DETAILED PROJECT REPORT

SILK BOARD – KR PURAM
CORRIDOR OF BANGALORE METRO

VOLUME - I

Bangalore Metro Rail Corporation Ltd.

October 2016

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FOREWARD

This DPR to construct a Metro line on the Outer Ring Road (ORR) between Central Silk Board and K.R.Puram has been prepared by an In-house Team of BMRCL. The team has relied upon the experience it has gained while implementing the Phase-1 of Namma Metro and also while preparing the DPR of Phase-2 of Namma Metro. The team was also assisted by M/s.Colliers International Bengaluru, who provided valuable inputs on the real estate growth potential in Bengaluru and specially this corridor.

I would like to place on record my appreciation to the following Officers who worked untiringly in completing this DPR within a record time of one month:

1. Sri Vijay Kumar Dhir, Director (Project & Planning)
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19. Sri Prabhakaran G, Assistant Engineer
20. Sri Veerendra Sheelawantar, Assistant Engineer
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22. Smt. Bhargavi Mutyala, Manager, Colliers International

PRADEEP SINGH KHAROLA
Managing Director
Bangalore Metro Rail Corporation Ltd.

EXECUTIVE SUMMARY

METRO LINE ON ORR – CENTRAL SILK BOARD TO K.R.PURAM

The emergence of Bangalore as IT Capital of India has been possible because of large scale growth of IT industries in the city. The IT industry in the past was concentrated in the Electronic City area in the South and the Whitefield area in the East. With these 2 areas getting saturated, the IT industry moved to along the Outer Ring Road (ORR) between Central Silk Board and K.R.Puram. This new stretch of ORR which was constructed in early 2000 acted as a major attraction for these IT industries to set up their facilities alongside. However, the rapid growth of IT sector along this corridor has placed a huge burden on the transport infrastructure. As a result, this growth corridor has become a transportation bottleneck. In spite of this, studies have shown that the growth of IT industry in this corridor has been phenomenal.

It is estimated that about half a million IT professionals are employed on this corridor and with various support services and indirect employment, this corridor which measures about 17 kms is providing employment close to one million people. The biggest challenge these people are facing is the long time spent during transportation thereby bringing down their efficiency and also affecting the overall economic efficiency of this corridor. Though the Phase-1 and Phase-2 of the Metro network has been planned and Phase-1 is nearing completion, this corridor has been left untouched by both Phase-1 and Phase-2. However, the Metro line in Phase-2 passes through the two extremities of this corridor. Thus connecting these two extremities one at Central Silk Board and other at K.R.Puram is not only necessary but at the same time it is also inevitable.

In this Detailed Project Report, the alignment between Central Silk Board and K.R.Puram junction has been planned. The entire stretch would be on an elevated viaduct and the availability of space in the middle of the road makes it an ideal situation for construction of the viaduct. An additional feature of this road corridor is that at all intersections, though flyovers have been constructed all these flyovers are split flyovers leaving adequate space between the two arms through which the Metro viaduct can easily run.

The use of innovative financing techniques for the metro line is a unique feature of this DPR. For the first time, an attempt has been made to capture the increase in the value of the land and other properties which fall within the vicinity of the metro line. Though such an appreciation of value of land has been observed along side of Metro

Phase-1 corridor, the Bangalore Metro or the State Government has not been able to leverage the increase in the value of the properties towards financing the Metro project. However, in this report an attempt has been made to use the innovative financing techniques to mobilise funds to partly fund the project and this enhances the finance and economic viability of the project.

This 17 km stretch would have 13 stations in all including the 2 junctions one at Central Silk Board and other at K.R.Puram and would cost Rs.4202 crores. All the intervening stations would be over the road and land space is required only for the providing entry to these stations. This has helped in minimising the land requirement for this project. Also provision has been made to extend this line further upto Hebbal and this extension would connect this line to the airport line which is expected to run from Nagawara.

The attractiveness of this project is brought by a detailed finance analysis. The FIRR of this project has been estimated to be 15.27% and EIRR of this project has been estimated to be 55.69%. The easy availability of land for construction and not many obstructions involving the shifting of utilities makes it possible to complete the project within a span of 3 years.

SALIENT FEATURES

1	Guage	Standard Gauge (1435mm)
2	Alignment	KR Puram to Silkboard
2.1	Route Length	17 km
2.2	No. of Stations	13 (including terminal station)
3	Traffic Forecast (estimated Ridership)	
3.1	2021 year	3.52 Lacs per day
3.2	2031 year	4.59 Lacs per day
3.3	2041 year	5.75 Lacs per day
4	Train Operation Plan	
4.1	2021 year	Peak headway- 4 min. Train configuration- 6 car No. of trains in service during peak hour- 17 No. of trains trips per direction per day- 220

4.2	2031 year	Peak headway- 3 min Train configuration- 6 car No. of trains in service during peak hour- 22 No. of trains trips per direction per day - 320
4.3	2041 year	Peak headway - 2.5 min. Train configuration – 6 car No. of trains in service during peak hour - 27 No. of trains trips per direction per day - 408
5	Speed	
5.1	Design Speed	80 kmph
5.2	Average Speed	34 kmph
6	Traction Power Supply	
6.1	Traction system voltage	750 V DC
6.2	Current collection	Third rail bottom collection
6.3	Power supply source	66 kV / 220kV
6.4	No. of Receiving Sub Stations	2
6.5	No. of Traction Sub Stations	11
6.6	SCADA	provided
7	Rolling Stock	
7.1	Type	Standard gauge 2.88m wide modern rolling stock with stainless steel body
7.2	Axle load	15t
7.3	Seating arrangement	Longitudinal
7.4	Maximum Capacity of 6 coach unit	2068 Passengers
8	Maintenance Facility	Baiyappanahalli Depot

9	Signaling, Telecommunication & Train Control and PSG	Communication Based Train Control (CBTC) Integrated system with fiber optic cable, SCADA, Train radio, PA system, etc... Train information system, control telephones and centralized clock system Platform Screen Doors
10	Construction Methodology	Elevated viaduct consisting of pre-stressed concrete box/'U' shaped girders on single pier/portal with pile/open foundation.
11	Automatic Fare Collection (AFC)	Integrated with existing AFC system.
12	Total Estimated Cost	4202 Crores (at July,2016 Prices, w/o taxes)
13	Financial Indices	
13.1	FIRR	15.27%
13.2	EIRR	55.69%

PRADEEP SINGH KHAROLA
Managing Director
Bangalore Metro Rail Corporation Ltd.

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ABBREVIATIONS

ASS	-	Auxiliary Sub-Stations
AQI	-	Air Quality Index
ATL	-	Average Trip Length
ATO	-	Automatic Train Operation
ATP	-	Automatic Train Protection
ATS	-	Automatic Train Supervision
BBMP	-	Brarhut Bangalore Mahangar Palike
BBRS	-	Broad Band Radio System
BDA	-	Bangalore Development Authority
BIAAPA	-	Bangalore International Airport Planning Area
BIEC	-	Bangalore International Exhibition Center
BMA	-	Bangalore Metropolitan Area
BMRCL	-	Bangalore Metro Rail Corporation Limited
BMS	-	Building Management System
BMTC	-	Bangalore Metropolitan Transport Corporation
BOD	-	Biological Oxygen Demand
BPCL	-	Bharat Petroleum Corporation Ltd
BWSSB	-	Bangalore Water Supply and Sewerage Board
c	-	Shear Cohesion of Soil
CATC	-	Continuous Automatic Train Control
CBI	-	Computer Based Interlocking
CBTC	-	Communication Based Train Control
CCTV	-	Closed Circuit Television
CI	-	Congestion Index
CPCB	-	Central Pollution Control Board
CR	-	Rock Core Recovery
CSBJ	-	Central Silk Board Junction
DCC	-	Depot Control Centre
DMC	-	Driving Motor Car
DMI	-	Driver Machine Interface
DMRC	-	Delhi Metro Rail Corporation
DPCS	-	Digital Protection Control System
DRDO	-	Defense Research Development Organisation
EB	-	Emergency Brake
EIRR	-	Economic Internal Rate of Return
EIU	-	Environmental Impact Unit
EMC	-	Electromagnetic Compatibility
EMI	-	Electromagnetic Interference
EMP	-	Environment Management Plan
EPA	-	Environmental Protection Act
ESI	-	Environmental and Social Impact
ETS	-	Emergency Trip System
FBR	-	Fare Box Revenue
FIRR	-	Financial Internal Rate of Return
FOTS	-	Fiber Optic Transmission System
FRLS	-	Fire Retardant Low Smoke

ABBREVIATIONS

FRLSOH	-	Fire Retardant Low Smoke Zero Halogen
FSB	-	Full Service Brake
GC	-	Generalized Costs
GSS	-	Grid Sub-Station
HAL	-	Hindustan Aeronautics Ltd
HBB	-	Home Based Business
HBE	-	Home Based Education
HBO	-	Home Based Other
HBW	-	Home Base Work
HSD	-	High Speed Diesel
HW	-	Hazardous Waste
IFC	-	International Finance Corporation
IGBT	-	Insulated Gate Bipolar Transistors
IIM	-	Indian Institute of Management
IISc	-	Indian Institute of Science
IMD	-	Indian Meteorological Department
IRC	-	Indian Road Congress
ISRO	-	Indian Space Research Organisation
KRDCL	-	Karnataka Road Development Corporation Limited
KSISF	-	Karnataka State Industrial Security Force
KSPCB	-	Karnataka State Pollution Control Board
KSRTC	-	Karnataka State Road Transport Corporation
MoEF	-	Ministry of Environment and Forest
MRTS	-	Mass Rapid Transport System
MS	-	Motor Spirit
MSW	-	Municipal Solid Waste
NAAQS	-	National Ambient Air Quality Standards
NAL	-	National Aerospace Laboratories
NFBR	-	Non Fare Box Revenue
NIMHANS	-	National Institute of Mental Health and Neurosciences
NLSIU	-	National Law School of India University
NMS	-	Network Management System
O&M	-	Operation & Maintenance
OCC	-	Operation Control Centre
OD	-	Origin Destination
ORR	-	Outer Ring Road
OVPD	-	Over Voltage Protection Device
PAPs	-	Project Affected Persons
PCU	-	Passenger Car Unit
PHPDT	-	Peak Hour Peak Direction Traffic
PIU	-	Parameter Importance Unit
PSD	-	Platform Screen Door
PT	-	Public Transport
PWL	-	Pit-Wheel lathe
R &R	-	Resettlement and Rehabilitation
ROW	-	Right of Way.
RPM	-	Respirable Particulate Matter
RQD	-	Rock Quality Designation

ABBREVIATIONS

SCADA	-	Supervisory Control and Data Acquisition
SER-O	-	Environmental and Social Responsibility in Operations
SEZ	-	Special Economic Zone
SIA	-	Social Impact Assessment
SOC	-	Soil Organic Carbon
SOD	-	Schedule of Dimension
SPM	-	Suspended Particulate Matter
SPT	-	Standard Penetration Tests
TEP	-	Track Earthing Panel
VOC	-	Vehicle Operating Cost -
VOT	-	Value of Time
WHO	-	World Health Organization
Φ	-	Angle of Internal Friction

1. INTRODUCTION

1.1. BANGALORE CITY – PROFILE

Bangalore officially known as Bengaluru (12.97° N 77.56° E) is the capital of the Indian state of Karnataka which is located in the southern part of India. Bangalore is located on the heart of Mysuru Plateau which is a part of Deccan Plateau.

This city spread across 741 sq. km is at an average elevation of 920 metres from sea level. Bangalore has a tropical savanna climate with distinct wet and dry seasons. Due to its high elevation, Bangalore usually enjoys a more moderate climate throughout the year. Although due recent real estate developments leading to reduction in green area the summers has become hotter comparatively. The mean annual temperature is 24.1 degrees Celsius. The geographic and climatic conditions of Bangalore make it as one of the best cities to live in.

Area (Urban)
741 km².

Gross Domestic Product
US$ 83 billion

Bangalore is an important urban centre and is recognized as the Silicon Valley of India, Technical capital of India and as the Centre for Advanced Sciences, Higher Education, Research and Development. Bangalore Generates about 5% of the national GDP and contributes over one third (33%) of the India's tax revenues. Bangalore has been acknowledged as the third wealthiest city in India according to a study. Bengaluru boasts of a total wealth of USD 320 billion. The city is home to 7,500 millionaires and 8 billionaires and is most cosmopolitan city in India, one among the top ten High-Tech cities of the world, one of the Futuristic Cities of the world and as one of the very successful commercial and industrial hubs of the Indian Sub-Continent.

Average Literacy Rate
87.67 % (2011)

Engineering Colleges
80 approx.

The city which was originally developed as a Garden City has over the years, slowly transformed into an industrial and software hub of India. Bangalore's IT industry grew during this period with the establishment of Domestic and Multi-National companies. Indian technological organizations ISRO, Infosys and Wipro are headquartered in the city. It is home to many educational and research institutions in India, such as Indian Institute of Science (IISc), Indian Institute of Management (IIMB), National Law School of India University (NLSIU) and National Institute of Mental Health and Neurosciences (NIMHANS). Numerous state-owned aerospace and defense, such as Bharat Electronics, Hindustan Aeronautics and National Aerospace Laboratories are located in Bangalore.

1.2. POPULATION GROWTH

The total population of Bangalore Urban Agglomeration is 9.62 Million as per Census 2011. Bangalore was the fastest-growing Indian metropolis after Delhi between 1991 and 2001, with a growth rate of 38% during the decade.

Bangalore is the Epi-Centre of economic activity. Rapid Industrialization and urban development in the Bangalore city has seen a tremendous growth in its population and is expected to be 14.1 Million by 2021. It had a metropolitan population of around 8.5 million as per 2011 census, making it the third mostpopulous city and fifth most populous urban agglomeration in India.

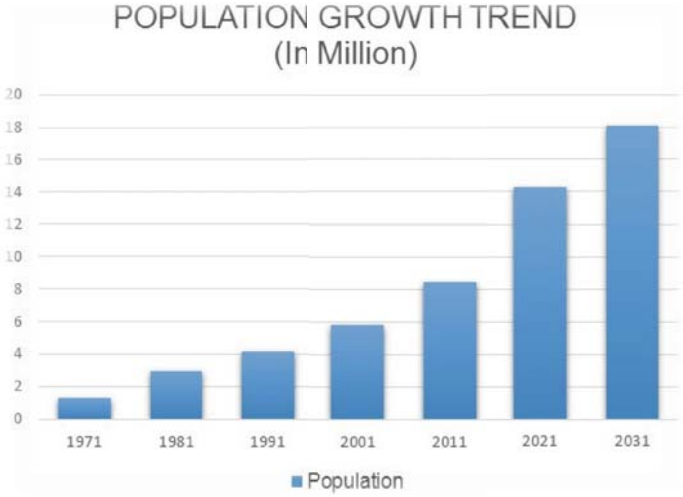


Figure 1.1: Population Growth Trend

The city has experienced major growth in the Information Technology sector making it a major technology hub in the country. Currently, Bangalore is the most stable real estate market in India driven by robust commercial absorption and job creation. Bangalore scores in terms of quality of schools, excellent climate and a cosmopolitan culture making it one of the most desirable cities to live in India.

1.3. GROWTH OF REAL ESTATE

Bangalore has historically been and continues to be one of the most stable real estate markets in India. The city has experienced major growth in the Information Technology sector making it a major technology hub in the country. It is now regarded as a high-tech city and is a home to professionals and a destination for investment in residential real estate assets.

A large majority of the office space absorption in Bangalore is contributed by IT companies, having appetite for acquisition of larger areas. The absorption for commercial space in Bangalore had been constantly increasing from 2009 to 2011 on a year-on year basis. This increasing trend in absorption was broken when 2012 could not reach the absorption levels

the city saw in 2011. The year 2013 was slightly lower than 2012 in terms of the total absorption. The absorption for the CY 2013 was approximately 8.66 million sq. ft. The absorption across SEZ space was approximately 1.57 million sq. ft. i.e. 18% of the total Bangalore absorption. The absorption of commercial real estate for the calendar year 2014 was approximately 14.31 million sq. ft. (including preleases). This is approximately 40% higher than the overall absorption in 2013. This is expected to be the highest absorption in the city since 2007. The absorption of commercial space for the calendar year 2015 was approximately 13.4 million sq. ft.

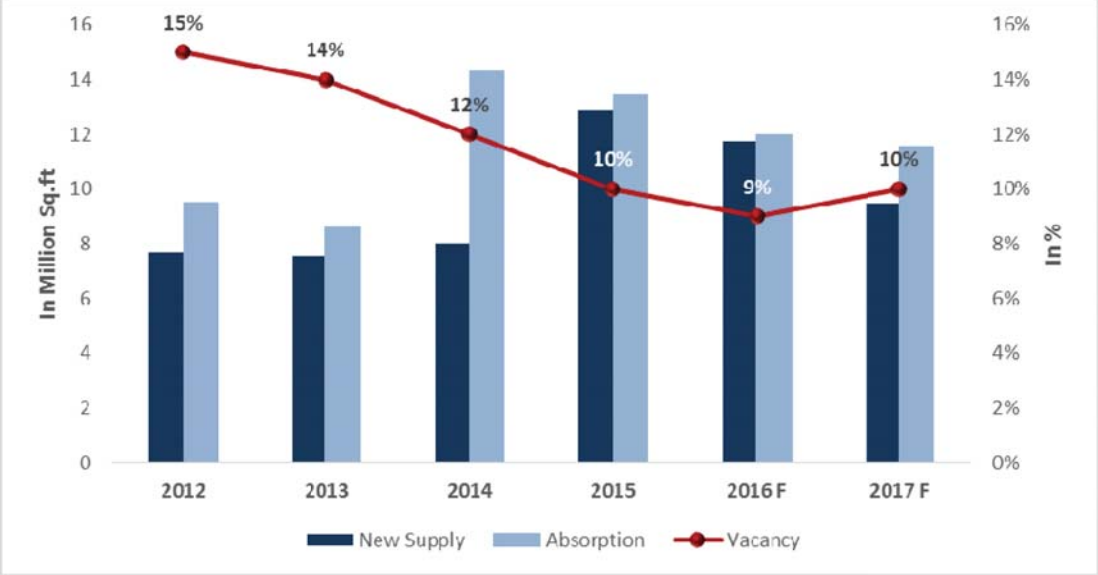


Figure 1.2: Commercial Office Space Supply Vs Absorption Vs Vacancy

The overall vacancy rate for office space in Bangalore was at its highest in 2012 at 15% and since then the same had been declining to reach 12% for the year 2014. The vacancy at the end of 2015 stood at 10%. With excellent absorption in 2015, the current vacancy in the city is approximately 9%.In 2016 (Till 30th June), Bengaluru's total unwavering demand in the office sector coupled with the inherent popularity of Bengaluru amongst global corporate is a positive sign for Bengaluru's residential sector in the mid and long term.

Bangalore continues to be a preferred destination for software professionals and original residents of Bangalore. The Eastern micro-market has done well and has improved its overall share in both launches and absorption. Proximity to the commercials hubs of Whitefield and ORR (70 million Sft of commercial stock) is the major reason for this pickup in demand. Markets like Old Madras Road, Budigere crossing, Hoskote, Varthur road etc have contributed in this regard. The below table highlights the major residential locations in Bangalore.

1.4. TRANSPORT NETWORK IN BANGALORE

The transport network of Bangalore is a ring-radial network. Ten intercity roads cut across Bangalore City. There are about 3000 Km of urban roads (about 500 – 600 Km of arterial and major roads). The major arterial roads have right of way (ROW) less than 25 m.

NH7 and NH4 (part of North South Corridor and Golden Quadrilateral, respectively) and NH209 pass through Bangalore forming five important radial roads within the Bangalore Metropolitan Area. State Highways linking Bangalore with Mysore, Bangalore with Bannerghatta, and Bangalore with Magadi form other major radial corridors. Developed as a radial town, Bangalore does not have a strong circumferential road system, except for the Outer Ring Road, despite the intervening space between the corridors developed. The main highways include:

- NH4 (National Highway 4) running from Mumbai to Chennai;
- NH7 from Varanasi to Kanyakumari;
- NH209 connecting Kanakapura and Kerala; and
- SH17 connecting Bangalore to Mysore.

Railway lines, all Broad Gauge, converge into the city from five different directions, viz. Mysore, Salem, Chennai, Guntakal and Hubli. Important Railway Stations serving the city are Bangalore city, Bangalore Cantonment, Yeshwantapur and Krishnarajapuram. Total route Kms within the City account for 62 Km.

1.4.1. VEHICULAR GROWTH

Bangalore population has been growing at a fast pace during the last two decades. There has been a phenomenal growth in the population of vehicles as well, especially the two and four wheelers in this period due to rising household incomes consequent to IT sector boom in the region. The number of motor vehicles registered has already crossed six millions. The issues relating to traffic and transportation in a large and growing city like Bangalore need to be viewed in the larger perspective of urban planning and development. Issues relating to land use planning and development control, public-private transportation policy, industrial locations and IT corridors would need to be integrated at the perspective planning level.

The vehicle population in all cities in India started growing rapidly since later part of 1980s. It has always had a reputation of having more two wheeler users. The liberalization policy of the country made availability of not only vehicles but also loans for buying vehicles. With the rapid growth of IT sector in Bangalore, the affordability of larger segment of employees increased for ownership of vehicles, more specially two wheelers. Coupled with inadequacy of comfortable and convenient public transport gave an impetus to more and more commuters shifting to cars and two wheelers for their commuting in Bangalore.

1.4.2. MODAL SPLIT

The main modes of transport in the city presently are two-wheelers, cars and Public Transport which comprise mainly of buses and three wheelers. The growth of registered motor vehicles has crossed 1.6 million with a growth rate of 10% per annum. There has been a 10 fold increase in the number of vehicles in the last 20 years. The share of two wheelers out of the total registered vehicles is over 70%. This is due to the inadequate supply of Public Transport along with its inadequate level of service. The bus fleet in the last 10 years has grown at less than 7.5 % per annum.

With the increase in population and the expansion of the city, the problem of connectivity of the populace has arisen. Quite obviously personalized modes of transport have grown at a tremendous rate and two wheelers along with the cars almost comprise 90% of the total registered vehicular population in the city.About 35% of the daily trips are Non-Motorized Transport (NMT) trips, 27% of the trips are carried by Public transport, 31% of the trips by private vehicles and 7% of the daily trips by Intermediate Public Transport (IPT).

Two wheelers constitute more than 70% of the total volume, while cars comprise 15%, autos 4% and the remaining 8% includes other vehicles such as buses, vans and tempos. All or most of the roads are operating above their capacity and the volume: capacity ranges from 1:2, 1:3 and 1:5.

1.4.3. PUBLIC TRANSPORT

Buses, auto three wheelers (paratransit mode) and taxis are the only mode of public transport available in the city. Buses (including factory buses) carry about 2.4 million passengers per day i.e., modal share of about 45%.

- BMTC
  The public transport in Bangalore is operated by Bangalore Metropolitan Transport Corporation (BMTC). At present BMTC is operating 2400 bus routes with a fleet size of 6,111 buses. About 43 lakh daily passengers' trips are carried by BMTC. Since the city is expanding in all directions, and roads already congested, buses alone are not able to cope up with the heavy commuter demand.
- Rail Network
  Bangalore city is having a fairly good rail network - about 62 kms, but its potential for commuter rail development has not been tapped. There are a few diesel operated passenger trains run to Bangalore City from Tumkur, Mysore and Kuppam on the Chennai line in the morning and as return train in the evening, mostly for commuters coming from suburban areas and satellite towns. They are well patronized and in the recent past the patronage has shown good growth rate. The Railway network carries hardly 1 % of the commuters for want of adequate number of services and their frequency.

- Metro Network

  Namma Metro (literally "Our Metro"), also known as Bangalore Metro, is a metro system serving the city of Bangalore in Karnataka, India. Namma Metro is India's second largest metro system in terms of both length and number of stations, after the Delhi Metro. The development of network was divided into phases, Phase I containing 2 lines is scheduled to be completed in 2016, and Phase II by 2022.Phase I comprises two lines spanning a length of 42.30 Km (26.28 mi), of which about 8.82 Km (5.48 mi) is underground and about 33.48 Km (20.80 mi) is elevated. There are 40 stations in Phase I, of which 8 stations are underground, 1 at grade and 32 are elevated. Phase II spans a length of 72.095 km – 13.79 km underground, 0.48 km at grade and 57.825 km elevated, and adds 61 stations to the network, of which 12 are underground.

1.5. CURRENT INFRASTRUCTURE CHALLENGES

Bangalore's vehicular traffic has increased manifold, with 40.46 lakhs registered vehicles in the city continues to grow at an annual rate of between 7-10%. The maintenance and construction of roads to address the growing traffic in the city has been a challenge to the State's governing bodies. Development of the city road infrastructure has revolved around imposing one-way traffic in certain areas, improving traffic flow in junctions, constructing ring roads, bridges, flyovers and other grade separators.

Everyday more than 30 accidents occur out of which 21 persons are injured and 2 to 3 persons killed. The economic loss caused due to traffic jams & accidents are unimaginable. This demands an effective multimodal integrated mass transportation network, which is cost effective, pollution free, covering large area & population. In the present work various options are investigated looking into the multifaceted traffic problems of Bangalore. This particular approach in the study is adoptable for cities facing similar problems. The experience of creating greater Bangalore has increased the number of trips to the city centre and work places in turn increasing the transportation needs. The average commercial speed during peak hour is 15.0 kmph.

1.6. CONCLUSION

As of now the Metro Rail Phase-1 is nearing completion and a complete corridor – East-West Corridor measuring 17 Kms. is in operation. The number of passenger trips being performed on this corridor has touched a peak of 1.4 lakhs per day. On an average on this corridor about 1.3 lakhs passengers are travelling. This has an indication of the potential of the metro system for Bangalore city besides it also indicates how the citizens of Bangalore have quickly changed their earlier modes of transport and switched over to the Metro rail system. The size of the City, the ever-growing congestions on the roads, an increase in investments in the IT and other Sectors are attracting more number of industries. All necessitate a modern public transport system. Therefore, a Metro rail system with a full-fledged network would be the ultimate solution for meeting the public transport needs of the citizens of Bangalore.

However, it needs to be noted that a bare rail based metro transport system cannot provide a full and comprehensive solution to the public transport problems and the metro rail system can work as the backbone of the public transport system but it would have to be complemented so that a complete solution is made available to the daily commuters. The following actions need to be taken along with the expansion of Bangalore Metro rail system:

1. Providing an efficient bus based feeder system to the Metro lines.
2. Focusing on the last mile connectivity
3. Providing seamless transportation points between Metro, Buses and other modes of transport
4. Providing user friendly facilities for the non-motorized transport.

With Phase-1 and Phase-2 getting operational, the Bangalore City would have about 114 Kms. of Metro rail systems which still be far below what is required for the city with a population of exceeding 10 million. In addition Bangalore City emerging as the growth engine for the State of Karnataka, the need for more public transport cannot be overemphasized. A Metro system, though highly efficient, is capital intensive one. The resource constraints do not permit taking up of the entire metro system in one go and therefore, the metro network is being expanded in phases. With the limited resources available, therefore the urgent metro lines need to be taken up which command the minimal marginal cost but at the same time offer the maximum benefits. The focus of this report has been on identifying the corridor which satisfy these conditions.

2 METRO ON ORR

2.1 BACKGROUND

Construction on both Phase 1 and Phase 2 Metro Line is underway right now. Commercial operations have started on 30.3 km of the 42.30 km Phase 1 and the rest is expected to open in phases in 2017. Construction for 15.1 km of the 72 km Phase 2 has started is expected to be completed in 2020.

As emphasized in Chapter 1, the existing metro network of 114.4 km would address the immediate traffic problems within the core areas and its immediate neighborhood but by the time the Revised Master Plan proposals get implemented and development of areas beyond the potential growth corridors takes place in right earnest, the above system will fall short and a more extensive system will become necessary. This is especially true because the Revised Master Plan 2015 and its detailed Zonal plans propose the development of around 816.4 Sq. Kms. of area for various urban uses. This brings very large spread of area on which various urban activities will take place. They would now be located right up to the Peripheral Ring Road in practically all directions and at a few places even beyond it. It is therefore necessary that the Metro gets ultimately extended to the most of the high density centers.

In this context, the following eight corridors have been identified for assessing the growth potential.

Yelahanka/ Hennur/ Hebbal:	➢ Well developed residential and upcoming commercial locality
Outer Ring Road:	➢ Major IT/ ITeS hub specially, K R Puram to Silk Board stretch
EPIP Zone/ Whitefield:	➢ A mix of High rise & Low rise structures
CBD:	➢ Planned commercial development ➢ Limited land availability/ Re-development potential
Mysore Road:	➢ Industrial establishments, includes some well-known automobile giants and IT majors.
Bannerghatta Road:	➢ Educational Hub, IIM B with presence of IT/ ITeS Companies
Hosur Road:	➢ Primarily residential and commercial market
Electronic City:	➢ Primarily IT/ ITeS Campus Development

Each of the above corridors growth index has been assessed to select the most potential corridor for extension of the existing metro rail network.

Detailed Assessment explores growth through two complementary lenses:

- A high growth index of places which identifies those places that have experienced the fastest growth over the past five years
- A dynamism index of places which focuses on the qualityof growth; places where growth has contributed towardslocal economic value.

This analysis has been supplemented by a small numberof in-depth, semi-structured interviews with a selection of local leaders and chief executives charged with overseeing the growth of their business areas.

2.2 HIGH GROWTH AND DYNAMIC AREA

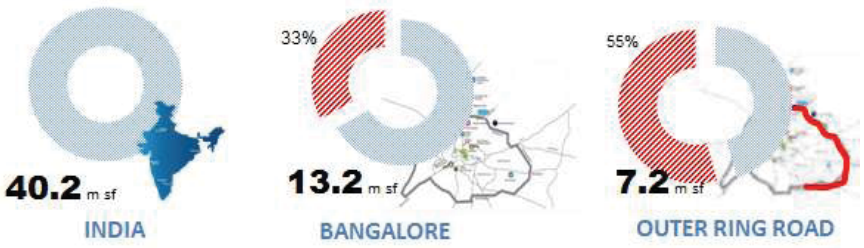
Further to assessment, **Outer Ring Road K.R.Puram – Silk Board**stretch emerged as potential growth corridors considering economic, demographic and spatial growth.

High Economicgrowth–includingbusinessstockandemploymentlevels

Demographic growth – including resident population and growth in` working age population

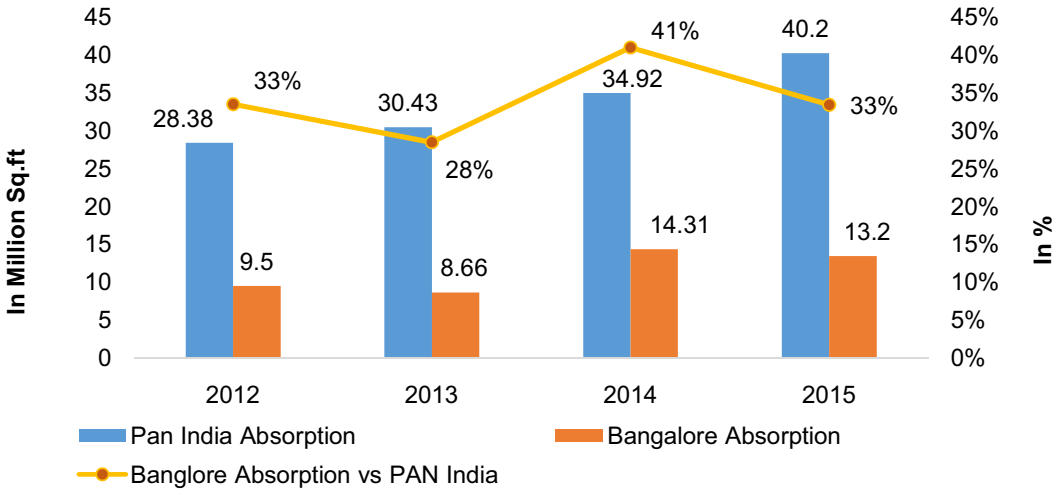
Spatial growth - dwelling stock and commercial floor space

Out of the entire commercial office space absorption in Bangalore, ORR accounts for a staggering 55% (7.2 Million Sft). To put things in perspective, the ORR stretch accounts for 20% of the total commercial office space absorption in India.



This staggering statistic alone gives us an idea of the amount of economic activity happening along the ORR and the level of strain being inflicted on an already fragile infrastructure.

With a standing stock of 130 Million Sft, Bangalore is one of the largest commercial office markets in India and accounts for the bulk of the annual office space absorption in India. In 2015, Bangalore accounted for 33% (13.2 Million Sft) of India's total commercial office space absorption.



ORR serves as the main artery between Bangalore International Airport and the IT hubs of Bangalore. The ORR has approximately 40 Million Sft of commercial office space which is 32% of the entire commercial office stock in Bangalore. The working population of ORR is 4,50,000 persons which results in approximately 800,000 commuters traveling on this stretch everyday (about 15% of Bangalore city's vehicular traffic).

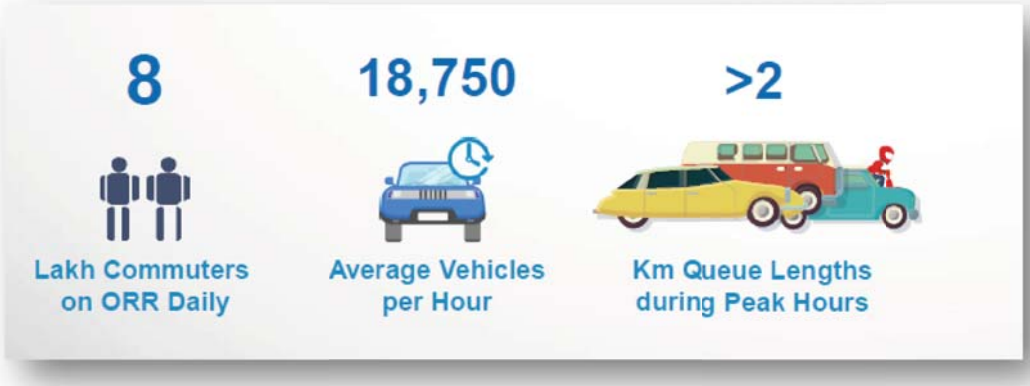
The stretch from K.R.Puram to Silk board is surrounded by IT companies and huge residential pockets. The road infrastructure is a 3-lane divided dual carriageway with 2- lane service roads. Grade Separators are provided at major Junctions on the corridor.

2.3 INFRASTRUCTURE CHALLENGES

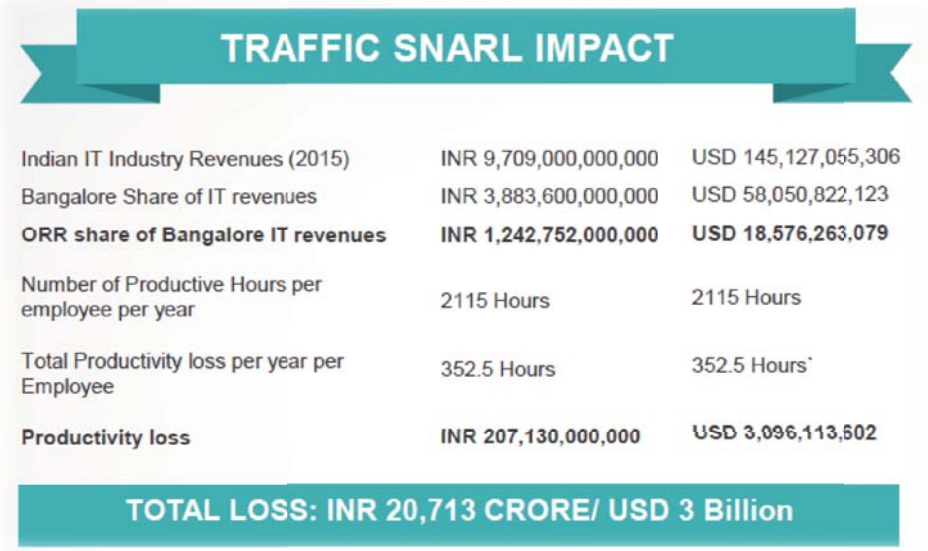
The city has a ring radial road pattern and the Bangalore Development Authority (BDA) had developed the Outer Ring Road (ORR) in 2002 in a bid to divert the heavy traffic load to ease the traffic situation in the city. ORR has eventually evolved as the most attractive IT growth corridors of Bangalore.

Currently, with around 4.5 Lakh employees working on this corridor, it is estimated that in the next 4 years, an additional 30 Million Sft. would be available for occupancy whichinturn projects a total of 8 lakhs working population by 2021. With immense growth in intra-city traffic, ORR is under tremendous pressure with high congestion index manifested in low speeds and high travel times. With rapid urbanization, in most of the stretches of ORR, the existing traffic volumes are far higher than the intended design of 5400 PCU's.

The Hebbal to Silk board stretch of ORR sees close to 4.5 Lakhs cars travel on it every day which means that on an average 18,750 vehicles are present on the ORR every hour. During peak hours, this number is almost 2-3 times of the average. As per urban planning guidelines, the minimum travel speed for a major city road is 25 Km/hour. Due to the heavy traffic presence, the average travel speed in major sections of the ORR is less than 10Km/ hour. Considering the existing and proposed network of metro rail in Bangalore City, there has been a clear identification of the Stretch from K.R.Puram to Silk Board as the missing link on the Namma Metro Network.



With absence of MRTS on ORR and increasing vehicular traffic there are longer queue lengths which lead to around 2-3 hours of travel time to cover a distance of 5-10 Km in peak hours. Employees loose approximately 90 minutes every day due to traffic snarls leading to an estimated loss of productivity amounting to INR 20,713 CR. per year.



2.4 INEVITABILITY OF HAVING A METRO ON ORR

The metro networks have to be planned and executed in totality. It becomes difficult to add to the metro network if the future extensions are not planned or made part of the earlier network.

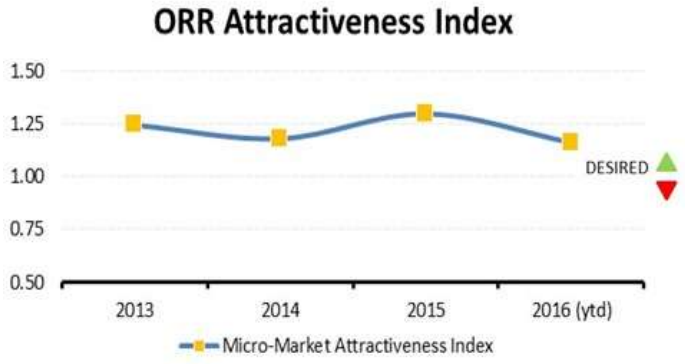
With Phase-1 and Phase-2, which is underway, the metro lines are passing through the two extremities of this corridor. The Electronic City line of Phase-2 which runs from Jayanagar to Electronic City passes through the Central Silk Board junction. At the same time the eastern reach of the East-West corridor which connects Majestic City Centre to Whitefield passes through the other extremity of this corridor i.e. at KR Puram. If this corridor has to be completed, the two junctions at KR Puram and Silk Board have to be designed and this corridor needs to be factored in the design of Phase-2 itself. As at present, Phase-2 does not accommodate this corridor and therefore, it is very much necessary that suitable modifications are done on the two junctions at KR Puram and Silk Board.

In addition, the most important technical factor which facilitates the metro on this corridor is that all intersections on this corridor are grade separated and at each intersection the grade separators is joined through a split flyovers. The splitting of flyovers on the intersection provides an ideal condition as the metro alignment would run between the gaps of the two flyovers, thereby making construction easy without disturbances to the road traffic. Non-utilization of this space between the flyovers at present may lead this space getting committed for some other uses which the Metro may find it difficult to get back at a later date. Therefore, it would be fitness of things that this alignment between KR Puram and Central Silk Board is being taken up alongside the Metro Phase-2 so that simultaneous to the completion of the two junctions at the extremities to connect the line also gets completed. The other technical feature which offers a metro system is that the entire alignment would be an elevated corridor and would not have to face the challenges of making an underground system which substantially delayed the Phase-1. Besides, this alignment runs on the outer ring road which is about 60 meters wide road and during construction phase, diversion of traffic would not pose a major challenge. Also the ORR is well designed with no sharp, horizontal or vertical curves which again make the construction of the line easy.

2.5 RETAINING THE ATTRACTIVENESS OF ORR

DECLINING ATTRACTIVENESS INDEX FOR ORR

Outer Ring Road remains a preferred choice from an occupier perspective but is marred by several factors such as supply scarcity on its preferred Marathahalli-Sarjapur belt and physical infrastructure crumbling under pressure from the mammoth developments and severe traffic bottlenecks.



It is gradually sliding down on crucial market attractiveness parameters but simultaneously several developments from Marathahalli – K.R. Puram and K.R. Puram to Hebbal belt are also in pipeline which

will keep the tenant interest alive in the long term. That said, similar tenant profile and pre-commitments in upcoming developments continue to drive demand in the busy ORR Belt.

The retention in attractiveness is a cause of concern and one of the major factors to reduce this attractiveness is the inadequate infrastructure and access through public transport. The BMTC buses are the only modes of public transport for people to access this corridor. This is evident from the fact that the IT Companies on this corridor engage 2800 chartered buses, maxi cabs and private buses to ferry their employees. Therefore, there is an urgent need to provide mass transport facilities in order to retain if not, make the attractiveness index of this area. A decline in attractiveness index may lead to the business units to short location and this shift may take place not only to other locations of the Bangalore city but even outside the Bangalore City.

2.6 CONCLUSION

Therefore, based on the above analysis it is extremely necessary that the ORR between KR Puram and Silk Board should get connected through the metro line. This line would not only offer the highest return but would also come at the least marginal cost.

3 TRAFFIC DEMAND ANALYSIS - ESTIMATION OF RIDERSHIP

3.1 INTRODUCTION:

Ridership is the most important factor to determine the desirability and also the viability of a new metro line. The ridership indicates the number of passengers using the metro train by paying notified fare. Generally, the ridership is estimated in terms of the number of people who would be travelling in the train per day. It is clarified that the ridership if the total number of passenger trips.

3.2 ESTIMATION OF RIDERSHIP FOR THE ORRMETRO LINE:

The ridership can be estimated by adopting different methodologies. For the purpose of this DPR, three different methodologies have been used to arrive at the ridership for the new line. These methodologies are:

- Travel demand modeling
- Estimation of ridership through assessment of built up areas
- Estimation of ridership by extrapolating the ridership on the East-West Corridor which is currently operational.

3.2.1 Travel Demand Modeling (This was done by M/s. RITES)

The transportation planning process consists of development of formulae (or models), enabling forecast of travel demand, and development of alternative strategies for handling this demand. It is not just one model, but also a series of inter-linked and inter-related models of varying levels of complexity, dealing with different facets of travel demand. Through these models, the transportation study process as a whole is checked and calibrated before it is used for future travel predictions.

The model has been built using CUBE software developed by Citilabs and Urban Analysis Group. The normal and easily available planning variables at zonal levels such as population, employment and student enrolment have been made use of in transport demand analysis. The model uses the analyzed data from household interview and other traffic surveys conducted as a part of this study and secondary data.

3.2.1.1 Methodology For Model Development

The model developed is a traditional four-stage transportation model, as illustrated in Figure 3.1

Figure 3.1 Four-Stage Model Structure

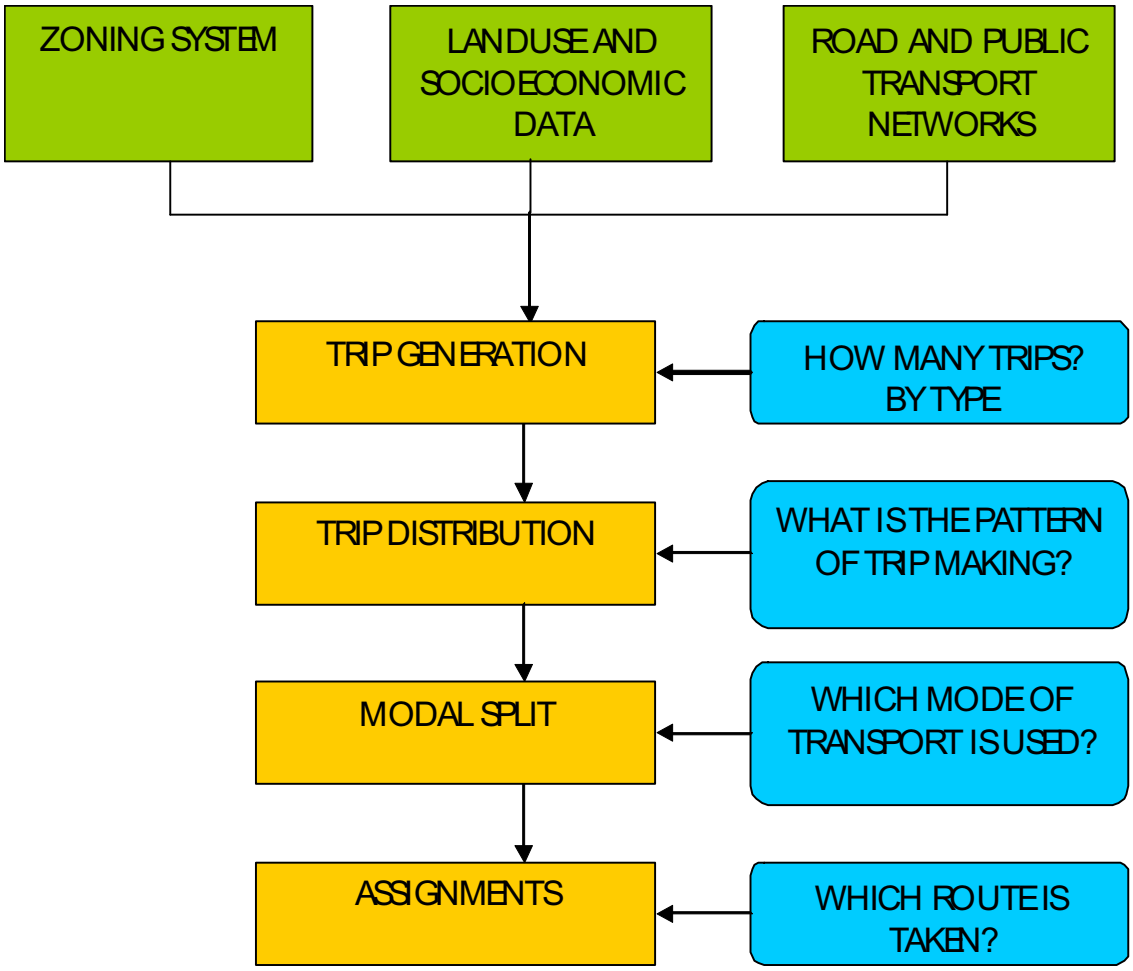
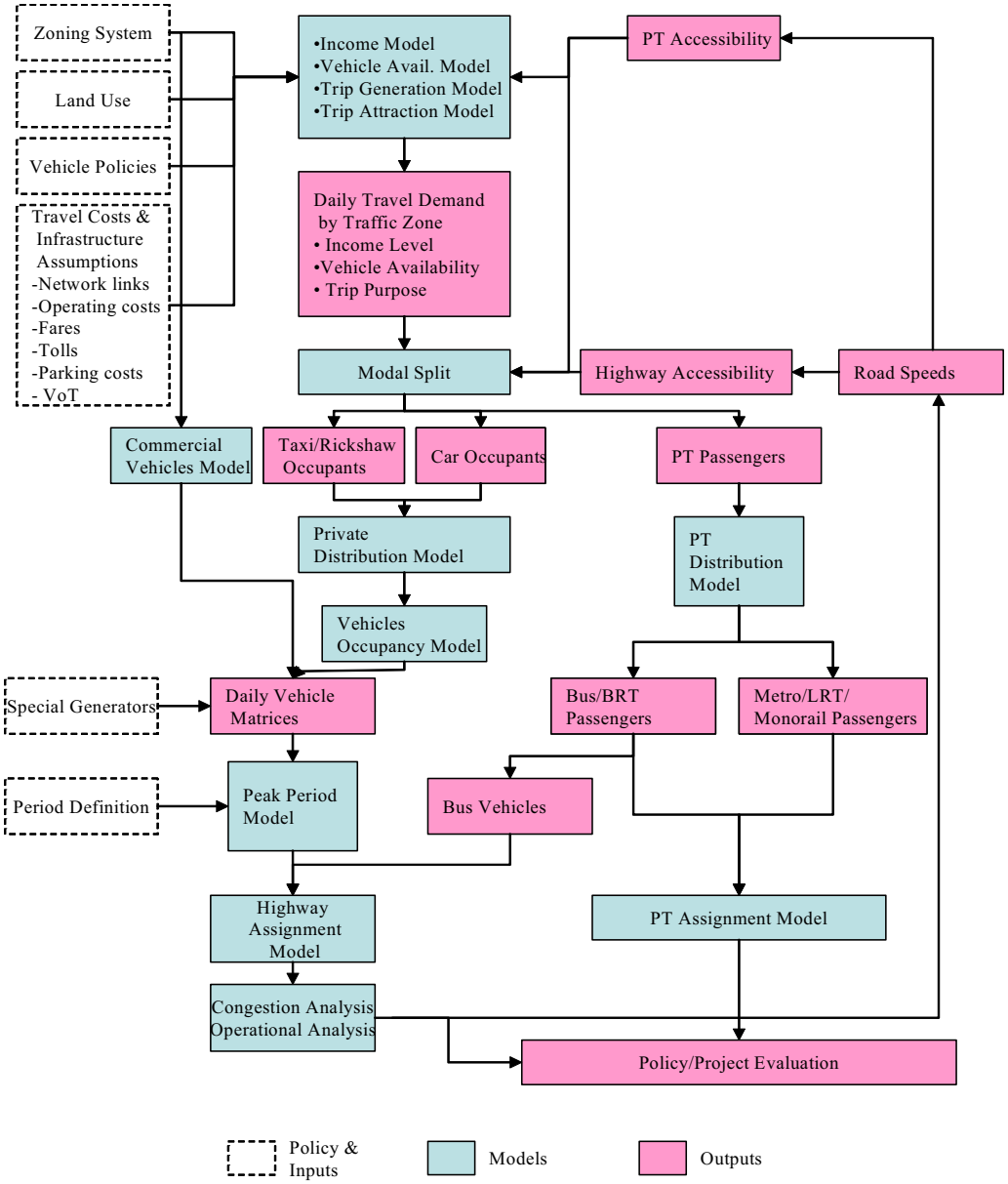


Figure 3.2 provides a summary of the interactions of the different part of the proposed transport model. The main inputs to the modelling are shown to the left of the figure in the uncolored boxes and include the zoning system (representing the spatial disaggregation of the study area), land use data, policies and travel costs by competing modes.

