1122.13	1032
2030	0.00	-90.47	-90.47	628.28	518.94	1147.22	1057
2031	0.00	-90.47	-90.47	641.83	530.48	1172.32	1082
2032	0.00	-90.47	-90.47	648.55	536.03	1184.58	1094
2033	0.00	-90.47	-90.47	655.26	541.58	1196.85	1106
2034	0.00	-90.47	-90.47	661.98	547.13	1209.11	1119
2035	0.00	-90.47	-90.47	668.69	552.68	1221.38	1131
2036	0.00	-90.47	-90.47	675.41	558.23	1233.64	1143
2037	0.00	-90.47	-90.47	682.12	563.78	1245.91	1155
2038	0.00	-90.47	-90.47	688.84	569.33	1258.17	1168
2039	0.00	-90.47	-90.47	695.55	574.88	1270.44	1180
2040	0.00	-90.47	-90.47	702.27	580.43	1282.70	1192
2041	0.00	-90.47	-90.47	708.98	585.98	1294.97	1204

2042	0.00	-90.47	-90.47	712.53	588.91	1301.44	1211
2043	0.00	-90.47	-90.47	716.09	591.86	1307.95	1217
2044	0.00	-90.47	-90.47	719.67	594.82	1314.49	1224
2045	0.00	-90.47	-90.47	723.27	597.79	1321.06	1231
<b>Total</b>	<b>-3015.80</b>	<b>-2714.22</b>	<b>-5730.02</b>	<b>17757.39</b>	<b>14596.89</b>	<b>32354.27</b>	<b>26624.25</b>
<b>IRR %</b>							<b>18.1%</b>
							<b>1229.7</b>

**CHAPTER-12**

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**IMPLEMENTATION PLAN**



## CHAPTER 12

### IMPLEMENTATION PLAN

#### 12.1 WAY FORWARD FOR IMPLEMENTING OF RV ROAD –BOMMASANDRA CORRIDOR

BMRCL is already implementing the Phase-I of Bangalore Metro Project comprising of North –South and East- West Corridor totaling to 42.26 Kms. Hence, on receipt of the Detailed Project Report, following actions will be required for implementing the proposed RV road –Bommasandra corridor.

.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.



## 12.2 INSTITUTIONAL ARRANGEMENTS

Institutional arrangements already existing for implementing Phase-1 of Bangalore Metro to continue for execution of this extension also.

### 12.2.1 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 12.1

**Table 12.1**  
**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+ 2 Months
3.	Approval of DPR by Central Government	D+ 4 Months
4.	Appointment of Interim Consultant for preliminary works	D+ 1 Months
5.	Appointment of General Consultant	D+ 12 Months
6.	Tendering, execution of works and procurement of equipment, coaches and installations	D+48 Months
7.	Testing and Commissioning	D+50 Months
8.	Revenue Operation	From D+50 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.

### 12.2.3 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 proposed extension.

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

### 12.3.1 CIVIL WORKS

Elevated viaduct will be part design and built basis while the elevated stations will be constructed on design and built basis.

Elevated viaduct can be done in two packages and 16 stations may be taken as 4 packages. Viaduct should be got done on part design and built basis Stations should be taken up on design and built basis with conceptual drawings finalized by BMRCL.

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.

### 12.3.3 DEPOT CONTRACTS

The contracts for Depot are required for Civil and E&M works . 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.

### 12.4. 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.

### 12.5 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 this extension also.

### 12.6 LEGAL FRAMEWORK

The Metro Railways (Amendment) Act -2009 as passed by Parliament will provide Legal cover for this extension also..

### 12.7 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.



**12.7.1** 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.

**12.7.2** 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.

## **12.8 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.