Figure 3.2 Methodologies for Model Development



The blue colored boxes in the figure represent the different sub-models. The pink colored boxes are model outputs and ultimately provide information for the project evaluation that will be carried out once the model is completed. The model features a “feedback loop” in which the changes in public transport accessibility (i.e. through provision of enhanced public transport) can affect the number of trips generated in the first stage of the 4-stage process.

3.2.1.2 Model Structure

The model developed has the following characteristics:

- Motorised daily model is based on productions / attractions and internal trips of Bangalore residents for base year 2015. These modes of travel (ie. Car+Taxi, two wheelers, auto-rickshaw, and bus) comprise 90.7 Lakhs daily trips. The remaining 33.1 Lakhs daily trips are those relating to non-mechanised trips (walk, cycle and cycle rickshaw) as well as external trips and those on the national rail network.
- The different sub-models i.e. vehicle availability, generation, attraction, distribution, modal choice and assignment models have the following characteristics:
- Vehicle availability model estimates the distribution of households by vehicle availability group, which has an impact on the number of trips and the chosen mode and destination;
- Generation and attraction models calculate trips generated and attracted by each zone, by purpose and vehicle availability group;
- Distribution models distribute trips generated into the possible destinations and provide all modes matrices;
- Modal choice models split total travel demand matrices by mode;
- Assignment models represent the last stage of the model, build paths, assign origin / destination (OD) matrices, and finally provide loaded networks for average hour and global AM peak hour. A standard average hour factor of 7% is applied to the daily OD matrices for hourly highway and public transport (PT) assignment.
- The model considers four modes i.e. car+taxi, two wheelers (2W), auto-rickshaw (Auto) and public transport (PT).
- The model considers four purposes i.e. Home Base Work (HBW), Home Based Education (HBE), Home Based Business (HBB) and Home Based Other (HBO).
- Three vehicle availability groups i.e. No Vehicle available (NV), car available (Car) and 2W available (2W) have been considered.
- The model area covers the Bangalore Metropolitan Area (BMA) and proposed development around Bangalore International Airport Planning Area (BIAAPA) including the new airport at Devanahalli. The adjoining areas are being treated as external zones. The model zoning system contains 225 zones, 215 internal zones (BMA) and 10 external zones. The model development is largely based on the Households Interview after expansion from sample to total population. This is calculated at a zonal level.

3.2.1.3 Base Year Highway Matrices Development

- The next step was to build the base year highway matrices necessary to obtain costs for the model development (distribution and modal choice):
- HIS matrices are converted to vehicles using occupancy and PCU factors and added to external matrices to get total traffic to get the final highway matrices (car, auto, 2W).

3.2.1.4 Vehicle Availability, Generation, and Attraction Models

3.2.1.4.1 Development and Calibration

The development and calibration of vehicle availability, generation, and attraction models, as estimated based on 2015 Households Interview Survey database are as follows:

- Vehicle availability model estimates the distribution of households by vehicle availability group (No Vehicle, car available, and two wheelers available) based on the households monthly average income by zone
- Generation model calculates daily person trips generated by purpose (Home Base Work, Home Based Education, Home Based Business, and Home Based Other), and households group (segmentation by size and vehicle availability);
- Attraction model produces daily person trip attracted by purpose and vehicle availability group.

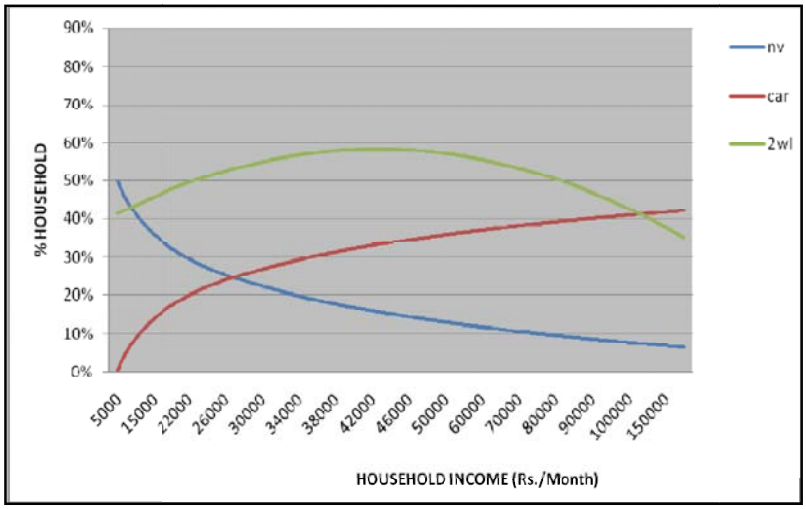
3.2.1.4.2 Vehicle Availability Model

Figure 3.3 shows the estimated distribution of households by income and vehicle availability group. The trends match the existing situation. The proportion of households with no vehicle logically decreases with income increase, and conversely the part of households with car available increases when income rises. The percentage of households with two wheelers available increases up to an income of Rs.50, 000 per month, then decreases, indicating that from this income point, households have more opportunity to buy a car. In terms of the model application, it should be noted that the households distributions are applied to the monthly average income, defined for each zone (total 215) from the HIS database. Table 3.1 presents the vehicle availability model calibration; the model household's distribution by vehicle availability is identical to the HIS data: no vehicle 21%, car available 24%, and two wheelers available 55%.

Table 3.1: Vehicle Availability Model Calibration Results

VA	NV	Car	2W	Total
HIS	538165	594833	1359497	2492495
Model	537666	593438	1358827	2489931
HIS	21.59%	23.86%	54.54%	100.00%
Model	21.59%	23.83%	54.57%	100.00%
Difference	0.00%	0.03%	0.03%	0.00%

Figure 3.3 Distributions of Households by Income and Vehicle Availability Group



3.2.1.4.3 Generation model

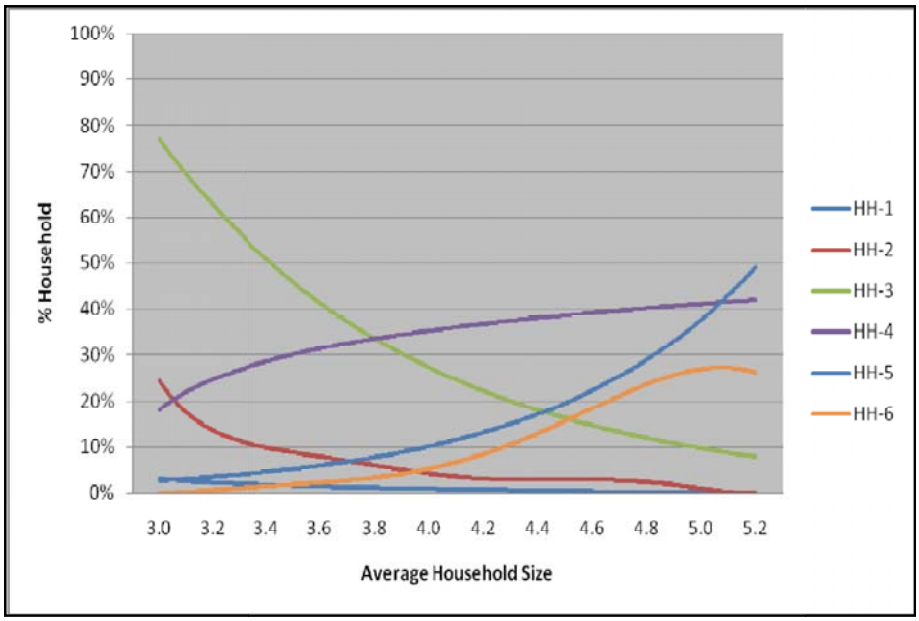
Vehicle availability model results are an input to the generation model, which also requires household size distribution. Therefore, a model estimating the distribution of households (HH) by household's size (1, 2, 3, 4, 5, and 6+ members) was also developed, as shown in Figure 3.4. In the model application, the distribution is calculated for each individual zone based on each zone average households size. Lines trends look sensible. The proportion of households with one, two, or three persons decrease when the average household size increases, and on the opposite side, the percentage of households with 5 or 6+ members increase.

As illustrated in Table 3.2, model distribution is very close to the HIS one: household proportion with only 1 member 1%, 2 members 8%, 3 members 35%, 4 members 39%, 5 members 12%, and 6+ members 5%.

Table 3.2: Generation Model Calibration Results (Household's Size Distribution)

HH Size	HH1	HH2	HH3	HH4	HH5	HH6+	Total
HIS	14954	191221	877657	975228	298354	135081	2492495
Model	14454	191621	877107	975478	297604	135381	2491646
HIS	0.60%	7.67%	35.21%	39.13%	11.97%	5.42%	100.0%
Model	0.58%	7.69%	35.20%	39.15%	11.94%	5.43%	100.0%
Difference	0.02%	0.02%	0.01%	0.02%	0.03%	0.01%	0.00%

Figure 3.4 Distributions of Households by Household Size



Vehicle availability and households size models predict the number of households per size and vehicle availability. Based on this segmentation (6 HH sizes x 3 vehicle availability group = 18 groups), daily person trip rates were extracted by purpose and are presented in Table 3.3 (18 groups x 4 trip purposes = 72 trip rates). Figures show a trip rate increase with household size increase, and the clear impact of the motorisation: people make more trips if they are motorised (even more if they have a car rather than a two wheelers) and also make longer trips. The generation is home based and therefore based on Productions / Attractions (PA), not Origins / Destinations. At the end of the generation models application, the segmentation by household size disappears since trips are aggregated by purpose and VA (4 x 3 = 12 groups).

Table 3.3 Zone Wise Distribution of Student Enrolment

Purpose	HBW			HBE			HBO			HBB		
HH size / VA	NV	Car	2W	NV	Car	2W	NV	Car	2W	NV	Car	2W
1	0.91	1.10	0.88	0.15	0.01	0.12	0.06	0.01	0.13	0.17	0.01	0.14
2	1.90	5.39	3.12	1.03	3.43	1.91	0.62	2.87	1.07	0.31	1.07	0.46
3	1.70	1.76	1.69	0.97	0.94	1.00	0.56	0.66	0.63	0.30	0.24	0.21
4	1.16	1.79	1.47	0.53	0.92	0.83	0.34	0.66	0.51	0.21	0.20	0.19
5	1.92	2.29	1.96	0.94	1.33	1.23	0.73	0.93	0.76	0.41	0.27	0.28
6+	1.75	1.57	1.95	1.15	0.90	1.17	0.62	0.47	0.66	0.38	0.17	0.30

Note: external, walk, cycle, cycle rickshaw, and train trips not included.

Table 3.4 shows the numbers of daily person trips by purpose and vehicle availability group in the HIS database.

Table 3.4 HIS database Daily Person Trips By Purpose And Vehicle Availability Group				
Purpose / VA	NV	Car	2W	Total
HBW	846856	1169541	2364848	4381245
HBE	426652	641530	1416558	2484740
HBO	265463	456721	863107	1585291
HBB	149328	151945	320627	621900
Total	1659299	2419737	4994140	9073176

3.2.1.4.4 Attraction Model

The Generation model produces daily person trips generated by zone, whilst the attraction model estimates daily person trips attracted by zone (by purpose and vehicle availability). For each of the 12 groups (4 purposes x 3 VA), a linear regression was estimated, explaining the number of trips attracted by the socio-economic data, total employment for HBW, HBB, and HBO, and school enrolment for HBE. Figure 3.5 presents for instance the linear regression of HBW - no vehicle available group: with a R-square value equal to 0.78, it shows a good match between the data from HIS and the estimated values from the linear regression (more R2 is near to 1, more the linear regression is reliable). To be consistent with the generation model, the attraction model is based on PA. The Attraction model calibration is summarised in Table 3.5, by purpose and vehicle availability: HIS and model figures are very similar, showing a very close correspondence between modelled and observed.

Figure 3.5 Attraction Model (HBW-NV Linear Regression)

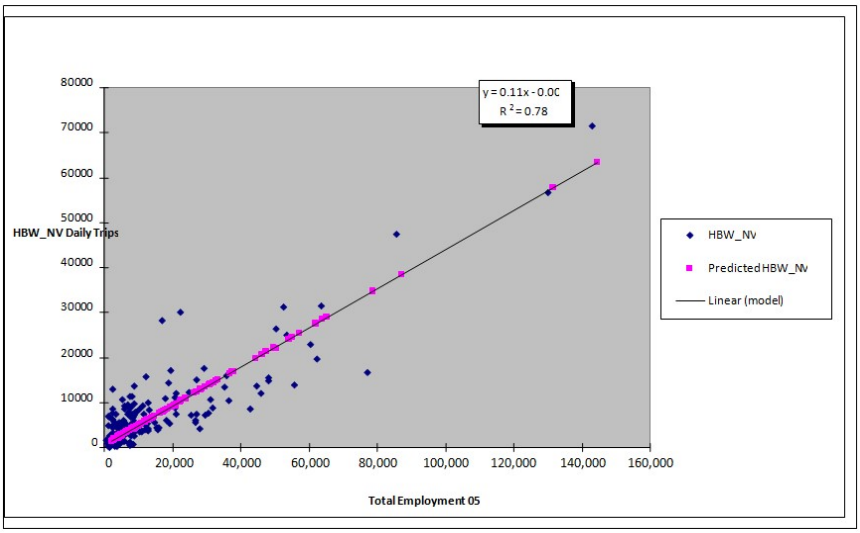


Table 3.5 Attraction Model Calibration Results			
Group	**HIS**	**Model**	**Difference**
HBW_NV	846856	848337	0.17%
HBW_Car	1169541	1165757	0.32%
HBW_2w	2364848	2367997	0.13%
HBE_NV	426652	426196	0.11%
HBE_Car	641530	640396	0.18%
HBE_2w	1416558	1418705	0.15%
HBB_NV	265463	264687	0.29%
HBB_Car	456721	457686	0.21%
HBB_2w	863107	862900	0.02%
HBO_NV	149329	149657	0.22%
HBO_Car	151944	151801	0.09%
HBO_2w	320627	320997	0.12%
TOTAL	9073176	9075116	0.02%

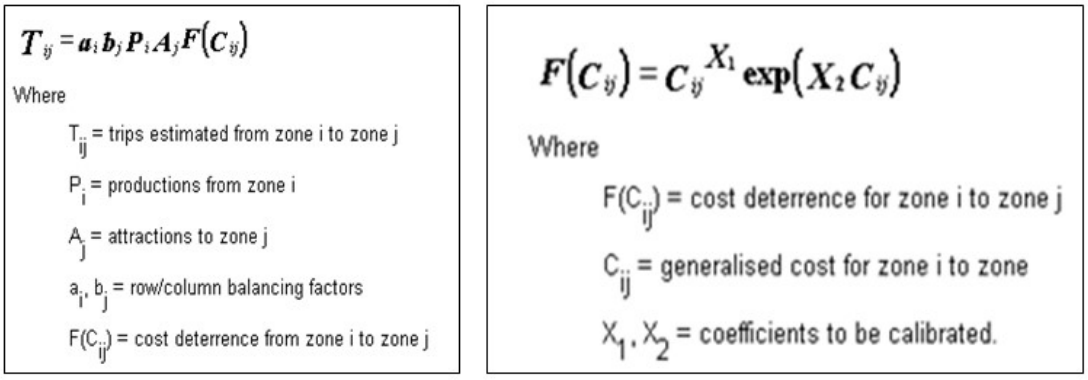
3.2.1.5 Distribution Models

3.2.1.5.1 Models were developed based on the HIS database

The models were developed based on the HIS database and the Generalized Costs (GC) produced from the highway and Public Transport cost models implemented in Cube Voyager. The main features of the models are as follows:

- 12 segments: 4 purposes (Home Base Work, Home Based Education, Home Based Business, and Home Based Other) x 3 vehicle availability groups (No Vehicle, car available, and two wheelers available);
- Unit: Person (Productions / Attractions – PA);
- Period: Daily;
- Model formulation: gravity model, based on composite GC presents in Figure 3.6

Figure 3.6 Gravity Model Formulation



- The composite GC is the average of the GC for individual modes weighted by modal split proportions (produced by modal split models) by Origin / Destination movements;
- For individual modes, the GC represents perceived costs, where the unit is minute equivalent, implying the use of Values of Time (VOT, 2007 prices, Rupees / hour) by mode to convert monetary costs (fare, Vehicle Operating Cost - VOC, and toll) into minutes. Occupancy factors (OCC) are also used for Car+Taxi, 2W, and Auto to obtain person based GC. Hereafter are described the GC by mode, IVT means In Vehicle Time;
- Car+Taxi GC = Time + [((VOC + Toll) / OCC) / VOT] x 60;
- 2W GC = Time + [((VOC + Toll) / OCC) / VOT] x 60;
- Auto GC = Time + 1.5 x Wait Time (4') + [(Fare / OCC) / VOT] x 60;
- PT GC = IVT + 1.5 x Walk Time + 2 x Wait Time + (Fare / VOT) x 60 + Transfer Time (Penalty of 5', apart for transfer from / to metro: 0.5');
- Table 3.6 summarises the model values of VOT, VOC, and OCC for use in the base year model calibration;

Table 3.6 Base Year Values of Time, Vehicle Operating Costs and Vehicle Occupancy Rates

Mode	VOT (Rs/hour)	VOC (Rs/km)	OCC
Car+Taxi	89	8.0	2.3
2W	54	3.0	1.2
Auto	43	-	2.4
PT	35	-	-

3.2.1.5.2 Calibration results

This section provides the distribution models calibration results by market segment: X1 and X2 parameters, intrazonal trips, average GC (in minutes), and trip GC distribution. As illustrated by Table 3.7, the overall models results are similar to the HIS database.

Table 3.7 Distribution Models Calibration Results

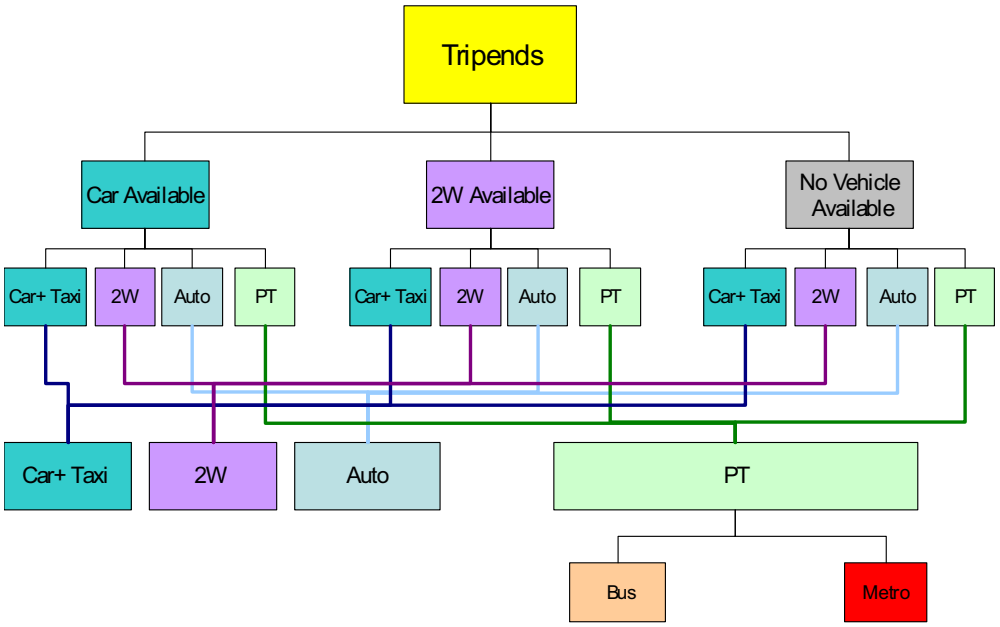
		HIS		Model	Difference
Segments	Trips	X1	X2	Trips	Trips
HBW NV	846856	-0.84316	-0.02398	844671	0.26%
HBW Car	1169541	-1.00283	-0.02232	1169116	0.04%
HBW 2W	2364848	-1.23621	-0.03486	2369203	0.18%
HBB NV	426652	-1.11578	-0.01350	425413	0.29%
HBB Car	641530	-2.47170	0.02378	641664	0.02%
HBB 2W	1416558	-1.87393	-0.01319	1419231	0.19%
HBE NV	265463	-0.69755	-0.02773	264667	0.30%
HBE Car	456721	-0.04748	-0.12299	457436	0.16%
HBE 2W	863107	-1.13519	-0.07329	864622	0.18%
HBO NV	149329	-0.30219	-0.03490	148815	0.34%
HBO Car	151944	-1.89740	-0.03161	152282	0.22%
HBO 2W	320627	-0.60915	-0.09566	321201	0.18%

3.2.1.6 Modal split models

The models were developed based on the HIS database and the Generalised Costs (GC) produced from the highway and Public Transport cost models implemented in Cube Voyager.

Figure 3.7 illustrates the modal split models structure: trips are split into the four modes (Car+Taxi, 2W, Auto, and PT) by vehicle availability group (Car, 2W, and NV), then added by mode, PT trips being separated between bus and metro services during the assignment stage. It should be noted that the PT matrix produced by the modal split models contains trips using school, chartered, and public buses, but only the last two categories are retained for the PT assignment, the other two groups (school and chartered buses) not using the public network. However, these are taken into account in the highway assignment.

Figure 3.7 Modal Split Models Structure



The main features of the modal split models are as follows:

- 12 segments: 4 purposes (Home Base Work, Home Based Education, Home Based Business, and Home Based Other) x 3 vehicle availability groups (No Vehicle, car available, and two wheelers available);
- modes: Car+Taxi, two wheelers, auto-rickshaw, and PT;
- Unit: person (Productions / Attractions – PA);
- Period: daily;
- Model formulation: combined split, multi-logit formulas (equations provided in Figure 3.8, where P means Probability and C is the Generalised Cost);

Figure 3.8 Multi-Logit Formulas (Combined Split)

$$P_{Car+taxi} = \frac{e^{(-\lambda C_{Car+taxi})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

$$P_{2W} = \frac{e^{(-\lambda C_{2W})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

$$P_{Auto} = \frac{e^{(-\lambda C_{Auto})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

$$P_{PT} = \frac{e^{(-\lambda C_{PT})}}{e^{(-\lambda C_{Car+taxi})} + e^{(-\lambda C_{2W})} + e^{(-\lambda C_{Auto})} + e^{(-\lambda C_{PT})}}$$

- Logit parameters estimation: the mode choice sensitivity revealed by the model is mainly determined by the parameter . This model parameter was developed based on statistical regression analysis, which also provided some initial estimates on the mode biases. As shown by Figure 3.17 for illustrative purpose only (example with two modes, car and PT),
- when λ increases, the model becomes more responsive to the difference in cost.
- The GC represents perceived costs, where the unit is minute equivalent, implying the use of Values of Time (VOT, Rupees / hour) by mode to convert monetary costs (fare, Vehicle Operating Cost - VOC, parking cost at destination, and toll) into minutes. Occupancy factors (OCC) are also used for Car+Taxi, 2W, and Auto to obtain person based GC. Below are described the GC by mode, IVT means In Vehicle Time:

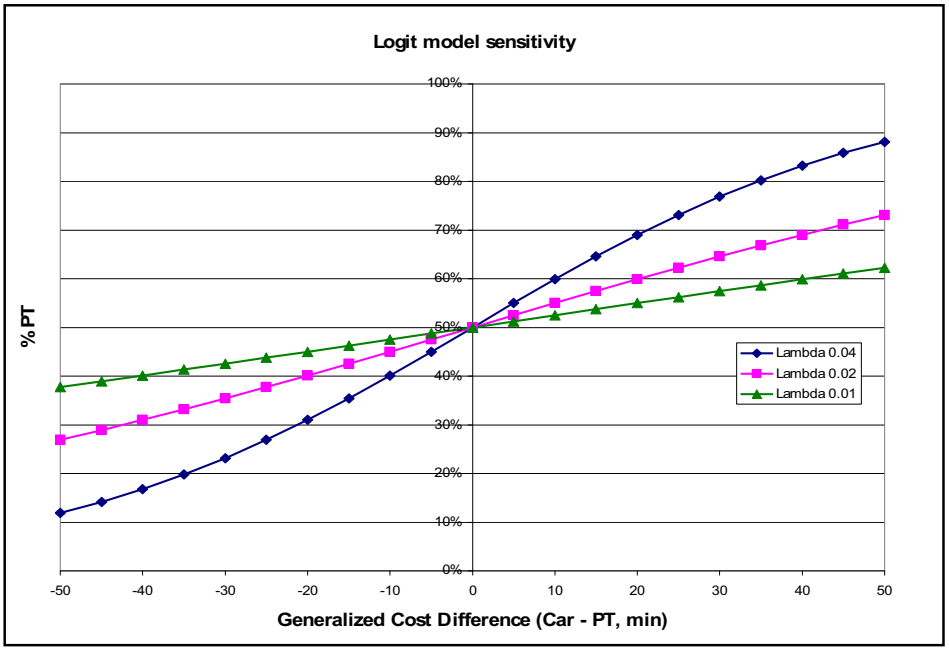
  Car+Taxi GC = Time + [((VOC + Toll + Parking Cost) / OCC) / VOT] x 60;

  2W GC = Time + [((VOC + Toll + Parking Cost) / OCC) / VOT] x 60;

  Auto GC = Time + 1.5 x Wait Time (4) + [(Fare / OCC) / VOT] x 60;

- PT GC = IVT + 1.5 x Walk Time + 2 x Wait Time + (Fare / VOT) x 60 + Transfer Time (Penalty of 5', apart for transfer from / to metro: 0.5').

Figure 3.9 Logit Model Sensitivity



Calibration Results

Tables 3.8 and 3.9 demonstrate that there is close correspondence between the synthesised and observed values from the HIS. Some specific comments can be made:

- In theory, for any multi-logit model with four possible choices, there are a maximum of three bias factors available;
- The Lambda parameters trends are sensible, lower for car and higher for NV, meaning less sensitivity to cost for car

Table 3.8 Calibrated Modal Choice Models Parameters

Segments	Lambda	Bias mode 1	Bias mode 2	Bias mode 3
HBW-NV	-0.008741	0.1630	0.1693	-0.5809
HBW-Car	-0.001107	0.8475	-1.0222	-0.6722
HBW-2W	-0.001001	-1.4256	-1.4354	-1.0109
HBE-NV	-0.019270	0.6813	0.6175	-0.0095
HBE-Car	-0.004949	0.9209	0.7873	0.7366
HBE-2W	-0.001891	0.8673	0.8412	0.5527
HBB-NV	-0.048537	-0.4106	-0.3348	-0.0662
HBB-Car	-0.022885	0.9182	-0.9870	-0.6417
HBB-2W	-0.003314	-1.8066	-1.1945	-1.0382
HBO-NV	-0.006025	2.1653	0.2985	0.1798
HBO-Car	-0.003072	0.7893	0.6357	0.9862
HBO-2W	-0.003737	0.2715	0.6260	0.6132

Table 3.9 Modal Split Models Calibration Results

Modes	HIS	Model	Difference
Car+Taxi	898827	903255	0.49%
2W	3353560	3343895	0.29%
Auto	826930	828330	0.17%
PT	3993859	4002845	0.22%
Total	9073176	9078325	0.06%

3.2.1.7 Model Validation

3.2.1.7.1 Introduction

This section describes the model validation results, which is the last step in the model development. Model validation is done for daily model. All the models built are linked together through the output files and therefore the model validation only uses synthetic data, all produced by the model itself.

The model validation has no impact on the vehicle availability, generation, and attraction models results, therefore they are the same as the ones presented earlier.

The model validation actually consists of a slight adjustment of the model calibration data to match the observed figures:

- For distribution and modal choice, some biases were added to the costs;
- For the PT assignment, transfer time was adjusted to 7.5 minutes (apart for transfer from / to metro, 1.5 minutes), in order to replicate observed metro trips and boardings.

These calibration adjustments will remain as part of the model for future years and scenario application. It should also be noted that the model validation results come from an iterative run of the model in order to ensure the convergence of the results and the consistency with the model runs for future years.

3.2.1.7.2 Distribution models

Table 3.10 illustrate the distribution models validation results by segment: X1 and X2 parameters, and trip distribution. Models results are generally close to the HIS database.

Table 3.10 Distribution Models Validation Results

		HIS		Model	Difference
Segments	Trips	X1	X2	Trips	Trips
HBW NV	846856	-0.84316	-0.02398	844671	0.26%
HBW Car	1169541	-1.00283	-0.02232	1169116	0.04%
HBW 2W	2364848	-1.23621	-0.03486	2369203	0.18%
HBB NV	426652	-1.11578	-0.01350	425413	0.29%
HBB Car	641530	-2.47170	0.02378	641664	0.02%
HBB 2W	1416558	-1.87393	-0.01319	1419231	0.19%
HBE NV	265463	-0.69755	-0.02773	264667	0.30%

Table 3.10 Distribution Models Validation Results					
		HIS		Model	Difference
Segments	Trips	X1	X2	Trips	Trips
HBE Car	456721	-0.04748	-0.12299	457436	0.16%
HBE 2W	863107	-1.13519	-0.07329	864622	0.18%
HBO NV	149329	-0.30219	-0.03490	148815	0.34%
HBO Car	151944	-1.89740	-0.03161	152282	0.22%
HBO 2W	320627	-0.60915	-0.09566	321201	0.18%

3.2.1.8 Modal Split Models

This section provides the modal split models validation results, based on a slight update of the costs compared to the model calibration. Similar to the distribution models, modal split percentages from the models are very close to the HIS database as shown in Table 3.11

Table 3.11 Modal Split Models Validation Results			
Modes	HIS	Model	Difference
Car+Taxi	9.91%	9.95%	0.04%
2W	36.96%	36.83%	0.13%
Auto	9.11%	9.12%	0.01%
PT	44.02%	44.09%	0.07%
Total	100.00%	100.00%	0.00%

3.2.1.9 Future Growth Scenario

Master Plan for Bangalore gives the likely growth to take place within the various areas of study area. The Master plan also gives locations of various land uses such as residential, commercial, industrial uses etc. The study area is estimated to have population of about 100.4 Lakh in 2015, 119.9 Lakh in 2021, 159.5 Lakh in 2031 and 192.1 Lakh by 2041. The employment in this area, which is 51.5 Lakh in 2015, is expected to grow to about 84.52 Lakh in 2041. Similarly, student enrolment is expected to grow from 26.4 Lakh to 42.3 Lakh in 2041. Traffic zone wise distribution of population, employment and student enrolment in 2015, 2021, 2031 and 2041.

The proposed growth of population and economy is expected to generate high travel demand. An integrated landuse transportation model has been built to enable estimation of future travel demand. The development of travel demand model has been discussed in detail in Chapter 5. As per travel demand modeling exercise, daily intra travel demand is expected to grow from 90 lakh person trips in year 2015 to 176 lakh in year 2041. The present chapter examines some transport scenarios to meet the travel demand and recommends the best scenario for Bangalore metro.

3.2.1.10 Assumptions for Transport Demand Forecasting

The following assumptions have been made for forecasting transport demand for the years 2021, 2031 and 2041.

(i) Calibrated and validated travel demand model has been used
(ii) Land use parameters (population, employment and student enrolment) have been distributed in various traffic zones for 2021, 2031 and 2041.
(iii) The fare levels of metro have been considered same as that of the existing Delhi Metro network.
(iv) Inter-city passenger to / from the study area will grow at the growth rate of 3%.
(v) The special generator passenger traffic of airport and railway stations in Bangalore is expected to grow at 4% per annum.
(vi) Inter-city goods traffic is expected to grow at 3% per annum up to 2041.
(vii) Intra-city goods traffic is expected to grow at 2% per annum up to 2041.

3.2.1.11 Transport Demand Forecast For Phase I & Ii Corridors Of Bangalore Metro 2021 & 2041-Business As Usual Scenario

Considering the above assumptions and calibrated / validated traffic demand model, forecasting of transport demand has been carried out for metro network with phase I and phase II network scenario only in the year 2041. The Bangalore Metro Phase I & II corridor is assumed as given metro network corridor for this scenario. Overall modal split intra trips for various modes in this scenario for the years 2015, 2021 and 2041 is given in Table 3.12. The modal split (% of trips by public transport to total motorised trips) in favour of public transport in 2041 is expected to be 48.9% which is less than the 2021 level of 49.5%. It indicates that in spite of phase I & II metro corridor, expansion of high capacity mass transport network will need to be done.

Table 3.12 Daily Trips (Intra-city) by Various Modes in Phase I & II Corridors of Bangalore Metro

SN	Mode	2015(Household)		2021 Phase I & II		2041 Phase I & II	
		Trips	Modal Share	Trips	Modal Share	Trips	Modal Share
1	Car	898827	9.9	771140	7.0	1175418	6.7
2	Two Wheeler	3353560	37.0	3809052	34.5	6167349	35.0

3	Auto	826930	9.1	986648	8.9	1673696	9.5
4	PT	3993689	44.0	5465250	49.5	8625342	48.9
	Total	9073006	100.0	11032090	100.0	17641804	100.0

The traffic assignment in 2041 on road network in this scenario for public transport and other vehicles are given in Figures 3.10 and 3.11 respectively. These figures show that many roads will still be overloaded beyond their capacity. Therefore mass transport system such as metro will be required on many corridors to cater to future transport demand.

Figure 3.10 Expected Peak Hour PT Passengers on Road Network in 2041 with Phase I & II Scenario

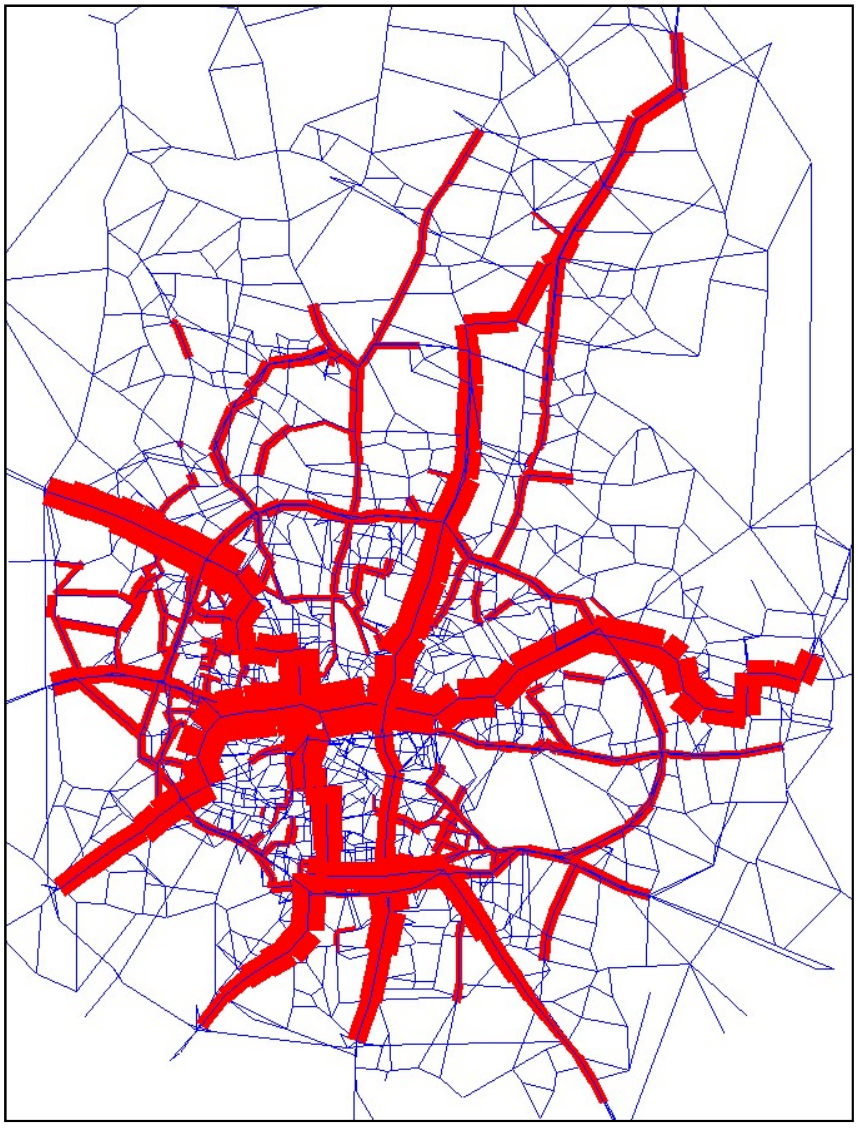
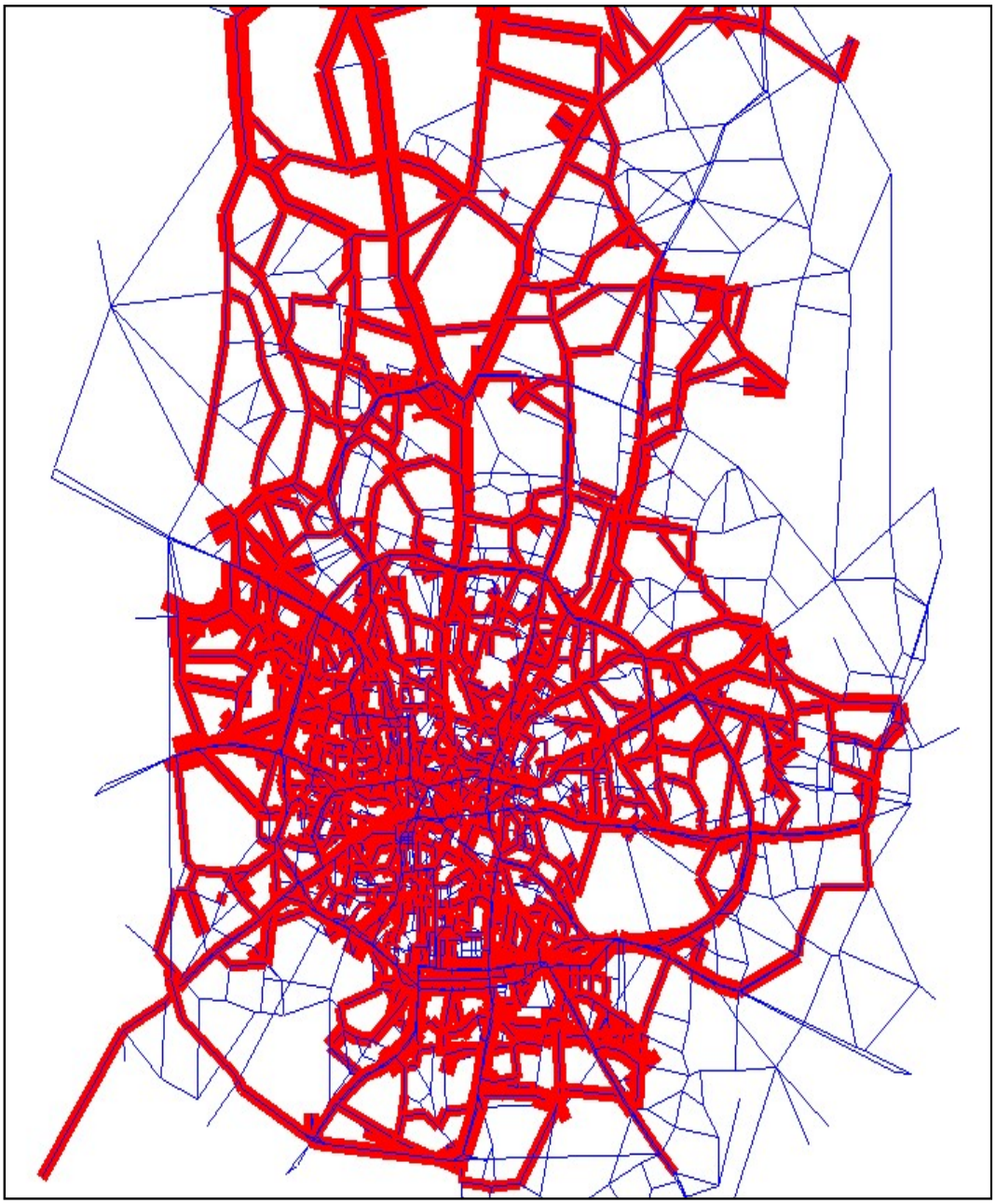


Figure 3.11 Expected Peak Hour traffic Volume (other than PT) on Road Network in 2041 with Phase I & II Scenario



3.2.1.12 ESTIMATION OF RIDERSHIP FOR PROPOSED NEW LINE:

The travel model generated by M/s RITES has made use of 215 traffic ones. These traffic zones were generally the wards of BBMP (Brarhut Bangalore Mahangar Palike). This metro line did not figure as a specific zone in the model. Therefore the wards (traffic zones) which were falling on this corridor were taken to project the population and employment figures. Furthermore, the employment figures

were suitably adjusted to reflect the high concentration of Software Technology Parks in this area. With these corrections, the model was run and the ridership figures have been estimated for the years 2021, 2031, 2041 and is given in Table 13.14. As the entire analysis in the present DPR starts from the year 2020, the Ridership i.e. no of passenger trips per day for the year 2020 has been taken as 3.1 lakhs.

Table 3.13 Employment Along Silk Board Outer Ring Road (ORR)

SN	Traffic Zone Name	Traffic zone	2015	2021	2031	2041
1	Devasandra	55	19796	27808	33400.5	39035.5
2	A Narayapura	56	34018	42714	46250.75	50730.75
3	Vijayanagar	81	27818	37924	42544.25	46131.75
4	Garudachala palya	82	63156	91948	138834.5	184996
5	Dodda Nekkundi	85	75510	106684	158067	207252.5
6	Marathahalli	86	115634	128678	127867.25	139116.25
7	Bellanduru	150	72162	102156	158679.5	217679
8	HSR Layout	174	82154	97320	112994	134457.75
9	Jakkasandra	173	20446	30384	37334.5	44691.5
	Total		510,694.00	665,616.00	855,972.25	1,064,091.00

3.2.1.13 Boarding Alighting

The boarding alighting of peak hour for 2031 and 2041 is given in table below:

The total boarding and alighting for 2031 is 458569 and 458569 respectively and for 2041 boarding and alighting during peak hour is 574745 and 574746 respectively. Thus estimated ridership in this section will be about 5 lakhs trips during peak hours by 2031.

Table 3.14 Corridor - K R Puram to Silk Board along ORR

Station Name	Daily Board 2021		Peak Board 2021		Daily Board 2031		Peak Board 2031		Daily Board 2041		Peak Board 2041	
	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight
K R Puram	31,016	30,916	8,317	8,256	35,237	34,834	9,189	9,405	40,973	40,481	10,789	10,648
Mahadevapura	13,068	13,199	3,625	3,573	15,479	15,808	4,903	4,837	17,352	17,930	5,422	5,417
DRDO Sports Complex	33,379	33,370	8,793	7,413	41,895	41,867	11,188	9,489	47,116	47,102	12,381	10,450
Doddanekundi	9,974	10,011	2,609	2,608	12,981	13,011	3,228	3,222	15,578	15,615	3,845	3,819
ISRO	24,259	24,366	4,831	6,039	32,180	32,298	6,886	8,452	38,155	38,287	8,598	10,402
Marathahalli	12,357	12,833	4,688	4,473	13,753	14,328	5,376	4,868	15,405	15,967	5,831	5,624
Kodibisanahalli	38,871	38,815	13,347	13,777	40,403	40,345	14,049	14,245	45,761	45,703	16,231	16,323
Kadubeesanahalli	21,261	21,261	3,872	4,405	36,374	36,374	6,421	7,083	51,577	51,577	8,802	9,603
Bellandur	42,024	42,010	13,526	13,799	66,483	66,464	20,123	20,538	94,108	94,083	27,918	28,450
Ibbalur	3,242	3,239	752	377	3,563	3,552	819	497	4,040	4,005	926	629
Agara Lake	2,250	2,404	837	829	2,797	2,957	1,011	996	3,299	3,438	1,140	1,131
HRS Layout	56,951	57,026	18,391	16,398	73,178	72,783	22,892	20,224	90,842	90,069	26,335	24,807
Slik Board	63,161	62,363	20,417	22,054	84,245	83,947	26,872	29,101	1,10,540	1,10,490	35,311	36,226
Total	3,51,813	3,51,813			4,58,569	4,58,569			5,74,745	5,74,746		

3.2.1.14 PHPDT:

Maximum PHPDT for the above section is 36226. The table below 3.15 shows the peak hour peak direction trip for above section.

Table 3.26 PHPDT Demand and Capacity Chart

Table 3.15 PHPDT Demand and Capacity Chart

From	To	Dir 1	Dir 2	PDPDT 2021	Dir 1	Dir 2	PDPDT 2031	Dir 1	Dir 2	PDPDT 2041
K R Puram	Mahadevapura	8317	8256	22054	9189	9405	29101	10789	10648	36226
Mahadevapura	DRDO Sports Complex	11078	10965		12744	12893		14494	14347	
DRDO Sports Complex	Doddanekundi	11625	10132		13045	11495		14959	12882	
Doddanekundi	ISRO	11371	9878		12488	10933		14209	12107	
ISRO	Marathahalli	11124	10838		12818	12828		15337	15038	
Marathahalli	Kodibisanhalli	10918	10418		12510	12013		14534	14029	
Kodibisanhalli	Kadubeesanahalli	11323	11254		15093	14791		19397	18984	
Kadubeesanahalli	Bellandur	10339	10803		14403	14764		19155	19542	
Bellandur	Ibbalur	12524	13261		17541	18316		23476	24396	
Ibbalur	Agara Lake	12343	12706		17350	17804		23294	23916	
Agara Lake	HSR Layout	19528	18648		25298	24169		32597	31413	
HSR Layout	Silk Board	22054	20417		29101	26872		36226	35311	

3.2.2 Estimation Of Ridership Through Assessment Of Built Up Areas.

M/s Colliers International has estimated the metro ridership over the next 30 years based on the current occupied and future estimated commercial stock in the influence zone of the ORR – Metro corridor. The current commercial stock estimated is around 55 Million Sq.Ft. and based upon current under construction projects, vacant land parcels available for commercial development and historical influx of commercial space in this corridor, new addition to the commercial office stock has also been estimated.

Using historical data, the total annual off take of space in this region has been computed and assumed. The result is the total occupied commercial office stock in this region for each year, projected for the next 30 years. Using an industry prevalent standard of 100 Sq.Ft per employee, the total number of employees working in the corridor over the next 30 years has been computed. Using empirical data, it is assumed that around the same number of people as those working in the commercial spaces (visitors, dependents, indirect employees, business owners etc) will be present on a daily basis in the influence zone of the ORR Metro corridor. Public transport in India usage depends heavily upon the secondary category of the people working in the influence area. Professionals with higher salaries generally prefer to use their own cars/ means of transport and employees in the lower salary brackets find it convenient and economically viable to use the public transport systems like a metro. Using prevalent salary data of IT companies in India, salary pyramid of professionals working in this region has been constructed.

Based upon estimates, following would be categories in income split.

- 2% of the employees have an annual salary of 50 Lacs Plus (Assumption: none of the people falling in this category would be regular users of the Metro)
- 3% of employees have an annual salary of 30 to 50 Lacs (Assumption: 5% of the people falling in this category would be regular users of the Metro)
- 15% of employees have an annual salary of 18 to 30 lacs (Assumption: 15% of the people falling in this category would be regular users of the Metro)
- 20% of employees have an annual salary of 10 to 18 lacs (Assumption: 20% of the people falling in this category would be regular users of the Metro)
- 60% of employees have an annual salary of 6 to 10 lacs (Assumption: 25% of the people falling in this category would be regular users of the Metro)

It has been assumed that around 15% of the total visitors and 30% of the people indirectly employed in this region would be regular users of the metro corridor.

Using the above estimate, the daily total number of users for the metro has been computed. It is estimated that in 2020 about 3 Lakh people would be using the metro thereby culminating a 6 lakh trips on the corridor per day.

Refer the Table 3.16 for the estimate. Thus there would be 3.0 Lakh passengers who would depend upon Metro. Thus the average number of passenger trips (Ridership) will be in the range of 6.0 Lakhs.

Table 3.16 Estimation Of Ridership Through Assessment Of Built Up Areas							
KR Puram to Silk Board Junction	1	5	10	15	20	25	30
Parameter	2016	2020	2025	2030	2035	2040	2045
Total Stock	41200000	61100000	71100000	79850000	88600000	97350000	106100000
Occupied stock	39140000	57434000	67545000	75857500	84170000	92482500	100795000
New Addition	1600000	2000000	1750000	1750000	1750000	1750000	1750000
Total Number of employees	391400	574340	675450	758575	841700	924825	1007950
Visitors + dependants	156560	229736	270180	303430	336680	369930	403180
Indirect employment	234840	344604	405270	455145	505020	554895	604770
Tier I	2%	2%	2%	2%	2%	2%	2%
Tier II	3%	3%	3%	3%	3%	3%	3%
Tier III	15%	15%	15%	15%	15%	15%	15%
Tier IV	20%	20%	20%	20%	20%	20%	20%
Tier V	60%	60%	60%	60%	60%	60%	60%
Estimated metro ridership (Direct)							
Tier I	0%	0%	5%	5%	5%	5%	5%
Tier II	5%	5%	10%	10%	10%	10%	10%
Tier III	15%	15%	20%	20%	20%	20%	20%
Tier IV	20%	30%	50%	50%	50%	50%	50%
Tier V	25%	30%	60%	70%	70%	70%	70%
Visitors + dependants	15%	20%	30%	35%	40%	40%	40%
Indirect employment	30%	30%	35%	40%	40%	40%	40%
TOTAL DIRECT METRO RIDERSHIP (Users)	83,760	151,626	333,672	420,251	466,302	512,353	558,404
DEMAND FROM VISITORS (Users)	23,484	45,947	81,054	106,201	134,672	147,972	161,272
DEMAND FROM INDIRECT (Users)	70,452	103,381	141,845	182,058	202,008	221,958	241,908
TOTAL DEMAND (Users)	177,696	300,954	556,571	708,509	802,982	882,283	961,584

3.2.3 Estimation of ridership by extrapolating the ridership on the east-west corridor which is currently operational.

The East – West Corridor of 18.1 Kms is fully operational from May-2016 and the average daily ridership achieved is 1.20 lakhs without an interchange with North – South Line. With the commissioning of North - South line in the year 2017 and an interchange at Kempegowda Station,the average daily ridership on East –West line alone will contribute to about 2.40 lakhs ridership per day. With an increase of 3% in ridership year on year, the ridership of East –West line of 18.1 Kms will be 2.62 lakhs per day for the year 2020.

The ORR line having a length of 17 km and having two interchanges with the Phase-II lines at KR Puram and the Central Silk Board Junction, the ridership of East- West line ridership of 2.62 lakhs per day for the year 2020 can be used as a base for the line. Extrapolating this figures, the ridership for this line in the year 2020 will definitively exceed 3.0 Lakhs.

On the East – West Corridor of Phase -1 of length of 18.1 Kms with 17 stations the average trip length presently being achieved is 7.8 Kms.The new line between K R Puram and Central Silk Board Junction (CSBJ) having a length of 18 Kms with 13 Stations, the Average Trip Length (ATL) which can be achieved is 9.00 Kms.

3.3 CONCLUSION:

The figures arrived by adopting different methodologies differ from one another. The travel demand modeling forecast a ridership of 351813 per day in 2021 as per Travel demand model. The estimation of ridership through assessment of built up areas comes to 310000per day in 2020 and the estimation of ridership by extrapolating the ridership on the East-West Corridor, the ridership for this line comes to 310000per day.

Based on the above projections, the ridership per day for the year 2020 can be taken as 310000per day. The breakup of this ridership on hourly basis is given in Table 3.17

Table 3.17 Ridership on Hourly Basis in the year 2020

6 Hrs	1048	15 Hrs	7860
7 Hrs	1572	16 Hrs	10480
8 Hrs	5240	17 Hrs	15720
9 Hrs	20960	18 Hrs	20960
10 Hrs	36680	19 Hrs	31140
11 Hrs	26200	20 Hrs	26200
12 Hrs	13100	21 Hrs	13100
13 Hrs	10480	22 Hrs	7860
14 Hrs	7860	23 Hrs	5240

4 CIVIL ENGINEERING WORKS

4.1 LINK LINE FROM SILK BOARD – KR PURAM

4.1.1 Description of Alignment

Silk Board and KR Puram stations are planned station in phase 2 of BMRCL. It is now planned to connect them and convert above stations as interchange stations. The proposed line from Silk board to KR Puram will run along Outer Ring Road and will be an elevated standard gauge corridor with double line section having a route length of 17.0 km (up to KR Puram) 11 stations are planned in the route apart from KR Puram and silk board existing stations. Provision has been kept for extending the line towards Hebbal.

- KR Puram station at the east end of E – W corridor of Ph - II is located on the Outer Ring Road as an elevated Station. This will be connected as an interchange station for the proposed route link.
- Silk board station is proposed station is in Reach-5 of RV road to Bommasandra section of phase 2. This proposed link will connect silk board station as an interchange station.
- Silk board to KR Puram line is planned along Outer Ring Road median and passes through a route in congested areas such as silk board and KR Puram. It will connect major IT industries and residential areas.
- This alignment will be served by existing Byappanahalli depot.
- Provision has been kept for extending the line in future towards Hebbal via ORR.

4.1.2 Reference point

The centre line of Silk board Metro station has been taken as 0.00 km for reckoning of chainage on ORR – KR Puram line. Chainage increases from Silk Board Metro station towards KR Puram Metro station.

4.1.3 Reference line

Line from Silk board station to KR Puram station has been named ‘Up Line’ and from KR Puram Terminal to Silk Board station has been named as ‘Down Line’.

4.1.4 Index Plan

Index Plan of the alignment from the Centre line of Silk board Metro station to end of KR Puram Terminal Metro station is given in Figure 4.1.

4.1.5 Alignment Planning and Design Norms

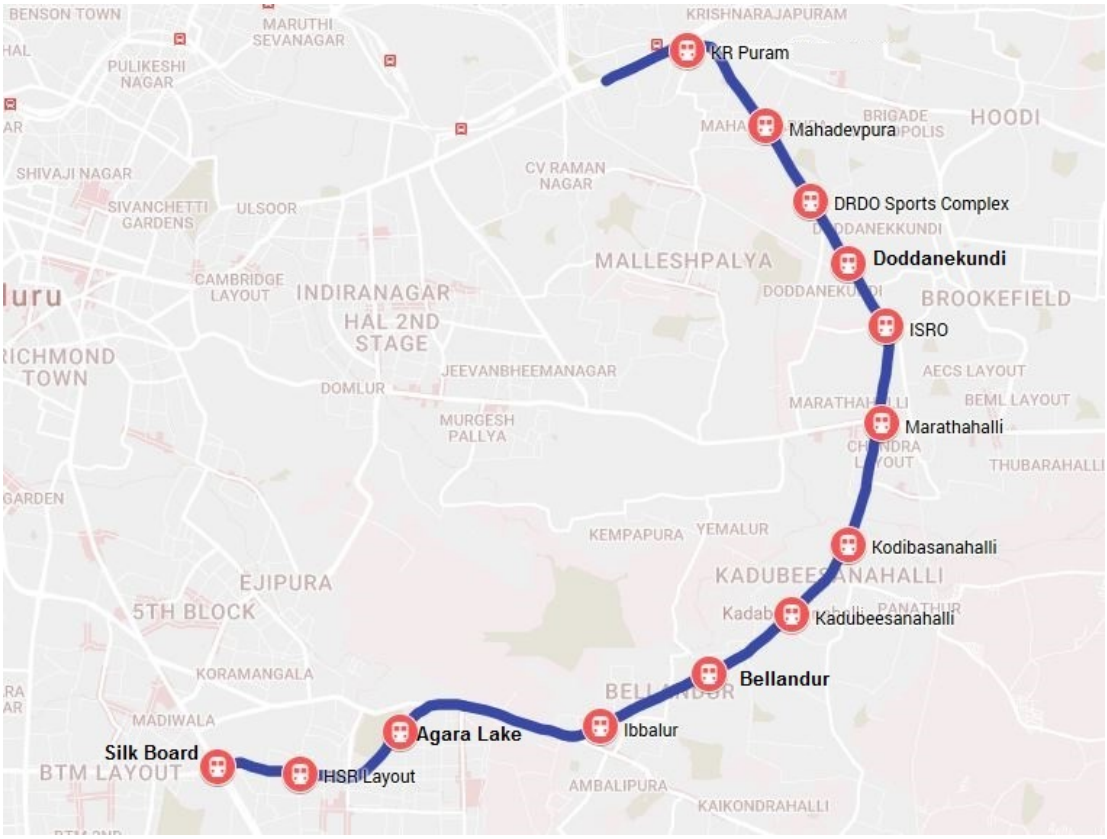
The entire alignment of this extension line is planned to be elevated. As the work on the elevated stretches of Phase-I of the project have already been completed and phase 2 works are in progress, the planning norms & design parameters viz., horizontal curves, vertical alignment, design speed,

track centre etc as finalized for phase-I and Phase-II, the same will be used for Silk board – KR Puram metro line. Section of Viaduct shown in Figure 4.2:

4.1.6 Terminal Station

1. KR Puram: It is proposed to plan elevated terminal station at KR Puram near the KR Puram hanging bridge as the interchange station on this corridor so as to facilitate the transit towards Silk board, Hebbal and towards Whitfield. At this station, the train interchange facilities are being proposed. The C/L of the KR Puram terminal station is at chainage 17.0 km whereas the Byappanahalli depot is at chainage 19.50 km.
2. Silk board: Silk board is planned as elevated station on Reach-5 metro line from RV road to Bommasandra and Silk board station is now proposed to be connected to interchange station which will allow commuters travelling from Electronic City and towards RV Road and KR Puram.

Figure 4.1 Silk board to KR Puram Metro Line



4.1.7 Horizontal Alignment

The line extending from the silk board station will generally follow median of the Outer Ring Road to KR Puram. Eleven stations are planned on Silk board – KR Puram line namely Silk board Jn. [Ch.(-) 0000.000], HSR Layout [Ch.(-) 1385.949], Agara Lake [Ch.(-)2630.425], Ibbalur [Ch.(-) 5485.695],

Bellandur [Ch.(-) 7142.716], Kadubeesanahalli [(-) 8567.283], Kodibisanahalli [(-) 9881.544], Marathahalli [(-) 10942.640], ISRO [(-) 12656.544], Doddanekundi [(-) 13437.806], DRDO Sports Complex [(-) 14393.523], Mahadevpura [(-) 15837.157], KR Puram [(-) 17000.000]. Schematic Plan of the alignment is enclosed.

4.1.8 Vertical Alignment

Track supporting structures on elevated sections are to permit a vertical clearance of 5.50m above road level for vehicular traffic. For meeting this requirement the rail level is planned to be least 8.50 m above the road level. Similarly, the rail level for the stations is kept as 9.8 m as it is single level station an d concourse level is eliminated. There is footbridge under the viaduct for cross platform interchange.

The minimum radius of Vertical curve is kept as 2000 Radius as per approved SOD, and track centers are kept at 4.20 m

4.1.9 Curves

33 numbers of horizontal curves have been proposed from silk board to KR Puram. The radius of curves varies from 200 m to 3000 m. The sharpest curve is 200 m. A statement of curves is given at Table 4.1.

Table 4.1 Statement of Curves

No.	Length	Radius	Start Station	End Station	Delta angle	Degree of Curvature by Arc
1	25.000m		0+249.85m	0+274.85m	3.5810 (d)	
	21.630m	200.000m	0+274.85m	0+296.48m	6.1965 (d)	8.5944 (d)
	25.000m		0+296.48m	0+321.48m	3.5810 (d)	
2	20.000m		0+357.54m	0+377.54m	2.8648 (d)	
	2.122m	200.000m	0+377.54m	0+379.66m	0.6079 (d)	8.5944 (d)
	20.000m		0+379.66m	0+399.66m	2.8648 (d)	
3	30.000m		0+455.64m	0+485.64m	2.4555 (d)	
	133.515m	350.000m	0+485.64m	0+619.16m	21.8567 (d)	4.9111 (d)
	30.000m		0+619.16m	0+649.16m	2.4555 (d)	
4	25.000m		0+874.66m	0+899.66m	2.8648 (d)	
	36.037m	250.000m	0+899.66m	0+935.69m	8.2591 (d)	6.8755 (d)
	25.000m		0+935.69m	0+960.69m	2.8648 (d)	
5	35.000m		1+146.98m	1+181.98m	0.5013 (d)	
	68.655m	2000.000m	1+181.98m	1+250.64m	1.9668 (d)	0.8594 (d)
	35.000m		1+250.64m	1+285.64m	0.5013 (d)	
6	30.000m		1+908.94m	1+938.94m	3.4377 (d)	
	84.674m	250.000m	1+938.94m	2+023.62m	19.4059 (d)	6.8755 (d)
	30.000m		2+023.62m	2+053.62m	3.4377 (d)	
7	30.000m		2+102.87m	2+132.87m	3.4377 (d)	
	74.122m	250.000m	2+132.87m	2+206.99m	16.9874 (d)	6.8755 (d)

Table 4.1 Statement of Curves						
No.	**Length**	**Radius**	**Start Station**	**End Station**	**Delta angle**	**Degree of Curvature by Arc**
	30.000m		2+206.99m	2+236.99m	3.4377 (d)	
	35.000m		2+369.93m	2+404.93m	1.4324 (d)	
8	58.630m	700.000m	2+404.93m	2+463.56m	4.7989 (d)	2.4555 (d)
	35.000m		2+463.56m	2+498.56m	1.4324 (d)	
	25.000m		2+927.45m	2+952.45m	3.5810 (d)	
9	8.029m	200.000m	2+952.45m	2+960.48m	2.3002 (d)	8.5944 (d)
	25.000m		2+960.48m	2+985.48m	3.5810 (d)	
	25.000m		3+184.79m	3+209.79m	2.0463 (d)	
10	35.804m	350.000m	3+209.79m	3+245.60m	5.8611 (d)	4.9111 (d)
	25.000m		3+245.60m	3+270.60m	2.0463 (d)	
	25.000m		3+279.02m	3+304.02m	3.5810 (d)	
11	0.525m	200.000m	3+304.02m	3+304.54m	0.1503 (d)	8.5944 (d)
	25.000m		3+304.54m	3+329.54m	3.5810 (d)	
	25.000m		3+396.01m	3+421.01m	3.5810 (d)	
12	5.697m	200.000m	3+421.01m	3+426.71m	1.6320 (d)	8.5944 (d)
	25.000m		3+426.71m	3+451.71m	3.5810 (d)	
	25.000m		3+629.50m	3+654.50m	2.3873 (d)	
13	2.990m	300.000m	3+654.50m	3+657.49m	0.5711 (d)	5.7296 (d)
	25.000m		3+657.49m	3+682.49m	2.3873 (d)	
	25.000m		3+685.17m	3+710.17m	3.5810 (d)	
14	5.922m	200.000m	3+710.17m	3+716.09m	1.6966 (d)	8.5944 (d)
	25.000m		3+716.09m	3+741.09m	3.5810 (d)	
	30.000m		4+170.81m	4+200.81m	0.8594 (d)	
15	124.497m	1000.000m	4+200.81m	4+325.31m	7.1331 (d)	1.7189 (d)
	30.000m		4+325.31m	4+355.31m	0.8594 (d)	
	30.000m		4+643.57m	4+673.57m	0.5730 (d)	
16	107.044m	1500.000m	4+673.57m	4+780.61m	4.0888 (d)	1.1459 (d)
	30.000m		4+780.61m	4+810.61m	0.5730 (d)	
	25.000m		5+159.62m	5+184.62m	2.8648 (d)	
17	148.661m	250.000m	5+184.62m	5+333.28m	34.0706 (d)	6.8755 (d)
	25.000m		5+333.28m	5+358.28m	2.8648 (d)	
	25.000m		5+565.91m	5+590.91m	2.8648 (d)	
18	21.950m	250.000m	5+590.91m	5+612.86m	5.0305 (d)	6.8755 (d)
	25.000m		5+612.86m	5+637.86m	2.8648 (d)	
	25.000m		5+696.75m	5+721.75m	2.8648 (d)	
19	25.514m	250.000m	5+721.75m	5+747.27m	5.8473 (d)	6.8755 (d)
	25.000m		5+747.27m	5+772.27m	2.8648 (d)	
	30.000m		5+990.86m	6+020.86m	0.2865 (d)	
20	35.159m	3000.000m	6+020.86m	6+056.02m	0.6715 (d)	0.5730 (d)
	30.000m		6+056.02m	6+086.02m	0.2865 (d)	

Table 4.1 Statement of Curves						
No.	**Length**	**Radius**	**Start Station**	**End Station**	**Delta angle**	**Degree of Curvature by Arc**
21	30.000m		6+390.61m	6+420.61m	0.4297 (d)	
	37.940m	2000.000m	6+420.61m	6+458.55m	1.0869 (d)	0.8594 (d)
	30.000m		6+458.55m	6+488.55m	0.4297 (d)	
22	30.000m		7+610.56m	7+640.56m	1.1459 (d)	
	189.767m	750.000m	7+640.56m	7+830.32m	14.4972 (d)	2.2918 (d)
	30.000m		7+830.32m	7+860.32m	1.1459 (d)	
23	30.000m		9+045.18m	9+075.18m	1.1459 (d)	
	188.762m	750.000m	9+075.18m	9+263.94m	14.4204 (d)	2.2918 (d)
	30.000m		9+263.94m	9+293.94m	1.1459 (d)	
24	30.000m		9+609.23m	9+639.23m	1.4324 (d)	
	90.847m	600.000m	9+639.23m	9+730.08m	8.6753 (d)	2.8648 (d)
	30.000m		9+730.08m	9+760.08m	1.4324 (d)	
25	30.000m		10+208.74m	10+238.74m	0.8594 (d)	
	125.618m	1000.000m	10+238.74m	10+364.36m	7.1974 (d)	1.7189 (d)
	30.000m		10+364.36m	10+394.36m	0.8594 (d)	
26	30.000m		10+657.41m	10+687.41m	0.4297 (d)	
	115.748m	2000.000m	10+687.41m	10+803.16m	3.3159 (d)	0.8594 (d)
	30.000m		10+803.16m	10+833.16m	0.4297 (d)	
27	30.000m		11+170.67m	11+200.67m	1.4324 (d)	
	147.494m	600.000m	11+200.67m	11+348.16m	14.0846 (d)	2.8648 (d)
	30.000m		11+348.16m	11+378.16m	1.4324 (d)	
28	30.000m		11+461.17m	11+491.17m	0.8594 (d)	
	97.104m	1000.000m	11+491.17m	11+588.28m	5.5636 (d)	1.7189 (d)
	30.000m		11+588.28m	11+618.28m	0.8594 (d)	
29	30.000m		12+233.87m	12+263.87m	2.1486 (d)	
	243.492m	400.000m	12+263.87m	12+507.36m	34.8776 (d)	4.2972 (d)
	30.000m		12+507.36m	12+537.36m	2.1486 (d)	
30	30.000m		15+133.33m	15+163.33m	0.2865 (d)	
	15.853m	3000.000m	15+163.33m	15+179.19m	0.3028 (d)	0.5730 (d)
	30.000m		15+179.19m	15+209.19m	0.2865 (d)	
31	30.000m		15+296.02m	15+326.02m	1.7189 (d)	
	21.131m	500.000m	15+326.02m	15+347.15m	2.4215 (d)	3.4377 (d)
	30.000m		15+347.15m	15+377.15m	1.7189 (d)	
32	30.000m		16+163.04m	16+193.04m	0.9549 (d)	
	42.515m	900.000m	16+193.04m	16+235.55m	2.7066 (d)	1.9099 (d)
	30.000m		16+235.55m	16+265.55m	0.9549 (d)	
33	30.000m		16+613.43m	16+643.43m	4.2972 (d)	
	172.973m	200.000m	16+643.43m	16+816.40m	49.5531 (d)	8.5944 (d)
	30.000m		16+816.40m	16+846.40m	4.2972 (d)	

Details of Horizontal Curves:

Total length of the stretch : 17.0 km

Number of Horizontal Curves : 28 nos.

Total length of curves : 2.5 Km

% length of Curves : 14.7%

Minimum Radius of horizontal curve : 200m

4.1.10 Gradients

The detail statement of gradients is placed in Table 4.2. There are no sharp gradient envisaged in the alignment as the road is fairly flat and we are following the road alignment. The straight gradient has been kept as 2.85%

Table 4.2 Statement of Gradients

No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	Curve Radius
1	0+000.00m	891.152m		0.00%				
2	0+100.00m	891.152m	0.00%	-0.66%	0.66%	Crest	13.243m	2000.000m
3	0+425.00m	889.000m	-0.66%	0.05%	0.71%	Sag	14.291m	2000.000m
4	1+302.71m	889.460m	0.05%	0.00%	0.05%	Crest	1.048m	2000.000m
5	1+500.00m	889.460m	0.00%	-0.53%	0.53%	Crest	10.618m	2000.000m
6	1+775.00m	888.000m	-0.53%	0.36%	0.89%	Sag	17.891m	2000.000m
7	2+325.00m	890.000m	0.36%	-0.79%	1.15%	Crest	23.073m	2000.000m
8	2+525.00m	888.420m	-0.79%	0.00%	0.79%	Sag	15.800m	2000.000m
9	2+725.00m	888.420m	0.00%	0.36%	0.36%	Sag	7.114m	2000.000m
10	4+575.00m	895.000m	0.36%	-0.91%	1.26%	Crest	25.295m	2000.000m
11	5+125.00m	890.000m	-0.91%	0.80%	1.71%	Sag	34.246m	2000.000m
12	5+375.00m	892.008m	0.80%	0.00%	0.81%	Crest	16.122m	2000.000m
13	5+650.00m	892.000m	0.00%	-0.16%	0.16%	Crest	3.142m	2000.000m
14	6+275.00m	891.000m	-0.16%	0.24%	0.40%	Sag	7.906m	2000.000m
15	6+700.00m	892.000m	0.24%	-2.04%	2.28%	Crest	45.523m	2000.000m
16	7+050.00m	884.857m	-2.04%	0.00%	2.04%	Sag	40.817m	2000.000m
17	7+250.00m	884.857m	0.00%	0.33%	0.33%	Sag	6.531m	2000.000m
18	7+600.00m	886.000m	0.33%	0.85%	0.52%	Sag	10.438m	2000.000m
19	8+425.00m	893.000m	0.85%	-0.03%	0.88%	Crest	17.586m	2000.000m
20	8+675.00m	892.923m	-0.03%	-1.67%	1.64%	Crest	32.734m	2000.000m
21	9+450.00m	880.000m	-1.67%	0.34%	2.01%	Sag	40.107m	2000.000m
22	9+775.00m	881.098m	0.34%	0.00%	0.34%	Crest	6.757m	2000.000m
23	9+975.00m	881.098m	0.00%	0.02%	0.02%	Sag	0.354m	2000.000m
24	10+400.00m	881.173m	0.02%	1.61%	1.59%	Sag	31.895m	2000.000m
25	10+825.00m	888.026m	1.61%	0.03%	1.59%	Crest	31.739m	2000.000m

Table 4.2 Statement of Gradients								
No.	**PVI Station**	**PVI Elevation**	**Grade In**	**Grade Out**	**A (Grade Change)**	**Profile Curve Type**	**Profile Curve Length**	**Curve Radius**
26	11+050.00m	888.083m	0.03%	2.46%	2.44%	Sag	48.759m	2000.000m
27	11+625.00m	902.248m	2.46%	0.15%	2.31%	Crest	46.206m	2000.000m
28	12+350.00m	903.358m	0.15%	0.75%	0.60%	Sag	11.981m	2000.000m
29	12+568.32m	905.000m	0.75%	0.00%	0.75%	Crest	15.043m	2000.000m
30	12+761.09m	905.000m	0.00%	-2.20%	2.20%	Crest	43.906m	2000.000m
31	13+325.00m	892.621m	-2.20%	0.00%	2.20%	Sag	43.906m	2000.000m
32	13+550.00m	892.621m	0.00%	-0.99%	0.99%	Crest	19.813m	2000.000m
33	13+925.00m	888.906m	-0.99%	1.22%	2.21%	Sag	44.257m	2000.000m
34	14+300.00m	893.489m	1.22%	0.00%	1.22%	Crest	24.445m	2000.000m
35	14+500.00m	893.489m	0.00%	-0.74%	0.74%	Crest	14.890m	2000.000m
36	14+700.00m	892.000m	-0.74%	0.91%	1.65%	Sag	33.097m	2000.000m
37	15+725.00m	901.331m	0.91%	0.06%	0.85%	Crest	17.073m	2000.000m
38	16+450.00m	901.742m	0.06%	2.85%	2.79%	Sag	55.866m	2000.000m
39	16+875.00m	913.854m	2.85%	1.13%	1.72%	Crest	34.429m	2000.000m
40	17+150.00m	916.958m	1.13%					

Details of Vertical Curves
Minimum Radius : 200 m
Maximum Gradient : 2.85%

4.1.11 Station Planning

Silk Board to KR Puram alignment covers 18.00 km and consists of the following stations:

Table 4.3 List of Station Name (DPR Locations)	
1	KR Puram Existing Metro station phase II
2	Mahadevpura
3	DRDO Sports Complex
4	Doddanekundi
5	ISRO
6	Marathahalli
7	Kodibisanahalli
8	Kadubeesanahalli
9	Bellandur
10	Ibbalur.
11	Agara Lake
12	HSR Layout
13	Silk board (Phase – II Existing)

4.1.12 Station Design

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

1. On the middle of the road – HSR Layout, Agara Lake, Bellandur, Kaadubeesanahalli, Kodibisanhalli, Marathahalli, ISRO, Doddanekundi, DRDO Sports Complex, Mahadevpura station.
2. Partially on the service road –Silk board, Ibbalur and KR Puram Terminal station.

4.1.13 Station Locations

I. Silk Board

Silk board Station is the 1st station on Silk board – KR Puram line. The elevated station has been proposed before the silk board junction. The chainage of the station is (-) 000.000. The main access to the station is proposed by the side of the road. Ancillary Structures required for operational activities have been housed in on LHS.

II. HSR Layout

HSR Layout Station is the 1st station on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The station is located on the centre of the ORR. The chainage of the station is (-) 1385.949. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

III. Agara Lake

This is an elevated station, on the middle of the ORR leading towards KR Puram. The station is located on the middle of ORR. The chainage of the station is (-) 2630.425. The main access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in vacant area on LHS.

IV. Ibbalur

This is the 3rd station on Silk board – KR Puram line. The elevated station has been proposed on the middle of left side service road of the ORR leading towards KR Puram. The chainage of the station is (-) 5485.695. The accesses to the station are proposed across the road. Ancillary Structures required for operational activities have been housed in part of the area on LHS.

V. Bellandur

This is the 4th station on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 7142.716. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

VI. Kadubeesanahalli

This is the 5th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 8567.283. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

VII. Kodibisanahalli

This is the 7th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 9881.544. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

VIII. Marathahalli

This is the 8th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 10942.640. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS. This Station is planned in the middle of ORR and direct entry and exit from above the under pass is considered.

IX. ISRO

This is the 9th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards Mysore. The chainage of the station is (-) 12656.544. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS.

X. Doddanekundi

This is the 10th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 13437.806. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS and due to hospital on the RHS.

XI. DRDO Sports Complex

This is the 11th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 14393.523. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS and due to IT industries on the RHS.

XII. Mahadevpura

This is the 12th on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 15837.157. The access

to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on LHS and due to Gas pipe lines on the RHS.

XIII. KR Puram

This is the last on Silk board – KR Puram line. The elevated station has been proposed on the middle of ORR leading towards KR Puram. The chainage of the station is (-) 17000.000. The access to the station is proposed across the road. Ancillary Structures required for operational activities have been housed in open area on RHS. This line will further continue to Byappanahalli Depot.

4.1.14 Station Facilities

The elevated alignment generally passes on median of the road and the station is also proposed above the road with entries planned on service road. The proposed stations will have two side platforms and the access to the platforms is through staircases and escalators, housed in the paid area of concourse. The commuters can access the platform at 10.8 m height. A connecting bridge is planned below the viaduct connecting the two platforms on either side to permit commuters to interchange platform.

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

Ticket / token counters and information have been proposed in the unpaid area of concourse.

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

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

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, and also paid toilets outside the station building.

4.1.15 Architectural Finishes

Light weight and sleek steel structures have been envisaged for roof of stations with translucent fabric sheeting for ambient day lighting within the stations. Granite floor, stainless steel and balustrade etc have been proposed for aesthetic reasons and for ease of maintenance. The structural system proposed is modern, sleek and aesthetically appealing and cost effective.

4.1.16 Passenger Facilities

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

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

4.1.17 Utilities and Services

The proposed alignment of Silk board to KR Puram is traversing along the Outer Ring 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.

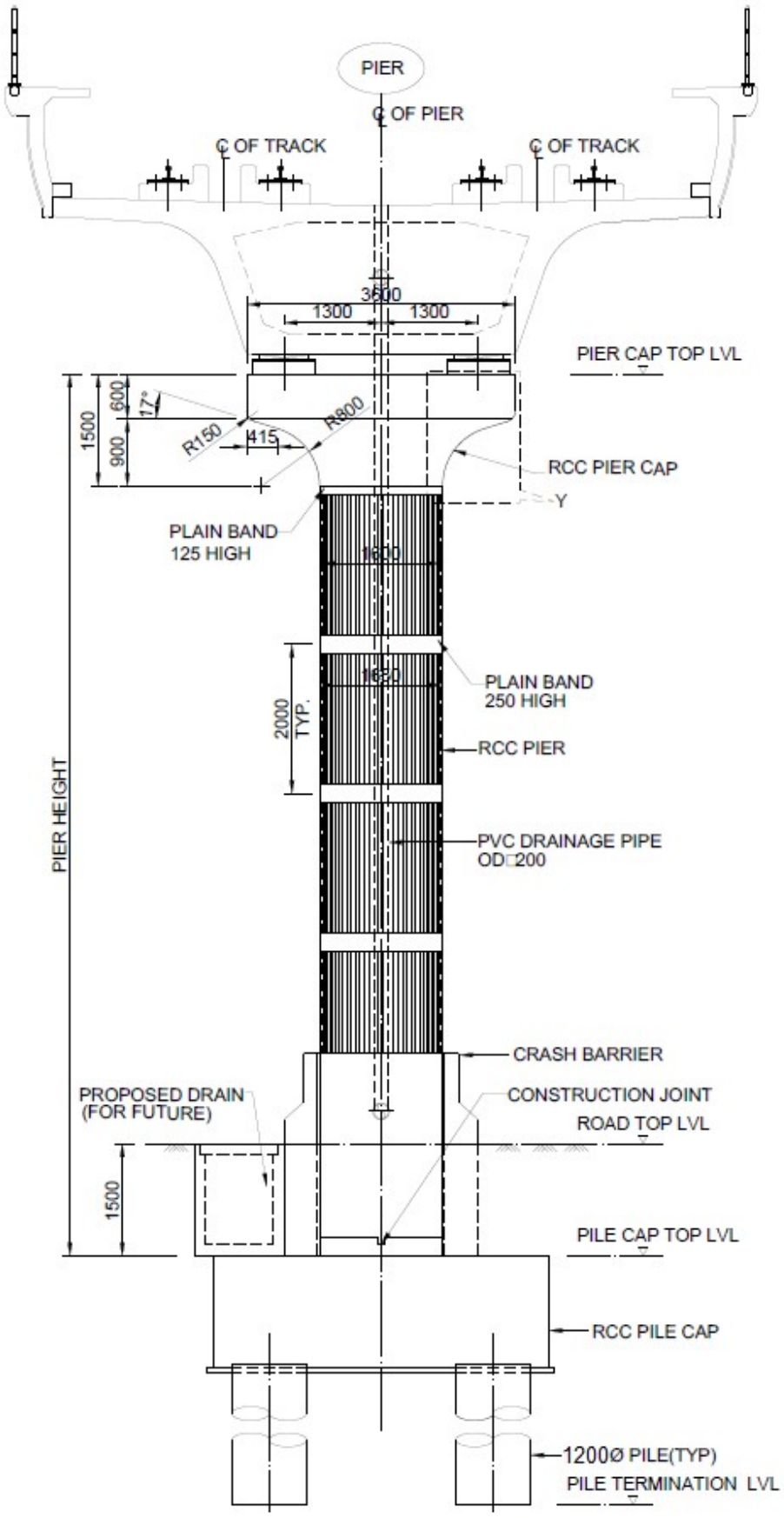
4.1.18 Typical Station

The station is proposed above of the road. The commuters can access the platform at 10.8 m height. A connecting bridge is planned below the viaduct connecting the two platforms on either side. The typical station plan and sections is given in Fig. 4.3 to Fig. 4.6 are enclosed.

4.1.19 Drawings

The detailed drawings including the General arrangement drawings for entire section and station plans and elevation is provided in **Volume – 2** in this report.

Table 4.4 List of Drawings			
Sl.No.	**Sl.No.**	**DRAWING No.**	**Drawings**
1		INDICATIVE	INDEX MAP SHOWING THE ALIGNMENT FROM SILKBOARD TO KR PURAM WITH STATION NAMES
		GENERAL ARRANGEMENT DRAWINGS	
2		SHEET 1 TO SHEET 27.	HORIZONTAL AND VERTICAL ALIGNMENT FROM CH: 0.000 m TO 17000.000 m (SILK BOARD TO KR PURAM)
		TYPICAL STATIONS (FROM AGARA TO MAHADEVPURA)	
3	1	BMRCL/SCH/TYP STAT/ARC/DRWG-001	INSERTION LEVEL PLAN
4	2	BMRCL/SCH/TYP STAT/ARC/DRWG-002	GROUND LEVEL PLAN
5	3	BMRCL/SCH/TYP STAT/ARC/DRWG-003	CONCOURSE LEVEL PLAN
6	4	BMRCL/SCH/TYP STAT/ARC/DRWG-004	PLATFORM LEVEL PLAN
7	5	BMRCL/SCH/TYP STAT/ARC/DRWG-005	ROOF LEVEL PLAN
8	6	BMRCL/SCH/TYP STAT/ARC/DRWG-006	ELEVATION 1 & 2
9	7	BMRCL/SCH/TYP STAT/ARC/DRWG-007	CROSS SECTION C-C, D-D & E-E
10	8	BMRCL/SCH/TYP STAT/ARC/DRWG-008	LONGITUDINAL SECTION A-A & B-B
		SILK BOARD INTERCHANGE STATION (CH: 0.000 m)	
11	1	BMRCL/SCH/SB/ARC/DRWG-001	INSERTION LEVEL PLAN
12	2	BMRCL/SCH/SB/ARC/DRWG-002	STREET LEVEL PLAN
13	3	BMRCL/SCH/SB/ARC/DRWG-003	INTERMIEDIATE LEVEL PLAN
14	4	BMRCL/SCH/SB/ARC/DRWG-004	CONCOURSE LEVEL PLAN
15	5	BMRCL/SCH/SB/ARC/DRWG-005	PLATFORM LEVEL PLAN
16	6	BMRCL/SCH/SB/ARC/DRWG-006	ROOF LEVEL PLAN
17	7	BMRCL/SCH/SB/ARC/DRWG-007	ELEVATION 1 & 2
18	8	BMRCL/SCH/SB/ARC/DRWG-008	CROSS SECTION A-A & B-B
19	9	BMRCL/SCH/SB/ARC/DRWG-009	CROSS SECTION C-C & D-D
20	10	BMRCL/SCH/SB/ARC/DRWG-010	LONGITUDINAL SECTION
		K. R. PURAM INTERCHANGE STATION (CH: 17000.000 m)	
21	1	BMRCL/SCH/KRP/ARC/DRWG-001	GROUND LEVEL PLAN
22	2	BMRCL/SCH/KRP/ARC/DRWG-002	CONCOURSE LEVEL PLAN
23	3	BMRCL/SCH/KRP/ARC/DRWG-003	PLATFORM LEVEL PLAN
24	4	BMRCL/SCH/KRP/ARC/DRWG-004	CROSS SECTION B-B.



Typical Cross Section of Viaduct

(SCALE 1:50)

Figure 4.2

T DESIGN
d

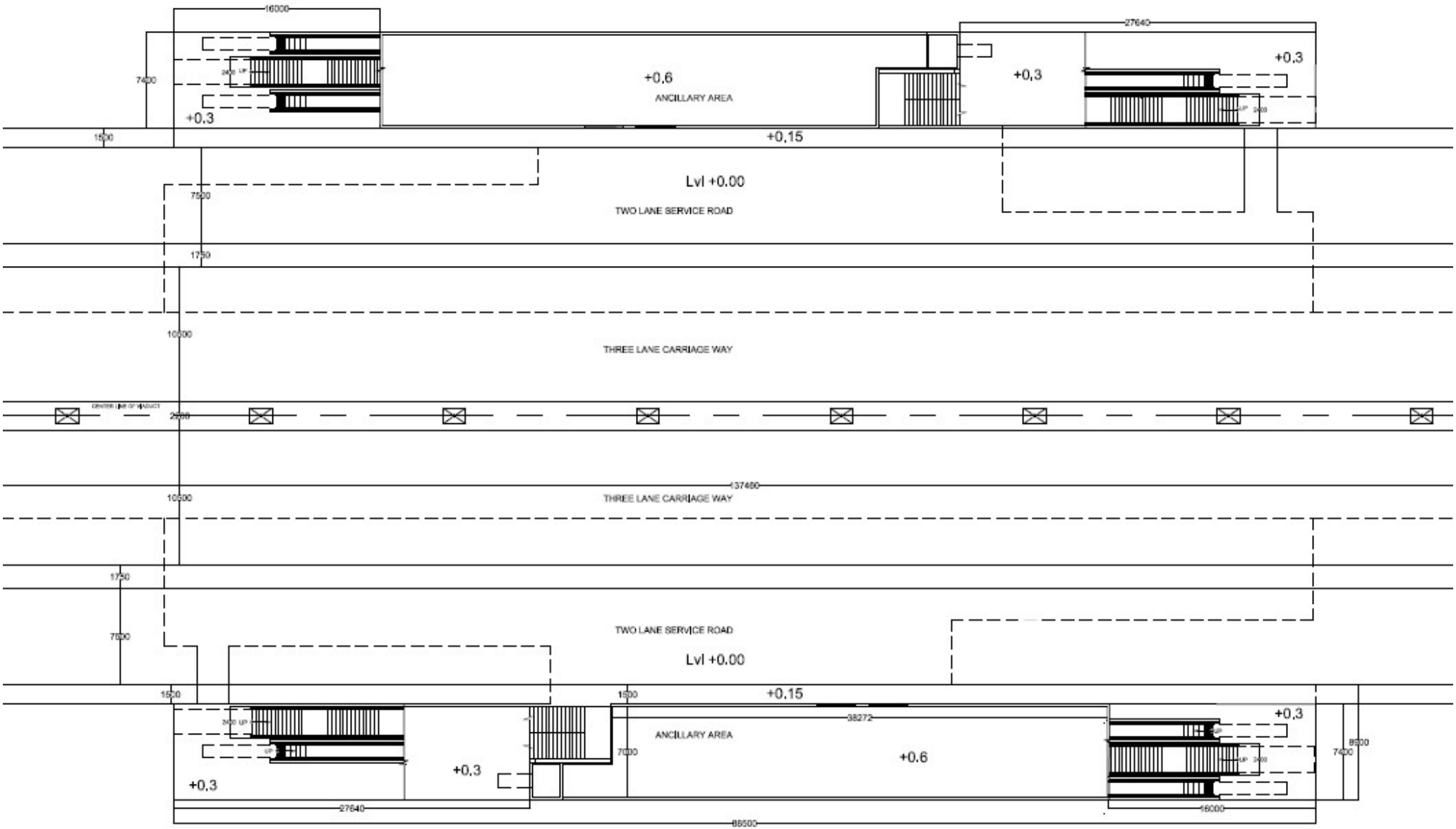


Figure 4.3 GROUND FLOOR PLAN

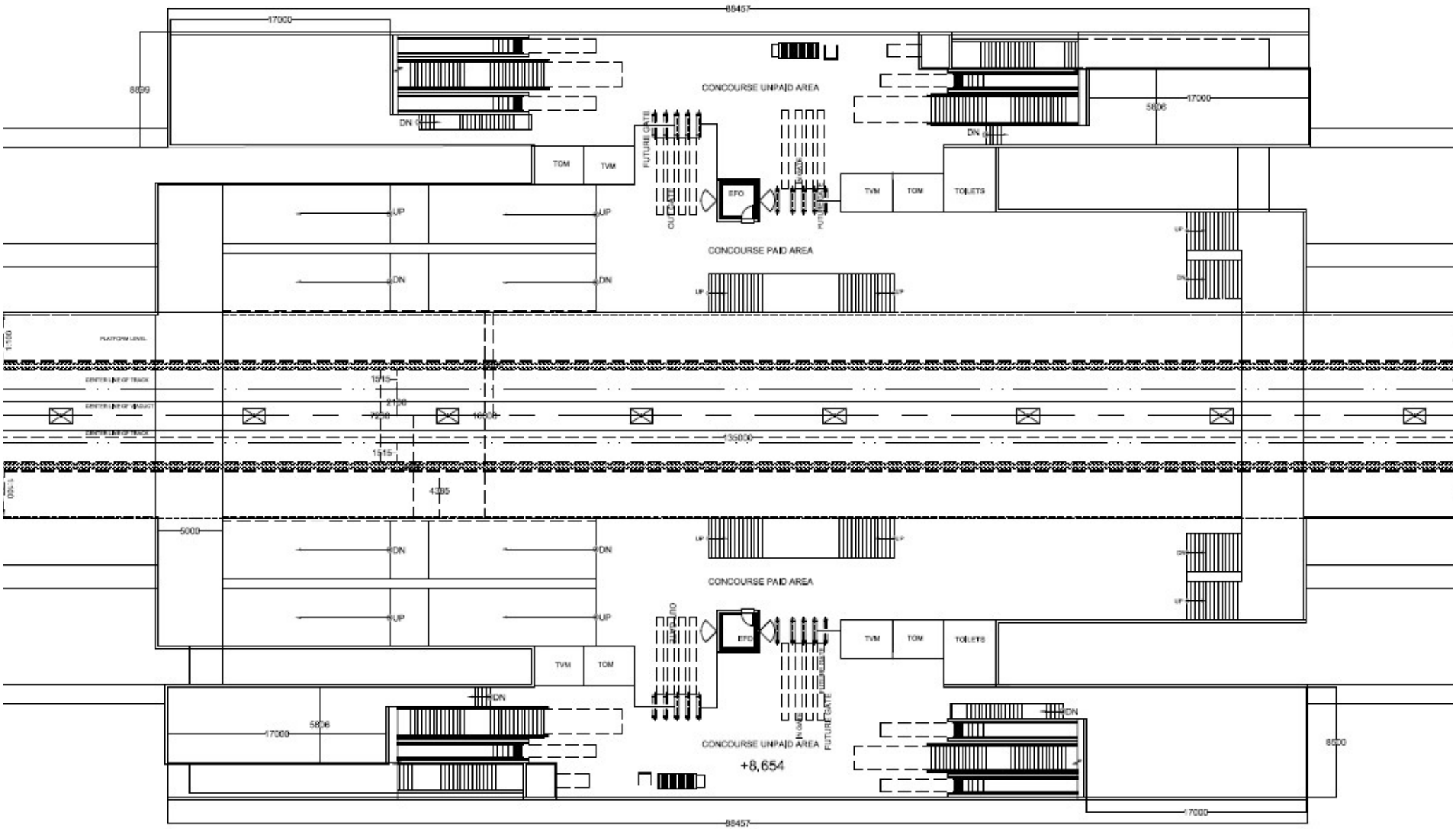


Figure 4.4 CONCOURSE LEVEL PLAN

DESIGN
d

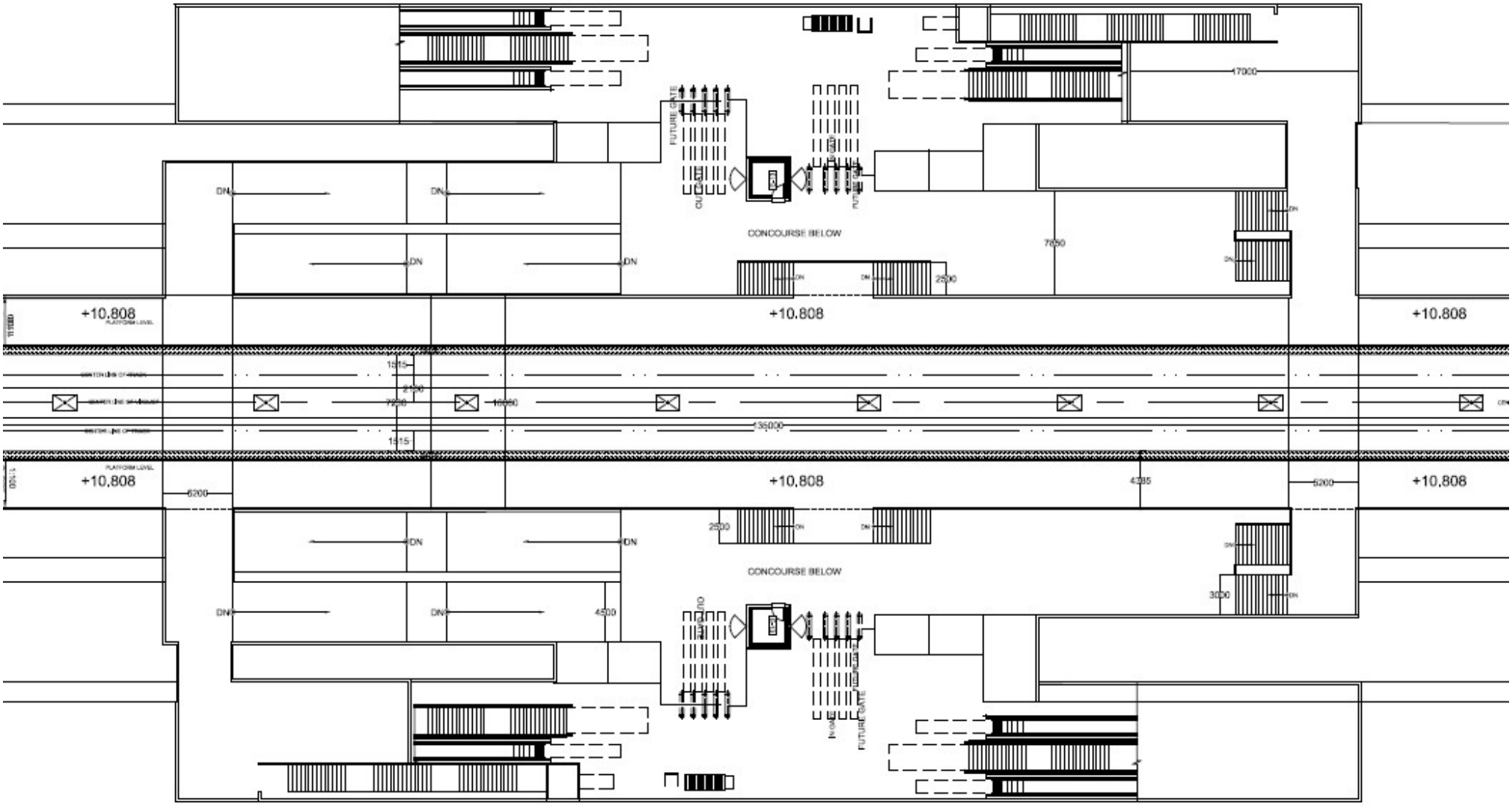


Figure 4.5 PLATFORM LEVEL PLAN

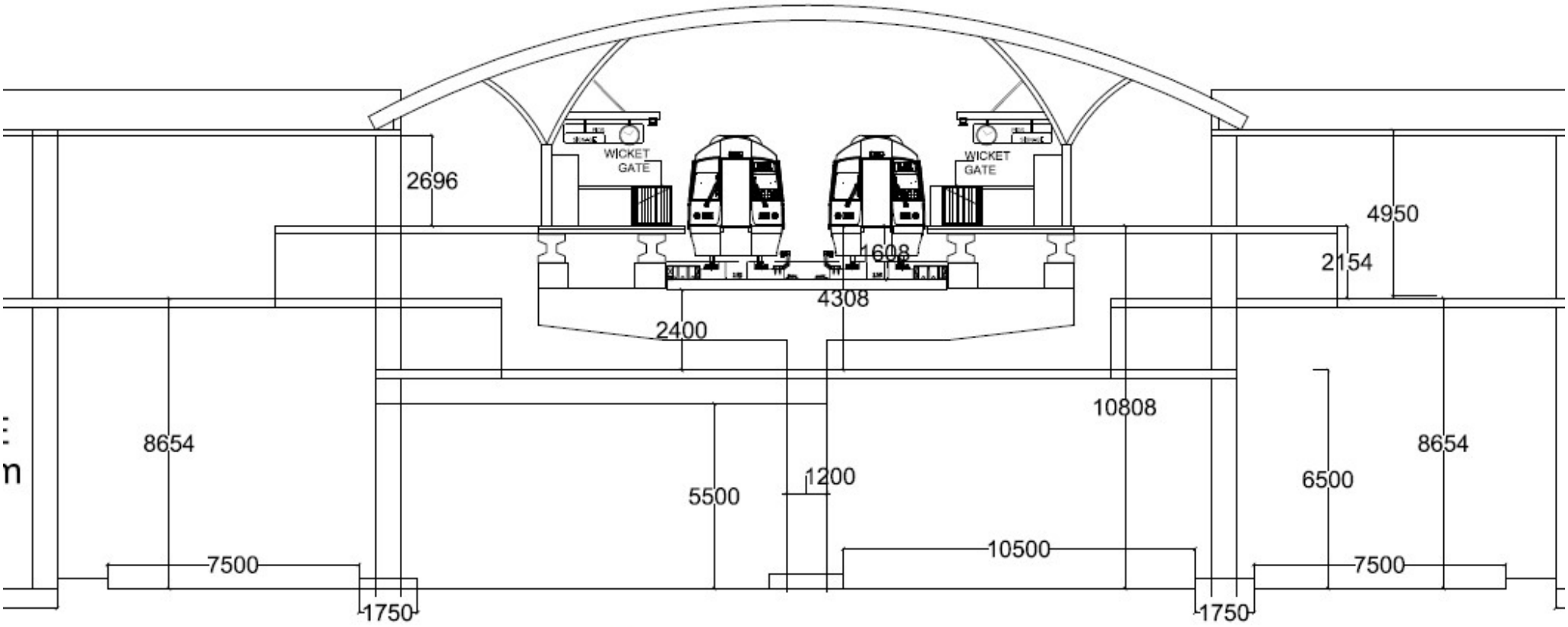


Figure 4.6 TRANSVERSE SECTION Schematic

5 PLANNING AND DESIGN PARAMETERS

5.1 GEOMETRIC DESIGN NORMS

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

5.2 HORIZONTAL CURVES

On consideration of maximum allowable cant of 125 mm and cant deficiency of 100 mm on Metro tracks, the safe speed on curves of radii of 400 m or more is 80 km/h. On elevated section use of curves with minimum radius of 200 m, having speed of 55 km/h shall be adopted. There are, however, exceptional situations where due to site constraints; use of sharper curves is unavoidable. Under such situations sharp curves up to 120 m radius (safe speed of 40 km/h) have been adopted. In curves sharper than 190m radius check rails are to be provided.

For maximum permissible speed on curve with various radii table 5.1 may be referred.

Curve radius in mid section: Elevated Section

Preferred Radius without check rail	: >190m
Minimum	: 200 m
Minimum curve radius at stations	: 1000 m
Maximum permissible cant (Ca)	: 125 mm (To be avoided as far as possible)
Maximum Desirable Cant (Ca)	: 110 mm
Maximum cant deficiency (Cd)	: 100 mm

If depot is coming in this reach, provision for minimum radius and curve is 100m as per SOD and the track spacing shall be suitable increased as per provisions of SOD.

5.3 TRANSITION CURVES

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

Minimum length of Transitions of

Horizontal curves (m)	: 0.5 cant gradient of 1 in 500

No overlap is allowed between transition curves and vertical curves.

Minimum straight between two	
Transition curves	: Either 25 m or NIL.
Minimum curve length between	
Two transition curves	: 25 m

5.4 VERTICAL ALIGNMENT

5.4.1 Elevated Sections

Track supporting structures on Elevated sections are to permit a vertical clearance of 5.5 m above road level. Similarly, the rail level for the stations on road locations (with concourse on sides on ground) shall be at least 10.5 m above the road level in the central portion and 9.5 m at ends. With elevated concourse the rail level at stations shall be 12.8 m. For the tracks carried on portals on roads, the minimum rail level shall be 9.5 m above the road level.

The track center to centre distance of 4.2 m will be provided on the elevated section keeping in view the minimum radius of 190 m.

5.4.2 Gradients

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

Switch over ramp between underground and elevated sections where a grade up to 4% is adopted to minimize the length of ramp. This included the grade compensation for curves.

Desirable gradient at stations	level
Maximum gradient at stations	: 1 in 400 %
Maximum gradient in mid section	
Normal	: 2.0 %
Exceptional	: 4.0 % (compensated for curves) Permissible Gradients in Turnouts
On Ballasted Tracks	: 0.25 %
Ballasted Tracks	: 2.5 %

There shall be no change of grade on and within 15.0 m of any turnout on ballast less track. Similarly, there shall be no change of grade on and within 30.0 m of any turnout on ballasted track. In case of turnout on gradient, there shall be no horizontal curve on and with 15.0 m of any turnout on ballast less track and 30.0 m of any turnout on ballasted track.

5.4.3 Vertical Curves

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

Minimum radius of vertical curves:	
On main line	: 1500 m
And other Locations	
Minimum length of vertical curve	: 25 m

5.5 DESIGN SPEED

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

5.5.1 Spacing of Tracks

The spacing of tracks shall be 4200mm. In depot, the spacing to be changed beyond 4.20 m as per provisions of SOD BMRCL 2015, for curves of gradient less than 120.0 m to 100.0 m

5.6 PERMANENT WAY

5.6.1 Track Structure

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

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

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

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

5.6.2 Rail Section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines, sharp curves and steep gradients would be present, the grade of rail on main lines should be 1080 Head Hardened. For the Depot lines, the grade of rails be 880 grade, which are manufactured indigenously.

5.6.3 Ballast less Track on Viaducts

On the viaducts, it is proposed to adopt plinth type ballast less track structure with RCC derailment guards integrated with the plinths. Further, it is proposed to adopt fastenings System or any other suitable system on both types of ballast less track structures, with a base-plate to base-plate spacing of 70 cm on viaducts and with fastenings systems for ballast less track which satisfy performance

criteria of fastening system for ballast less track on Metro Rails issued by Government of India, Ministry of Railways December 2015.

5.6.4 Ballast less Track in Depot

The ballast less track in Depot may be of the following types:

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

5.6.5 Turnouts

- From considerations of maintainability and riding comfort, it is proposed to lay the turnouts also with 1 in 20 cant. Further, it is proposed to adopt the following two types of turnouts:
- On main lines, 1 in 9 type turnout with a lead radius of 300 metres which has speed potential of 45 km/h as divergent track.
    i. On Depot lines, 1 in 7 type turnout with a lead radius of 400 meters which has a speed potential of 35 km/h as divergent track.
- The Scissors cross-overs on Main Lines (1 in 9 type) will be with a minimum track centre of 5.5 m.
- The proposed specifications for turnouts are given below: -
    i. The turnouts should have fan-shaped layout 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 minimising the additional LWR forces transmitted from tongue rail to stock rail.
- The crossings should be made of cast manganese steel and with welded leg extensions. These crossings should be explosive hardened type for main lines and without surface hardening for Depot lines.
- The check rails should be with UIC-33 rail section without being directly connected to the running rails.

5.6.6 Buffer Stops

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

5.6.7 Welding

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

5.7 OPERATING ENVIRONMENT:

Track Structure should fulfill generally the following conditions:

- Standard gauge – 1435mm.
- Rail Seat inclination (slope): 1 in 20
- Speed potential – 80 Kmph (max.)
- Static axle load – 15 T (max.)
- Design rail temperature range – (-) 10 degree Celsius to (+) 70 degree Celsius
- Maximum curvature and ruling gradient – As specified in SOD

5.8 TRACK STRUCTURE:

- General: The track structure should fulfill the following requirements:
- The track structure should confirm to / satisfy Schedule of Dimension requirement and other maintenance instructions of Metro systems.
- Ride comfort and running safety of track vehicle dynamics should be satisfied.
- The track structure should be designed with long welded / continuously welded rail on main line track in case of ballasted as well as ballastless track.
- The horizontal alignment shall consist of a series of straights joined to circular curves generally with transition curves. Curvature and cant shall be calculated based on the train speed for each train type on the section. Compound and reverse curves are acceptable, provided they are connected by an adequate transition curve.
- The vertical alignment should be designed to achieve a smooth profile line with gradual changes. Changes in the profile should be connected by vertical curves, which shall be as generous in length as the location allows. Vertical curves including its transition shall not be located at stations within the length of platform. A vertical curve within the length of transition and turnouts is also not desirable. Vertical curve radius is constrained by the need to limit the vertical acceleration for passenger ride comfort.

5.9 THE TECHNICAL STANDARDS FOR TRACK STRUCTURE DEALS WITH THE FOLLOWING COMPONENTS –

I. Rail and Welding
II. Sleeper and Fastening for ballasted track
III. Track slab for ballastless track
IV. Fastening system for ballastless track
V. Insulated glued joint

VI. Turnout, scissors crossover
VII. Switch Expansion Joints
VIII. Gradients

5.10 RAILS AND RAIL WELDING

Rails

For Main Line Track: The rail used on main line on curves and approaches of stations shall be 60E1 (UIC 60), 1080 grade Head Hardened. At other locations on straight line of main line, the use of 60E1 (UIC 60), 1080 grade HH/60E1 (UIC 60), 880 grade rail shall be decided by Metro Railway depending upon speed, axle load and other factors pertaining to safety and life of rail. However on curves with small straight track in between, the 60E1 (UIC 60), 1080 grade Head hardened rail should be continued on straight patches also. It is essential to have preventive rail grinding arrangements in case 60E1 (UIC 60), 1080 HH rails are used.

For Depot lines:

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

Specification:

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

Welding of Rail:

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

Alumino Thermit Welding:

i. Indian Railway Standard specifications for Alumino Thermit Welding of Rails (IRS/T-19 with latest amendments)
ii. Manual for Fusion Welding of Rails by the Alumino-Thermic Process: Revised- 2012 with latest amendments.

Flash Butt Welding:

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

Special attention is required by Metros for provisions of these instructions regarding procurement, execution of works and areas requiring prior approval / standardization by RDSO.

Ultrasonic Testing of Rail and Welds:

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

5.11 SLEEPER AND FASTENING FOR BALLASTED TRACK

Sleepers:

Standard Gauge

PSC sleeper for standard gauge will be designed by Metro Railways following in principal guidelines of Indian Railway and the same shall be approved by Metro.

Fastening System:

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

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

5.12 TRACK SLAB FOR BALLASTLESS TRACK

Track shall be laid on cast in situ / precast reinforced plinth or slab, herein referred to as the 'track slab'. The track slab shall be designed as plinth beam or slab type ballast less track structure with derailment guards. It shall accommodate the base plates of the fastening system. In general, track slab (including sleeper, if any) on which the fastening and rail are to be fitted shall perform the following functions:

I. Resist the track forces. (Static and dynamic).
II. Have adequate edge distance of concrete beyond the anchor bolts to provide resistance against edge failure.
III. Provide a level base for uniform transmission of track / rail forces.
IV. Have geometrical accuracy and enable installation of track to the tolerances laid down.
V. Ensure drainage.
VI. Resist Weathering
VII. Be construction friendly, maintainable and quickly repairable in the event of a derailment. The 'Repair and Maintenance Methods' shall be detailed in a Manual to be prepared and made available.
VIII. Ensure provision for electrical continuity between consecutive plinths / slabs by an appropriate design.
IX. Plinth beam or slab of ballastless track should be suitable for embankment or viaduct or tunnel / Underground structure.
X. Proper design of expansion joints suitable for joints of viaduct structure.
XI. Design should be suitable for curves as per SOD of Metro system.

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

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

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

5.13 CHECK RAIL / RESTRAINING RAIL:

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

5.14 DERAILMENT GUARDS

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

NOTE:

Location for providing Derailment Guard in single track tunnel

I. Entry of tunnel: 200 m from tunnel portal outside the tunnel to 50m inside the tunnel.

II. Exit of tunnel: 50 m from inside of tunnel portal to 200 m outside the tunnel.

III. In curved track having radius 500 m or less including transition portion but excluding locations where check rail is provided.

IV. Covering locations of all important installations e.g. Location of any sub-station or hazardous structures inside the tunnel, etc damage to which in the assessment of Metro rail administration can result into serious loss of life or / and infrastructure as a result of derailment in tunnel.

The above is subject to the condition that Metro Railway shall carry out the risk assessment analysis for derailment in tunnels and ensure that the maintenance practices in the maintenance manual are as per the risk assessment mitigation plan. The lateral clearance between the running rail and the derailment guard shall be 210±30 mm. It shall not be lower than 25 mm below the top of the running rail and should be clear of the rail fastenings to permit installation, replacement and maintenance.

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

i. The wheels of a derailed vehicle under crush load, moving at maximum speed are retained on the viaduct or tunnel.
ii. Damage to track and supporting structures is minimum

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

5.15 GLUED INSULATED RAIL JOINT

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

5.16 TURNOUTS, SCISSORS CROSSOVER

Standard of Turnout:

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

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

On depot and other non-running lines, the turnouts and diamond crossing shall be of the following standards:

i. Standard Gauge
    a. 1 in 7 type or flatter turnout
    b. Scissors crossover of 1 in 7 type consisting of 4 turnouts and 1 diamond crossing
    c. 1 in 7 derailing switches / 1 in 7 type symmetrical split turnout

If any Metro railway decides to use sharper angle layout, they should establish the adequacy of the speed potential of the turnout for the purpose for which it is used and the negotiability of the turn out by the rolling stock with a safety margin. The requirement for turnouts as specified in the following clauses shall include switch devices, crossings and associated check and lead rails as appropriate.

i. Turnouts (switches, lead, crossing and associated closure & check rails) shall be suitable for installation on PSC sleepers for ballasted track or concrete slab for ballastless track.
ii. Turnouts shall be manufactured to allow for installation of continuously welded track.
iii. Turnout shall be compatible with proposed rolling stock and its operational characteristics.
iv. The assembly must ensure continuous electrical contact with the train and all the points shall be operated by electric motors.
v. The CMS crossing to be used on mainline shall be subjected to explosive hardening.

vi. All turnouts shall be laid with cant with a rail slope as that of main line towards centre of track.

vii. All turnouts and their components shall be designed to minimize electrical leakage from running rails to the ground.

viii. Scissor crossover should be designed for Track centres not infringing SOD.

Type and Geometry of Turnout

Detailed design of all turnouts, scissors, and crossover should comply the following geometrical parameters.

(A) Standard Gauge

i. 1 in 9 turnout:
The design shall be tangential with a switch angle not exceeding 0020'00". It is desirable that the radius of lead rail of turnout is not less than 300m. Lead curve of 190m radius may be laid as an exception. All clearances shall be in accordance with relevant provisions of SOD.

ii. 1 in 7 turnout:
The design shall be tangential with a switch angle not exceeding 0020'00". It is desirable that the radius of lead rail of turnout is not less than 190m. Lead curve of 140m radius may be laid as an exception. All clearances shall be in accordance with relevant provisions of SOD.

iii. Scissors Crossover
The basic geometry of the turnouts of scissors crossover shall be same as that of corresponding ordinary turnouts as mentioned in clause 10.2 (i) (ii) above.

Operating requirement of turnout, scissor crossover:

Track layout design shall permit trains to operate at maximum capability wherever possible. Turnouts and crossover shall be selected such that they do not form a restriction to the operating speed on main line. Switches and crossings shall not be located on transition curves or vertical curves.

Speed: The turnout shall be designed for the speed on mainline side equal to the speed as on mainline track. The minimum speed potential of the various turnouts and scissors crossover on the turnout side should be as follows:

Standard Gauge

i. 1 in 9 type turnout with 300 m radius (speed potential of 45Kmph)
ii. 1 in 7 / 1 in 9 type turnout with 190 m radius (speed potential of 35Kmph)
iii. 1 in 7 type turnout with 140m radius (speed potential of 25 Kmph)
iv. Scissors crossover 1 in 9 type with 300 m radius (speed potential of 45 Kmph)
v. Scissors crossover 1 in 9/1 in 7 type with 190 m radius (speed potential of 35 Kmph)
vi. Scissors crossover 1 in 7 type with 140 m radius (speed potential of 25 Kmph)
vii. 1 in 7 type symmetrical spilt turnout (speed potential of 45 Kmph)

Technical Specification

General

a) All the points shall be capable of being operated by electric motors in accordance with the signaling specification.
b) The top surfaces of PSC sleeper / RCC slab supporting rail seat of turnout and scissors crossover shall be flat without any cant / slope.
c) The track form of the turnout shall have uniform resilience as that of the adjoining track form.
d) The fixation of turnouts, scissor cross-over on track slab shall be through base plates / bearing plates.

Rails

1. The rails used in turnouts shall be 1080 grade Head Hardened, However, rails used in turnouts on depot and other non-running lines may be of 880 grade.
2. The rails used for manufacturing of turnouts shall satisfy the following conditions:
   a) The rails shall be manufactured and tested in accordance with IRS/T-12-2009 with latest amendment.
   b) The section of rails shall be 60E1 (UIC60) for stock, lead and 60E!A1 (ZU1-60)/60E!A4 for switch rail.
   c) The rails shall qualify as Class 'A' rails as per IRS/T-12-2009.
   d) The rails shall be with ends un-drilled.
   e) The rails shall be of grade 1080HH and be suitable for being welded by alumnio-thermic or flash butt welding technique.

Switches

1. Each switch device shall consist of two stock rails, one left hand one right hand and two switch rails, one left hand one right hand.
2. The switch rail shall be one piece with no weld or joint within the switch rail length.
3. The end of the asymmetrical switch rail shall be forged to 60E1 (UIC60) rail profile with minimum length of 500mm. The forged switch rail end shall be suitable for welding or installation of insulated rail joint.
4. Slide chairs in the switch portion shall be coated with an appropriate special coating, so as to reduce the point operating force and to eliminate the requirement of lubrication of sliding surfaces during service.
5. Switches shall provide suitable flange way clearance between the stock rail and the switch rail with the switch rail in open position (minimum 60mm). The 1 in 12 and 1 in 9 (with radius of 300 mts) and flatter turnouts shall be provided with second drive or other suitable arrangement to ensure minimum gap of 60mm at JOH as well as proper housing of switch rail with stock rail up to JoH. 1 in 8.5, 1 in 9 turnout (with radius of 190m) and 1 in 7 and sharper turnouts may not be provided with second drive arrangement, however minimum gap of

60mm at JOH as well as proper housing of switch rail with stock rail up to JoH should be ensured. The normal opening of switch at toe of switch shall be kept as 160mm.

6. The switch manufacturer shall include provision for all holes required to main drive machines, stretcher bars and detection equipment to suit the requirements of the signaling and switch operating system duly chamfered to avoid stress concentration at the edge of the holes.
7. The switches shall be designed with an anti-creep device at the heel of switch to withstand thermal forces of the CWR track.
8. The switches and all slide chairs shall be same for ballasted and ballastless turnouts.

Crossings

1. All crossings shall be cast manganese steel (CMS) crossings with weldable rails of minimum 1.2m length undrilled for welding into the overall turnout.
2. The CMS crossings shall be manufactured from Austenitic Manganese Steel as per UIC 866.
3. All CMS crossings shall have welded leg extensions of 60E1 (UIC60) rails. This shall be achieved by flash butt welding of buffer transition rail piece of suitable thickness to CMS crossings and rail leg extension.
4. All CMS crossings on main line shall have a minimum initial hardness of 340 BHN.
5. All CMS crossings and their welded leg extensions for all scissor crossover shall be suitably dimensioned so as to eliminate the necessity of providing small cut rail pieces for the purpose of inter-connection. However, the need for providing insulated glued joints from signaling requirement point of view shall be taken care of in the design, if required.
6. The provision of rail cant shall be taken care of on the tope surface of the CMS crossing and the bottom surface of all CMS crossing shall be flat.

Check Rails

1. The check rail section shall be 33C1 (UIC33) or similar without any direct connection with running rails.
2. Check rails shall have the facility for the adjustment of check rail clearances upto 10mm over and above the initial designed clearance.
3. Each check rail end shall be flared by machining to have minimum clearance of 62mm at end.
4. The check rail connections in turnouts shall be through specially designed bearing plates / brackets.
5. All the check rails shall be higher by 25mm above running rails. The lengths and positions of the check rail in diamond crossings shall provide safety and be compatible with the overall track layout.

Sleeper for Turnouts, Scissor Crossover (Ballasted Track)

1. Sleeper shall be of pre-stressed concrete, mono-block, suitable for installation in track both with and without signaling circuits and with and without electrification.

2. Sleepers shall be designed to provide a minimum service life of fifty years under nominal axle load as that of main line for the Metro system. Rail seat pads and rail clip etc shall be designed to provide a minimum service life of 15 years.
3. The sleeper base surface shall be rough cast while the top and side surface shall be smooth to prevent retention of moisture and foreign materials.
4. Sleepers must be suitable for installation by track laying machines and sleeper insertion equipment of a type used for isolated sleeper laying.
5. The sleeper must be able to transfer all the relevant track forces generated by train operations and the forces of rail expansion and contraction to the ballast.

Design requirements for PSC sleepers:

(A) The sleepers should satisfy the following design requirement:

Design Parameters

i. Rail sleeper fastening – Elastic resilient type.
ii. Spacing of sleepers – 600mm (max) for main line and 650 mm (max) for Depots and other non-running lines, except at few locations such as near point machine locations where it may be varied to meet the design requirements.
iii. Ballast cushion – 300mm for mainline and 250mm for Depots and sidings.
iv. Ballast profile suitable for LWR/CWR.

Specifications and Drawings (with latest amendment)

i. Special cement – IRS T 40 1985
ii. HTS wire plain and strand – BIS – 1785 (Pt-1) 1983 and BIS 6006.
iii. Polyethylene dowels – Provisional 1997 Drg. No. RDSO 3002 Alt-3
iv. IRS Specification for turnout sleeper T-45 1996
v. IRS Bridge Code 1982
vi. Code of Practice for Pre-Stressed concrete IS-1343

(B) The design should satisfy the following additional requirements: -

i. The connections of the slide chairs and bearing plates/special bearing plates/brackets shall be designed for easy installation and maintenance. All the fittings shall be suitably designed to ensure full compatibility and also to ensure interchangeability of slide chairs between ballasted and ballastless turnouts.
ii. For attaining suitable cant of the rail, as provided on mainline, (excluding crossing and switch portion), suitably designed pads of appropriate material shall be provided between rail pad & PSC sleeper. Also fastening system should be designed to get the desired Toe Load.
iii. The detailed design of Monoblock PSC sleepers for the turnouts along with structural drawings shall be checked and approved by Metro Railways.

5.17 SWITCH EXPANSION JOINT

1. The SEJ for ballasted track shall be laid on PSC sleepers whereas the SEJs for ballastless track, if required, shall be laid on reinforced concrete slab.
2. The rail section for all SEJs shall be UIC 60, 1080 HH grade as per IRS-T-12-2009.
3. The SEJ for ballasted track shall be designed for a maximum gap of 80mm.
4. The SEJ for ballastless track should be designed for the maximum gap required as per design.
5. The ballasted SEJ shall be as per RDSO drawing T-6902 & T-6922
6. The ballasted SEJ for BG shall be laid with PSC sleepers as per RDSO drawing T-4149. For Standard Gauge, PSC sleeper shall be designed such that SEJ to RDSo drawing along with its bearing plates / chairs may be accommodated for installation of SEJ.
7. Sleepers used for SEJs shall be flat and cant will be provided through CI chair.
8. The SEJ shall be suitable for two way directional traffic.

5.18 NOISE AND VIBRATION

Metro system shall be designed to ensure that noise emitted is well within the prescribed limits for the particular area. Each Metro system shall specify the prescribed limits of permissible Noise and vibration parameters as per legal and statutory requirement of India.

5.19 GRADIENTS

The maximum grade (compensated) shall be 4%.

Note:

i. There will be no change of gradient in transition portion of curves.
ii. The gradient will be compensated for curvature at the rate of 0.04% per degree of curve.

Maximum permissible gradient on turnouts

i. On Ballasted Track 0.25%
ii. On Ballastless Track 2.5%

Note:

i. There shall be no change of grade on and within 15m of any turnout on ballastless track. Similarly, there shall be no change of grade on and within 30 meters of any turnout on ballasted track.
ii. In case of turnouts on gradient, there shall be no horizontal curve on and within 15 meters of any turnout on ballastless track and 30 meters of any turnout on ballasted track.

Track Gradient in Platform

a) Maximum 1 in 400
b) Desirable level

Note: There shall be no change of gradient in platform track.

6 GEOTECHNICAL INVESTIGATIONS

6.1 REFERENCE POINT

The main purpose of the Geotechnical Investigations undertaken is to have an in-sight into the geological conditions along the proposed corridors of extension of Bengaluru Metro Phase-II, so as to arrive at the type of foundations to be adopted for elevated corridors.

The geotechnical investigations were carried out by M/s. Geo Quest Limited, Bengaluru, In addition, soil investigation reports for various flyovers and underpasses already conducted on the route were also studied.

The detailed Geotechnical report is enclosed as separate volume.

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

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

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

6.2 FIELD INVESTIGATION

Field investigation has been carried out along the Outer Ring Road at 50 locations of borehole exploration up to a maximum depth of 23.0 m. If rock was encountered with in 10.5 m, drilling was carried up to a depth of 3 m in intact hard rock. Boreholes were generally located at about 500 m intervals in elevated portion along the alignment.

Borehole exploration was carried out by rotary drilling method using heavy duty rotary drilling rigs. Drilling in soil was carried out by MS soil cutters having suitable cutting edges. In soft/weathered rock,

where strata are very dense, advancement of borehole was done by Tungsten Carbide (TC) bits of Nx size. In moderately weathered and hard rock, core drilling was progressed using Nx size Diamond bits with double tube core barrel.

Standard Penetration Tests (SPT) were carried out in the boreholes as per IS 2131 at regular intervals of generally at 1.5 m depth. Undisturbed soil samples were collected by using thin walled steel tubes of 150 mm diameter, 450 mm long as per IS 2132, in cohesive soil strata. Both DS and UDS samples were sealed and labelled properly and brought to the laboratory for further testing. Rock cores were collected from core barrel after the completion of each drill run and marked with borehole numbers and sequential core piece numbers. Rock Core Recovery (CR) and Rock Quality Designation (RQD) have been recorded for each drill run. The rock core samples were stored in wooden core boxes and brought to laboratory for further testing.

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

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

The details of stratification, SPT values, Ground Water Table etc., are indicated in the Sub-Soil Profiles enclosed in Figure 6.1 to 6.4.

6.3 LABORATORY TESTING

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

Tests on soil samples:

- Grain size analysis - Sieve and Hydrometer Analysis
- Atterberg's Limits - Liquid & Plastic Limit
- Natural Moisture Content
- Bulk and Dry Density
- Consolidation Test
- Shear Strength - Triaxial/Direct Shear test
- Lab Permeability Test
- Specific Gravity

Tests on Rock samples:

- Specific Gravity, Density, Water Absorption and Porosity of rock
- Hardness
- Uni-axial compressive strength
- Point Load Index strength

- Modulus of Elasticity
- Abrasion test
- Shear strength

Chemical Tests on Soil and Water Samples:

- pH
- Chloride
- Sulphates
- Organic matter

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

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

6.5 ANALYSIS OF RESULTS

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

The formation of successive layers is varying along the route. In general, the stratification follow regular pattern as described above. Standard Penetration Test (SPT) in weathered rock indicate very high 'N' value of 50 or more and 100 or more virtually no penetration of SPT tube in this layer. The colour and structure of the soil samples collected in split spoon closely resembles underlying mineralogical constituents of weathered rock / hard rock.

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

Consolidated Undrained shear test and Direct Shear Test indicates in general, the average values of cohesive strength of soil is ranging from 0.04 to 0.14 kg/cm2 and angle of internal friction is ranging from 26 to 34 degrees.

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

Rock cores extracted from the boreholes show the presence of grey granites with pockets of amphibolites, granodiorite and mylorite rock. The rock is intruded with pegmatite veins at some places. The granite rock shows coarse grain structure due to metamorphic activity.

In general, core recovery obtained in moderately weathered rock is ranging from Nil to 95% with Rock Quality Designation (RQD) values of Nil to 95%. In the hard rock, the percentage core recovery is ranging from 62 to 100% and RQD is varying from 52 to 100%.

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

Uniaxial compressive strength results indicate that strength of hard rock varies from 17.3 MPa to 100.48 MPa. Point load strength index values in the range of 0.35 to 11.76 MPa.

Modulus of Elasticity (E) values of rock varies from 0.039 x105 MPa to 0.78 x 105 MPa.

6.6 RECOMMENDATIONS

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

6.6.1 Shallow Foundations

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

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

6.6.2 Deep Foundations

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

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

Depending on the hard strata encountered at pile termination, the following depth of socketing is recommended: Stratum at Socket Level Depth of socketing (D=pile diameter), Highly weathered rock/Fractured rock 4 D, Moderately weathered rock 2 D, Hard rock 1 D.

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

The safe load carrying capacity of end bearing pile depends on the characteristics of strata at pile termination, anchoring depth and structural capacity of pile section. The piles of diameter 900 mm, 1000 mm, 1200 mm and 1500 mm are considered for evaluation. The safe load capacity of piles in this case is generally governed by structural capacity of pile.

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

Table 6.1 Recommended safe Axial Load for piles with diameter

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

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

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

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

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

Figure 6.1 Bore Log Details

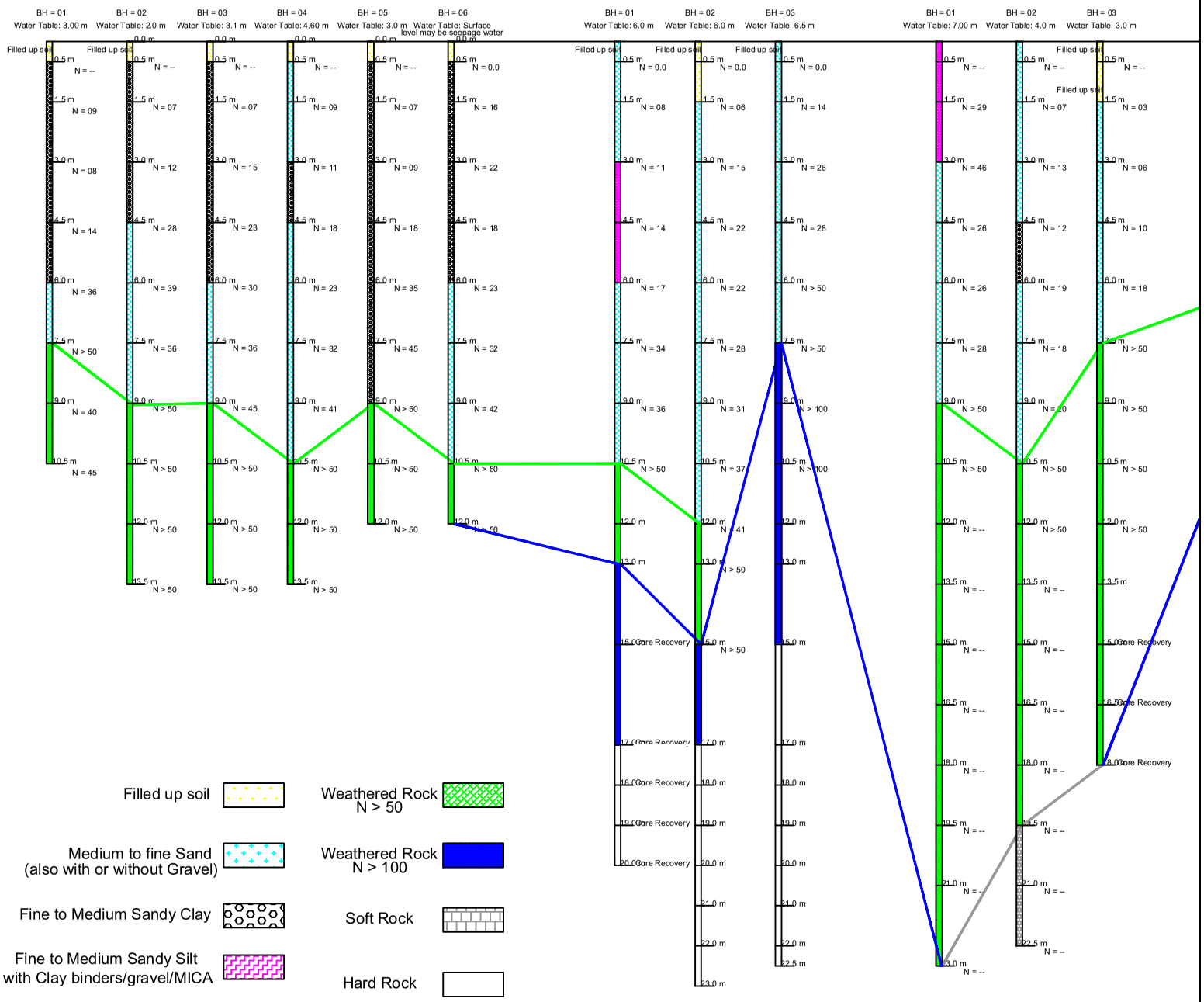
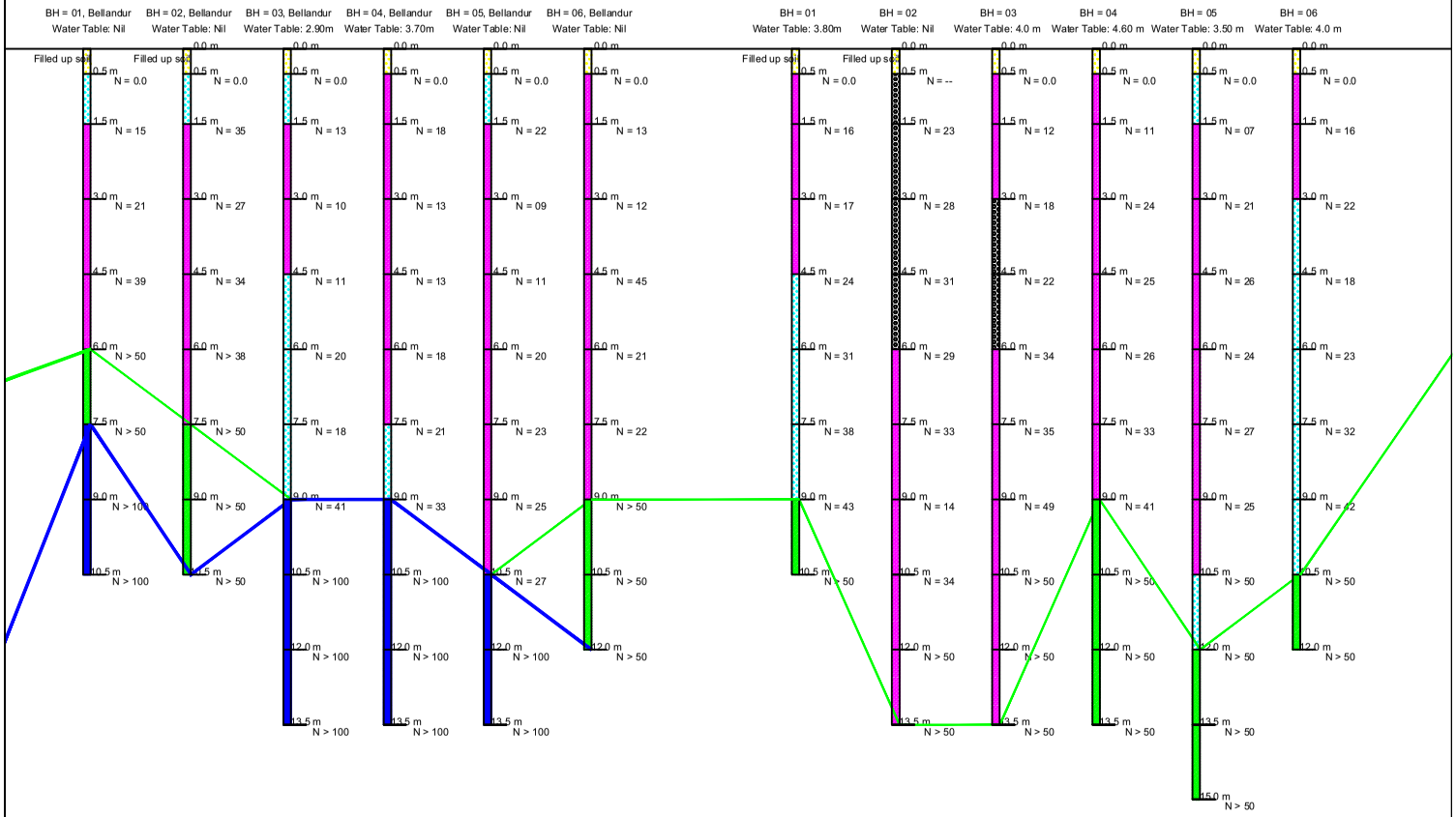


Figure 6.2 Bore Log Details

Bellandur

Devarabeesanahalli



Filled up soil

Medium to fine Sand
(also with or without Gravel)

Fine to Medium Sandy Clay

Fine to Medium Sandy Silt
with Clay binders/gravel/MICA

Weathered Rock
N > 50

Weathered Rock
N > 100

Soft Rock

Hard Rock

Figure 6.3 Bore Log Details

Kadubeesanahalli

Doddanekundi
ISRO Junction

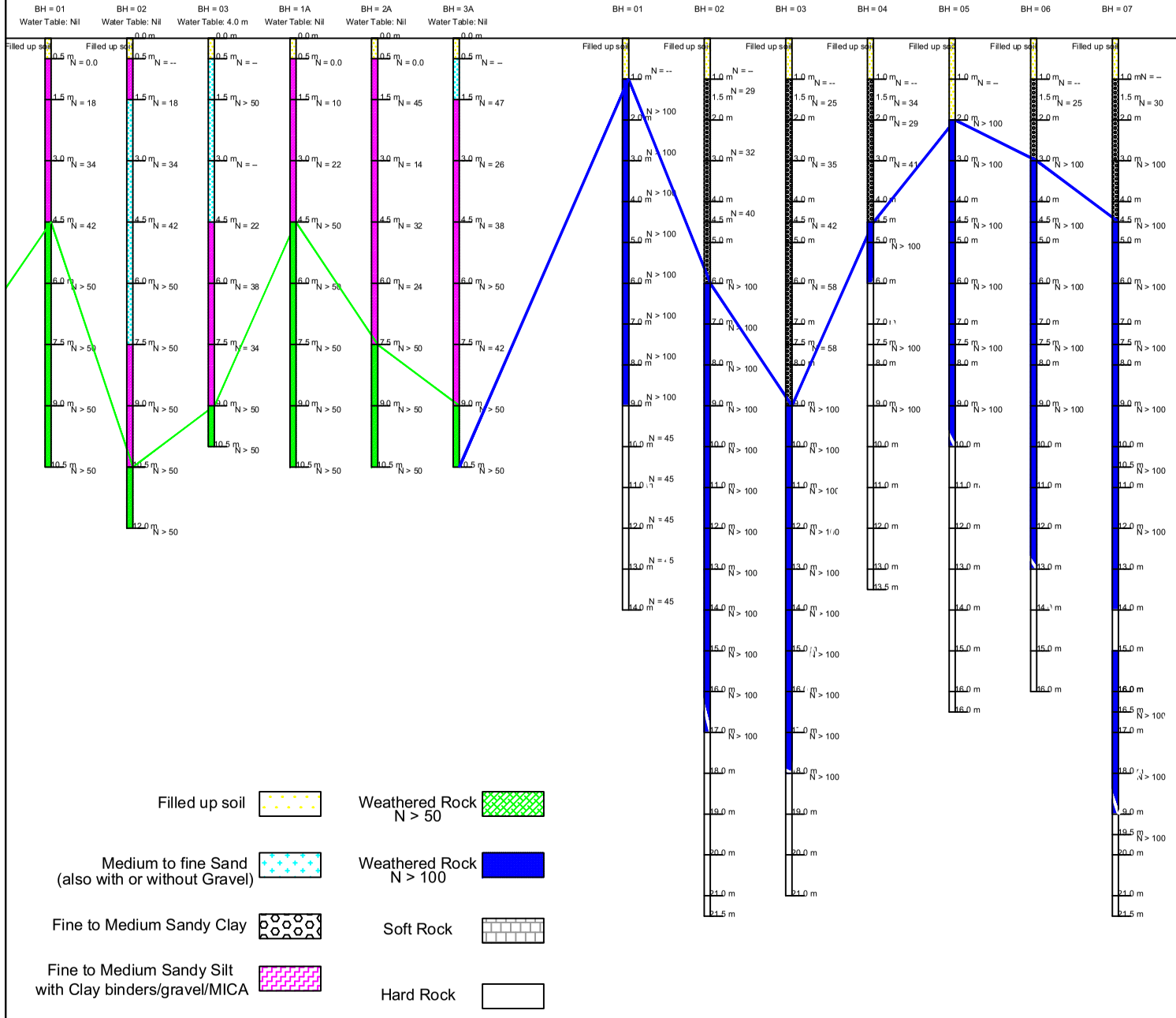
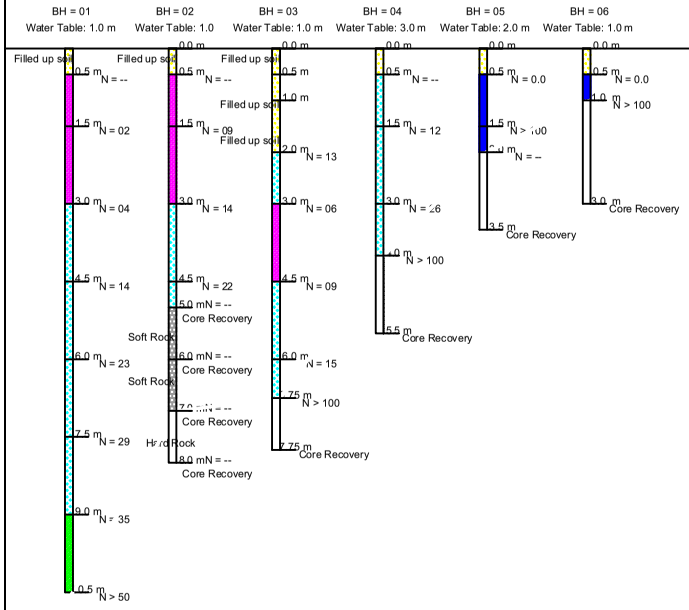
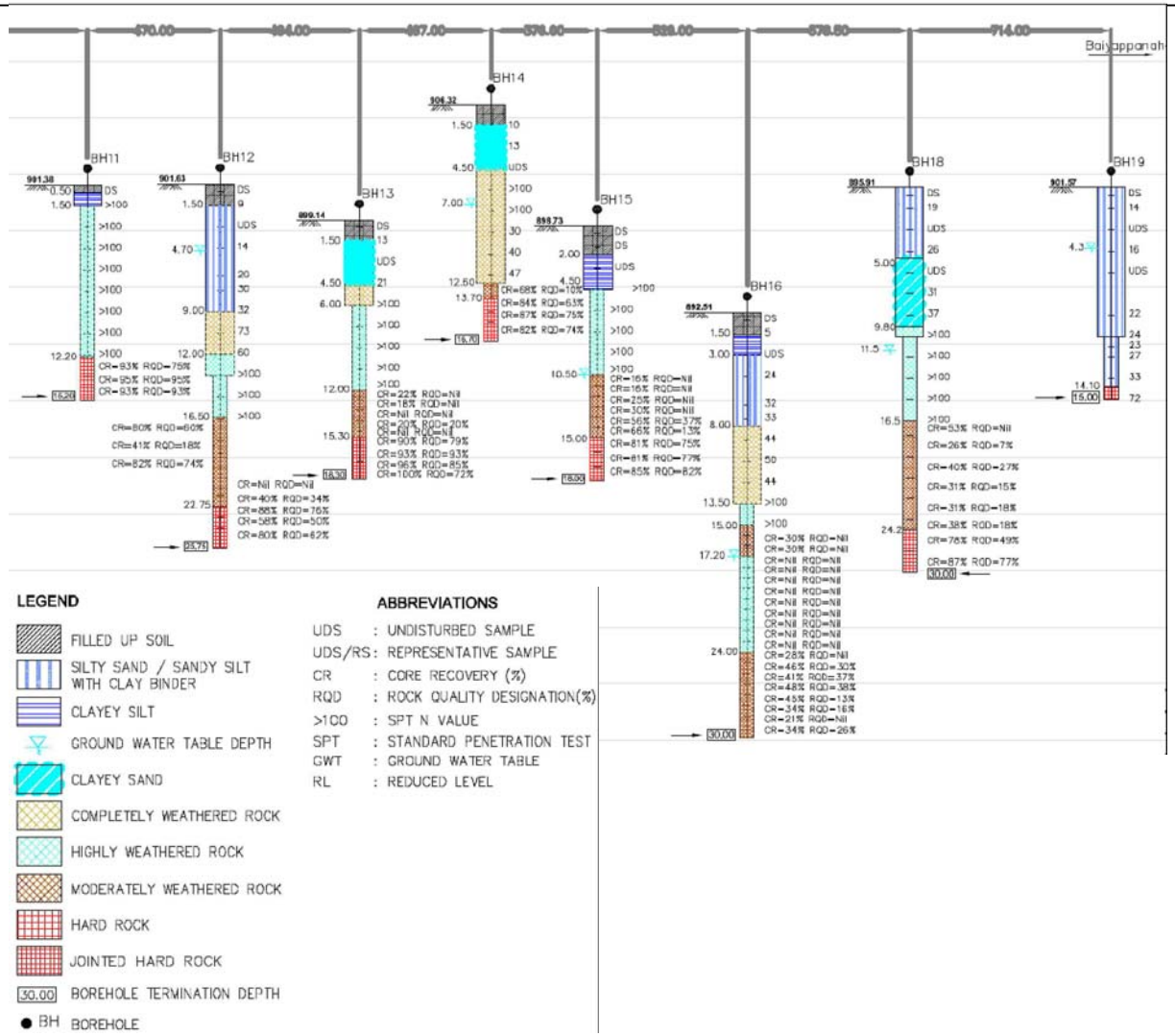


Figure 6.4 Bore Log Details

Mahadevpura KR Puram Jyothipura Byappanahalli





Filled up soil

Medium to fine Sand (also with or without Gravel)

Fine to Medium Sandy Clay

Fine to Medium Sandy Silt with Clay binders/gravel/MICA

Weathered Rock N > 50

Weathered Rock N > 100

Soft Rock

Hard Rock

7 TRAIN MAINTENANCE DEPOT

7.1 INTRODUCTION

It is proposed to create a full-fledged separate maintenance Depot at Kadugodi to cater operational and maintenance requirements for East-West corridor in lieu of Baiyappanahalli Depot for which cost provision has been considered in the project cost of Silk Board to K R Puram line.

It is also proposed to designate the Baiyappanahalli Depot for maintenance and repair of the Rolling Stock for Silk Board - K. R. Puram line. It is seen that with present PHPDT and head way of this line, the stabling, repair and maintenance facility presently available at Baiyappanahalli Depot is adequate to cater the requirement for the year 2021. However, in future if this line extended beyond K R Puram towards Hebbal, the requirement of additional stabling lines would be provided at Hebbal or at terminal stations.

For the maintenance of CBTC equipped trains, the Baiyappanahalli Depot shall be planned with full-fledged facilities with an overlapping period during which some lines will exclusively cater for CBTC equipped trains and balance will be for DTG system and finally Baiyappanahalli Depot shall be converted to serve the CBTC equipped train of Silk Board to k R Puram only.

The existing test track in Baiyappanahalli Depot will be modified for testing of CBTC train sets.

7.1.1 Rolling Stock Maintenance Schedule

The following maintenance schedule has been envisaged for conceptual design of Depots assuming 495 km running per train per day, and taking in to consideration of the passenger load with average 3 min headway of 2021, 2031 and 2041.

Table 7.1 Rolling Stock maintenance needs Maintenance Schedule

Type of Schedule	Interval	Work Content	Locations
Daily	Daily	Interval cleaning/mopping of floor and walls with vacuum cleaner.	Stabling lines
72 hours Check	3days	Safety checks, CCD, microphone, brake and checks on the train condition.	Stabling lines/ Inspection bays
“A” Service Check	6,000 km (15days)	Safety checks, inspection of lights, CCD, traction motor, bogie suspension, brake, window, micro phone and checks on the train condition.	Inspection bays
“B1” Service Check	18,000 km (45days)	Detailed Inspection of ‘A’ type tasks plus items at multiples of 18,000 Km (‘B1’ type tasks)	Inspection bays
B2 Service Check	36,000 km (90days)	Detailed Inspection of ‘B1’ type tasks plus items at multiples of 36,000 Km (‘B2’ type tasks)	Inspection bays
B4 Service Check	72,000 km (180days)	Detailed Inspection of ‘B2’ type tasks plus items at multiples of 72,000 Km (‘B4’ type tasks)	Inspection bays

Table 7.1 Rolling Stock maintenance needs Maintenance Schedule			
Type of Schedule	Interval	Work Content	Locations
B8 Service Check	150,000 km (360days)	Detailed Inspection of 'B4' type tasks plus items at multiples of 1,50,000 Km ('B8' type tasks)	Inspection bays
B16 Service Check	300,000 km (2years)	Detailed Inspection of 'B8' type tasks plus items at multiples of 3,00,000 Km ('B16' type tasks)	Inspection bays
C1 Overhaul	520,000 km (3.5years)	Check and testing of all sub-assemblies, overhaul of pneumatic valves, Compressor. Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
C2 Overhaul	1,040,000 km (7years)	Check and testing of all sub-assemblies, Overhaul of pneumatic valves, Compressor. Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
C3 Overhaul	1,560,000 km (10.5years)	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
C4 Overhaul	2,250,000 km (15years)	Changing of heavy item such as bogies, traction motor, axles, gear cases & axle boxes etc.	Workshop

7.1.2 Year-wise planning of maintenance facility setup at Baiyappanahalli Depot-cum-workshop is as under:

The existing 16 stabling lines at Baiyappanahalli Depot will be connected to Silk Board to K R Puram line by merging into two lines and further connected to the K R Puram Station through via-duct. Thus stabling lines at Baiyappanahalli Depot will have entry from both East-West and new line from either side. The transition of Baiyappanahalli Depot from DTG signaling system to complete CBTC system is planned in phased manner.

i) Rake requirement:

Table 7.2 Rake Requirement			
Year	Silk Board to K R Puram Corridor		
	Head way in minutes	No. of trains	No. of Coaches
2021	4.0	20 X 6-Cars	120
2031	3.0	25 X 6-Cars	150
2041	2.5	31 X 6-Cars	186

ii) Bare Requirement of stabling, inspection and work shop lines:

Table 7.3 Bare Requirement of stabling, inspection and work shop lines					
Year	Silk Board to K R Puram Corridor				
	Baiyappanahalli Depot			Hebbal Depot (proposed)	
	SBLs	IBLs	WSLs	SBLs	IBLs
2021	16 lines X 6-Car	3 lines X 6- Cars	4 lines X 6-Car		
2031	16 lines X 6-Car	3 lines X 6- Cars	4 lines X 6-Car	13 lines X 6-Car	2 lines
2041	16 lines X 6-Car	3 lines X 6- Cars	4 lines X 6-Car	13 lines X 6-Car	2 lines

Note:-

Presently, Baiyappanahalli Depot can cater for 21 rakes which meet the stabling and inspection requirement of Silk Board - K. R. Puram line for the year 2021. However, the proposed upcoming Depot at Hebbal shall be planned stabling lines to meet rake requirement arises from extension of Silk Board - K. R. Puram corridor up to Hebbal by 12 km (18 km+12 km= 30 km total length) and in addition rake requirement to meet PHPDT for the year 2031 and 2041.

7.1.3 Depot Control Centre (DCC)

For the CBTC equipped trains, the existing DCC at Baiyappanahalli Depot shall be converted in phased manner from DTG system to CBTC system to control operation of train movement in co-ordination with OCC.

7.1.4 Operation Control Centre (OCC)

To cater operation requirement for Silk Board - K. R. Puram new line, the equipment and display boards of CBTC system shall be accommodated in existing Operation Control Centre (OCC) at Baiyappanahalli.

7.1.5 Washing Needs of Rolling Stock

To cater train wash requirement for Silk Board - K. R. Puram new line a separate wash plant is proposed on the entry line from K R Puram to Depot. The existing washing plant at Baiyappanahalli Depot will continue to serve washing of East-West trains.

7.2 TRAIN DEPOT CUM WORKSHOP AT KADUGODI DEPOT

Full-fledged separate maintenance Depot at Kadugodi is planned to cater operational and maintenance requirements for East-West corridor in lieu of the existing Baiyappanahalli Depot, which is at present serving the East-West line.

In phase-II, under extension of phase-I, one more maintenance Depot at Challagatta has been proposed to cater East-West corridor requirements. With this the Challagatta Depot and Kadugodi

will be most ideal for operational and maintenance requirements for East-West corridor being at the both ends.

(i) Year-wise planning of maintenance facility setup at Challagatta and at Kadugodi Depot-cum-workshop is tabulated below:

Table 7.4 Year-wise planning of maintenance

Year	East- West Corridor Challagatta Depot			East- West Corridor Kadugodi Depot		
	Head way in minutes	No. of trains	No. of Coaches	Head way in minutes	No. of trains	No. of Coaches
2021	4	27 (6-Car)	162	4	19 (6-Car)	114
2031	3	37 (6-Car)	222	3	19 (6-Car)	114
2041	3	37 (6-Car)	222	3	19 (6-Car)	114

(ii) Bare Requirement of inspection lines:

Table 7.5 Bare Requirement of inspection lines

East- West Corridor Challagatta Depot		East- West Corridor Kadugodi Depot	
Year	IBL	Year	IBL
2021	3 lines X 6-Car	2021	3 lines X 6-Car
2031	4 lines X 6-Car	2031	-do-
2041	-do-	2041	-do-

(iii) Distribution of stabling lines at Depot:

Table 7.6 Distribution of stabling lines at Depot

Year	East- West Corridor Requirement			
	Challagatta Depot		Kadugodi Depot	
2021	23 lines X 6-Car	4 lines X 6-Car	16 lines X 6-Car	3 lines X 6-Car
2031	33 lines X 6-Car	-do-	-do-	-do-
2041	-do-	-do-	-do-	-do-

Initially, Challagatta Depot shall be planned for 23 stabling lines and the expansion shall be executed in staged manner for accommodating 37 rakes required in 2041.

(iv) Distribution of SBLs, IBLs and WSLs in Depot-cum-Workshops:

Table 7.7 Distribution of SBLs, IBLs and WSLs in Depot-cum-Workshops						
Year	East- West Corridor					
	Depot-cum-Workshop / Challagatta)			Depot-cum-Workshop / Kadugodi		
	SBLs	IBLs	WSLs	SBLs	IBLs	WSLs
2021	23 lines X 6-Car + 1 line for Exigency	4 lines X 6- Cars	4 lines X 6- Cars	16 lines X 6-Car + 1 line for Exigency	3 lines X 6- Cars	4 lines X 6- Cars
2031	33 lines X 6-Car + 1 line for Exigency	-do-	-do-	16 lines X 6-Car + 1 line for Exigency	-do-	-do-
2041	33 lines X 6-Car + 1 line for Exigency	-do-	-do-	16 lines X 6-Car + 1 line for Exigency	-do-	-do-

7.3 PROVISION OF INFRASTRUCTURE FACILITIES AT KADUGODI DEPOT -CUM-WORKSHOPS:

I. Inspection Sheds

The length of Inspection lines, Workshop lines shall be 159 mtrs. (Say 160m) and Inspection / Maintenance / minor repair shall be done. The A & B inspections shall be carried out at a frequency of 15 days and 45 days respectively keeping in view the average Km Earning /Train. Apart from this 72 hrs checks will have to be carried out in inspection bay.

II. Stabling Lines in Depot

a) The length of stabling lines shall be of the order of 160 mtrs.
b) The requirement of lines shall be in accordance with the table indicated above; the stabling siding in the Depot shall be covered with a roof in order to facilitate testing of air-conditioning of trains and their pre-cooling under controlled condition of temperature.
c) Separate toilets adjacent to stabling lines shall be provided with small room for keeping cleaning aids and for utilization by the contractor's staff.

III. Workshop lines

d) All the Workshop lines shall be interconnected through turn–tables.
e) Each bay shall be spanned with two 15T / 3T overhead Cranes.
f) One embedded line shall be provided with Pit-jacks for lifting of 3-Car unit simultaneously.
g) The unscheduled line shall be provided with Pits of complete Coach length for facilitating under-carriage inspection and roof platform with suitable HVAC unit approach facility for repair and maintenance.
h) Workshop will have an array of service rooms which cater for servicing & overhauling of Equipments.

i) Assembling / disassembling overhauling testing facilities shall be facilitated and suitably placed.
j) There shall be washing & cleaning equipment available on shop floor. Air circulators, Power supply points, compressed air lines shall be provided on every column.
k) Repair & stacking of heavy equipments such as HVAC, Convertors and Motors shall be so located that it does not affect movement inside the workshop.
l) Interconnectivity with mechanical repair section shall be so available that Wheels / Bogies / brake equipments are carried in and out of the repair section without causing inconvenience to any other activity.
m) The unscheduled heavy lifting bay lines shall be extended up to half of the workshop bay length beyond which space shall be kept overhauling, repairs, cleaning disassembling / assembling of Bogies.

IV. Train Operators Booking Office

Suitable office facility adjacent to the stabling lines shall 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 shall have an attached a cycle/scooter/car stand facility for convenience of the train operating staff.

V. Test Track

A test track of 1000 m in length 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 directly from repair and inspection bay. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized tress passing across or along the track with red flashing lights all along the fencing line to indicate "live" on rail.

VI. Heavy Cleaning Shed

Monthly heavy cleaning of interior walls, floors, seats, windows glasses done by manually in the interior cleaning plant shall be designed for cleaning of one six car train at a time. A line adjacent to inspection shed to be provided that placement of rakes is possible from workshop or inspection lines & vice – versa conveniently & with ease.

VII. Power Supply

Auxiliary substations are planned for catering 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. The details of power supply is as under,

Table 7.8 Power Supply Details		
Sl.No.	Details of supply	Installed capacity
1.	Normal supply Transformer	2.5 MW 2000 KVA
2.	D.G supply	380 KVA
3.	Solar PV system	1.45 MWp at peak hour (to be installed in future)

VIII. Compressed Air Supply

An independent compressor unit shall be provided at designated/required locations for the supply of compressed air in workshop and Inspection bay.

IX. 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 underground reserves.

X. 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.

XI. Watch Towers

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

XII. 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.

XIII. Parking Facilities

a) Ample parking space shall be provided for the two wheelers and four wheelers at the following points.
   - Close to the Depot entry.
   - Close to the stabling lines.
   - Close to repair bay.

b) Space for parking of road vehicles and re-railing equipments.

Since IOH/POH of equipments of Extension line has to be done at Challagatta and Kadugodi Depot–cum-Workshop, a lot of road transport will have to be utilized. Both the Depots need to have enough space for parking of Road vehicles. Enough space will also have to be earmarked adjacent to workshop and repair bay.

Similarly provision of space for parking of re-railing equipments shall have to be made close to the main exit gate of the Depots.

XIV. 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.

Moreover, the shed and buildings shall be suitable for installation of solar system in future.

XV. 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.

XVI. Requirement of buildings, major plants and machinery, is given in Annexure I and II for Kadugodi Depot:

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

a) Access to the under-carriages to be interlocked with 3rd rail supply system so that inspection of under carriage is possible only when Supply is isolated and grounded.
b) Installation of red flashers lights along the inspection lines at conspicuous location to indicate the 3rd rail supply is 'Live'.
c) In heavy repair bay inbuilt arrangement for multi level wheel stacking and TM stacking.
d) Power sockets shall be provided on pillars in the inspection bay & workshop.
e) At cleaning area power supply and its isolation shall be interlinked for safety reasons.
f) The roof inspection platform shall have at least two doors to facilitate staff to go up the roof for cleaning of roof. Suitable safety interlock shall be provided to power supply.
g) Control Centre, PPIO & store Depot must be located close to Workshop.
h) The door width of repair section shall be 2 meters to enable free passage of equipment through them.
i) Provision of water hydrants shall be available in workshops and stabling yards.
j) Water supply shall be provided in all the buildings for cleaning.
k) Provision of natural ventilation shall be made for both inspection and workshop shed.

Table 7.9 List of Buildings at upcoming Depot at Kadugodi to be planned.			
Sl. No.	**Name of Building**	**Size**	**Brief Function**
1.	Inspection Shed	160 x 40 m	Servicing of Cars for 15 days & 45 days inspection.
	Workshop	160 X 63 m	Repair of overhauling of Rolling Stock
	Associated sections	160 x 8m	Rooms for carrying out the inspection & workshop activity.
	Pit Wheel lathe building	40 x 20m	For installation of PWL
2.	Stores Depot & offices including goods platform with ramp	40 x 40m	Stocking of spares for regular & emergency requirement including consumable items. This store caters for the requirement of Depot for rolling stock & other disciplines. To be provided with computerized inventory control. Loading/unloading of material received by road.
3.	Elect. Sub-station DG set room	25 x 22 m	To cater for normal and emergency power supply for Depot, workshop, service and all other ancillary buildings, essential power supply essential loads and security light.
4.	Traction repair Depot and E&M repair shop	80 x 30m	Stabling and routine maintenance of shunting engine etc. & traction maintenance Depot. For maintenance of lifts/escalators and other General service works.
5.	Cycle / Scooter / Car Parking	60 x 6 m x 6 m 40 x 10 m	Close to the Depot entry. Close to the stabling lines. Close to the repair bay.
6.	(i) Auto coach washing plant (ii) Space for AWP control room	40 x 10m 20 x 10	For automatic washing of coaches and its proper drainage.
7.	Interior cleaning and washing.	130 x 6.5m	Heavy wet washing of rakes from inside, under frame, roof at 30 days interval.
8.	P. way office, store & Workshop including Welding plant	80 x 20m	For track maintenance of section and Depot. To weld rails for construction period only. To stable track Tamping machine.
9.	Security office & time office garages (4 Nos.)	15 x 8m	For security personnel. For time punching. For parking vehicle jeep, truck etc.
10.	Check post (2 Nos.)	5 x 3m	For security check of incoming/outgoing staff, material and coaches.
11.	Watch tower (3 Nos.)	3.5 x 2.5m	For security of the Depot especially during night time.
12.	Depot control 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.	Storage of water, capacity 1, 00,000 Ltrs each.

Table 7.9 List of Buildings at upcoming Depot at Kadugodi to be planned.			
Sl. No.	**Name of Building**	**Size**	**Brief Function**
		Capacity	
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 33 KV/750 VDC	15m x 10m	For Storage of paints, inflammables & Lubricants
16.	Traction 33kV sub station	15m x 10m	Traction Power Supply
17.	Waste Collection Bin	10m x 10m	Garbage dumping
18.	Work shop Manager Office	30 x 20m	Office of Depot in charge
19.	ATP & ATO Room	10 x 8m	To keep equipments of ATP/ATO
20.	Waste Water Treatment Plant	12 x 6m	For treating the discharge waters from Depot and remove the oil, acids etc. before discharging into the river, with U/G tank.
21.	Canteen	400 Sqm.	Canteen to cater staff of Depot and workshop staff shall be in a separate building with modern kitchen ware and facilities. Obligatory as per statuary requirements
22.	Toilets (Gents & Ladies)	10 x 7m 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.

Table 7.10 List of Plants &Equipment at upcoming Depot at Kadugodi	
Sl. No.	**Equipment**
1	Under floor Pit wheel lathe, Chip crusher and conveyor Electric tractor.
2	Mobile jacks 15T for lifting cars
3	Pit jacks (complete set on one line)
4	Run through type Automatic Washing plant for Metro cars.
5	Bogie Test Stand
6	Bogie wash Plant
7	Wheel mounting and demounting press
8	CNC vertical Turret Lathe
9	CNC Axle Journal Turning and burnishing lathe

Table 7.10 List of Plants &Equipment at upcoming Depot at Kadugodi	
Sl. No.	**Equipment**
10	Road cum Rail vehicle with re-railing equipment
11	Battery powered locomotive
12	Synchronized double acting high tonnage hydraulic jack of 200 ton capacity with power pack.
13	Truck mounted hydraulic platform for inspection of viaduct.
14	Savage and cleaning machine
15	Work lift platform
16	Electric bogie tractor for pulling cars and bogies inside workshop
17	Compressor for Inspection shed & shop air supply
18	Travelling O/H crane repair-shop 15 T:- 2 Nos; 3 T :- 2 Nos
19	Mobile jib crane
20	Mobile lifting table
21	Bogie turn tables
22	Under frame & Bogie blowing plant
23	AC filter cleaning machine
24	High-pressure washing pump for front and rear end cleaning of car
25	Industrial furniture
26	Minor equipment and collective tools
27	EMU battery charger
28	Welding equipments (Mobile welding, oxyacetylene, fixed arc welding)
29	Electric and pneumatic tools
30	Measuring and testing equipment
31	Tool kits
32	Mobile safety steps
33	Fork lift tractor

Table 7.10 List of Plants &Equipment at upcoming Depot at Kadugodi	
Sl. No.	**Equipment**
34	Pallet trucks
35	Road vehicles (pickup van/ truck)
36	Miscellaneous office equipments
37	Special jigs and fixtures and test benches for Rolling Stock
38	Aerial work lift platform

Figure 7.1 - Biayappanahalli Depot

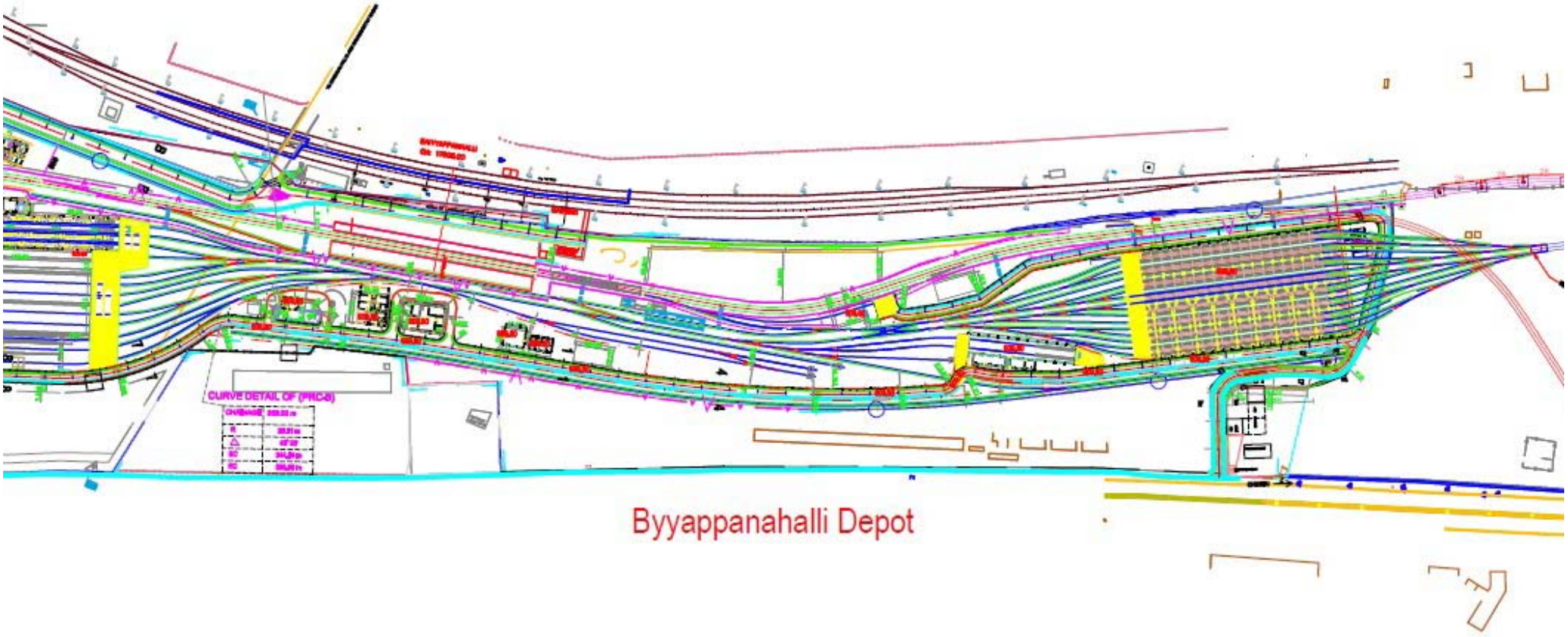


Figure 7.2 Whitefield Depot

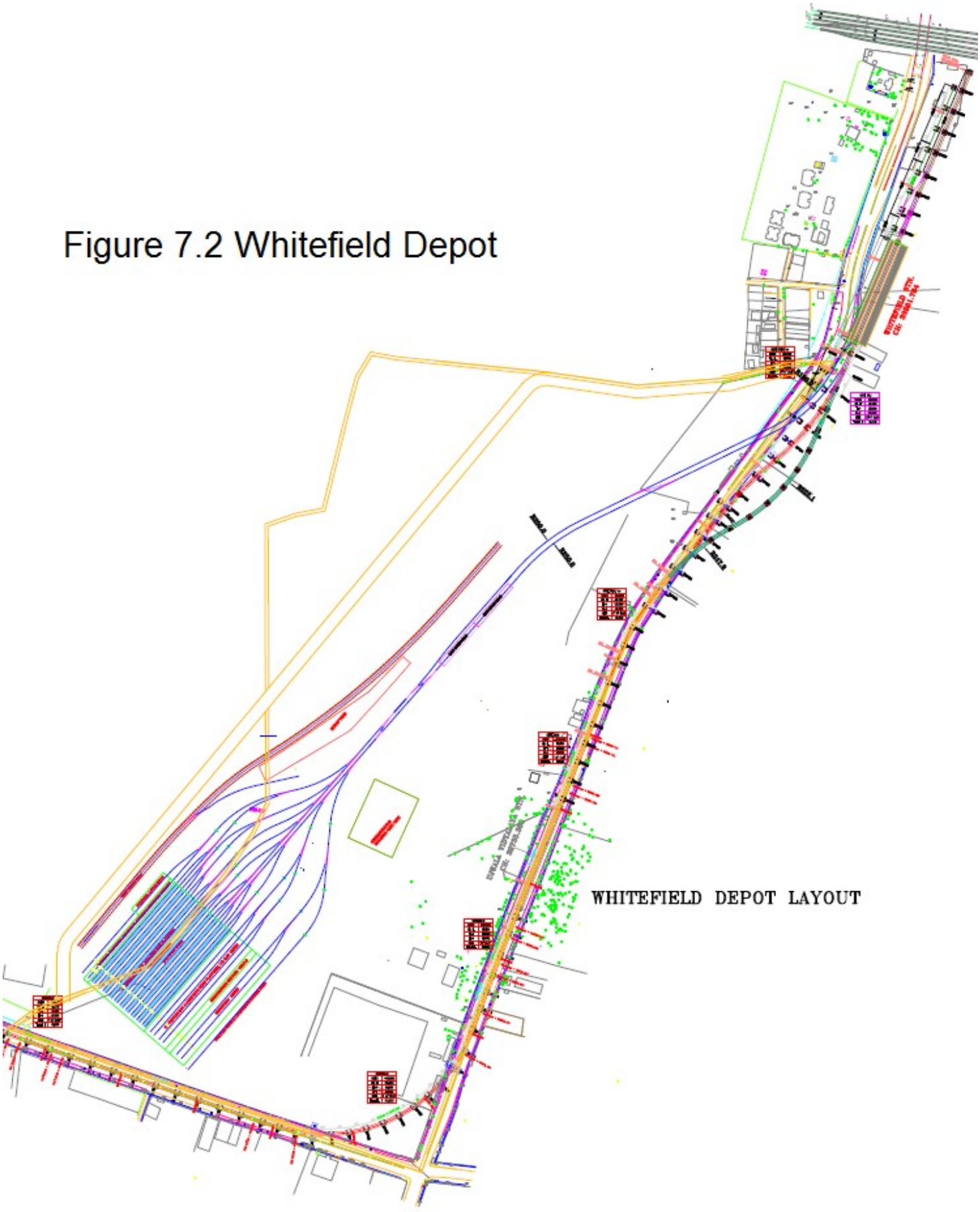
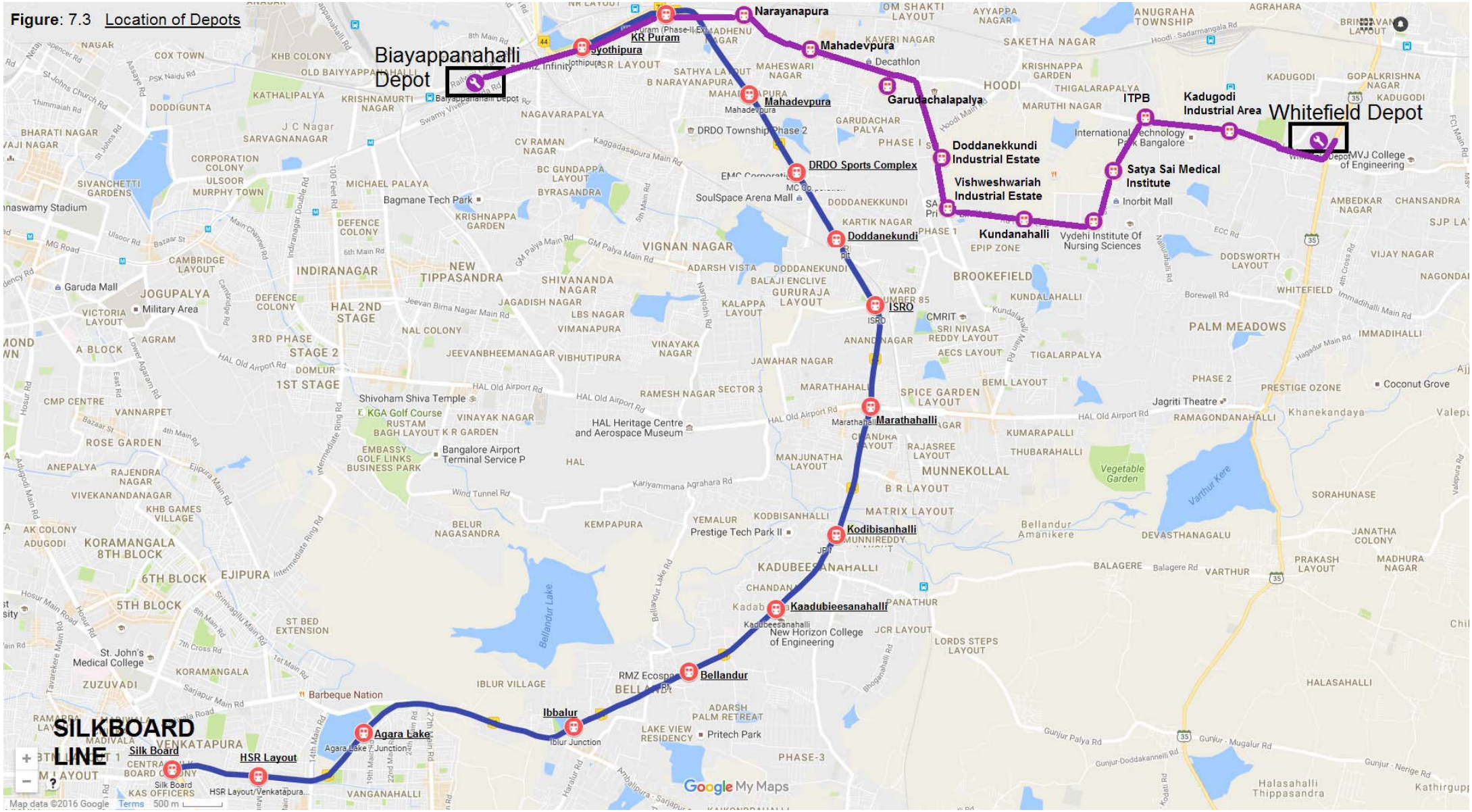


Figure: 7.3 Location of Depots



8 POWER SUPPLY, SYSTEM OF TRACTION AND POWER TARIFF

8.1 BACKGROUND

The traction system for Bangalore Metro is already selected as 750 V DC third rail bottom current collection system. This line is a spread out of R V Road to Bommasandra and Baiyappanahalli to Whitefield line therefore the same traction system i.e. 750 V DC third rail bottom current collection system is proposed.

Accordingly power supply arrangement and approach philosophy for traction and auxiliary is detailed in the following paras:-

8.2 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, 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 the traction requirement for elevated section.

8.2.1 Power Demand Estimation

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

i. Specific energy consumption of rolling stock – 75KWh/1000 GTKM
ii. Regeneration by rolling stock for 750V DC traction – 20%
iii. Elevated station load – initially (2021) 200 kW, which will increase to 500 kW in the year 2041
iv. Depot auxiliary load – initially 1000 kW in the year 2021, which will increase to 1350 kW in the year 2041.

Keeping in view of the Train Operation Plan and demand of auxiliary and traction power, power requirement for Silk Board Junction to K R Puram has been worked out for the year 2021, 2031 and 2041 which is summarized in Table 8.1:

Table 8.1 Power Demand Estimation (MVA)				
Corridor		Year		
		2021	2031	2041
Silk Board Junction to K R Puram	Traction	12.98	16.75	20.24
	Auxiliary	3.21	4.82	6.42
	Total	16.19	21.57	26.66

The detailed calculations of Power Requirements are given at Table 8.1.

8.2.2 Need for High Reliability of Power Supply

The proposed line from Silk Board Junction to K R Puram of Bangalore metro system is being designed to handle about 36,226 passengers per direction during peak hours when trains are expected to run at about 2.5 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.

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

8.2.3 Source of power Supply

The high voltage power supply network of Bangalore city was studied in brief. The city has got 220 kV and 66 kV network to cater to the various types of demand. 220 kV sub-stations are generally located at outskirts of the city. 66 kV sub-stations are located near to the alignment. It is proposed to avail power supply for traction as well as auxiliary services at 66 kV voltage levels through single circuit cable feeder.

Electric Power requirement for this line is likely to be 16.19 MVA approximately in year 2021 and which is likely to increase to 26.66 MVA by the year 2041.

Under normal conditions, this power will be supplied by the RSS at Silk Board Junction. 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 Silk Board Junction RSS, power requirement will be provided by RSS at K R Puram/Baiyappanahalli.

The transformers capacity of 25 MVA 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 8.2 Sources of Power Supply		
Corridor/Line	KPTCL Grid sub-station (GSS) (Input source)	Location of RSS of Metro Authority
Silk Board Junction to K R Puram	HSR Layout (220/66 kV) NIMHANS (220/66 kV) Jayadeva (66 kV) St. Johns (66 kV) Adugodi (66 kV) Koramangala(66 kV)	Silk Board Junction
	Hoody (220/66 kV) HAL (220/66 kV) ITI (66 kV) Bagmane WTC (66 kV)	K R Puram/ Baiyappanahalli

At the stage of detailed design and engineering, the 66 kV input sources from KPTCL GSS may be suitably chosen in consultation and agreement with KPTCL. RSS layout and power supply arrangement proposed is similar to Phase I RSSs.

The summary of expected power demand from receiving sub-stations is given in Table 8.3:

Table 8.3 Power Demand							
Corridor	RSS	Peak demand – Normal (MVA)			Peak demand – Emergency (MVA)		
		Year (2021)	Year (2031)	Year (2041)	Year (2021)	Year (2031)	Year (2041)
Silk Board Junction to K R Puram	RSS at Silk Board Junction	9.7	12.94	16.0	16.19	21.57	26.66
	RSS at K R Puram	6.49	8.63	10.66	16.19	21.57	26.66

Normal (MVA) – Both the RSS are sharing the loads

Emergency (MVA) – Only one RSS in service

The 66 kV power supply will be stepped down to 33 kV level at the above RSSs of metro authority. The 33 kV power supply drawn from the RSS will be distributed along the alignment through 33 kV Ring main cable network for feeding to traction as well as auxiliary loads. These cables will be laid in dedicated ducts/hangers/brackets along the viaduct. Interconnection of 33 kV power supply between the corridors i.e, Reach 5 & Reach 1 Extension has been planned at Silk Board Junction and K R Puram Station respectively, 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 66 kV cables will be single core XLPE insulated with 630 sq.mm copper conductor. The cables shall be laid through public pathways to RSSs of Metro Authority. Both the RSS shall be provided with 2 nos. (1 as standby) 66/33 kV, 3 phase main receiving transformers for feeding to traction as well as auxiliary loads. In the normal condition both the RSS shall be sharing the loads i.e., feeding half of the section. In case of failure/interruption of power supply to any one of the RSS, the other RSS shall feed the entire line.

Conventional outdoor type 66 kV switchgear is proposed for RSS 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. However, requirement and feasibility of GIS can be assessed at detailed design and engineering stage. The typical RSS layout as being used in Phase-1may be followed.

8.3 DESIGN CRITERIA FOR POWER SUPPLY AND TRACTION SYSTEM:

Train Operation Plan envisages running of trains is 6 cars with 4 mins headway for year 2021, 3 mins in 2031 and 2.5 mins to year 2041.

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 2031 & 2041, the power supply system will need slight augmentation by way of adding traction transformer-rectifier sets.

8.3.1 Train Operation Plan

Train operation plan considered:

Table 8.4 Train Operation Plan

Year	Peak Headway in mins	Train configuration#	No. of trains in service during peak hours	No. of train trips per direction per day
2021	4	6 car	17	220
2031	3	6 car	22	315
2041	2.5	6 car	27	404

DMC - TC - MC + MC – TC – DMC

8.3.2 Traction Sub-stations (33 kV/750 V DC)

Traction sub-stations (33 kV/750 V DC) are required to be set up for feeding 750 V DC power supply to the third rail. In order to cater to traction load as per design criteria, it is envisaged to provide traction sub-stations (TSS) at alternate stations and also at terminal station which is to be determined by simulation studies as well. The requirement comes to 10 TSSs for proposed line as shown in the power supply schematic drawing attached as Figure 8.1. The TSS along with Auxiliary Sub-Stations (ASS) will be located at station building itself at concourse level inside a room. Self-cooled, cast resin dry type rectifier-transformer is proposed, which is suitable for indoor application. From the traction sub-stations, 750 V DC cables will be laid upto third rail and return current cables will be connected to running rails.

8.3.3 Rating of Major Equipment

Based on emergency demand expected at each RSS as shown in Table 8.3, 2 nos. 66/33 kV main receiving transformers of 2 x 25 MVA capacity at Silk Board Junction, one to be in service and second one to serve as standby. The RSS to be located at K R Puram/Baiyappanahalli end will be provided 2 x 25 MVA with a provision for future with 1 x 25 MVA to cater further extension. The 66 kV cable shall be 3-phase single core XLPE insulated with 630 mm2 Copper conductor to meet the normal & emergency loading requirements and fault level of the 66 kV supply.

Traction transformer-rectifier set (33 kV/750 V DC) shall be of 2.8 MW rated continuous capacity with overload requirement of 150% for 3 hours and 300% for 1 minute. The traction transformer - rectifier set shall produce 750 V DC nominal output voltage with 12-pulse rectification so as to minimize the ripple content in the output dc voltage. During detailed design and engineering stage, feasibility of using 24 pulse rectifier/reversible TSS can also be explored. All the connected equipment of traction i.e., 33 kV switchgear, rectifier transformer, bus duct, rectifier, HSCB, negative return panel, DC cables, third rail etc., shall comply with the overload duty cycle 100% continuous, 150% for 3 hours and 300% for 1 minute all in sequential.

The IEC 60850:2000-08 (Railway applications – Supply voltages of traction systems) envisages the maximum and minimum voltages for 750 V DC system with regenerative braking is as under:

Table 8.5 Lowest, Nominal and Permanent Voltage

Lowest permanent voltage	Nominal voltage	Highest permanent voltage	Highest non-permanent voltage
Umin1	Un	Umax1	Umax2
V	V	V	V
500	750	900	1000

DC equipment shall be capable of giving desired performance in above mentioned voltage range.

33 kV cable network shall be adequately rated to transfer requisite power during normal as well as emergency situations and to meet the fault current requirement of the system. Accordingly, proposed 33kV cables sizes are as under:-

- 3 core x 400 mm2 copper from RSS to 33 kV cable network (nearest ASS/TSS)
- 3 core x 300/240 mm2 copper for 33 kV ring main cable network.

Entire 33 kV cables shall be 3 phase, XLPE insulated with copper conductors. Cables shall be of FRLS (Fire Retardant Low Smoke)/ FRLSOH (Fire Retardant Low Smoke Zero Halogen) as section envisaged is elevated.

Adequate number of cables are required for transfer of power from TSS to third rail. Single phase XLPE insulated cables with 300 mm2 copper conductor are proposed for 750 V DC as well as return current circuit. Positive cables shall be of 3.3 kV insulation class and negative/return cables of

minimum 1.1 kV insulation class. Based on current requirements, 4 x 1C x 300 mm2 cables are required for each of the four runs to feed power to third rail and accordingly 6 x 1C x 300 mm2 cables for each track for return circuit.

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.

8.3.4 Third RAIL AND STINGER SYSTEM

Third rail with bottom collection system with shroud on top and sides is proposed considering the safety, which is also the prevailing arrangement in Phase - 1 4500 A rating conductor rail is proposed and the manufacturing process can be co-extrusion, mechanically embossed, mechanically welded etc., which complies with the required contact resistance between aluminum & stainless steel and with proven record.

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

8.4 AUXILIARY SUPPLY ARRANGEMENTS FOR STATIONS & DEPOT

Auxiliary sub-stations (ASS) are envisaged to be provided at each station. A separate ASS is required at Whitefield depot. The ASS will be located at mezzanine/concourse 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 kVA for elevated, accordingly two dry type cast resin transformers (33/0.415 kV) of 500 kVA for elevated stations (with one transformer as standby) are proposed to be installed. The Depot ASSs will also be provided with 2 x 1500 kVA auxiliary transformers.

8.5 STANDBY DIESEL GENERATOR (DG) SETS

In the unlikely event of simultaneous tripping of two RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is, therefore, proposed to provide standby DG set of 180 kVA capacity at elevated stations to cater the following essential services:

I. Lift operation
II. Essential lighting at Stations and on viaduct on account of emergency evacuation
III. Ventilation requirements of stations
IV. Signaling & telecommunications
V. Fire fighting system
VI. (vi) Platform screen gates (PSG)

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

8.6 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical 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, inter-tripping and monitoring of the entire power supply system consisting of 66/33 kV ac switchgear, transformers, 750 V DC switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system.

8.7 EMERGENCY TRIP SYSTEM (ETS)

Emergency Trip System (ETS) shall be provided at platform ends, station control room TSS in accordance with the requirements of NFPA-130. ETS can be operated by passengers and metro staff in case of emergency situations to disconnect the power supply to the train(s). Operation of ETS push button will result in tripping of relevant section of third rail in order to stop the trains in that section. An interlock to be incorporated with the signaling system to block the train(s) entering the station/section of the ETS pressed. ETS cable shall be fire rated for one hour at 5000 C.

ETS cabinet housing shall be constructed of steel, painted with international orange, with the Blue light on the facia and red mushroom-shaped heavy duty push button capable of being padlocked in a locked position when pressed, can only be reset by a master key. The tripping logics are to be hardwired and locally functional i.e., not through SCADA.

8.8 STRAY CURRENT CORROSION PROTECTION MEASURES

8.8.1 Concept of dc Stray Current Corrosion

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

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

The dc stray currents cause metal detraction in watery (aqueous) electrolytes as per the following chemical reactions:-

- Stray current enters in the metal

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \text{ (development of Hydrogen gas)}$$

- Stray current exits from metal

$$Fe \rightarrow Fe^{2+} + 2e^- \text{ (} Fe^{2+} \text{ ions migrate away from the metal)}$$

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.

8.8.2 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.

8.8.3 Measures for Protection against Stray Current Corrosion

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

Following measures are required to restrict the stay current:-

I. Decreasing the resistance of rail-return circuit – by usage of low resistance rails, long welded rails, suitably cross-bonding between rails and tracks, running insulated parallel conductors etc.,

II. Increasing the resistance of rail to ground insulation – by providing suitable fastening system for DC railway

Whenever buried pipes and cables are in the vicinity of DC railway, efforts shall be made to ensure that metal parts are kept away as far as practicable to restrict stray current by means of isolation and insulation.

Generally, 3 types of earthing arrangements (viz. Earthed System, Floating System & Hybrid Earthing System) are prevalent on metros 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 - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock
- EN 50122-2:- Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by d.c. traction systems

The conceptual scheme of proposed floating system is described below:-

I. The running rails shall be adequately insulated as per EN50122-2.The worst conductance per unit length for single track sections are as under:- Elevated section: 0.5 Siemens/km

II. Stray Current Collector Cables {commonly known as structural earth (SE) cable} of suitable size (calculated in accordance with EN 50122-2) shall be provided along the viaduct and all the metallic parts of equipment, cable sheath, viaduct reinforcement, signal post etc. shall be connected to SE cable.

III. The longitudinal continuity of the reinforcement bars of the viaduct as well as track slabs has to be ensured along with a tapping point for connection with SE cable in order to drain back the stray current.

IV. A provision shall be made to earth the running rail (i.e. negative bus) in case of rail potential being higher than limits prescribed in relevant standard (EN 50122-1) in order to ensure safety of personnel. This will be achieved by providing track earthing panel (TEP)/over voltage protection device (OVPD) in all stations irrespective of ASS or ASS/TSS.

V. Provisions shall be made on the structures for measurement of average potential shift +200 mV for steel in concrete structures.

VI. In addition, stray current assessment by continuous monitoring rail insulation assessment using rail potential in accordance with EN 50122-2 to be installed in OCC for monitoring of the rail potential supports the supervision of the continuity of the return circuit, detects connections between the return circuit and earth and degradation of insulation in rail fastenings.

I. Measurements recommended in EN 50122-2 to be practiced to ensure the stray currents are not deteriorating the metro railway structures and public structures/utilities as well.

8.8.4 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 disconnection/sectionalizing switches shall be provided to feed power from depot to mainline and vice-versa in case of failure of depot TSS and nearest mainline TSS.

The prescribed limit of highest touch potential in depot is 60V as per EN 50122-1 and therefore Track Earthing Panels (TEP)/Over Voltage Protection Device (OVPD) shall be provided at suitable locations to earth the rail in case the rail potential exceeds this limit.

8.9 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

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

8.10 ENERGY SAVING MEASURES

Energy charges of any metro system constitute a substantial portion of operation & maintenance (O & M) costs. Therefore, it becomes imperative to incorporate energy saving measures in the system design itself. The 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. Therefore, suitable system for recuperation of braking energy to be considered during detailed design and engineering stage.

II. Rolling stock has regeneration features and it is expected that 20% of total traction energy will be regenerated and fed back to 750 V DC third rail to be consumed by nearby trains.

III. Use of energy efficient LED lights and fittings is proposed. 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.

VIII. Solar panels to harvest the solar energy available on the station roofs, depot, parking and top of the buildings

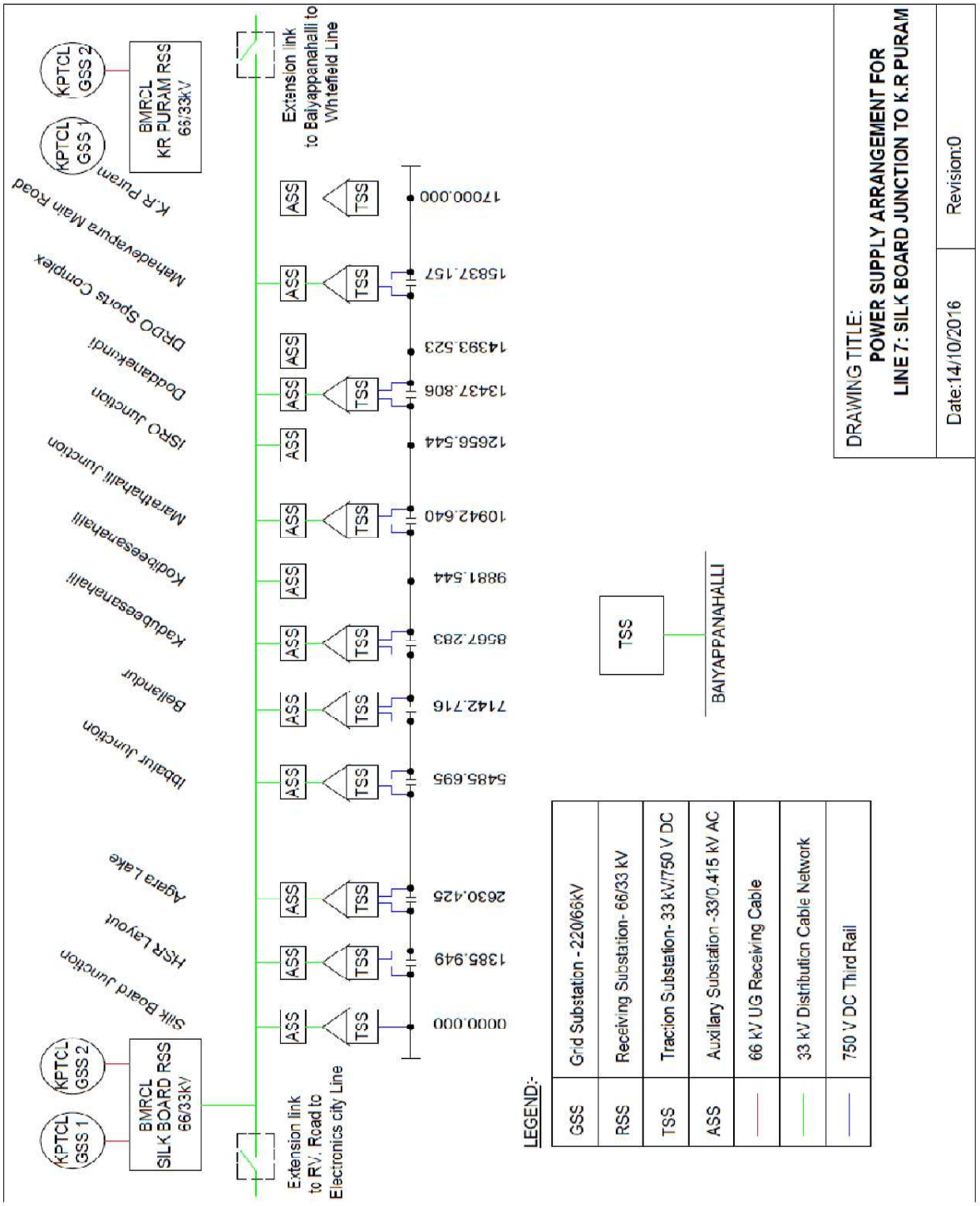
8.11 ELECTRIC POWER TARIFF

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of a metro system and it is expected to constitute about 20-30% of total annual operating cost. Therefore, it is the key element for the financial viability of the Project. The annual energy consumption is assessed to be about 67.7 million units in initial years (2021), which will reach 126.9 million units by horizon year 2041. The detailed calculations of Power Requirements are given at Table 8.2. In addition to keep the energy consumption to optimum, it is also necessary that the electric power tariff be kept at minimum in order to contain the O& M costs. Therefore, the power tariff for 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 adopted in other Metros in India.

Table 8.6 POWER REQUIREMENTS						
Traction power requirements		Year 2021		Year 2031		Year 2041
No of cars	6	(2DMC+2TC +2MC)	6	(2DMC+2TC+ 2MC)	6	(2DMC+2TC +2MC)
Tare weight of train	222	T	222	T	222	T
Passenger weight	130	T	130	T	130	T
Total Train weight	352	T	352	T	352	T
Length (Route km)	17	km	17	km	17	km
Headway (during peak hours)	4	mts	3	mts	2.5	mts
Specific Energy Consumption (SEC)	75	KWhr/1000 GTkm	75	KWhr/1000 GTkm	75	KWhr/1000 GTkm
Power demand from one train set	0.79	MW	0.79	MW	0.79	MW
No. of train sets in opeartion during peak hour	17	Train sets	22	Train sets	27	Train sets
Total traction demand	13.43	MW	17.38	MW	21.33	MW
Less Regeneration @20%	2.69	MW	3.48	MW	4.27	MW
Depot traction power requirement	1.0	MW	1.25	MW	1.25	MW
Net traction power requirement	11.74	MW	15.15	MW	18.31	MW
Total traction power requirement (MVA) assuming 5% energy losses and .95 pf for traction loads.	12.98	MVA	16.75	MVA	20.24	MVA
Station auxiliary power requirement						
Elevated station load	0.20	MW	0.30	MW	0.40	MW
No. of elevated stations	13		13		13	
Total auxiliary power requirement	2.6	MW	3.9	MW	5.2	MW
Depot auxiliary power requirement	0.0	MW	0.0	MW	0.00	MW
Total auxiliary power requirement	2.6	MW	3.9	MW	5.2	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for auxiliary loads.	3.21	MVA	4.82	MVA	6.42	MVA
Total traction & aux power requirement (MW)	14.34	MW	19.05	MW	23.51	MW
Total power requirement (MVA) assuming 5% energy losses and .95 & .85 pf for traction & aux loads respectively	16.19	MVA	21.57	MVA	26.66	MVA
Note:-						
Property Development (PD) requirement not considering in estimation of power calculation.						
Depot auxiliary load has been considered 0 MW, as already Depot ASS exists in Baiyappanahalli						
Depot TSS has been considered for feeding the section from Baiyappanahalli Depot to K R Puram						

Table 8.7 ENERGY CONSUMPTION						
Year	**Year 2021**		**Year 2031**		**Year 2041**	
No of cars	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)	6	(2DMC+2TC+2MC)
Length (Route km)	17	KM	17	KM	17	KM
No. of trains per direction in a day*	220		320		408	
Weight of train and passenger	352	T	352	T	352	T
SEC (net) with 20% regen	60	KWH/1000 GTKM	60	KWH/1000 GTKM	60	KWH/1000 GTKM
Yearly traction energy consumption with 365 days working with 20% regen	57.70	million units	83.93	million units	106.94	million units
Station aux power requirement						
Elevated	0.20	MW	0.30	MW	0.40	MW
No. of elevated stations	13		13		13	
Depot auxiliary power requirement	0	MW	0	MW	0	MW
Total auxiliary power requirement	2.6	MW	3.9	MW	5.2	MW
Total auxiliary power requirement (MVA) assuming 5% energy losses and .85 pf for aux loads	3.2	MVA	4.8	MVA	6.4	MVA
Diversity factor of auxiliary loads	0.5		0.5		0.5	
Yearly auxiliary energy consumption 20 hrs/day and 365 days working (million units)	9.96	million units	14.95	million units	19.93	million units
Net Annual Energy Consumption (Traction & Auxiliary)	67.7	million units	98.9	million units	126.9	million units
Note:-						
PD energy not considering in estimation of energy calculation.						

Figure 8.1 Power Supply Arrangements



9 ROLLING STOCK

9.1 BACKGROUND

KR Puram to Silk board section (Line no.7) is to be operated with CBTC signaling system and with the existing Schedule of Dimension (SOD) so that with changes in onboard signaling, coaches can be interchanged in other reaches/sections with 750 V DC systems as per the requirements.

However, the governing factor for deciding the requirements of coaches, forecasted Peak Hour Peak Direction Traffic (PHPDT) of this line was taken into consideration.

To facilitate the ease in operation, the present Baiyappanahalli depot is planned to cater the maintenance requirement of the new line 7 and in place of Baiyappanahalli depot a new depot is planned to be constructed at Whitefield for East-West Corridor. In addition, a major depot at Challagatta in west end of East-west corridor is under construction and new depot at Kadugodi in Phase-II which can cater for maintenance of Rakes together for the year 2041.

Salient features of Coach Dimension & performance parameters have been described in the following para:-

9.2 SIZE OF COACH

Since the maintenance of the rake of line 7 will be done at baiyappanahalli depot which has already been constructed in compliance to the schedule of dimensions, it is proposed to adopt the schedule of dimension of line 7 is same as schedule of dimension of line 1. As such the dimensions of the coach of line 7 shall be same as dimensions of the coach of phase 1 Rolling Stock.

Accordingly optimum size of the coach, as opted for Line 7 has been chosen for this corridor as mentioned in Table 9.1.

Table 9.1 - Size of the coach

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

* Over the body excluding coupler length.

9.3 PASSENGER CARRYING CAPACITY

In order to maximize the passenger carrying capacity, longitudinal seating arrangement shall be adopted. The whole train shall be vestibule to distribute the passenger evenly in all the coaches. Criteria for the calculation of standing passengers are 4 persons per square meter of standing floor area in normal state (AW2) and crush load 6 persons standee per sq meter (AW3) and exceptional dense crush load of 8 persons/sq meter (AW4).

Therefore, for the Rail Vehicles with 2.88 m maximum width and longitudinal seat arrangement, conceptually the exceptional dense crush capacity (AW4) of 43 seated, 273 standing thus a total of 316 passengers for a Driving Motor Car, and 50 seated, 293 standing thus a total of 343 for a trailer and motor car is envisaged.

Following train composition is recommended:

6-car Train: *DMC–TC–MC+MC–TC–DMC*

This train composition has been adopted in Phase II for 6-Car train composition. Also this composition is used in DMRC RS10 project. Thus for line 7, it is recommended to adopt the above composition only.

Table 9.2 and 9.3 shows the carrying capacity of the individual cars and 6-Car train set with standing passenger @ 4 passenger per sq meter of standee area, with standing passenger @ 6 passenger per sq meter of standee area and @ 8 passenger per sq meter of standee area respectively.

The seating and Standee capacity of DMC, MC and TC in the unit of "*DMC–TC–MC+MC–TC–DMC*" with external sliding door are given as under Table 9.2:-

Table 9.2 Carrying Capacity of Mass Rail Vehicles (Crush@6 P/sqm of standee area)

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	204	147	220	862	1288
Total	180	247	197	270	1148	1574

NORMAL (AW2) -4 P/sqm of standee area

CRUSH (AW3) -6 P/sqm of standee area

Table 9.3 Carrying Capacity of Mass Rail Vehicles (Exceptional dense Crush @8 P/sqm of standee area)

	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	273	147	293	862	1718
Total	180	316	197	343	1148	2004

NORMAL (AW2) - 4 P/sqm of standee area

EXCEPTIONAL DENSE CRUSH (AW4) - 8 P/sqm of standee area

Based on the experience of Phase I after commissioning of East-West Corridor, it is recommended to adopt AW3 Passenger loading (1574 passengers in 6 car) for calculation of the passenger carrying capacity to meet the projected maximum PHPDT. Whereas, in emergency it shall be possible to carry the passenger under AW4 loading condition. However, axle load is to be calculated under AW4 loading condition.

9.4 WEIGHT

The weights of driving motor car, motor car and trailer car have been estimated as in Table 9.4, referring to the experiences in BMRCL Phase I Project. The average passenger weight has been taken as 65 kg.

Table 9.4 - Weight of Mass Rail Vehicles (TONNES)

	DMC	TC	MC	6 Car train
TARE (maximum)	38.00	36.00	37.00	222.00
Passenger				
(Normal)	11.70	12.80	12.80	74.60
(Crush @6p/sqm)	16.05	17.55	17.55	102.30
(Exceptional Dense Crush @8p/sqm)	20.54	22.29	22.29	130.24
Gross				
(Normal)	49.70	48.80	49.8	296.60
(Crush @6p/sqm)	54.05	53.55	54.55	324.30
(Exceptional Dense Crush @8p/sqm)	58.54	58.29	59.29	352.24
Axle Load @6 p/sqm	13.51	13.39	13.64	
Axle Load @8 p/sqm	14.63	14.57	14.82	

The axle load @ 6p/sqm (AW3) of standing area works out in the range of 13.39 T to 13.64 T. Heavy rush of passenger, having 8 standees per sq. meter (AW4) can be experienced occasionally. It is advisable to design the coach with sufficient strength so that even with this overload, the design will not result in over stresses in the coach. Coach and bogie should, therefore, be designed for 15 T axle load. Hence it is recommended to procure Rolling Stock for new Line 7 with maximum axle load of 15 T only.

9.5 PERRFORMANCE PARAMETERS

The recommended performance parameters are:

I. Maximum Design Speed : 90 Kmph
II. Maximum Operating Speed : 80 Kmph

9.5.1 Traction Performance

I. Average acceleration rate from 0 to 30 km/h : 1 m/s² ± 5%
II. Jerk : 0.7 m/s3 ± 0.05

9.5.2 Brake Performances

I. Average service deceleration from 80 to 0 km/h : 0.95 m/s² ± 5%
II. Instantaneous full service deceleration : 1.1 m/s²
III. Maximum jerk (dγ/dt) : 0.7 m/s3 ± 0.05
IV. Minimum average emergency deceleration : 1.3 m/s²

9.5.3 Speed vs. Time curve

Torque vs. Speed characteristics.

Constant torque zone in powering is recommended up to a speed of 30 Kmph. Constant torque zone in braking is recommended up to a speed of 60 Kmph to maximize the regenerated energy.

9.6 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.

9.7 SELECTION OF TECHNOLOGY

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 technologies has been recommended to ensure low life cycle cost.

9.7.1 Car body

It is now a standard practice to adopt stainless steel or aluminum for car body. However, the car bodies with aluminum require long and complex extruded sections which are still not manufactured in India. Therefore aluminum car body has not been considered for use. With the improvement in Steel manufacturing technology, now it is possible to manufacture austenitic steel with carbon percentage of 0.03% and this increases the mechanical strength and hence it is possible to manufacture light weight stainless steel car body with higher mechanical strength and therefore, high tensile austenitic stainless steel with carbon content not more than 0.03% car bodies have been specified. No corrosion repair is necessary on stainless steel cars during their service life.

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

9.7.2 Bogies

Bolster less lightweight fabricated bogies with conical rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 520,000 km. Use of air spring at secondary stage is considered with a view to keep the floor levels of the cars constant irrespective of passenger loading unlike those with coil spring. Perturbation from the track is also dampened inside the car body on account of the secondary air spring along with suitable Vertical Hydraulic Damper. The primary suspension system improves the curve running performance by reducing lateral forces through application of conical rubber spring. A smooth curving performance with better ride index is being ensured by provision of above type of bogies.

9.7.3 Brake System

The brake system shall consist of:-

Compressed air supply by an oil free piston type air compressor and air dryer unit.

An electro-pneumatic, microprocessor controlled direct service brake which performs the blending function depending on the brake demand signal and the dynamic brake performance.

I. A fail safe, pneumatic friction emergency brake.
II. A pneumatic indirect BP backup brake which is applied during rescue operation or in case of failure of direct service brake.
III. A spring applied air-release parking brake.
IV. Air applied holding brake.
V. An electric regenerative service brake.
VI. Provision of smooth and continuous blending of EP and regenerative braking

Direct service brake is blending of Electro-Pneumatic brake (EP) and Electro-Dynamic brake (ED). The electro-dynamic (ED) brake shall take priority over the electro-pneumatic friction brake (EP) and full use of its capability shall be made in attaining any rate of service braking. The objective is to use the regenerative brake to the maximum degree possible in order to reduce wear on the friction brakes.

The ED (regenerative braking) brake will be the main brake power of the train and will regenerate energy during braking and part of the regenerated energy is used by the auxiliary circuit of the train and the balanced is pumped back in to third rail system. The Electro-dynamic braking is possible because of the adoption of 3-Phase technology.

To maximize the regenerated energy, it is recommended to extend the constant torque zone in braking up to 60 Kmph. Further it is recommended to improve the logic of ED brake so that in case of failure of any driving motor car/ motor car, ED brake by the other driving motor /motor car is increased automatically by the propulsion system.

During the stopping of the train when ED brake starts fading out, the propulsion system detects the fading out of ED brake and correspondingly holding brake (EP) is applied by the brake system to ensure safety of the train in case of ED becoming zero.

In addition, speed sensors mounted on each axle, control the braking force of the axles with anti skid valves, prompting re-adhesion in case of a skid .The brake actuator shall operate either a tread brake or a wheel mounted disc brake, and preferably a wheel mounted disc brake.

In Phase I Rolling Stock, oil free piston type compressor was used to avoid the frequent need to toping of oil in the compressor. These oil free compressors have been in service in Reach-1 for more than 4 years and so far no failure case was reported. As such it is recommended to use oil free piston type compressor only.

To improve the overall reliability of brake system, it is recommended to adopt brake system with Ethernet backbone where it shall be possible to feed MR pressure in the failed train from the healthy train and also braking can be controlled from the healthy train in the failed train.

9.7.4 Propulsion System Technology

The brush less 3 phase induction motors which is lighter in weight and ideally suited for rail based Mass Rapid Transit applications is proposed to be used for this corridor. The motor tractive effort and speed is regulated by 'Variable Voltage and Variable frequency' control and can be programmed to suit the track profile and operating requirements. Another advantage of 3 phase a.c. drive and VVVF control is that regenerative braking can be introduced by lowering the frequency and the voltage to reverse the power flow and to allow braking to very low speed. Also, it is self-ventilated, highly reliable, robust construction and back up by slip/slide control, hence same have been recommended for adoption.

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

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

9.7.5 Interior and Gangways

Passenger capacity of a car is maximized in a Metro System by providing longitudinal seats for seating and utilizing the remaining space for standing passenger. Therefore all the equipments are mounted on the under frame for maximum space utilization. The gangways are designed to give a

wider comfortable standing space during peak hours along with easy and faster passenger movement especially in case of emergency. However, detailed design to be finalized at Mock-up stage.

Figure 9.1 Interior View of Metro Train

9.7.6 Passenger Doors

For swift evacuation of the passenger in short dwell period, four doors of minimum 1400mm width, on each side of the coach have been considered. These doors shall be of such dimensions and location that all the passenger inside the train is able to evacuate within least possible time without conflicting movement. As the alignment passes through elevated section above ground, automatic door closing mechanism is envisaged from consideration of passenger safety. Passenger doors are controlled electrically by a switch or Pushbutton in Driver cab. Electrically controlled door operating mechanism has been preferred over pneumatically operated door to avoid cases of air leakage and sluggish operation of doors.

The door shall be of Bi-parting Sliding Type as in the existing coaches of BMRCL.

In the present design of door leaf, top aluminium skin is bonded over aluminium honeycomb and bonding between these two materials is frequently failing and as such door swelling problems are being observed in several Rolling Stock Projects. Thus it is recommended to adopt a new door design with single material without any bonding.

Figure 9.2 Passenger Doors

9.7.7 Air–conditioning

With heavy passenger loading of 6 p/sqm for standee area and doors being closed from consideration of safety and with windows being sealed type to avoid transmission of noise, air conditioning of coaches has been considered essential. Each coach shall be provided with two air conditioning units capable of cooling, heating and dehumidifying and thus automatically controlling interior temperature throughout the passenger area at up to 25°C and relative humidity of 60%RH respectively all the times under varying ambient conditions up to full load. For emergency situations such as power failure or both AC failures etc, ventilation provision supplied from battery will be made. Provision shall be made to shut off the fresh air intake and re-circulate the internal air of the coach, during an emergency condition, such as fire outside the train causing excessive heat and smoke to be drawn in to the coach.

9.7.8 Cab Layout and Emergency Detrainment Doors.

The modern stylish driver panel shall be FRP moulded which give maximum comfort and easy accessibility of different monitoring equipments to the driver along with clear visibility .

The driver seat is recommended to be provided either in the middle or in the side of the cab.

Figure 9.3 Driving Cab

Emergency evacuation is recommended only through the side doors.

9.7.9 Communication

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

Public Address and Passenger Information Display System is provided in the car so that passengers are continuously advised of the next stoppage station, final destination station, interchange station, emergency situations if any, and other messages. Station announcement is recommended to be based on the bits provided by ATC. In case of failure of ATC announcement can be made manually. The rolling stock is recommended to be provided with Talk Back Units inside the cars, which permit conversation between passengers and the drivers in case of any emergency.

With the improvement in display technology, it is recommended to use Digital Display board on interior coving panel for advertisement as well as for station announcement.

9.7.10 Noise and Vibration

The trains will pass through heavily populated urban area .The noise and vibration for a metro railway becomes an important criterion from public acceptance view point. The source of noise are (i) rail-wheel interaction (ii) noise generated from equipment like Blower, Compressor, air conditioner, door,

Inverter etc. (iii) traction motor in running train. For elimination and reduction of noise following feature are incorporated: -

- Provision of anti drumming floor and noise absorption material.
- Sound absorbent panels to under-frame.
- Insertion of sound absorbent infill in key-ways of load key place.
- Low speed compressor, blower and air conditioner.
- Mounting of under frame equipments on anti-vibration pad.
- Smooth and gradual control of door.
- Provision of GRP baffle on the via-duct for elimination of noise transmission.
- Provision of sound absorbing material in the supply duct and return grill of air conditioner.
- Sealing design to reduce the aspiration of noise through the gap in the sliding doors and piping holes.

The lower vibration level has been achieved by provision of bolster less type bogies having secondary air spring.

9.7.11 Passenger Safety Features

I. ATP/ATO

The rolling stock is provided with Continuous Automatic Train Protection to ensure absolute safety in the train operation. It is an accepted fact that 60-70% of the accidents take place on account of human error. Adoption of this system reduces the possibility of human error. The on-board computerized ATC system compares and verifies the continuous actual driving speed of the train with the target speed displayed on Driver Machine Interface (DMI) and in case speed of the train increases beyond the specified limit, Full Service Brake (FSB) and Emergency Brake (EB) are applied by the signaling system (ATC).

In ATO mode, the manual function of the driver with respect to driving such as powering, coasting and braking is made automatic through Automatic Train Control (ATC).

The Signaling system is recommended to be “Communication Based Train Control (CBTC)” system as the current “Distance To Go (DTG)” signaling system implemented in Phase I project has become obsolete.

II. Fire

The rolling stock is provided with flame-retarded materials having low fire load, low heat release rate, low smoke and toxicity inside the cars.

Flammability, Smoke Emission and Toxicity requirements of the material used in the car is recommended to be based on EN standard EN 45545, HL3, Flammable materials shall not be used or contained. Material emitting poisonous gas during combustion will not be used.

The insulation of all wires and cables including those used within equipment / subsystem is provided with halogen-free flame-retardant and formulated to minimise generation of smoke, noxious emissions and corrosive fumes.

III. Emergency door

Each passenger saloon doors is provided with Emergency Egress device to ensure well directed evacuation of passengers in case of any emergency including fire in the train.

IV. Crash worthiness features

The driving motor car and other cars of the train shall be designed to ensure safety of the train operator in case of collision as specified in EN 15227 under the collision scenario in clause-5 of EN15227 for Load Category C-II.

The rolling stock is provided with inter car couplers with energy absorption device in the front automatic/ semi-automatic coupler.

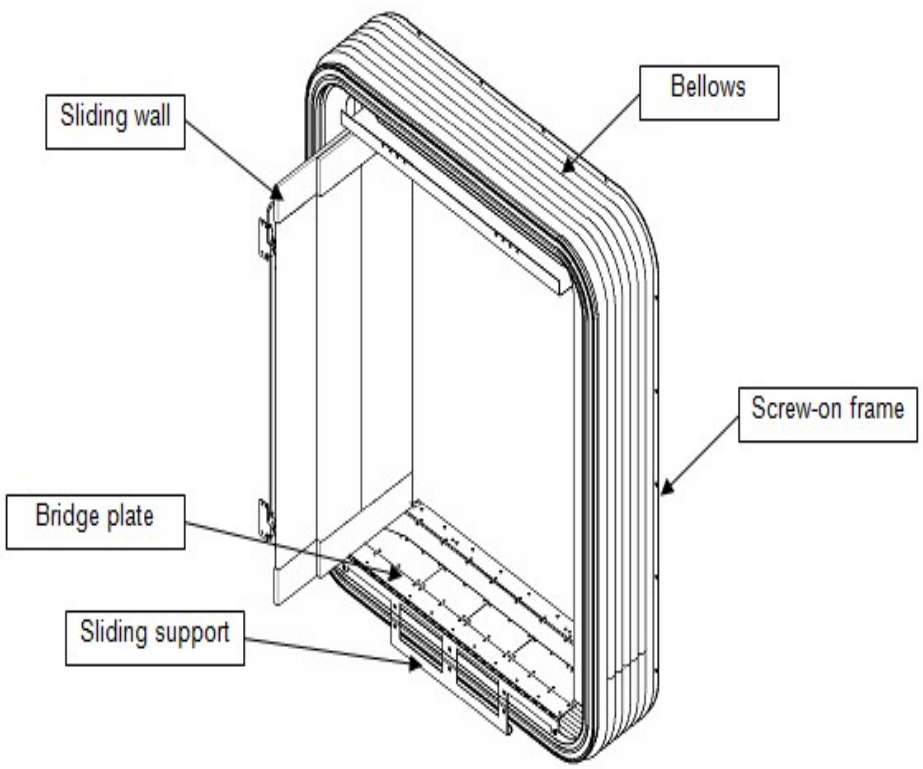
The car ends is designed to prevent over-riding and telescoping of the car in to any passenger area in the event of the collision. The anti-telescoping structure includes elements such as corner post, collision post and anti-climbers.

V. Gangways

Broad gangways with interior paneling of minimum clear height of 1900mm are provided in between the cars to ensure free passenger movement between cars in case of any emergency.

Figure 9.4 Gangway

Figure 9.5 Gangway Isometric View



The salient features of the proposed Rolling Stock is furnished in Table 9.5

Table 9.5 Salient Features of Rolling Stock for Mass Rapid Transit System		
S.No.	**Parameter**	**Details**
1	Gauge (Nominal)	1435mm
2	Traction system	
2.1	Voltage	750 V dc
2.2	Method of current collection	Third Rail Bottom Current Collection System
3	Train composition	
3.2	6 car train	*DMC-TC-MC+MC-TC-DMC*
4	Coach Body	Stainless Steel
5	Coach Dimensions	
5.1	Height	3.88 m
5.2	Width	2.88 m
5.3	Length over body (approx)	
	- Driving Motor Car (DMC)	21.05 m
	- Trailer Car (TC)	20.8 m
	- Motor Car (MC)	20.8 m

Table 9.5 Salient Features of Rolling Stock for Mass Rapid Transit System		
S.No.	**Parameter**	**Details**
5.4	Floor height	1130mm (Maximum) for unloaded vehicle, 1100mm (Minimum) for loaded vehicle.
6	Designed - Passenger Loading	
6.1	Design of Propulsion equipment	8 Passenger/ m2
6.2	Design of Mechanical systems	10 Passenger/ m2
7	Carrying capacity- @ 8 standees/sqm	
7.1	Coach carrying capacity	
	DMC	316 (seating - 43 ; standing - 273)
	TC	343 (seating - 50 ; standing - 293)
	MC	343 (seating - 50 ; standing - 293)
7.2	Maximum Train Carrying capacity	
	6 car train	2004 (seating - 286 ; standing - 1718)
8	Weight (Tonnes)	
8.1	Tare weight (maximum)	
	DMC	38
	TC	36
	MC	37
8.2	Passenger Weight in tons(@ 8 person per sqm)	@ 0.065 T per passenger
	DMC	20.54
	TC	22.29
	MC	22.29
8.3	Gross weight in tons	
	DMC	58.54
	TC	59.29
	MC	59.29
9	Axle load(T)(@ 8 persons per sqm of standee area)	Not more than 15T
		System should be designed for 15T axleload
10	Speed	
10.1	Maximum Design Speed	90 Kmph
10.2	Maximum Operating Speed	80 Kmph
11	Wheel Profile	UIC 510-2, Appendix B
12	Traction Motors Ventilation	Self
13	Average acceleration rate from 0-30 Kmph	1.0 m/sec2 ± 5%
14	Average deceleration from 80 Kmph to 0 Kmph	0.95 m/sec2 ± 5%
15	Instantaneous full service deceleration	1.1 m/sec2 (>1.3 m/sec2 during emergency)
16	Type of Bogie	Fabricated
17	Secondary Suspension springs	Air

Table 9.5 Salient Features of Rolling Stock for Mass Rapid Transit System		
S.No.	**Parameter**	**Details**
18	Brake system	(i) Compressed air supply by an oil free piston type air compressor and air dryer unit. (ii) An electro-pneumatic, microprocessor controlled direct service brake which performs the blending function depending on the brake demand signal and the dynamic brake performance. (iii) A fail safe, pneumatic friction emergency brake. (iv) A pneumatic indirect BP backup brake which is applied during rescue operation or in case of failure of direct service brake. (v) A spring applied air-release parking brake. (vi) Air applied holding brake. (vii) An electric regenerative service brake. (viii) Provision of smooth and continuous blending of EP and regenerative braking
19	Coupler	Auto Coupler in front and middle and remaining
19.1	For 6 car Train between two MC car	Automatic coupler with mechanical, electrical & pneumatic coupling
19.2	Front cab end of DMC car	Automatic coupler with mechanical & pneumatic coupling but without electrical coupling head
19.3	Between cars of same Unit	Semi-permanent couplers
20	Detrainment Door	Side doors
21	Type of Doors	External sliding
22	Passenger Seats	Stainless Steel
23	Cooling	
23.1	VVVF & APS	Self/Forced
23.2	TM	Self ventilated
24	Control System	Train line control by 110V dc signals for vital safety equipments/items and Train Management System for other control equipment monitoring
25	Traction Motors	3 phase VVVF controlled
26	Temperature Rise Limits	
26.1	Traction Motor	The temperature rise limit for the stator winding shall be the maximum temperature index of the insulation minus 70°C.
26.2	VVVF & APS	The current rating of the semiconductor shall be such that the junction temperature has the minimum thermal margin of 10°C in the worst loading conditions taking into account the extreme ambient conditions in Bangalore and surrounding.
27	HVAC	- Cooling, Heating & Humidifier (As required) - Automatic controlling of interior temperature throughout the passenger area at 25°C with 60% RH all the times under varying ambient conditions up to full load. - Cab cooling for DMC car shall be provided by saloon HVAC only.
28	PA/PIS (CCTV)	ATC based station announcement.
29	Passenger Surveillance CCTV system	CCTV with automatic IP selection.

Table 9.5 Salient Features of Rolling Stock for Mass Rapid Transit System		
S.No.	**Parameter**	**Details**
30	Battery System	Nickel Cadmium batteries with closed water loop system.
31	Type of Headlight, Flasher & Taillight	LED based
32	Saloon Illumination	Energy efficient, power LED based lights, in luminaries for saloon & gangway
33	Cubical lighting	LED based
34	Coasting	Minimum 8% coasting to achieve specified commercial speed.

10 TRAIN OPERATION PLAN

10.1 OPERATION PHILOSOPHY

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

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

10.2. STATIONS

Table 10.1 List of stations for the K.R. Puram to Silk Board

S. No	Name of Stations	Chainage (in m)	Inter - Station Distance (in m)	Remarks
	Dead End			
1	K.R Puram	17000.000	1162.843	Elevated
2	Mahadevapura	15837.157	1443.634	Elevated
3	DRDO Sports Complex	14393.523	955.717	Elevated
4	Doddanekundi	13437.806	781.262	Elevated
5	ISRO	12656.544	1713.904	Elevated
6	Marathahalli	10942.640	1061.096	Elevated
7	Kodibisanahalli	9881.544	1314.261	Elevated
8	Kadubeesanahalli	8567.283	1424.567	Elevated
9	Bellandur	7142.716	1657.021	Elevated
10	Ibbalur	5485.695	2855.270	Elevated
11	Agara Lake	2630.425	1244.476	Elevated
12	HSR Layout	1385.949	1385.949	Elevated
13	Silk Board	0000.000	0000.00	Elevated
	Dead End			

10.3 PHPDT DEMAND

Peak hour peak direction traffic (PHPDT) demand for the K R Puram to Silk Board Line for the year 2021, 2031 and 2041 for the purpose train operation planning is as under: :-

Table 10.2 : PHPDT Demand for the Year 2021,2031 & 2041

From	To	Dir 1	Dir 2	PHPDT 2021	Dir 1	Dir 2	PHPDT 2031	Dir 1	Dir 2	PHPDT 2041
K R Puram	Mahadevapura	8317	8256		9189	9405		10789	10648	
Mahadevapura	DRDO Sports Complex	11078	10965		12744	12893		14494	14347	
DRDO Sports Complex	Doddanekundi	11625	10132		13045	11495		14959	12882	
Doddanekundi	ISRO	11371	9878		12488	10933		14209	12107	
ISRO	Marathahalli	11124	10838		12818	12828		15337	15038	
Marathahalli	Kodibisanahalli	10918	10418		12510	12013		14534	14029	
Kodibisanahalli	Kadubeesanahalli	11323	11254	22054	15093	14791	29101	19397	18984	36226
Kadubeesanahalli	Bellandur	10339	10803		14403	14764		19155	19542	
Bellandur	Ibbalur	12524	13261		17541	18316		23476	24396	
Ibbalur	Agara Lake	12343	12706		17350	17804		23294	23916	
Agara Lake	HSR Layout	19528	18648		25298	24169		32597	31413	
HSR Layout	Silk Board	22054	20417		29101	26872		36226	35311	

10.4 TRAIN OPERATION PLAN

10.4.1 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 8-10% coasting.
- Scheduled speed has been assumed as 34 KMPH

10.4.2 Train Formation

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

Composition

DMC : Driving Motor Car

MC : Motor Car

TC : Trailer Car

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

Passenger Capacity (with @6 standees per square meter standee area (AW3))

DMC : 247 Passengers (Sitting-43, Crush Standing-204)

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

6 Car Train Passenger capacity : 1574 Passengers (Sitting-286, Crush Standing-1288)

Passenger Capacity (with @8 standees per square meter standee area (AW4))

DMC : 316 Passengers (Sitting-43, Crush Standing-273)

TC/MC : 343 Passengers (Sitting-50, Crush Standing-293)

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

Based on the experience of Phase-I and commissioning of East-West Corridor, it is recommended to adopt AW3 Passenger loading for calculation of the passenger carrying capacity to meet the projected maximum PHPDT whereas, in emergency, it shall be possible to carry the passenger under AW4 loading condition.

Table 10.3 : Carrying Capacity of Mass Rail Vehicles (Crush@6 P/sq.m of standee area)

	Driving Motor car		Trailer car /Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	204	147	220	862	1288
Total	**180**	**247**	**197**	**270**	**1148**	**1574**

NORMAL (AW2) - 4 P/sqm of standee area

CRUSH (AW3) - 6 P/sqm of standee area

Table 10.4 : Carrying Capacity of Mass Rail Vehicles (Exceptional dense Crush@8P/sqm of standee area)						
	Driving Motor car		Trailer car / Motor car		6 Car Train	
	Normal	Crush	Normal	Crush	Normal	Crush
Seated	43	43	50	50	286	286
Standing	137	273	147	293	862	1718
Total	180	316	197	343	1148	2004

NORMAL (AW2) - 4 P/sqm of standee area

EXCEPTIONAL DENSE CRUSH (AW4) - 8 P/sqm of standee area

10.4.3 Train Operation Plan

Train operation plan with train carrying capacity @6 persons per square meter of standee area on K R Puram to Silk Board Junction for the year 2021, 2031 & 2041 given below:-

10.4.3.1 Planning for Year 2021:

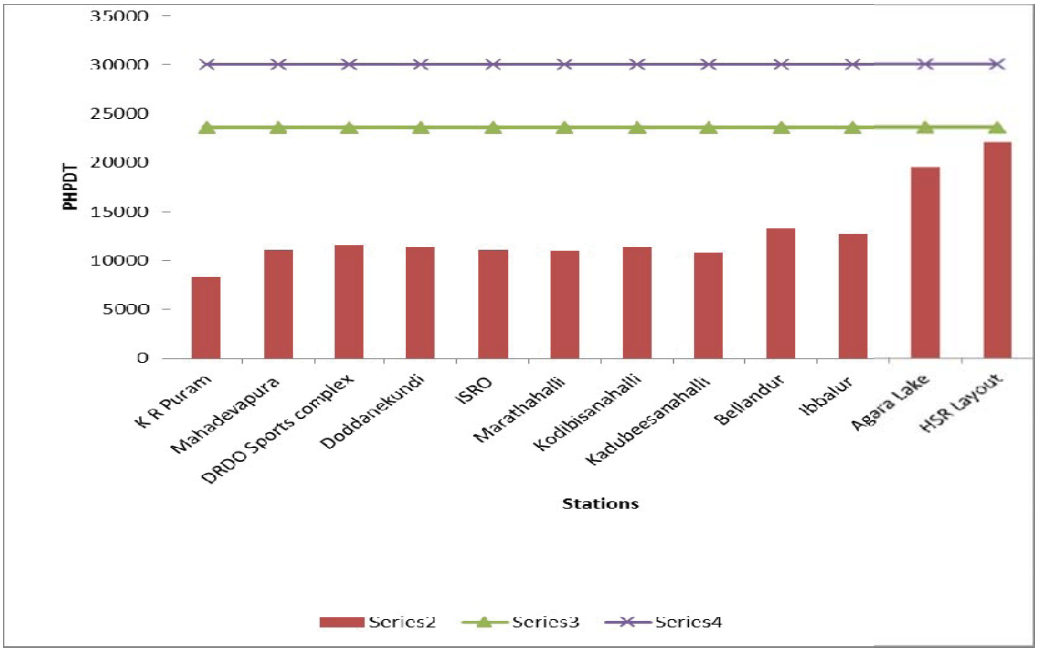
- 6 car Train Composition : *DMC - TC - MC + MC – TC - DMC*
- Capacity of train : 1574 in AW3 condition
- Schedule Speed : 34 Kmph
- Headway with 6- car train : 4 minutes
- During peak hour, No.of trains per hour : 15
- Available Peak Hour Peak Direction Capacity of 23610@6 passengers per square meter of standee area(AW3).
- Available Peak Hour Peak Direction Capacity of 30060@8 passengers per square meter of standee area(AW4).
- Traffic reserve is taken as one/two train per train operation loop to cater to failure of train on line and to make up for operational time lost.
- Repair and maintenance reserve has been estimated as 8% of total requirement (Bare + Traffic Reserve).
- The calculated number of rakes in fraction is rounded off to next higher number.

Traffic demand and train capacity for this corridor in the year 2021 is tabulated and represented on a chart as follows:

Table 10.5: Peak Hour Demand and Train Requirement						
Sl. No	Section	R Km	Peak Traffic Demand as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
1	K R Puram to Silk board.	17	22054	23610 (15 x 1574)	4 minute	20 Rakes (120 Cars)

TABLE 10.6: YEAR 2021- PHPDT AND CAPACITY CHART					
S No.	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sq.m of standee area	Train carrying capacity @8p/sq.m of standee area
1	K R Puram	Mahadevapura	8317	23610	30060
2	Mahadevapura	DRDO Sports Complex	11078	23610	30060
3	DRDO Sports Complex	Doddanekundi	11625	23610	30060
4	Doddanekundi	ISRO	11371	23610	30060
5	ISRO	Marathahalli	11124	23610	30060
6	Marathahalli	Kodibisanahalli	10918	23610	30060
7	Kodibisanahalli	Kadubeesanahalli	11323	23610	30060
8	Kadubeesanahalli	Bellandur	10803	23610	30060
9	Bellandur	Ibbalur	13261	23610	30060
10	Ibbalur	Agara Lake	12706	23610	30060
11	Agara Lake	HSR Layout	19528	23610	30060
12	HSR Layout	Silk Board	22054	23610	30060

Figure 10.1 YEAR 2021- PHPDT AND CAPACITY CHART



10.4.3.2 Planning for Year 2031:

- 6 car Train Composition : *DMC - TC - MC + MC – TC - DMC*
- Capacity of train : 1574 in AW3 condition
- Schedule Speed : 34 Kmph
- Headway with 6- car train : 3 minutes

- During peak hours, No.of trains per hour : 20
- Available Peak Hour Peak Direction Capacity of 31480 @6 passengers per square meter of standee area(AW3).
- Available Peak Hour Peak Direction Capacity of 40080 @8 passengers per square meter of standee area (AW4).
- Traffic reserve is taken as one/two train per train operation loop to cater to failure of train on line and to make up for operational time lost.
- Repair and maintenance reserve has been estimated as 8% of total requirement (Bare + Traffic Reserve).
- The calculated number of rakes in fraction is rounded off to next higher number.

Traffic demand and train capacity for this corridor in the year 2031 is tabulated and represented on a chart as follows:

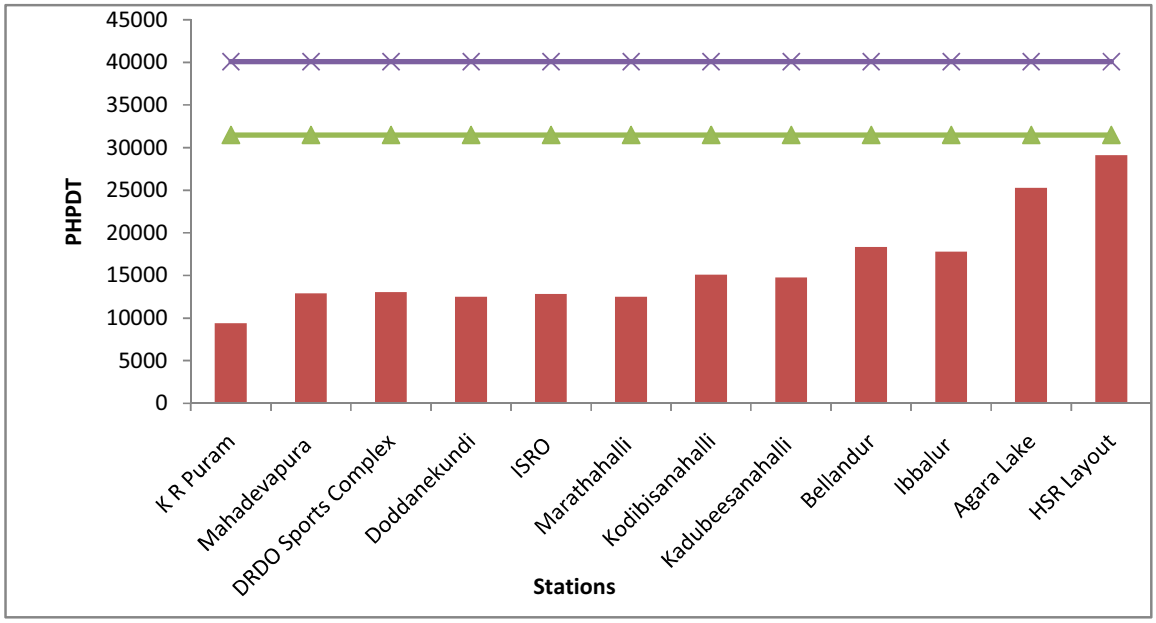
Table 10.7 Peak Hour Demand and Train Requirement

Sl. No	Section	R Km	Peak Traffic Demand as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
1	K R Puram to Silk board	17	29101	31480 (20x1574)	3 minute	25 Rakes (150 Cars)

TABLE 10.8 : YEAR 2031 - PHPDT AND CAPACITY CHART

S No.	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1	K R Puram	Mahadevapura	9405	31480	40080
2	Mahadevapura	DRDO Sports Complex	12893	31480	40080
3	DRDO Sports Complex	Doddanekundi	13045	31480	40080
4	Doddanekundi	ISRO	12488	31480	40080
5	ISRO	Marathahalli	12828	31480	40080
6	Marathahalli	Kodibisanahalli	12510	31480	40080
7	Kodibisanahalli	Kadubeesanahalli	15093	31480	40080
8	Kadubeesanahalli	Bellandur	14764	31480	40080
9	Bellandur	Ibbalur	18316	31480	40080
10	Ibbalur	Agara Lake	17804	31480	40080
11	Agara Lake	HSR Layout	25298	31480	40080
12	HSR Layout	Silk Board	29101	31480	40080

Figure 10.2 YEAR 2031- PHPDT AND CAPACITY CHART



10.4.3.3 Planning for Year 2041:

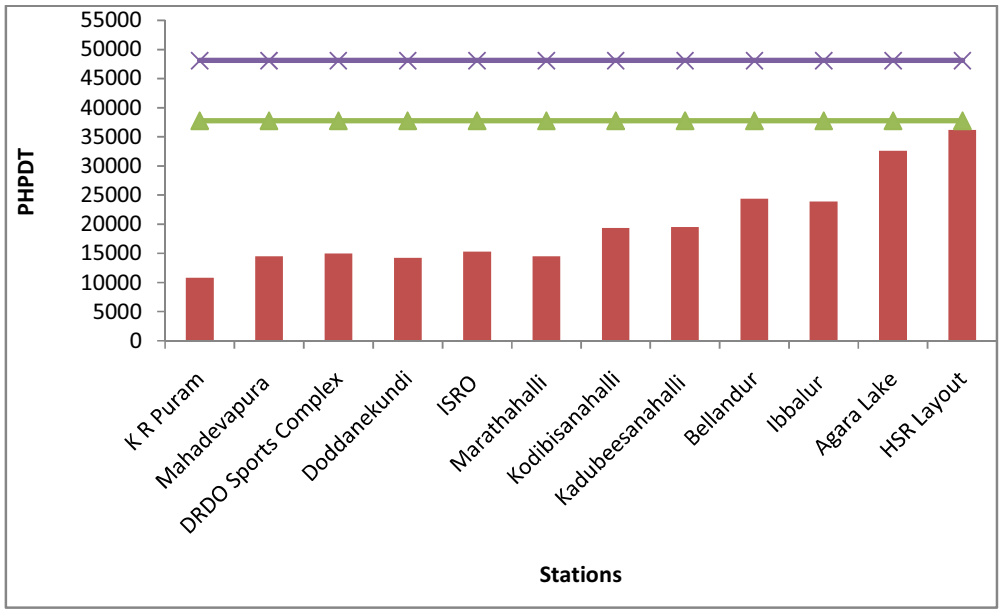
- 6 car Train Composition : *DMC - TC - MC + MC – TC - DMC*
- Capacity of train : 1574 in AW3 condition
- Schedule Speed : 34 Kmph
- Headway with 6- car train : 2.5 minutes
- During peak hours, No.of trains per hour : 24
- Available Peak Hour Peak Direction Capacity of 37776 @6 passenger per square meter of standee area (AW3).
- Available Peak Hour Peak Direction Capacity of 48096 @8 passenger per square meter of standee area (AW4).
- Traffic reserve is taken as one/two train per train operation loop to cater to failure of train on line and to make up for operational time lost.
- Repair and maintenance reserve has been estimated as 8% of total requirement (Bare + Traffic Reserve).
- The calculated number of rakes in fraction is rounded off to next higher number.
- Traffic demand and train capacity for this corridor in the year 2041 is tabulated and represented on a chart as follows:

Table 10.9 Peak Hour Demand and Train Requirement

Sl. No	Section	R Km	Peak Traffic Demand as per DPR	PHPDT provided	Headway during peak	No. of Trains requirement
1	K R Puram to Silk board	17	36236	37776 (24x1574)	2.5 minute	31 Rakes (186 Cars)

TABLE 10.10: YEAR 2041 - PHPDT AND CAPACITY CHART					
S No.	From	To	Traffic Demand in PHPDT	Train carrying capacity @6p/sqm of standee area	Train carrying capacity @8p/sqm of standee area
1	K R Puram	Mahadevapura	10789	37776	48096
2	Mahadevapura	DRDO Sports Complex	14494	37776	48096
3	DRDO Sports Complex	Doddanekundi	14959	37776	48096
4	Doddanekundi	ISRO	14209	37776	48096
5	ISRO	Marathahalli	15337	37776	48096
6	Marathahalli	Kodibisanahalli	14534	37776	48096
7	Kodibisanahalli	Kadubeesanahalli	19397	37776	48096
8	Kadubeesanahalli	Bellandur	19542	37776	48096
9	Bellandur	Ibbalur	24396	37776	48096
10	Ibbalur	Agara Lake	23916	37776	48096
11	Agara Lake	HSR Layout	32597	37776	48096
12	HSR Layout	Silk Board	36226	37776	48096

Figure 10.3 YEAR 2041- PHPDT AND CAPACITY CHART



The above Train Operation Plan is based on 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 during operation phase

10.4.4 Summarizing above, the PHPDT Capacity on the rake requirement for different headway in different years of operation is tabulated below:-

Table 10.11: Capacity Provided for K R Puram to Silk Board							
Corridor	**Year**	**Headway (min)**	**No. of Rakes**	**Rake Consist**	**No. of Coaches**	**Max. PHPDT Demand**	**PHPDT Capacity Available**
K R Puram to Silk Board	2021	4	20	6-car	120	22054	23610 (30060*)
	2031	3	25	6-car	150	29101	31480 (40080*)
	2041	2.5	31	6-car	186	36236	37776 (48096*)

***** @8 passengers per square meter of standee area (AW4)

10.4.5 Train Frequency

The train operation for K R Puram to Silk Board provides the following train frequency:-

Table 10.12 : Train Frequency						
Corridor	**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**
K R Puram To Silk Board	4 min	6 min	3 min	4 min	2.5 min	3 min

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

10.4.6 Hourly Train Operation plan*

The hourly distribution of daily transport capacity is presented in Table 10.17, 10.18, and 10.19 for K R Puram to Silk Board and enclosed. Number of train trips per direction per day for above corridors are worked out as 220 in the year 2021, 315 in the year 2031 and 404 in the year 2041 respectively.

10.4.7 Vehicle Kilometer

Based on above planning, after considering maintenance period and assuming 340 days in service in a year, Vehicle Kilometer is tabulated below.

Table 10.13 : Vehicle Kilometer			
Year	**2021**	**2031**	**2041**
Section Length	17	17	17
No. of cars Per train	6	6	6
No.of working days in a year	340	340	340
Number of trains per day each way	220	315	404
Daily Train-KM	7480	10710	13736
Annual Train-KM (10^5)	25.43	36.41	46.70
Annual Vehicle- KM (10^5)	153	218	280

10.5 YEAR WISE RAKE REQUIREMENT

Based on Train formation operation plan as detailed above, to meet Peak Hour Peak Direction Traffic Demand, year wise Rake requirement are tabulated below:

Table 10.14 : Rake Requirement for the Year 2021

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No. of rakes	No. of cars per rake	No. of cars
				Bare	Traffic Reserve	R&M			
K.R. Puram to Silk board	17	34	4	17	1	2	20	6	120

* Total Turn Around Time (min) = 6 min

Table 10.15 : Rake Requirement for the Year 2031

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No. of rakes	No. of cars per rake	No. of cars
				Bare	Traffic Reserve	R&M			
K.R. Puram to Silk board	17	34	3	22	1	2	25	6	150

* Total Turn Around Time (min) = 6 min

Table 10.16- Rake Requirement for the Year 2041

Section	Distance (kms)	Schedule Speed in kmph	Headway (min)	Rake Requirement			Total No. of rakes	No.of cars per rake	No.of cars
				Bare	Traffic Reserve	R&M			
K.R. Puram to Silk board	17	34	2.5	27	1	3	31	6	186

* Total Turn Around Time (min) = 6 min

10.6 COST ESTIMATE

The estimated cost per car inclusive of all taxes, duties etc., is considered as Rs.9.50 Crores.

The hourly distribution of daily transport capacity is shown in Table 10.17, 10.18, and 10.19.

***Table 10.17 Hourly Train Operation Plan for K.R.PURAM TO SILK BOARD**			
YEAR : 2021			
Configuration : 6 car			
Headway in Minutes : 4			
TIME OF DAY IN HOURS	HEADWAY IN IMINUTES	NO. OF TRAINS PER DAY	
		UP	DOWN
05-06	6	10	10
06-07	6	10	10
07-08	6	10	10
08-09	4	15	15
09-10	4	15	15
10-11	4	15	15
11-12	6	10	10
12-13	6	10	10
13-14	6	10	10
14-15	6	10	10
15-16	6	10	10
16-17	6	10	10
17-18	4	15	15
18-19	4	15	15
19-20	4	15	15
20-21	6	10	10
21-22	6	10	10
22-23	6	10	10
23-24	6	10	10
TOTAL NO. OF TRAINS TRIPS PER DIRECTION PER DAY		**220**	**220**

TABLE 10.18 Hourly Train Operation Plan for K.R.PURAM TO SILK BOARD			
YEAR : 2031			
Configuration : 6 car			
Headway in Minutes : 3			
TIME OF DAY IN HOURS	HEADWAY IN IMINUTES	NO. OF TRAINS PER DAY	
		UP	DOWN
05-06	4	15	15
06-07	4	15	15
07-08	4	15	15
08-09	3	20	20
09-10	3	20	20
10-11	3	20	20
11-12	4	15	15
12-13	4	15	15
13-14	4	15	15
14-15	4	15	15
15-16	4	15	15
16-17	4	15	15
17-18	3	20	20
18-19	3	20	20
19-20	3	20	20
20-21	4	15	15
21-22	4	15	15
22-23	4	15	15
23-24	4	15	15
TOTAL NO. OF TRAINS TRIPS PER DIRECTION PER DAY		**315**	**315**

TABLE : 10.19 Hourly Train Operation Plan for K.R.PURAM TO SILK BOARD			
YEAR : 2041			
Configuration : 6 car			
Headway in Minutes : 2.5			
TIME OF DAY IN HOURS	HEADWAY IN IMINUTES	NO. OF TRAINS PER DAY	
		UP	DOWN
05-06	3	20	20
06-07	3	20	20
07-08	3	20	20
08-09	2.5	24	20
09-10	2.5	24	24
10-11	2.5	24	24
11-12	3	20	24
12-13	3	20	20
13-14	3	20	20
14-15	3	20	20
15-16	3	20	20
16-17	3	20	20
17-18	2.5	24	24
18-19	2.5	24	24
19-20	2.5	24	24
20-21	3	20	20
21-22	3	20	20
22-23	3	20	20
23-24	3	20	20
TOTAL NO. OF TRAINS TRIPS PER DIRECTION PER DAY		**404**	**404**

11 SIGNALLING SYSTEM AND TELECOMMUNICATION

11.1 SIGNALLING AND TRAIN CONTROL

11.1.1 INTRODUCTION

Metro carries a large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability as well as availability. At the same time heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. The Signalling & Train Control system in Metro Railway plays a major role to provide frequent, fast and safe journeys in the urban areas. The telecommunication system acts as the communication backbone for signaling system and provides telecommunication services to meet operational and administrative requirements of rail / metro network.

Presently, BMRCL's operational Purple and Green lines are having Distance to Go (DTG) system for its Train control. This system has several track circuits detecting the presence/absence of a train in the zone and a failure of any one track circuit leads to operational delay as in such cases, the train position gets non-determined. When the trains are running in tight headway, normalization process gets prolonged due to the need for Power Block etc.

The DTG system has also become obsolete and the latest Signalling / Train Control technology available is the Communication based Trail control (CBTC). Most of the vendors are switching their design expertise and manufacturing line from DTG to CBTC system as the new metros globally are going with CBTC signalling only. Same has been the trend in India too as recently taken up lines on Delhi Metro, Hyderabad Metro and Kochi Metro too are being equipped with this technology only and the same is to be adopted for the proposed New Line.

11.1.2 ADOPTION OF CBTC BASED SIGNALLING SYSTEM:

Train control requirements of the metro are planned to be achieved by adopting Continuous Automatic Train Control (CATC) based on Communication Based Train Control (CBTC) System. The train location is determined by continuous communication with Central control. The track circuits/ Axle counters are installed as a fall back option and to manage non-equipped vehicle movements. This system includes Automatic Train Protection (ATP) and Automatic Train Operation (ATO) sub-systems using continuous bi-directional radio communication between track side and train and Automatic Train Supervision (ATS) sub systems.

The CBTC system offers following advantages:

a) High reliability, better availability and less prone to failures.
b) Easier to maintain.
c) Provides higher traffic capacity.
d) They are reported to be more energy efficient systems compared to DTG signalling.
e) Adaptable to any Grade of Automation and Scalable too.

This will:

a) Provide high level of safety with trains running at close headway, ensuring continuous safe train separation and for bidirectional working.
b) 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.
c) Provides safety and enforces speed limit on section having permanent and temporary speed restrictions.
d) Improves capacity with safer and smoother operations. Driver will have continuous display of Target Speed and other information in his cab enabling him to optimize the speed potential of the track section. It provides signal / speed status in the cab even in bad weather.
e) 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 Train Control system shall be designed to meet the required headway during peak hours. The signalling system shall also have secondary detection of trains through Axle counters/Track circuits. Radio for CBTC shall work in license free ISM band.

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

11.1.3 SYSTEM DESCRIPTION AND SPECIFICATIONS

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

a) Continuous Automatic Train Control:

Continuous Automatic Train Control based on CBTC will consist of – Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) sub-Systems. The train borne Automatic Train Control system will consist of Automatic Train Operation (ATO) & Automatic Train Protection (ATP). This will work on moving block principle.

i. Automatic Train Protection (ATP)

Automatic Train Protection (ATP) is the primary function of the train control system. This sub-system will be inherently capable of achieving the following objectives in a fail safe manner.

- Cab Signaling
- Moving block
- Generation of track related speed profile based on continuous data from track to train
- Continuous monitoring of braking curve
- Monitoring maximum permitted speed on the line and speed restrictions

- Detection of overspeed and generation of audio visual warning and application of brake if necessary
- Maintaining safe distance between trains
- Monitoring of stopping points
- Monitoring of direction of travel and roll back
- Issuing command for correct side door opening in trains and PSG if provided

The train borne equipment will be of modular sub assemblies for each function for easy maintenance and replacement.

ii. Automatic Train Operation (ATO)

This system will operate the trains automatically from station to station within the safety envelope of ATP and open the train doors on the correct side. In conjunction with ATP/ATS, ATO can control the dwell time at stations and manage the train running in accordance with headway / time table.

iii. Automatic Train Supervision (ATS)

A train supervision system will be installed to facilitate the monitoring of the train operation and also remote control of the station. The train supervision will log each train movement and display it on work stations with traffic controller at OCC and in a work station for the station controller.

The centralized system will be installed in Operation Control Centre (OCC). The OCC will have a projection display panel showing the panoramic view indicating the dynamic position of train movement on a particular track / points. This will aggregate the train movements in various sections and display in a common video wall. ATS will provide the following main functionalities:

- Automatic Route Setting
- Automatic Train Regulation
- Continuous tracking of train position
- Display panel and work station
- Link to passenger information display system for online information
- Computation of train schedule and time table
- Issue special commands to train such as train hold, skip station etc.

b) Interlocking system

i. Computer Based Interlocking (CBI)

The entire line including turnback, transfer track, pocket track and stabling depot will be equipped with CBI system for operation of points and crossings and setting of routes. The route setting and clearance of signals will be done from a workstation, which can be either locally (at station) operated or operated remotely from the OCC/BCC.

This system is used for controlling vehicle movements into or out of stations automatically from a workstation. All stations having points and crossings will be provided with workstations for local control. Track occupancy, point position, signal aspect etc will be clearly indicated on the workstation. It will be possible to operate the workstation locally if the central control hands over such control. The interlocking system design shall be of fail-safe design principle.

The signals operate for every train movement, points operate for every train turn back, short-loop and for induction/withdrawal and therefore the equipment will withstand tough environmental conditions encountered in a Metro system. Suitable IRS, IS standards or equivalent international standards will be followed in case wiring, installation, earthing, cabling, power supply and for material used in track circuits, axle counters, relays, point machine etc.

ii. Track vacancy detection

Primary mode for track vacancy detection system on main line may be through radio and for secondary detection it can be through track circuit/axle counters.

iii. Signals on main line including pocket track, Stabling depot

a) Line side signals

Line side signals will be provided at diverging routes (i.e at point and crossing) as well as at other required locations, which shall serve as backup arrangements in case of failure of the ATP system. This consists of multi aspects colour light LED type signals installed on the main line and for depot entry/exit. All stations with points and crossing shall have the signalling arrangement to provide for bi-directional train operation.

b) Point machines

Non trailable electrical point machines capable of operating on 3 phase 380v AC will be used on main line, pocket track and stabling depot. The depot point machine will be trailable/non-trailable type electrical point machine capable of operating with either 3 phase 380v AC or 110v DC. The depot test track point machines and point machines on the route leading from main line to stabling lines shall be non-trailable type electrical point machine capable of operating with 3 phase 380v AC having availability performance.

c) Platform Screen Door (PSD) or Platform Screen Gates (PSG)

All Stations shall be equipped with PSD/PSG that are necessary for achieving automatic turn back of trains and also ensuring passenger safety. The PSD/PSG shall be interlocked such that their opening and closing is controlled automatically by the signalling system. Adequate provisions shall be provided to meet the emergency requirements for passenger detrainment.

d) Train Depot cum workshop signalling

The existing depot at Baiyappanahalli is equipped for repairs and maintenance of rolling stock running on Purple line. The signalling system already commissioned on the Purple Line is of Distance To Go (DTG) type whereas the new line from K R Puram to Silk Board will be of Communication Based Train

Control (CBTC) type. Full-fledged facilities for maintenance of CBTC equipped trains shall be planned at Baiyappanahalli in a phased manner such that it will not affect either the train operations on purple line or the rolling stock maintenance.

The transition of the Baiyapanahalli depot from DTG signalling to complete CBTC system involves an overlapping period during which some depot line will cater exclusively to CBTC equipped trains and balance meeting the requirements of DTG system. Once alternative arrangements for DTG equipped trains is established, Baiyappanahalli depot will be converted to service CBTC equipped trains only.

The existing test track in Baiyappanahalli depot will also be equipped with CBTC signalling with ATP to facilitate testing of the trains before induction to revenue service.

All depot lines except the one which is used for shunting and in the work shop shall be interlocked as far as possible subject to track constrains if any. The work station shall be provided in the depot control centre for electric operation of points, signals and routes of the depot yard. Audio frequency track circuits/axle counters shall be used in the depot as well.

The signals in the depot will be of position light shunt signal or main line signals.

e) Signalling for Stabling Depot

The main line is planned to be connected to a set of stabling lines at Hebbal to form a stabling depot once the section is extended beyond KR Puram in future on ORR corridor. These stabling lines shall also be interlocked and provided with main line signals controlled from OCC. These stabling lines shall be equipped with CATC, ATS, ATO and interlocking systems and all points within the stabling depot shall be controlled by point machines that are similar to those of main line. Direct induction of trains from stabling lines will be possible as per timetable.

11.1.4 SIGNALLING SCHEME PLAN

Conceptual Signalling Plan based on engineering layout of the P-way for KR Puram- Silk Board corridor is enclosed.

11.1.5 STANDARDS

Table 11.1 shows the standards that will be adopted with regard to the Signaling system.

Table 11.1 Standards Adopted With Regards To Signalling System

Description	Standards
Interlocking	Computer Based Interlocking, adopted for station having switches and crossing. All related equipment as far as possible will be centralized in the equipment room at the station. All Depot lines shall be interlocked subject to track layout constraints.
Block working	Moving block principle
Operation of Points	With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.
Track Vacancy Detection systems	Primary mode for track vacancy detection system on main line, stabling lines and test track in depot may be through radio and for depot/secondary detection it can be through track circuit/axle counters.
Signals at Stations with points and crossings	Line Side signals to protect the points (switches). LED type signals for reduced maintenance.
UPS (uninterrupted power at stations as well as for OCC)	For Signaling, Telecommunications, AFC and PSG and at stations to cover all equipments in Station Control Room.
Train protection systems	Train protection system shall be based on Communication Based Train Control (CBTC) system. The system architecture shall provide for redundancy. The system will conform to IEEE 1474 standards.
Train Describer System	Automatic train supervision system. Movement of all trains to be logged on to a central computer and displayed on workstations in the OCC/BCC and at the SCR. Remote control of stations from the OCC/BCC. The system architecture shall provide for redundancy.
Cables	Outdoor Cables will be steel armoured, as far as possible.
Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for Signalling and Train Control system
Immunity to External Interface.	All data transmission on telecom cables/ OFC/Radio. All signaling and telecom cables will be separated from power cables as per standards. CENELEC standards to be implemented for EMC.
Train Working Under Emergency	Running on site with line side signal with speed automatically restricted to 25kmph.
Environmental Conditions	All equipment rooms shall be Air conditioned
Maintenance Philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of 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. Annual Maintenance contract for obsolescence and evolution management of relevant hardware and software with the vendor/OEM.

11.1.6 SPACE REQUIREMENT FOR SIGNALING INSTALLATIONS

Adequate space for proper installations of all Signalling equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for Signalling equipment shall be generally 50 sqm for UPS room (common for signalling, telecom, AFC and PSG) and for signalling equipment room 55 sqm at all the stations with points and crossing & 25 sqm at stations without points and crossings and 80 sqm for depot (depends on layout). These areas shall also cater to local storage and space for maintenance personnel to work. The Station Control Room including storage space shall be of 55 sqm and Maintainer Room shall be of 25 sqm located at stations with points and crossings.

At the OCC/BCC and the Depot, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

11.1.7 MAINTENANCE PHILOSOPHY FOR SIGNALLING SYSTEMS

The philosophy of continuous monitoring of systems status and preventive & corrective maintenance of Signaling and Telecommunication equipments shall be followed. Card/module/sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Sub-system wise expert team of shall be built-up for sustenance of the signaling system. Since the signaling system is mostly software based, the maintenance team shall have proficiency in IT/computer background. 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 in the section/depot. Cards/modules/equipments requiring major repairs shall be sent to manufacturer's workshop.

Most of the computer systems undergo changes to their hardware and software on account of obsolescence, evolution and software patches within the specified life span. Annual Maintenance contract for such system with the vendor/OEM may be considered for sustainability and maintainability of the installed systems which are safety critical in nature.

11.2 TELECOMMUNICATION SYSTEM

11.2.1 INTRODUCTION

The telecommunication system acts as communication backbone for Signaling, Power SCADA, BMS and AFC systems and provides telecommunication services to meet operational and administrative requirements of metro network. Telecommunication system consists of following sub-systems viz:

i. Fiber Optic Transmission System (FOTS) - Main Telecommunication Bearer

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a 96 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, depot 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. Alternately, a fully IP based, high capacity (Minimum 1 Gbps), highly reliable and fault tolerant Ethernet Network (MAN/ LAN) can be provided. Further small routers and switches shall be provided for LAN network at stations.

ii. Telephone Exchange

The System shall be IP Based. The telephone extensions can be combination of IP, digital and Analog. For an optimized cost effective solution small exchanges of 30 port each shall be planned at each station and a 60 Port Exchange at the Terminal Stations and Depots shall be provided. The station exchanges will be connected to the OCC main exchange. The Exchanges will serve the subscribers at all the stations and Central Control. The exchanges will be interconnected at the channel level on optical backbone. The exchanges shall be software partitioned for EPABX and Direct Line Communication from which the phones shall be extended to the stations. For the critical control communication, the Availability and Reliability should be high.

iii. Mobile Radio Communication

Mobile Radio communication system having 8 channels is proposed for on-line emergency communication between Train operator (Front end and Rear end) of moving train and the Central Control. The system shall be based on Digital Trunk Radio Technology to TETRA International standard. All the stations, depots and the OCC will be provided with fixed radio sets. Mobile communication facility for maintenance parties and Security Personnel will be provided with handheld sets. These persons will be able to communicate with each other as well as with central control.

The frequency band for operation of the system will be that for TETRA in 400/800 MHz band, depending on frequency availability. The system shall provide Instant mobile radio communication between the Train Operator of the moving cars from any place and the Central Control .The Train Operator can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

To provide adequate coverage, based on the RF site survey to be carried out during Detailed Design stage, base stations for the system will be located at sites conveniently selected after detailed survey. Tentatively, 3 Base Stations with a 40m tower shall be required along the route. During design stage, further Radio survey will need to be carried out, in case coverage is to be further improved. The increased passenger footfalls at stations may call for improvement of signal strength of mobile telephone system. Enhancement of Mobile communication will be made available to the public by

providing equipment on roof top of stations for which adequate Electrical power shall be made available.

iv. Passenger Announcement System

The system shall be capable of announcements from the local station as well as from OCC. Announcements from OCC will have over-riding priority in all announcements. The system shall be linked to Signalling System for automatic train actuated announcements.

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 FOTS, Exchanges, Radio, Signalling etc.. 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. The System shall be integrated with the PA system and available from same MMI.

vii. Closed Circuit Television (CCTV) System

The CCTV system shall provide surveillance and recording function for the operations to monitor each station. All areas in stations where security, safety and crowd control purpose is necessary like Entry, concourse, Entry to lift, escalators, Platforms, Passages to operation rooms, entry to PFs from emergency stair case, External station area for about 20 metres in front of entry gates shall be covered by CCTV coverage. CCTV shall consist of a mix of High definition Fixed camera and PTZ cameras The monitoring shall be possible both locally at each station and remotely from the OCC on the Video Wall. Voice communication between OCC and station Controller will also have video coverage functionality.

The Surveillance of Trains shall be possible at a central location/OCC through a Broad Band Radio System (BBRS) system, which may make use of the track side infrastructure like poles provided for the Signalling/Train control system. Start to end surveillance of passengers will be possible through the BBRS facility to monitor the on-Board images in OCC/BCC.

viii. Network Monitoring and Management

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

be covering radio communication, Optical Fiber Transmission system, Telephone Exchange and summary alarms of PA/PIDS, CCTV and Clock and UPS systems. The NMS will collect and monitor status from the individual NMS of the respective sub-systems and display on a common Work Station.

11.2.2 STANDARDS

Table 11.2 shows the standards proposed to be adopted for telecommunication systems are shown in Table below:

Table 11.2 Standards to be adopted for telecommunication systems

System	Standards
Transmission System	SDH or Ethernet based MAN/LAN
Transmission Media	Optical Fibre system as the main bearer for bulk of the telecommunication network.
Telephone Exchange	IP EPABX of minimum 30 ports is to be provided at all Stations, an Exchange of 60 Ports to be provided at Terminal Stations and Depot.
Train Radio System	Digital Train radio (TETRA) communication between Train Operator of moving cars, stations, maintenance personnel ,depots and central control.
Train Destination Indicator System	LED/LCD based boards with adequate visibility to be provided at convenient location at all stations to provide bilingual visual indication of the status of the running trains, and also special messages in emergencies.
Centralized clock system	Accurate display of time through a 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 of other systems.
Passenger Announcement System	Passenger Announcement System covering all platform and concourse areas with local as well as Central Announcement.
Video Surveillance	IP based High definition CCTV cameras with Network video Recorders at stations, Centralized management, Video Analytic features and Video wall display.
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. Maintenance contract for hardware / software as necessary to manage the technology advancement.

11.2.3 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 Telecom equipment shall be generally 40 sq.m each for Telecom Room and 50 sq.m. for UPS Room (common for signal, telecom ,AFC and PSG). At the OCC and BCC, the areas required shall be as per the final configuration of the equipments and network configuration keeping space for further expansion.

11.2.4 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.

Maintenance contract for hardware / software as necessary to manage the technology advancement/obsolescence will be undertaken.

11.3 AUTOMATIC FARE COLLECTION

11.3.1 INTRODUCTION

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

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

A. Manual fare collection systems have the following inherent disadvantages:

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

B. Automatic fare collection systems have the following advantages:

i. Less number of staff required.
ii. Less possibility of leakage of revenue due to 100% ticket check by control gates.
iii. Recycling of ticket fraudulently by staff avoided.
iv. Efficient and easy to operate, faster evacuation both in normal and emergency.
v. System is amenable for quick fare changes.
vi. Management information reports generation easy.
vii. System has multi-operator capabilities. Same Smart Card can be used for other applications also.
viii. AFC systems are the worldwide accepted systems for Metro environment.

The proposed ticketing system shall be same as that to be provided on the other lines of Phase-1 and Phase-2 i.e. of Contactless Smart Token/ Card type. The equipment for the same shall be provided at each station Counter/Booking office and at convenient locations and will be connected to a local area network with a computer in the Station Control room.

The AFC system shall support simultaneously ISO 14443 based type ‘A’ cards compatible with MiFare and EMV based (National Common Mobility Cards, RuPay etc.). The system shall also be capable of processing and accepting NFC based fare media.

C. Choice of Control Gates

Retractable flap or Paddle swing type Control Gates are proposed which offer high throughput, require less maintenance and are latest in modern metros internationally. Tripod turnstile type gates offer less through put and require more maintenance and hence not proposed. The traffic on this line will reach peaks in one direction in morning and in the other direction during evening hours. Therefore, a set of Entry, Exit and Bi-directional gates in between shall be provided as far as possible to better manage the traffic.

D. Passenger Operated Ticket Vending Machines (TVMs)

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

E. Ticket Readers:

These machines will be used to analyze Card/ Token and display card/ Token balance, validity of card and last few transactions.

F. Add Value Machines:

These machines will be used to recharge the card using Credit/ Debit card and/ or bank note module. These machines will also be used as add value device in case payment for card recharge is made through Internet based channels such as net banking, Credit/ Debit card (Payment Gateway) etc.

G. NFC based mobile ticketing

As NFC technology is advancing fast, mobile based ticketing is likely to be widely used in near future by Metro Rail operators. Hence a NFC based mobile ticketing solution is proposed to be included.

11.3.2 AFC EQUIPMENT REQUIREMENT

AFC equipment requirement for Silk Board Junction to K.R. Puram section are given in Table 11.3 as under.

Table 11.3 AFC Equipments for Bangalore Metro New line from KR Puram to Silk Board

S.N	Station	Daily Boarding (2031)	Daily Alighting (2031)	Hourly Boarding	Hourly Alighting	Peak Min Boarding	Peak Min Alighting	Entry Gate	Exit Gate	Bi directional gate	Wide Gate	TOM	Customer Care	TR	AVM
1	K R Puram	35,237	34,834	7047	6967	141	139	4	5	2	2	6	2	2	2
2	Mahadevpura	15,479	15,808	3096	3162	62	63	4	4	0	2	4	2	2	2
3	DRDO Sports Complex	41,895	41,867	8379	8373	168	167	4	6	2	2	7	2	2	2
4	Doddanekundi	12,981	13,011	2596	2602	52	52	4	4	0	2	4	2	2	2
5	ISRO	32,180	32,298	6436	6460	129	129	4	5	1	2	5	2	2	2
6	Marathahalli	13,753	14,328	2751	2866	55	57	4	4	0	2	4	2	2	2
7	Kodibisanahalli	40,403	40,345	8081	8069	162	161	4	6	2	2	6	2	2	2
8	Kadubeesanahalli	36,374	36,374	7275	7275	145	145	4	6	2	2	6	2	2	2
9	Bellandur	66,483	66,464	13297	13293	266	266	6	10	4	2	11	2	2	2
10	Ibbalur	3,563	3,552	713	710	14	14	4	4	0	2	4	2	2	2
11	Agara Lake	2,797	2,957	559	591	11	12	4	4	0	2	4	2	2	2
12	HSR Layout	73,178	72,783	14636	14757	293	295	6	11	5	2	12	2	2	2
13	Silk Board (Interchange)	84,245	83,947	16849	16789	337	336	8	12	5	2	13	2	2	2
Total		458,568	458,568	91714	91914	1834	1838	60	81	23	26	86	26	26	26

Minimum AFC equipment at a station with "2 access- 2 for entry, 2 for exit": 4 entry gates, 4 exit gates, 2 Customer Care, 4 TOM, 2 TR, 2 AVM.
Two Wide gates for Disabled at each station.
Throughput of gate 28 passengers per minute, TOM 10 transactions per minute
Peak hour traffic = 20% of day traffic. Peak Minute traffic = 2% of peak hour traffic.
For Calculation purpose, It is assumed that 60 % passenger will use Smart Card.

11.3.3 STANDARDS

The standard proposed for AFC systems are as under:

Table 11.4 The standard proposed for AFC systems

Standards	Description
Fare Media	a) Contact less smart token – For single journey. They shall have stored value amount for a particular journey. Tokens are captured at the exit gate. b) Contact less smart card – For multiple journeys.
Gates	Computer controlled retractable flap or paddle type automatic gates at entry and exit. There will be following types of gates: Entry / Exit Bidirectional – can be set to entry or exit Wide Bidirectional -gate for disabled people.
Station computer, Central computer and AFC Net work	All the fare collection equipments shall be connected in a local area network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control center through the optic fibre communication channels. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.
Ticket office machine (TOM/Customer Care)	Manned Ticket office machine shall be installed in the stations for selling cards/ tokens to the passengers.
Ticket Reader and Portable Ticket Decoder.	Ticket reader shall be installed near Customer Care for passengers to check information stored in the token / cards.
UPS (uninterrupted power at stations as well as for OCC).	Common UPS of S&T system will be utilized.
Add Value Machines	These machines will be used for analysis of fare media and recharge of smart cards using credit/ debit cards and/ or bank note module.

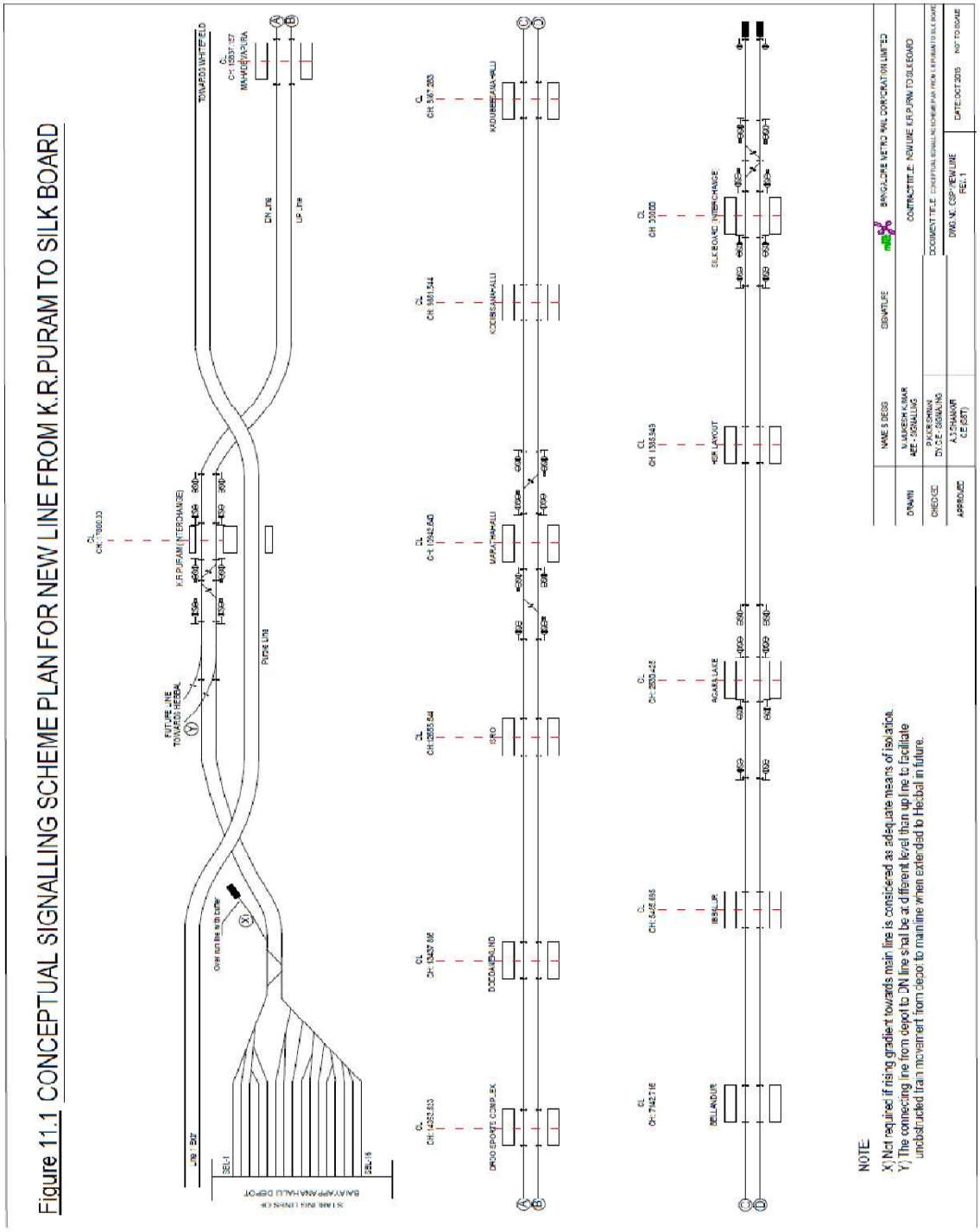
11.3.4 INTEGRATION OF AFC WITH EXISTING AFC SYSTEMS OF BMRCL AND AFC SYSTEMS OF SUBURBAN/BUS SYSTEM

A provision for Common Smart Card (NCMC) based ticketing having multi-operator capability for integration with for both Suburban and Bus systems and other agencies shall be included in the design. The system shall also be integrated with existing AFC systems of BMRCL for seamless travel.

11.3.5 TICKET OFFICES

Ticket offices of 3 m width to accommodate required Ticket issue machines with future provision to add additional counters shall be constructed. The Customer care shall be constructed at suitable location.

Figure 11.1 CONCEPTUAL SIGNALLING SCHEME PLAN FOR NEW LINE FROM K.R.PURAM TO SILK BOARD



12 LAND ACQUISITION

12.1 LAND PLAN

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

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

12.2 BREAK-UP OF LAND REQUIREMENT

Out of the total land requirement of 15179.00 Sqm, the Private Land is 9268.00 Sqm and the Government Land is 5911.00 Sqm. This Government land does not however include the land required for depot at Kadugodi Plantation. Section-wise land requirement for elevated section and ownership of the land is given at table 12.1.

Table 12.1 LAND REQUIREMENT AND OWNERSHIP

Sl. No.	Plot No.	Area (Sq. mtrs)	Ownership
H.S.R. Layout			
1	H.S.R. -1	800.00	Government (BDA Park)
2	H.S.R. -2	800.00	Government (Drain)
AGARA LAKE			
3	AGARA-1	800.00	Government (Park)
4	AGARA-2	800.00	Government (BMTC Depot Area)
IBBALUR			
5	PLOT No.-1	800.00	BBMP Park
BELLANDUR			
6	PLOT No.-1	800.00	Government (Abandoned quarry)
7	PLOT No.-2	800.00	Private (RMZ Ecospace Property)
KAADUBEESANAHALLI			
8	PLOT No.-1	800.00	Private (Salarpuria Tech Park)
9	PLOT No.-2	800.00	Private
KODIBISANAHALLI			
10	PLOT No.-1	800.00	Government
11	PLOT No.-2	800.00	Private
MARATHAHALLI			
12	PLOT No.1	166.00	Private
13	PLOT No.-2	84.00	Private
14	PLOT No.-3	102.00	Private
15	PLOT No.-4	96.00	Private
16	PLOT No.-5	95.00	Private
17	PLOT No.-6	49.00	Private

Table 12.1 LAND REQUIREMENT AND OWNERSHIP			
Sl. No.	Plot No.	Area (Sq. mtrs)	Ownership
18	PLOT No.-7	187.00	Private
ISRO			
19	PLOT No.-1	311.00	Government (ISRO)
20	PLOT No.-2	74.00	Private
21	PLOT No.-3	88.00	Private
22	PLOT No.-4	88.00	Private
23	PLOT No.-5	88.00	Private
24	PLOT No.-6	111.00	Private
25	PLOT No.-7	40.00	Private
DOODANEKUNDI			
26	PLOT No.-1	800.00	Private
27	PLOT No.-2	800.00	Private
DRDO SPORTS COMPLEX			
28	PLOT No.-1	800.00	Private
29	PLOT No.-2	800.00	Private
MAHADEVAPURA			
30	PLOT No.-1	800.00	Private
31	PLOT No.-2	800.00	Private
Grant Total		**15179.00**	

12.3 VIADUCT BETWEEN K.R.PURAM AND JYOTHIPURA STATION

This line is proposed to be further extended to Hebbal along the Outer Ring Road. Furthermore this line is proposed to be connected to Baiyappanahalli Depot also through a parallel line from K.R.Puram Station to Jyothipura Station is planned. For this, additional land of 5502.00 sq mtrs is proposed to be acquired. This involves shifting of 15 commercial properties and there will be no shifting of any residential premises. However, there is one Mosque which gets partially affected. For this, BMRCL will be paying adequate compensation to relocate the Mosque in the remaining portion of their land apart from paying compensation for the land acquired.

No land is required for viaduct between Central Silk Board and K.R.Puram Stations as the viaduct is proposed to be constructed on the median of the Ring Road. The land required for Central Silk Board and K.R.Puram Stations has already been acquired in Phase-2 of Metro Rail Project.

12.4 RELOCATION / RESETTLEMENT

There will be no relocation of any residential buildings along the alignment. However, few shops and establishments need to be relocated. Compensation for relocation of these affected structures shall be paid and it has been considered in the project cost estimate. The alignment and the location of the stations have been so chosen that it remains mostly within the government land and the road median.

12.5 MAINTENANCE DEPOT

A train maintenance depot to provide train maintenance facilities for the trains of the above section is planned at Kadugodi Plantation where about 50.00 acres of government land is available.

13 ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

13.1 BACKGROUND

Environmental impact assessment has not been done for this project. **Ministry of Environment and Forests (MoEF), Government of India, has issued various notifications on Environmental Impact Assessment since 1994 and the latest being in 2009. According to the notification, 32 types of projects under Schedule-I require environmental clearance from MoEF while Rail projects are exempted from this schedule. This clearly indicates that the proposed project does not require Environmental Clearance and don't create any major environmental problems. (**The Notification of 14th September 2006, MOEF, Government of India, has been given in Annexure 13.1). However, this chapter tries to identify environmental and social impacts and their mitigation measures.

13.2 PROJECT DESCRIPTION

The present study consists of one new alignment which is an addition of Phase II corridors. It will start from K. R. Puram and terminate at Silk Board on Outer Ring Road (ORR) covering an area of 17 km consisting having entire elevated stretch. There are 13 stations in this alignment. The proposed alignment will also mean that stations of K. R. Puram and Silk Board will act as interchanges as they are part of other extensions planned in Phase-2. K. R. Puram is a part of the 15.5 km line between Byappanahalli and Whitefield whereas Silk Board is part of the 18.82 km stretch planned between R. V. Road and Bommasandra.

The salient features of the proposed corridor are given in Table 13.1.

Table 13.1: Salient Features

1	Guage	Standard Gauge (1435mm)
2	Alignment	KR Puram to Silkboard
2.1	Route Length	17km
2.2	No. of Stations	13 (including terminal station)
3	Traffic Forecast (estimated Ridership)	
3.1	2021 year	3.52 Lacs
3.2	2031 year	4.59 Lacs
3.3	2041 year	5.75 Lacs
4	Train Operation Plan	
4.1	2021 year	Peak headway-4min Train configuration-6car No. of trains in service during peak hour-17 No. of trains trips per direction per day-220
4.2	2031 year	Peak headway-3min Train configuration-6car

		No. of trains in service during peak hour-22 No. of trains trips per direction per day-320
4.3	2041 year	Peak headway-2.5min Train configuration-6car No. of trains in service during peak hour-27 No. of trains trips per direction per day-408
5	Speed	
5.1	Design Speed	80kmph
5.2	Average Speed	34kmph
6	Traction Power Supply	
6.1	Traction system voltage	750V DC
6.2	Current collection	Third rail bottom collection
6.3	Power supply source	66kV/220kV
6.4	No. of Receiving Sub Stations	2
6.5	No. of Traction Sub Stations	11
6.6	SCADA	provided
7	Rolling Stock	
7.1	Type	2.88m wide modern rolling stock with stainless steel body, Standard guage
7.2	Axle load	15t
7.3	Seating arrangement	Longitudinal
7.4	Capacity of 6 coach unit	2068 Passengers
7.5	Class of accommodation	One
8	Maintenance Facility	Baiyappanahalli Depot
9	Signaling, Telecommunication & Train Control	
9.1	Signaling and Train Control	Communication Based Train Control
9.2	Telecommunication	Integrated system with fiber optic cable, SCADA, Train radio, PA system, etc... Train information system, control telephones and centralized clock system
10	Construction Methodology	Elevated viaduct consisting of pre-stressed concrete box/'U' shaped girders on single pier/portal with pile/open foundation.
11	Total Estimated Cost	4202 Crores (at July,2016 Prices, w/o taxes)
12	Financial Indices	
12.1	FIRR	13.90%
12.2	EIRR	52.63%

The list of stations is given in Table 13.2.

Table 13.2 List of stations				
S. No	Name of Stations	Chainage (in m)	Inter - Station Distance (in m)	Remarks
	Dead End			
1	K.R Puram	17000.000	1162.843	Elevated
2	Mahadevapura	15837.157	1443.634	Elevated
3	DRDO Sports Complex	14393.523	955.717	Elevated
4	Doddanekundi	13437.806	781.262	Elevated
5	ISRO	12656.544	1713.904	Elevated
6	Marathahalli	10942.640	1061.096	Elevated
7	Kodibisanahalli	9881.544	1314.261	Elevated
8	Kadubeesanahalli	8567.283	1424.567	Elevated
9	Bellandur	7142.716	1657.021	Elevated
10	Ibbalur	5485.695	2855.270	Elevated
11	Agara Lake	2630.425	1244.476	Elevated
12	HSR Layout	1385.949	1385.949	Elevated
13	Silk Board	0000.000	0000.00	Elevated
	Dead End			

13.3 ENVIRONMENTAL IMPACT

13.3.1 Loss of Trees/Forests

There is no forest area existing along the proposed alignment. The green cover on either side of the alignment and median of the road has been assessed and trees to be affected are identified and recorded.

The details of affected tree population are given in Table 13.3

Table 13.3: Overall affected trees		
SN	Locations	No. of trees to be affected
1	Stations	212
2	Road median (length of a tree: 8-10 feet)	1200
	Total	1412

The trees along the median are small trees 8-10 feet height and with small girth. Only trees required for constructing pier will be cut and remaining will be allowed to grow underneath the viaduct.

13.3.2 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.

13.3.3 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. As the vehicle movement is of temporary nature and restricted only to the construction period, these impacts relatively would be insignificant.

13.3.4 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.

13.3.5 Traffic Diversion

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, the vehicle movement of two wheelers ranges from 3898 to 17171, three wheelers ranges from 490 to 1064, four wheelers ranges from 2684 to 6624 and buses ranges from 528 to 766 during peak hours. Temporary traffic diversion is essential for smooth flow during construction hence this will result in temporary impact on commuters using the existing roads.

13.4 BENEFITS OF THE PROJECT

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.

13.4.1 Time saving

One of the major advantages of having a metro system would be saving in the time for people using this corridor. It is estimated that everyday there would be 3.1 lakhs passenger trips on this corridor though the passengers would be coming on the metro would be arriving from far away distance and for the purpose of present analysis, we have confined the benefit accruing out of this stretch. On an average passengers would be travelling a length of about 18 kms in this corridor resulting in saving of 15 minutes per day per person per trip. This estimation is on the conservative side. Furthermore, the factors like value of comfort, value of certainty of travel and value of safety would be a further add on.

However, for the purpose of present analysis, the benefit which has been quantified is only the money value of the travel time saved. The total travel time saved per day for all the passengers put together would be 77,500 hours. Assuming a salary of Rs.200 per hour (which is again on the conservative side), the total money value for time saved would be Rs.1.55 crores (77,500 x 200) per day. For the entire year, this saving would translate into Rs.527 crores.

13.4.2 Saving in Cost of Emissions

It is estimated that in the year 2020, there would be 3.1 lakh passenger trip per day on this corridor. In effect, emissions with these many trips by other modes would come down as passengers would shift from other modes and adopt the metro. The daily passenger trips of 3.1 lakhs would be a switch over from 2 wheelers, 4 wheelers and buses in the following ratio.

a) Buses 40%
b) 2 Wheelers 30%
c) 4 wheelers 30%

Applying the above modal shift shown in the figure above, the vehicle kms (VKM) saved in different modes is estimated as follows:

a) Buses 31,886 vkm
b) 2 Wheelers 5,97,857 vkm
c) 4 wheelers 3,34,800 vkm

The marginal external cost for each one of these modes has been taken from a study – Estimating marginal external cost of transport in Delhi (Akshaya Kumar Sen , GeetamT iwari, Vrajaindra Upadhyay) 2009.

Applying the above marginal cost, the saving on account of switch over from other modes of transport to Metro for this corridor is estimated as follows:

Table 13.4: Savings on Account per Day

Mode	Savings (Rs. In Lakhs)
Buses	16.58
2 Wheelers	21.52
4 wheelers	43.52
Total	**81.62**

(This has been calculated based on paper "Estimating marginal external cost of transport in Delhi", Aksaya Kumar Sen, Geetam Tiwari, Vrajaindraa Upadhayay 2009, Transport Policy, 17 Page: 27-37.)

13.5 MITGATION MEASURES

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, reduce traffic congestion and

time saving. On the contrary some of the adverse affects have also been identified viz. cutting trees, air/noise pollution, traffic diversion, utility dislocation etc. These adverse impacts can be minimized by proper mitigation measures.

13.5.1 Compensation for Loss of Trees

On the ORR all along the median, trees have been planted by the BDA in the recent years and these trees are growing. The number of trees coming on the median is about 1200. A survey has been done for all these trees and it is noted that all these trees are small in size with girth less than 12". BMRCL will have to ensure that not all trees are uprooted but only those trees are removed where foundations are coming. Other trees can be allowed to grow under the viaduct. In addition, efforts have to be made to transplant some of these trees as these trees are not very big and it can be possible to transplant such trees.

13.5.2 Noise Pollution Control

For elevated corridors, ballast less track structure is supported on two layers of rubber pads to reduce noise and vibrations. In addition, baffle wall as parapets will be constructed upto the rail level so as reduce sound levels. Noise at source will be controlled or reduced by incorporating suitable feature in the design of structures and layout of machines and by use of resilient mounting and dampers etc.

To reduce the harmful effects, personnel working at high noise levels would be provided with noise protective gears such as ear mufflers, sound barriers etc. Vehicles used for transportation of construction materials would be equipped with proper silencers. Careful planning has been made to operate the construction equipments to have minimal disturbances. Establishment of tree cover all along the corridor will further reduce the noise levels during operation phase.

However during construction, the noise levels will be controlled below 80 DB which will be almost equal ambient noise level due to vehicular traffic.

13.5.3 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.

13.5.4 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.

13.6 LAND ACQUISITION

There would be no land acquisition involved for the construction of viaduct from Silk Board to KR Puram. For station construction and entry structures, land acquisition is involved. In addition, the land acquisition would also be required for running the viaduct as four lines for depot extension line from KR Puram to Baiyyappanahalli depot along with reach-2 viaduct line Baiyyappanahalli to White filed. As far as the land for viaduct between KR Puram and Jyothipuram is concerned, this viaduct would run alongside the Reach-1 viaduct of Phase-2 for which the land is already being acquired. Therefore, what is required is acquisition of additional strip of about 7 to 8 meters to accommodate one more viaduct on this stretch and total area of land acquired about 0.50 hectares.

As far as the land for depot at Whitefield is concerned, there is about 400 acres of Govt. land available at Whitefield and it should be possible for the Government to grant 30 acres of land for construction of Depot. As far as the land at Silk Board is concerned, the design and construction of the Silk Board Metro Station as well as the roads at the intersections are a part of the Phase-2 and it is expected that the Central Silk Board would be in a position to spare the requisite land.

13.7 SOCIAL IMPACT

Social impact assessment and rehabilitation plan is required when the project results in either physical or economic displacement of the people. The proposed alignment will be on the median of the road, there will be no relocation of any residential buildings along the alignment. So, resettlement issue doesn't arise in this project

However, few shops and establishments need to be relocated along the proposed corridor. Compensation for relocation of these affected structures shall be paid. BMRCL has its own rehabilitation policy which was adopted for Phase-I of the metro project. It is comprehensive and covers most of the aspects of National Rehabilitation and Resettlement Policy. BMRCL rehabilitation policy is enclosed in Annexure 13.2.

This line is proposed to be further extended to Hebbal along the Outer Ring Road. Furthermore this line is proposed to be connected to Baiyappanahalli Depot also through a parallel line from K.R.Puram Station to Jyothipura Station is planned. For this, additional land of 5502.00 sq mtrs is proposed to be acquired. This involves shifting of 15 commercial properties and there will be no shifting of any residential premises. However, there is one Mosque which gets partially affected. For this, BMRCL will be paying adequate compensation to relocate the Mosque in the remaining portion of their land apart from paying compensation for the land acquired.

Annexure 13.1

NOTIFICATION OF 14TH SEPTEMBER 2006, MOEF, GOVERNMENT OF INDIA

(Published in the Gazette of India, Extraordinary, Part-II, and Section 3, Sub-section (ii)
MINISTRY OF ENVIRONMENT AND FORESTS

New Delhi 14th September, 2006

Notification

S.O. 1533 Whereas, a draft notification **under sub-rule (3) of Rule 5 of the Environment (Protection) Rules, 1986 for imposing** certain restrictions and prohibitions on new projects or activities, or on the expansion or modernization of existing projects or activities based on their potential environmental impacts as indicated in the Schedule to the notification, being undertaken in any part of India[1], unless prior environmental clearance has been accorded in accordance with the objectives of National Environment Policy **as approved by the Union Cabinet on 18th May, 2006** and the procedure specified in the notification, by the Central Government or the State or Union territory Level Environment Impact Assessment Authority (SEIAA), to be constituted by the Central Government in consultation with the State Government or the Union territory Administration concerned under sub-section (3) of section 3 of the Environment (Protection) Act, 1986 for the purpose of this notification, was published in the Gazette of India ,Extraordinary, Part II, section 3, sub-section (ii) vide number S.O. 1324 (E) dated the 15th September ,2005 inviting objections and suggestions from all persons likely to be affected thereby within a period of sixty days from the date on which copies of Gazette containing the said notification were made available to the public;

And whereas, copies of the said notification were made available to the public on 15th September, 2005;

And whereas, all objections and suggestions received in response to the above mentioned draft notification have been duly considered by the Central Government;

Now, therefore, in exercise of the powers conferred by sub-section (1) and clause (v) of sub-section (2) of section 3 of the Environment (Protection) Act, 1986, read with clause (d) of sub-rule (3) of rule 5 of the Environment (Protection) Rules, 1986 and in supersession of the notification number S.O. 60 (E) dated the 27th January, 1994, except in respect of things done or omitted to be done before such supersession, the Central Government hereby directs that on and from the date of its publication the required construction of new projects or activities or the expansion or modernization of existing projects or activities listed in the Schedule to this notification entailing capacity addition with change in process and or technology shall be undertaken in any part of India only after the prior environmental clearance from the Central Government or as the case may be, by the State Level Environment Impact Assessment Authority, duly constituted by the Central Government under sub-section (3) of section 3 of the said Act, in accordance with the procedure specified hereinafter in this notification.

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[1]Includes the territorial waters

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2. Requirements of prior Environmental Clearance (EC):- The following projects or activities shall require prior environmental clearance from the concerned regulatory authority, which shall hereinafter referred to be as the Central Government in the Ministry of Environment and Forests for matters falling under Category 'A' in the Schedule and at State level the State Environment Impact Assessment Authority (SEIAA) for matters falling under Category 'B' in the said Schedule, before any construction work, or preparation of land by the project management except for securing the land, is started on the project or activity:

(i) All new projects or activities listed in the Schedule to this notification;

(ii) Expansion and modernization of existing projects or activities listed in the Schedule to this notification with addition of capacity beyond the limits specified for the concerned sector, that is, projects or activities which cross the threshold limits given in the Schedule, after expansion or modernization;

(iii) Any change in product - mix in an existing manufacturing unit included in Schedule beyond the specified range.

3. State Level Environment Impact Assessment Authority:- (1) A State Level Environment Impact Assessment Authority hereinafter referred to as the SEIAA shall be constituted by the Central Government under sub-section (3) of section 3 of the Environment (Protection) Act, 1986 comprising of three Members including a Chairman and a Member – Secretary to be nominated by the State Government or the Union territory Administration concerned.

(2) The Member-Secretary shall be a serving officer of the concerned State Government or Union territory administration familiar with environmental laws.

(3) The other two Members shall be either a professional or expert fulfilling the eligibility criteria given in Appendix VI to this notification.

(4) One of the specified Members in sub-paragraph (3) above who is an expert in the Environmental Impact Assessment process shall be the Chairman of the SEIAA.

(5) The State Government or Union territory Administration shall forward the names of the Members and the Chairman referred in sub- paragraph 3 to 4 above to the Central Government and the Central Government shall constitute the SEIAA as an authority for the purposes of this notification within thirty days of the date of receipt of the names.

(6) The non-official Member and the Chairman shall have a fixed term of three years (from the date of the publication of the notification by the Central Government constituting the authority).

(7) All decisions of the SEIAA shall be unanimous and taken in a meeting.

4. Categorization of projects and activities:-

(i) All projects and activities are broadly categorized in to two categories - Category A and Category B, based on the spatial extent of potential impacts and potential impacts on human health and natural and man made resources.

(ii) All projects or activities included as Category 'A' in the Schedule, including expansion and modernization of existing projects or activities and change in product mix, shall require prior environmental clearance from the Central Government in the Ministry of Environment and Forests (MoEF) on the recommendations of an Expert Appraisal Committee (EAC) to be constituted by the Central Government for the purposes of this notification;

(iii) All projects or activities included as Category 'B' in the Schedule, including expansion and modernization of existing projects or activities as specified in sub paragraph (ii) of paragraph 2, or change in product mix as specified in sub paragraph (iii) of paragraph 2, but excluding those which fulfill the General Conditions (GC) stipulated in the Schedule, *will* require prior environmental clearance from the State/Union territory Environment Impact Assessment Authority (SEIAA). The SEIAA shall base its decision on the recommendations of a State or Union territory level Expert Appraisal Committee (SEAC) as to be constituted for in this notification. In the absence of a duly constituted SEIAA or SEAC, a Category 'B' project shall be treated as a Category 'A' project;

5. Screening, Scoping and Appraisal Committees:-

The same Expert Appraisal Committees (EACs) at the Central Government and SEACs (hereinafter referred to as the (EAC) and (SEAC) at the State or the Union territory level shall screen, scope and appraise projects or activities in Category 'A' and Category 'B' respectively. EAC and SEAC's shall meet at least once every month.

(a) The composition of the EAC shall be as given in Appendix VI. The SEAC at the State or the Union territory level shall be constituted by the Central Government in consultation with the concerned State Government or the Union territory Administration with identical composition;

(b) The Central Government may, with the prior concurrence of the concerned State Governments or the Union territory Administrations, constitutes one SEAC for more than one State or Union territory for reasons of administrative convenience and cost;

(c) The EAC and SEAC shall be reconstituted after every three years;

(d) The authorised members of the EAC and SEAC, concerned, may inspect any site(s) connected with the project or activity in respect of which the prior environmental clearance is sought, for the purposes of screening or scoping or appraisal, with prior notice of at least seven days to the applicant, who shall provide necessary facilities for the inspection;

(e) The EAC and SEACs shall function on the principle of collective responsibility. The Chairperson shall endeavour to reach a consensus in each case, and if consensus cannot be reached, the view of the majority shall prevail.

6. Application for Prior Environmental Clearance (EC):-

An application seeking prior environmental clearance in all cases shall be made in the prescribed Form 1 annexed herewith and Supplementary Form 1A, if applicable, as given in Appendix II, after the identification of prospective site(s) for the project and/or activities to which the application relates, before commencing any construction activity, or preparation of land, at the site by the applicant. The applicant shall furnish, along with the application, a copy of the pre-feasibility project report except that, in case of construction projects or activities (item 8 of the Schedule) in addition to Form 1 and the Supplementary Form 1A, a copy of the conceptual plan shall be provided, instead of the pre-feasibility report.

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7. Stages in the Prior Environmental Clearance (EC) Process for New Projects:-

7(i) The environmental clearance process for new projects will comprise of a maximum of four stages, all of which may not apply to particular cases as set forth below in this notification. These four stages in sequential order are:-

- Stage (1) Screening (Only for Category 'B' projects and activities)
- Stage (2) Scoping
- Stage (3) Public Consultation
- Stage (4) Appraisal

I. **Stage (1) - Screening**:

In case of Category 'B' projects or activities, this stage will entail the scrutiny of an application seeking prior environmental clearance made in Form 1 by the concerned State level Expert Appraisal Committee (SEAC) for determining whether or not the project or activity requires further environmental studies for preparation of an Environmental Impact Assessment (EIA) for its appraisal prior to the grant of environmental clearance depending up on the nature and location specificity of the project . The projects requiring an Environmental Impact Assessment report shall be termed Category 'B1' and remaining projects shall be termed Category 'B2' and will not require an Environment Impact Assessment report. For categorization of projects into B1 or B2 except item 8 (b), the Ministry of Environment and Forests shall issue appropriate guidelines from time to time.

II. **Stage (2) - Scoping**:

(i) "Scoping": refers to the process by which the Expert Appraisal Committee in the case of Category 'A' projects or activities, and State level Expert Appraisal Committee in the case of Category 'B1' projects or activities, including applications for expansion and/or modernization and/or change in product mix of existing projects or activities, determine detailed and comprehensive Terms Of Reference (TOR) addressing all relevant environmental concerns for the preparation of an Environment Impact Assessment (EIA) Report in respect of the project or activity for which prior environmental clearance is sought. The Expert Appraisal Committee or State level Expert Appraisal Committee concerned shall determine the Terms of Reference on the basis of the information furnished in the prescribed application Form1/Form 1A including Terns of Reference proposed by the applicant, a site visit by a sub- group of Expert Appraisal Committee or State level Expert Appraisal Committee concerned only if considered necessary by the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned, Terms of Reference suggested by the applicant if furnished and other information that may be available with the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned. All projects and activities listed as Category 'B' in Item 8 of the Schedule (Construction/Township/Commercial Complexes /Housing) shall not require Scoping and will be appraised on the basis of Form 1/ Form 1A and the conceptual plan.

(ii) The Terms of Reference (TOR) shall be conveyed to the applicant by the Expert Appraisal Committee or State Level Expert Appraisal Committee as concerned within sixty days of the receipt of Form 1. In the case of Category A Hydroelectric projects Item 1(c) (i) of the Schedule the Terms of Reference shall be conveyed along with the clearance for pre-construction activities .If the Terms of Reference are not finalized and conveyed to the applicant within sixty days of the receipt of Form 1, the Terms of Reference suggested by the applicant shall be deemed as the final Terms of Reference approved for the EIA studies. The approved Terms of

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Reference shall be displayed on the website of the Ministry of Environment and Forests and the concerned State Level Environment Impact Assessment Authority.

(iii) Applications for prior environmental clearance may be rejected by the regulatory authority concerned on the recommendation of the EAC or SEAC concerned at this stage itself. In case of such rejection, the decision together with reasons for the same shall be communicated to the applicant in writing within sixty days of the receipt of the application.

III. **Stage (3) - Public Consultation**:

(i) "Public Consultation" refers to the process by which the concerns of local affected persons and others who have plausible stake in the environmental impacts of the project or activity are ascertained with a view to taking into account all the material concerns in the project or activity design as appropriate. All Category 'A' and Category B1 projects or activities shall undertake Public Consultation, except the following:-

(a) modernization of irrigation projects (item 1(c) (ii) of the Schedule).

(b) all projects or activities located within industrial estates or parks (item 7(c) of the Schedule) approved by the concerned authorities, and which are not disallowed in such approvals.

(c) expansion of Roads and Highways (item 7 (f) of the Schedule) which do not involve any further acquisition of land.

(d) all Building /Construction projects/Area Development projects and Townships (item 8).

(e) all Category 'B2' projects and activities.

(f) all projects or activities concerning national defence and security or involving other strategic considerations as determined by the Central Government.

(ii) The Public Consultation shall ordinarily have two components comprising of:-

(a) a public hearing at the site or in its close proximity- district wise, to be carried out in the manner prescribed in Appendix IV, for ascertaining concerns of local affected persons;

(b) obtain responses in writing from other concerned persons having a plausible stake in the environmental aspects of the project or activity.

(iii) the public hearing at, or in close proximity to, the site(s) in all cases shall be conducted by the State Pollution Control Board (SPCB) or the Union territory Pollution Control Committee (UTPCC) concerned in the specified manner and forward the proceedings to the regulatory authority concerned within 45(forty five) of a request to the effect from the applicant.

(iv) in case the State Pollution Control Board or the Union territory Pollution Control Committee concerned does not undertake and complete the public hearing within the specified period, and/or does not convey the proceedings of the public hearing within the prescribed period

directly to the regulatory authority concerned as above, the regulatory authority shall engage another public agency or authority which is not subordinate to the regulatory authority, to complete the process within a further period of forty five days,.

(v) If the public agency or authority nominated under the sub paragraph (iii) above reports to the regulatory authority concerned that owing to the local situation, it is not possible to conduct the public hearing in a manner which will enable the views of the concerned local persons to be freely expressed, it shall report the facts in detail to the concerned regulatory authority, which may, after due consideration of the report and other reliable information that it may have, decide that the public consultation in the case need not include the public hearing.

(vi) For obtaining responses in writing from other concerned persons having a plausible stake in the environmental aspects of the project or activity, the concerned regulatory authority and the State Pollution Control Board (SPCB) or the Union territory Pollution Control Committee (UTPCC) shall invite responses from such concerned persons by placing on their website the Summary EIA report prepared in the format given in Appendix IIIA by the applicant along with a copy of the application in the prescribed form , within seven days of the receipt of a written request for arranging the public hearing . Confidential information including non-disclosable or legally privileged information involving Intellectual Property Right, source specified in the application shall not be placed on the web site. The regulatory authority concerned may also use other appropriate media for ensuring wide publicity about the project or activity. The regulatory authority shall, however, make available on a written request from any concerned person the Draft EIA report for inspection at a notified place during normal office hours till the date of the public hearing. All the responses received as part of this public consultation process shall be forwarded to the applicant through the quickest available means.

(vii) After completion of the public consultation, the applicant shall address all the material environmental concerns expressed during this process, and make appropriate changes in the draft EIA and EMP. The final EIA report, so prepared, shall be submitted by the applicant to the concerned regulatory authority for appraisal. The applicant may alternatively submit a supplementary report to draft EIA and EMP addressing all the concerns expressed during the public consultation.

IV. Stage (4) - Appraisal:

(i) Appraisal means the detailed scrutiny by the Expert Appraisal Committee or State Level Expert Appraisal Committee of the application and other documents like the Final EIA report, outcome of the public consultations including public hearing proceedings, submitted by the applicant to the regulatory authority concerned for grant of environmental clearance. This appraisal shall be made by Expert Appraisal Committee or State Level Expert Appraisal Committee concerned in a transparent manner in a proceeding to which the applicant shall be invited for furnishing necessary clarifications in person or through an authorized representative. On conclusion of this proceeding, the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned shall make categorical recommendations to the regulatory authority concerned either for grant of prior environmental clearance on stipulated terms and conditions, or rejection of the application for prior environmental clearance, together with reasons for the same.

(ii) The appraisal of all projects or activities which are not required to undergo public consultation, or submit an Environment Impact Assessment report, shall be carried out on the basis of the prescribed application Form 1 and Form 1A as applicable, any other relevant

validated information available and the site visit wherever the same is considered as necessary by the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned.

(iii) The appraisal of an application be shall be completed by the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned within sixty days of the receipt of the final Environment Impact Assessment report and other documents or the receipt of Form 1 and Form 1 A, where public consultation is not necessary and the recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee shall be placed before the competent authority for a final decision within the next fifteen days .The prescribed procedure for appraisal is given in Appendix V ;

7(ii). Prior Environmental Clearance (EC) process for Expansion or Modernization or Change of product mix in existing projects:

All applications seeking prior environmental clearance for expansion with increase in the production capacity beyond the capacity for which prior environmental clearance has been granted under this notification or with increase in either lease area or production capacity in the case of mining projects or for the modernization of an existing unit with increase in the total production capacity beyond the threshold limit prescribed in the Schedule to this notification through change in process and or technology or involving a change in the product –mix shall be made in Form I and they shall be considered by the concerned Expert Appraisal Committee or State Level Expert Appraisal Committee within sixty days, who will decide on the due diligence necessary including preparation of EIA and public consultations and the application shall be appraised accordingly for grant of environmental clearance.

8.Grant or Rejection of Prior Environmental Clearance (EC):

(i) The regulatory authority shall consider the recommendations of the EAC or SEAC concerned and convey its decision to the applicant within forty five days of the receipt of the recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned or in other words within one hundred and five days of the receipt of the final Environment Impact Assessment Report, and where Environment Impact Assessment is not required, within one hundred and five days of the receipt of the complete application with requisite documents, except as provided below.

(ii) The regulatory authority shall normally accept the recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned. In cases where it disagrees with the recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned, the regulatory authority shall request reconsideration by the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned within forty five days of the receipt of the recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned while stating the reasons for the disagreement. An intimation of this decision shall be simultaneously conveyed to the applicant. The Expert Appraisal Committee or State Level Expert Appraisal Committee concerned, in turn, shall consider the observations of the regulatory authority and furnish its views on the same within a further period of sixty days. The decision of the regulatory authority after considering the views of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned shall be final and conveyed to the applicant by the regulatory authority concerned within the next thirty days.

(iii) In the event that the decision of the regulatory authority is not communicated to the applicant within the period specified in sub-paragraphs (i) or (ii) above, as applicable, the

applicant may proceed as if the environment clearance sought for has been granted or denied by the regulatory authority in terms of the final recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned.

(iv) On expiry of the period specified for decision by the regulatory authority under paragraph (i) and (ii) above, as applicable, the decision of the regulatory authority, and the final recommendations of the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned shall be public documents.

(v) Clearances from other regulatory bodies or authorities shall not be required prior to receipt of applications for prior environmental clearance of projects or activities, or screening, or scoping, or appraisal, or decision by the regulatory authority concerned, unless any of these is sequentially dependent on such clearance either due to a requirement of law, or for necessary technical reasons.

(vi) Deliberate concealment and/or submission of false or misleading information or data which is material to screening or scoping or appraisal or decision on the application shall make the application liable for rejection, and cancellation of prior environmental clearance granted on that basis. Rejection of an application or cancellation of a prior environmental clearance already granted, on such ground, shall be decided by the regulatory authority, after giving a personal hearing to the applicant, and following the principles of natural justice.

9. Validity of Environmental Clearance (EC):

The "Validity of Environmental Clearance" is meant the period from which a prior environmental clearance is granted by the regulatory authority, or may be presumed by the applicant to have been granted under sub paragraph (iv) of paragraph 7 above, to the start of production operations by the project or activity, or completion of all construction operations in case of construction projects (item 8 of the Schedule), to which the application for prior environmental clearance refers. The prior environmental clearance granted for a project or activity shall be valid for a period of ten years in the case of River Valley projects (item 1(c) of the Schedule), project life as estimated by Expert Appraisal Committee or State Level Expert Appraisal Committee subject to a maximum of thirty years for mining projects and five years in the case of all other projects and activities. However, in the case of Area Development projects and Townships [item 8(b)], the validity period shall be limited only to such activities as may be the responsibility of the applicant as a developer. This period of validity may be extended by the regulatory authority concerned by a maximum period of five years provided an application is made to the regulatory authority by the applicant within the validity period, together with an updated Form 1, and Supplementary Form 1A, for Construction projects or activities (item 8 of the Schedule). In this regard the regulatory authority may also consult the Expert Appraisal Committee or State Level Expert Appraisal Committee as the case may be.

10. Post Environmental Clearance Monitoring:

(i) It shall be mandatory for the project management to submit half-yearly compliance reports in respect of the stipulated prior environmental clearance terms and conditions in hard and soft copies to the regulatory authority concerned, on 1st June and 1st December of each calendar year.

(ii) All such compliance reports submitted by the project management shall be public documents. Copies of the same shall be given to any person on application to the concerned regulatory authority. The latest such compliance report shall also be displayed on the web site of the concerned regulatory authority.

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11. Transferability of Environmental Clearance (EC):

A prior environmental clearance granted for a specific project or activity to an applicant may be transferred during its validity to another legal person entitled to undertake the project or activity on application by the transferor, or by the transferee with a written "no objection" by the transferor, to, and by the regulatory authority concerned, on the same terms and conditions under which the prior environmental clearance was initially granted, and for the same validity period. No reference to the Expert Appraisal Committee or State Level Expert Appraisal Committee concerned is necessary in such cases.

12. Operation of EIA Notification, 1994, till disposal of pending cases:

From the date of final publication of this notification the Environment Impact Assessment (EIA) notification number S.O.60 (E) dated 27th January, 1994 is hereby superseded, except in suppression of the things done or omitted to be done before such suppression to the extent that in case of all or some types of applications made for prior environmental clearance and pending on the date of final publication of this notification, the Central Government may relax any one or all provisions of this notification except the list of the projects or activities requiring prior environmental clearance in Schedule I , or continue operation of some or all provisions of the said notification, for a period not exceeding one year from the date of issue of this notification.

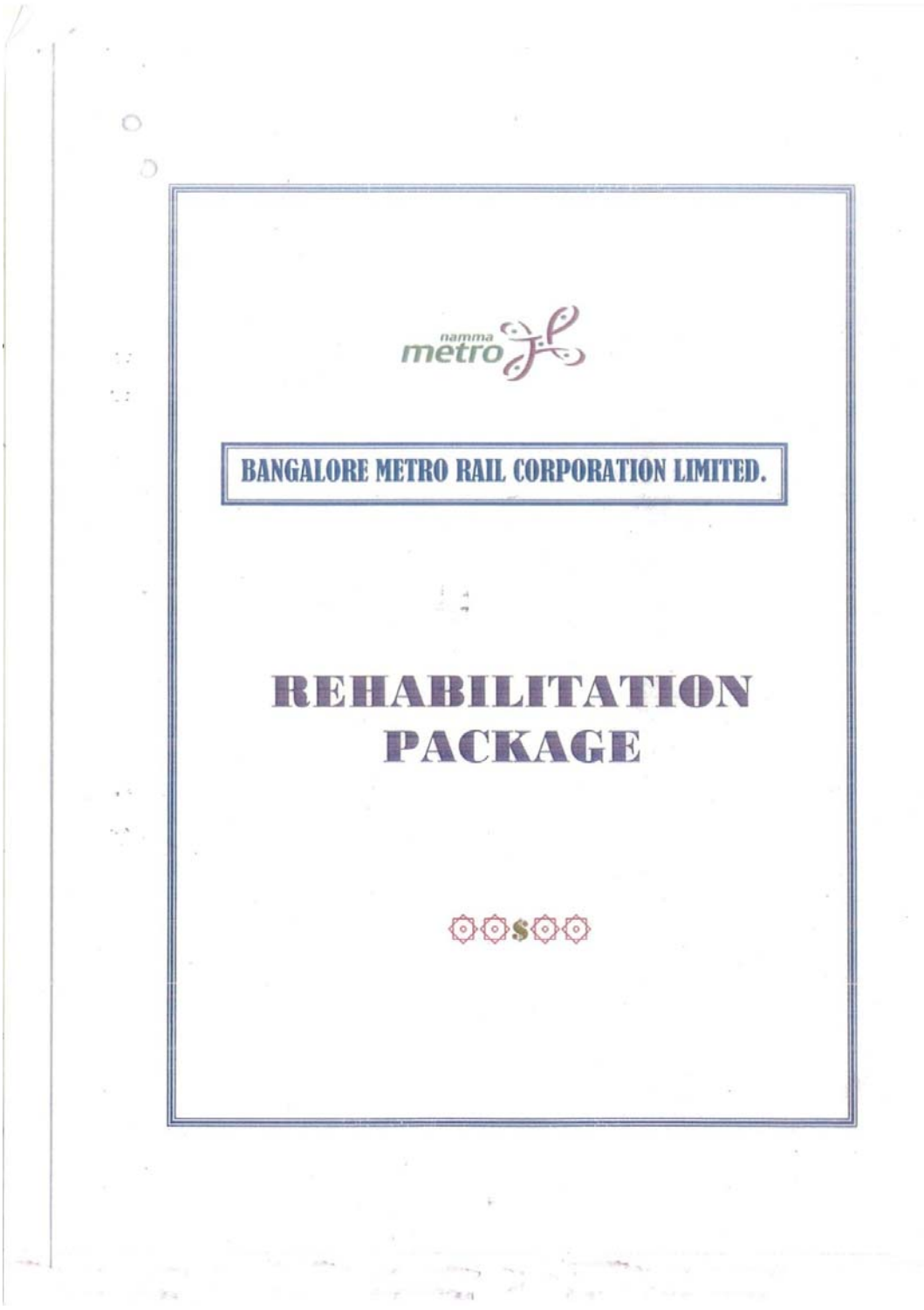
[No. J-11013/56/2004-IA-II (I)]

(R.CHANDRAMOHAN)
JOINT SECRETARY TO THE GOVERNMENT OF INDIA

(In the schedule to this notification, Railways or Metro Railways are not included)

Annexure 13.2

REHABILITATION PACKAGE - BANGALORE METRO RAIL CORPORATION LTD.



BANGALORE METRO RAIL CORPORATION LIMITED

REHABILITATION PACKAGE

I. Introduction

1. Bangalore is a fast growing city. In 1971 its population was about 1.6 million; this is now about 6.5 million and is likely to reach 10 million by the year 2021. The vehicle population in the city has been growing phenomenally, causing air and noise pollution, health problems besides heavily congesting the roads and reducing the pace of movement. The city has over 2.5 million vehicles; 75% of them are two wheelers and 5% are three wheelers. On an average about 900 new vehicles are being registered in the city every day.

2. The inadequacy of public transport system has caused mushrooming growth of two wheelers and three wheelers in the city. The road accidents in the city are highest (per lakh population) in comparison to any other city in the country. On an average, three persons get killed and 18 injured, daily, in such accidents. The city needs a reliable Mass Rapid Transit System.

3. The Government of Karnataka has conveyed approval for undertaking Metro Rail Project on 24.03.2005. The Government of India in its order dated 11th May 2006 has accorded approval for the Bangalore Metro Rail Project to be taken up as a joint venture project of Government of India and Government of Karnataka and designated the Bangalore Metro Rail Corporation Limited as the implementing agency. In I-Phase, the metro will cover 33 Kms in two corridors, i.e. East-west corridor of 18.1 km from Byappanahalli to Mysore Road and North-south corridor of 14.9 kms. From Yeshwantpur to RV Road. In the East-west corridor, initially 7 Kms from Byappanahalli to Cricket Stadium is proposed to be taken up in stage I and is likely to be completed by 2009. The entire project is proposed to be completed by 2011.

The project requires acquisition of public and private properties. The project would affect about 1500 families. The details of acquisition of properties are as below:

II. Details of properties

REQUIREMENT OF THE PROPERTIES FOR THE BANGALORE METRO RAIL PROJECT			
PROPERTIES TO BE ACQUIRED (NUMBERS)			
Details	Number of properties		
	Developed	Vacant	Total
Private Commercial	374	11	385
Private Residential	172	4	176
Others like temples, Churches etc.	7	0	7
Total number of private commercial, residential & other properties			568
Total number of Government, Defence and public sector properties			54
Total number of Government, Defence, public sector, private and community properties			629

PROPERTY ACQUISITION (SQ. MTRS)				
	Developed	Vacant	Total Area Of Com, Res. etc. in Sq. Mtrs.	Total Area Of Com, Res. etc. in Acres.
Details	Affected Area	Affected Area	Affected Area	Affected Area
Private Commercial	44585.47	37916	82502	20.6
Private Residential	15708.09	6203	21912	5.5
Others like temples, Churches etc.	1349.71	0	1350	0.3
Total area of Private Commercial, Residential & other properties.	61643	44120	105763	26.13
Government land			130463	32.2
Defence / Lands / HAL / BHEL / BSNL / NPCIL / Railways / Central Silk Board			551925	136.35
NGEF			137280	33.91
Total area of Private and Government properties.			925430.4	228.614

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The properties would be acquired in part or in full. An acceptable rehabilitation package should address the hardships and inconveniences due to loss of residential premises/ land and the loss of economic activity. While it is difficult to mitigate the disruption in social life, the negative impacts of displacing persons from their residences and economic activities is attempted to be mitigated through an economic package. In framing this package, the BMRCL drew lessons from similar packages implemented in the other projects in the State and elsewhere, e.g.: KSHIP, NHAI, Delhi- MRTS project, etc. The World Bank and The Asian Development Bank gives special emphasis in rehabilitating families who are involuntary displaced in projects. The Government have also been moved to increase the FAR near the station.

This package is extended to those affected due to acquisition of private property only. This package does not apply to Government property / Public property etc.

III Principles

The basic principles that guide BMRCL in this package are that the families/ persons affected shall be enabled to:

a) Replace the assets lost;

b) Receive, for a while, i.e.: until the affected persons had time to resettle, an economic assistance

c) Compensate to the extent of costs that they would incur in shifting residences, and commercial establishments, through provision of shifting allowance, transitional allowances, inconvenience allowances, etc.

Annexure A describes the details of entitlements and type of assistance to be extended to the affected persons.

IV. Losses

a. The most direct and immediate impacts are:
   - Loss of asset- land, residential accommodation, business establishment;
   - Loss of livelihood- loss of business income/ loss of rental income;
   - Loss of common property resources- schools, hospitals, religious structures etc and;

b. Social links.

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V. Entitlement

The overall entitlement package is as follows:

Type of Loss	Rehabilitation package
Loss of residential property	1. Compensation as per KIADB. Act or consent award–Market value to be used for obtaining consent. 2. Shifting allowance 3. Inconvenience allowance 4. Right to salvage material 5. Transitional Allowance 6. Rental income loss compensation
Loss of commercial property	1. Compensation as per KIADB Act or consent award – Market value to be used for obtaining consent. 2. Business loss 3. Business premises reestablishment allowance 4. Shifting Allowance 5. Right to salvage material 6. Rental income loss
Tenants commercial	1. Shifting Allowance 2. Business loss allowance 3. Business premises reestablishment allowance
Tenants residential	1. Shifting Allowance 2. Inconvenience Allowance
Common Property Resources	The Project will meet the cost of restoring the affected portion of public property- schools , hospitals, parks, religious structures etc.

VI. Definitions and Rationale

a. Project affected person:

Any individual who resides or has economic interest within the area being acquired and who may be directly affected by the project due to losing of commercial or residential structures in whole or part and as a result of the project.

b. Owners:

Are those who have legal title to land, structure and other assets.

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c. **Award/ Compensation:**

Refers to the amount paid under Land Acquisition Act for private property, structures and any other assets acquired for the project. In this context, Award/ compensation refers to payments made by the Land acquisition officer acting under the KIADB Act, 1966 (the Land acquisition is being done under the KIADB Act).

d. **Consent Award:**

Is the amount that the Project Affected Person negotiates with the Land acquisition officer for the loss incurred, on a willing buyer-seller basis. Once the amount is agreed upon the project affected person cannot move court for enhancement of the amount. This amount is a mutually agreed price without any pre-conditions. Consent award has been provided as an option to the affected person, if he opts not to go for compensation determined unilaterally under the KIADB Act.

e. **Tenants[1]:**

Are those persons having bonafide tenancy agreements, written or unwritten, with a private property owner with clear property titles, to occupy a structure or land for residences and business. Those who do not have any written documents need to furnish documentary proof such as telephone bills, electricity bills, ration cards, any postal evidence, passport or other legal documents to prove occupation of the premises.

f. **Business loss:**

This is to offset the loss of livelihood/ business. Compensation for business loss of 10 months is provided (at the lowest slab), as below. Those businesses which do not have any documentation on VAT will also be considered, but for a lesser compensation. i.e, 50% of the first category.

[1] Tenants have been identified as project affected persons, as a good number of residential and commercial structures in the project corridor are tenanted premises.

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1.	Payment of ST /VAT upto and including Rs.5000.	Rs. 50,000
2.	Payment of ST /VAT between Rs 5001 to Rs. 15,000	Rs. 75,000
3.	Payment of ST /VAT above Rs.15001	Rs. 1,00,000
4.	If without ST/VAT documentation	Rs. 25,000

g. Commercial/ Residential Rental income lost:

This is the loss of rental income for the owner. It is assumed that the rental income is Rs.10 per square foot for residential property and Rs. 20 per square foot for commercial property, for six months. The land loser is compensated on the basis as under:

	Area lost	Residential	Commercial
1.	Upto 1000 sq. ft.	Rs. 60,000	Rs. 1,20,000
2.	1001 sq. ft – 1500 sq .ft.	Rs. 75,000	Rs. 1,50,000
3.	Above 1501 sq. ft.	Rs. 90,000	Rs. 1,80,000

h. Inconvenience Allowance:

This is a one time allowance paid to all project affected persons losing structure and land, for the inconvenience caused due to acquisition. The inconvenience is in terms of finding new gas connection, telephone connections, ration cards, new schools, colleges, arranging conveyance including deposits for the same. Inconvenience allowance has been provided at the rate of Rs. 30,000 as a one time payment for those losing total residential structure. If the residential property loser continues to remain in the same premises he is provided an allowance of Rs. 24,000 as he has to put up with various other inconveniences during project construction period. In case of tenant-families, the same allowance will be provided at Rs. 30,000 for each family. For single person tenant Rs. 15,000 will be provided.

i. Transitional allowance:

This is allowance paid on the basis of the area lost. This amount is to offset interim rental/rent deposit costs to the affected persons because of shifting. The rate considered is Rs.10 per sq. ft for 6 months. This is provided for those losing owned residential properties where shifting is required.

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1.	Up to 1000 sq.ft.	Rs. 60,000
2.	1001 sqft – 1500 sq.ft.	Rs. 75,000
3.	Above 1501 sq.ft.	Rs. 90,000

j. Shifting Allowance:

For all affected persons who have to shift, this allowance has been provided based on the area lost. This amount is the transportation of belongings of the affected persons who have to shift. This amount differs for commercial and residential loss.

Commercial

1.	up to 150 sq. ft.	Rs. 10,000
2.	151 sq. ft to 300 sq. ft.	Rs. 15,000
3.	Above 301 sq. ft.	Rs. 20,000

Residential

1.	upto 1000 sq. ft.	Rs. 10,000
2.	1001 sq. ft to 1500 sq. ft.	Rs. 12,500
3.	Above 1501 sq. ft.	Rs. 15,000

k. Business premises reestablishment allowance:

This is given to those persons losing their commercial establishments, to re-establish their business @ Rs.240/- per sqft. of area lost. This is intended to meet the cost of rent @ Rs. 20 for 12 months

l. Right to salvage material totally:

Owners can take whatever material possible from their existing structure.

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m. **Cut- off date:**

The date of Notification under Section 28 (1) under the KIADB Act is 17th of January 2006 in most cases. In some cases the lands have been notified on subsequent date & the date of notification under section 28(1) is 13-11-2006. These dates will be taken as the cut-off dates for owners and also tenants, where land acquisition will be required. Any person moving into the project impact area after these dates will not be considered.

n. **Any other unidentified category:**

Any category not identified, shall be documented and mitigated based on the principles agreed upon in this rehabilitation package.

VII. Implementation

During project implementation, the resettlement program will be coordinated with the timing of the civil works in the various construction packages. The project will provide adequate notification, counseling and assistance to the affected persons so that they are able to move or give up their assets without undue hardship before civil works are to start.

VIII. Basveshwara / Jai Bhim habitations

The two habitations would be relocated at BMRCL's cost.

IX. Land Acquisition procedure

The normal procedures for Land acquisition under the KIADB act will be followed in this project. In respect of any additional land /structure which the project affected person opts to give up to the Project Authorities, acquisition will be made by issue of fresh notification as per the provisions of KIADB Act.

X. Institutional Arrangements

A Rehabilitation Implementation Unit (RIU) will be set up.

XI. Clarifications and doubts

Clarifications and doubts in implementation of this package would be issued by BMRCL and would be final.

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Annexure - A

BANGALORE METRO RAIL PROJECT
REHABILITATION PACKAGE

	Affected Category	Compensation and Entitlements
I. a.	**Owner losing land and residential structure totally (Only owner staying in the premises)**	1. Compensation as per KIADB for land and structure acquired (Award) or 2. Consent award based on market value of land and building[2]. and 3. Shifting allowance: a. upto 1000 sq. ft. – Rs. 10,000 b. 1001sq ft – 1500 sq. ft.– Rs. Rs. 12,500 c. > 1501 sq.ft. – Rs. 15,000 4. Inconvenience Allowance: One time payment of Rs. 30,000. 5. Transitional Allowance a. upto 1000 sq. ft. – Rs. 60,000 b. 1001 sq. ft. – 1500 sq.ft.– Rs. Rs. 75,000 c. > 1501 sq. ft.– Rs. 90,000 6. Right to salvage material totally
I b.	**Owner losing land and residential structure totally (owner and tenant staying in the same building premises in separate parts)**	1. Same as in I a (1-6) Rental income lost in respect of rental area lost (*Rs. 10 per sq .ft. pm, for 6 months, for residential)*: a. upto 1000 sq. ft. – Rs.60,000 b. 1001 sq. ft.– 1500 sq. ft.–Rs. Rs. 75,000 c. >1501 sq. ft.– Rs. 90,000

[2] In case the amount of Consent Award is more than the mentioned entitlements there will be no deductions from the affected person.

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I c.	**Owner losing land and residential structure partially but continues to remain in the balance portion of the same premises**	1. Compensation as per KIADB for land and structure acquired (Award) or 2. Consent award based on market value of land and building[3] and 3. Inconvenience Allowance One time payment of Rs. 24,000
I d.	**Owner losing land and residential structure partially and willing to surrender the same completely to Project Authority.**	1. Owner has the option of giving up the remaining part of the property to the Project Authority. (*A separate notification will be given for the remaining area)* 2. Compensation and Entitlements will be the same as in Category **I a. (1-6)** or **I b.** as the case may be for the area lost including 1 above.
II a.	**Owner losing land and commercial structure totally (owner operating own business in the acquired premises)**	1. Compensation as per KIADB for land and structure acquired (Award) or 2. Consent award based on market value of land and building[4] 3. Shifting Allowance: a. upto 150 sq. ft. – Rs. 10,000 b. 151 sq. ft to 300 sq. ft. – Rs. 15,000 c. > 301 sq. ft. – Rs. 20,000 4. Business loss: In case of, a. Payment of ST /VAT upto and including Rs. 5000 will be paid Rs. 50,000. b. Payment of ST /VAT between Rs 5001 to Rs. 15,000 will be paid Rs. 75,000. c. Payment of ST /VAT above Rs. 15001 will be paid Rs. 1,00,000. d. If without ST/VAT documentation, will be paid Rs. 25,000. 5. Business premises re-establishment allowance: Rs. 240 per sq. ft. of area lost 6. Right to salvage material totally

[3] Market value of land and building will be determined by BMRCL.
[4] Market value of land and building will be determined by BMRCL

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II b.	**Owner losing land and commercial structure partially but continues to run business in the same premises**	1. Compensation as per KIADB for land and structure acquired (Award) or 2. Consent award based on market value of land and building[5] 3. Business loss: In respect of, a. Payment of ST / VAT upto and including Rs. 5000 will be paid Rs. 50,000 b. Payment of ST /VAT between Rs 5001 to Rs. 15,000 will be paid Rs. 75,000 c. Payment of ST /VAT above Rs. 15001 will be paid Rs. 1,00,000. d. If without ST/VAT documentation will be paid Rs. 25,000. 4. Right to Salvage material
II c.	**Owner losing land and commercial structure partially and unwilling to continue in the same premises**	1. Owner has the option of giving up the remaining part of the property to the Project Authority. (*Separate notification will be given for the additional area)* 2. Compensation and Entitlements will be the same as in Category II a.
II d.	**Owner losing land and commercial structure, but structure fully rented out**	1. Compensation for the land and structure acquired as per KIADB for land and structure Award or 2. Consent award based on market value of land and building[6] and 3. Commercial Rental income lost (*Rs. 20 per sq. ft. pm for 6 months, twice of residential)* a. upto 1000 sq. ft. – Rs. 1,20,000 b. 1001 sq. ft.–1500 sq. ft.– Rs. Rs. 1,50,000 c.> 1501 sq. ft. – Rs. 1,80,000 4. Right to Salvage material

[5] Market value of land and building will be determined by BMRCL
[6] Market value of land and building will be determined by BMRCL

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II e.	**Owner losing land and commercial structure partially, but structure fully rented out.**	1. Compensation as per KIADB for land and structure acquired (Award) or 2. Consent award based on market value of land and building[7] and 3. Right to Salvage material 4. Commercial Rental income lost, in respect of area lost (*Rs.20 per sq.ft. pm for 6 months, twice of residential)* a. upto 1000 sq. ft. – Rs. 1,20,000 b. 1001 sq. ft.–1500 sq. ft.–Rs. Rs. 1,50,000 c. > 1501 sq.ft. – Rs. 1,80,000
II f.	**Owner losing land and commercial structure fully, commercial activity being run by owner as well as tenant.**	1. Compensation as per KIADB for land and structure acquired (Award) or 2. Consent Award based on market value of land and building[8]. and 3. Shifting Allowance: a. upto 150 sq.ft.. – Rs.10,000 b. 151 sq.ft. to 300 sqft – Rs.15,000 c. > 301 sq.ft. – Rs.20,000 4. Business loss: In respect of, a. Payment of ST /VAT upto and including Rs. 5000 will be paid Rs. 50,000 b. Payment of ST /VAT between Rs 5001 to Rs. 15,000 will be paid Rs. 75,000 c. Payment of ST /VAT above Rs. 15001 will be paid Rs. 1,00,000 . d. If without ST/VAT documentation will be paid Rs. 25,000. 5. Business premises re-establishment allowance: Rs. 240 per sq. ft. of area lost

[7] Market value of land and building will be determined by BMRCL
[8] Market value of land and building will be determined by BMRCL

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		6. Commercial Rental income lost (*Rs. 20 per sq. ft. for 6 months, twice of residential)* a. upto 1000 sq. ft.– Rs. 1,20,000 b. 1001 sq. ft.–1500 sq. ft.–Rs. Rs. 1, 50,000 c. > 1501 sq. ft. – Rs. 1,80,000 7. Right to Salvage material
III	**Owner losing land and residential cum commercial structure (both totally)**	1. Compensation for the land and structure acquired as per KIADB for land and structure or 2. Consent award based on market value of land and building[9] 3. Shifting Allowance: **For commercial:** a. upto 150 sq. ft.. – Rs. 10,000 b. 151 sq. ft. to 300 sq. ft. – Rs. 15,000 c. > 301 sq. ft. – Rs. 20,000 **For residential** a. upto 1000 sq. ft. – Rs. 10,000 b. 1001 – 1500 sq ft.– Rs. Rs. 12,500 c. > 1501 – Rs. 15,000 4. Inconvenience Allowance: One time payment of Rs. 30,000 5. Business loss: In case of, a. Payment of ST /VAT upto and including Rs. 5000 will be paid Rs. 50,000 b. Payment of ST /VAT between Rs 5001 to Rs. 15,000 will be paid Rs. 75,000 c. Payment of ST /VAT above Rs. 15001 will be paid Rs. 1,00,000. d. If without ST/VAT documentation will be paid Rs. 25,000. 6. Business premises re-establishment a. 240 per sq. ft. in respect of commercial portion only 7. Right to salvage material totally

[9] Market value of land and building will be determined by BMRCL

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IV	**Owner Losing only land**	1. Compensation for the land and structure acquired as per KIADB (Award) or 2. Consent award based on market value of land and building[10]
V	**Tenant - Residential**[11]	1. Shifting allowance per tenant single/family tenants a. Rs. 12,500 2. Inconvenience Allowance a. Rs. 30,000 per tenant family. b. Rs. 15,000 for tenant single
VI	**Tenant – Commercial**	1. Shifting allowance per tenant: a. Rs. 15,000 2. Business loss per tenant: a. Payment of ST /VAT upto and including Rs. 5000 will be paid Rs. 50,000 b. Payment of ST /VAT between Rs 5001 to Rs. 15,000 will be paid Rs. 75,000 c. Payment of ST /VAT above Rs. 15001 will be paid Rs. 1,00,000 d. Without ST/VAT documentation will be paid Rs. 25,000 3. Business premises reestablishment per tenant (12 months): Rs. 240 per sq. ft.
VII	**Tenant – Residential cum Commercial**	**A. For residential** 1. Shifting allowance per residential tenant a. Rs. 12,500 2. Inconvenience Allowance a. Rs. 30,000 per tenant family b. Rs. 15,000 for tenant single **AND**

[10] Market value of land and building will be determined by BMRCL
[11] Documents showing proof of his/her tenancy or occupancy.

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		B. For Commercial 1. Shifting allowance per tenant a. Rs. 15,000 2. Business loss per tenant: a. Payment of ST /VAT upto and including Rs. 5000 will be paid Rs. 50,000 b. Payment of ST /VAT between Rs 5001 to Rs. 15,000 will be paid Rs. 75,000 c. Payment of ST /VAT above Rs. 15001 will be paid Rs. 1,00,000 . d. Without ST/VAT documentation will be paid Rs. 25,000. 3. Business premises re-establishment per tenant (12 months) Rs. 240 per sq. ft.
VIII	**Common Property resources**	Project Authority will compensate/replace for affected portion of schools, hospitals, parks, religious structures etc.
IX	**Any other impact not identified**	Unforeseen impacts shall be documented and mitigated based on the principles provided in this package.

Note:

Business dealer shall show certified copy of documents of VAT/ST filing of 12 months of the previous year or one annual filing before Commercial Tax Authorities.

Bangalore
17th August 2007

Managing Director

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14 ESTIMATING CAPITAL COST

14.1 INTRODUCTION

Detailed cost estimates for Bangalore Metro Phase-II extension KR Puram to Silk Board have been prepared covering Civil, Electrical, Signaling and Telecommunication Works, Rolling Stock etc., considering 750v DC Traction at July 2016 Price level.

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 items and (iii) Items being an independent entity. All items related with elevated alignment, permanent way, third rail, signaling & telecommunications, whether in main line 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 Rolling Stock, Lifts, and Escalators etc. costs have been estimated in terms of number of units required for each item. In remaining items, viz. land, utility diversions, rehabilitations, etc., the costs have been assessed on the basis of each item, taken as an independent entity.

In order to arrive at realistic costs of various items, costs have been assessed on basis of accepted rates in various contracts recently awarded by BMRCL for their ongoing works. A suitable escalation factor has been applied to bring these costs to July-20116 price level. In some of these tenders, there is an element of Customs Duty (CD) on the equipment / components to be imported for the work, VAT, etc., built in the quoted rates. The element of customs duty and works tax has been excluded for working out the project cost. However, the details of taxes are worked out separately.

The overall capital cost of Bangalore Metro Phase – II, at July 2016 price level, works out to be Rs. 4202.2 Crores for the KR Puram to Silk Board extension. However, for estimation, a last accepted rate in another Metro Project recently awarded is adopted (the last tendered rate of Bangalore Metro Phase-2). These are figures including taxes and duties. The cost of consultancy contingencies and overheads has been included in the individual components. The capital cost estimates are shown at Table14.4.

14.2 CIVIL ENGINEERING WORKS

14.2.1 Land

The alignment is passing through the centre of the carriage way from Silk board to KR Puram. Thus there is no land acquisition required for the viaduct on this section.

The stations are located above the carriage way and only the Entry / Exit structure at each stations requires 10m x 80m land on either side is proposed to be acquired. The land for terminal station namely Silk board and KR Puram is already in possession with BMRCL. Thus in each station, 1600 sq.mt is required. Out of 11 new stations, 4 stations are on Government lands. Thus land acquisition

for balance 7 stations is 15179 sq.mt (Refer Table 12.1). The land acquisition rate is Rs. 10,000 per sq.ft. of which the total land cost works out to Rs. 173.326 Cr.

Summary of the land cost is placed at Table 14.4.

14.2.2 Alignment / Viaduct

The cost of the viaduct per kilometer in the latest accepted tender estimated is Rs. 43 Cr of Bangalore Metro Phase - 2. In the alignment proposed for the silk board KR Puram line, rail levels at stations are kept 1.50 m below the normal stations designed in the phase – 2. Thus there will be some savings in the cost, which is Rs. 0.8 Lakhs per km. Hence for the estimate purpose, Rs. 42.0 Cr per km is considered. Thus the total cost for 19.5km of viaduct works out to be Rs. 819.0 Cr.

14.2.3 Station Buildings

The cost of the station building is based on the cost of the station buildings of phase 2 for which the contracts have already been awarded. In phase 2 the cost of each station building is coming to Rs. 29.0 Cr. The track height on the ORR line will be about 2.0m lower than in the phase 2. Also, the stations on the ORR line will not a full deck of concourse. Thus, there would be a reduction in cost of station building. Therefore, the cost of each building has been taken as Rs. 27.0 Cr. There are 13 stations on this new line, therefore the total cost of station is Rs. 351.0 Cr.

In addition, a provision of Rs. 5 Cr has been kept for Architectural works has been kept in each station. Thus the total cost for station building including architectural finishes works out to be Rs. 416.0 Cr.

14.2.4 Permanent Way

The cost for laying the track for ballasted and ballast less is based on actual cost incurred in phase 1. The cost of laying ballast less track (Twin tracks – both up and down lines) is taken as Rs 9.0 Cr per running km. And the cost of Ballasted track is taken as Rs. 2.5 Cr. per km. the total length of running viaduct is 20.5 km and therefore the total cost of ballasted track is 184.5 Cr. The length of ballasted is 9.5 km and the cost of Rs. 24.0 Cr. Thus the total cost of track is Rs. 208.0 Cr.

14.2.5 Depot:

Since there is no land along this corridor this line will have to be serviced from the existing Biayappanahalli Depot. The Biayappanahalli Depot was supposed to cater the East West line. Now a new depot has to be constructed on the east west line of Whitefield. The cost of construction of the new depot as well as cost of modification of the Biayapanahalli depot is included in the DPR. Based on the experience of phase 1 a total provision of 232 Cr. has been made for this depot at Whitefield. This includes Rs. 140. Cr for Civil works and Rs. 55 Cr for E&M works and Rs. 32 Cr for plant and Machinery. Also, for remodeling of Biayappanahalli depot a provision of Rs. 5.0 Cr has been kept.

14.2.6 Utility Diversions

The viaduct is passing through centre of carriageway, the station columns are placed in median and acquired land. No major utility shifting is envisaged.

However, the following utilities are to be shifted:

i. Raising of 66 kV tower
ii. Shifting of street lights along median

The costs of utility diversions involved in elevated stretches have been considered under head utility diversions i.e. civil utilities and electrical utilities. Provision under electrical utilities compensates for diversion of HT line crossings, street lights, BSNL utilities, traffic signal posts, high masts etc. Cost estimation is based on the actual route survey estimation. Cost considered for shifting/diversions of Electrical utilities: INR 80.5 Cr. (Lumpsum)

Since the columns are at the centre of the road, no major civil utilities is envisaged, however, for any unchartered utility that might infringe with the construction a lump sum provision of Rs. 10. Cr. is considered. Estimated cost is inclusive of duties, taxes etc.

14.2.7 Traction & Power Supply

Provisions have been made to cover following subheads:

- Receiving Substations including incoming cables from KPTCL Grid Substation
- 33 kV MV distribution network along the corridor
- Auxiliary substations
- Traction substations
- Third rail system
- 1 depot traction electrification (including stinger at inspection lines)
- SCADA System
- Earthing, Bonding and Stray Current Monitoring System
- Spares tools, plant, manuals etc.

The rates adopted for various items are based on the last accepted rates of Bangalore Metro Phase I. Cost considered are INR 14.0 Cr per km of traction electrification. Estimation cost inclusive of duties, taxes etc. The breakup of this cost is given in Table 14.1

Thus the average cost per running km comes to Rs. 14.0 Cr. The total running km is estimated to be Rs 19.5. Therefore the total cost of traction and power supply would be Rs. 273.0 Cr.

Table14.1 Breakup cost of Traction and Power supply

Sl. No	Installation	Unit	Rate	Qty	Amount	Remarks
1	66 kV Cable (3 x 1C)	km	1,27,20,582	24	30,52,93,956	4 feeders, 6 km each
2	RSS - 2 x 25 MVA, AIS	No.	13,08,62,873	2	26,17,25,746	
3	33 kV Cable (3 x 1C)	km	42,29,087	42	17,76,21,667	40 km mainline + 2 km for depot
4	ASS, 2 x 500 kVA	No.	1,14,87,687	13	14,93,39,927	Mainline ASS
5	ASS, 2 x 1500 kVA	No.	1,45,00,000	1	1,45,00,000	Depot ASS
5	TSS, 2 x 2850 kVA	No.	4,23,94,208	11	46,63,36,286	10 mainline + 1 Depot
6	Third Rail	km	1,37,24,562	44	60,38,80,739	38 km for mainline + 6 km for Depot
7	Earthing & Bonding (per st	No.	2,59,288	13	33,70,742	Mainline
8	Viaduct Bonding & SC	km	8,38,929	38	3,18,79,319	Mainline
9	SCADA	LS	4,00,00,000		4,00,00,000	
10	Spares, Manuals Document	LS	3,00,00,000		3,00,00,000	
11	Price Variation (Cables & Ec	km	1,25,00,000	19	23,75,00,000	
					2,32,14,48,382	
	178 weeks upto 2013				12,21,81,494	
	Year 2014 with 5% Escalation				12,82,90,568	
	Year 2015 with 5% Escalation				13,47,05,096	
	Year 2016 with 5% Escalation				14,14,40,351	
	Rounding Off				14,00,00,000	
Notes:						
a	Rates inclusive of duties, taxes, royalties etc.,					
b	Route km - 19					
c	Track km - 38					
d	No. of Station - 13					
e	No. TSS - 11 (10 Mainline + 1 Depot), Considered Baiyappanahalli OCC for SCADA					
f	Rates derived from EP1-CC Contract of Phase I					

14.2.8 Electrical and Mechanical Works

Electrical and Mechanical Works (E&M): The Electrical and Mechanical works comprise of various lighting, building Management system (BMS), fire fighting systems, and lifts and escalators. These costs have been estimated based on the actual cost for the phase 1 station. Further a price escalation of 5% per annum has been provided. The E&M cost per station comes to Rs. 10.24 Cr and the cost for lifts and escalators as Rs. 4.34 Cr. Thus for all the 13 stations on this line the total E&M cost for this line comes to Rs. 190.0 Cr.

Table 14.2 Total E&M Cost of all stations

E&M Costing as executed in Reach 2 (Elevated-VJN)			
BOQ Details		Actual Cost as Executed	in Crores
S.No.	Description		
FIRE FIGHTING WORKS			
S-27.1	FIRE PUMP ROOM EQUIPMENT	12,16,777	
S-27.2	FIRE HYDRANT SYSTEM	20,80,020	
S-27.3	FIRE EXTINGUISHERS - FIRST AID	3,09,380	
S-27.4	SIGNAGES	19,721	
S-27.5	CIVIL WORK	79,199	
S-27.6	FIRE DETECTION & ALARM SYSTEM	17,62,649	
	TOTAL OF FIRE PROTECTION AND DETECTION SYSTEM WORKS	**54,67,746**	₹ 0.55
ELECTRICAL & MECHANICAL WORKS			
28.1	WIRING SYSTEM	3,80,17,682	
28.2	M.V.DISTRIBUTION BOARDS	84,23,169	
28.3	M.V.CABLES & CABLES TRAYS	1,04,00,437	
28.4	LIGHT FIXTURES	39,57,508	
28.5	EARTHING SYSTEM	29,14,484	
28.6	LIGHTNING PROTECTION SYSTEM	1,61,618	
28.7	MISCELLANEOUS ITEMS	15,60,448	
28.8	DG SET	21,83,400	
28.9	HVAC Equipment	37,43,848	
28.1	BUILDING MANAGEMENT SYSTEM (OPTIONAL ITEM)	33,73,125	
	TOTAL OF ELECTRICAL AND MECHANICAL WORKS	**7,47,35,718**	₹ 7.47
	Grand Total (Fire+E&M)	**8,02,03,464**	₹ 8.02
	As contract was executed with the rates quoted in the year 2009, we are considering price escalation of 5% per annum till 2016. (05 Years)	**₹ 10,23,62,202**	**₹ 10.24**

Rate considered for lifts and escalators per station INR 4.34 Cr. Per station (2 lifts & 4 escalators). The breakup of this cost is given in Table 14.3.

Table 14.3 Cost Breakup of Escalators and Lifts

Cost Analysis per station (Elevated/Under Ground)							
S.No	Station Type	Equipment detail	Planned Qty	Unit Cost	Current Rate	Amount in INR	in Crores
1	Elevated	Lifts/Elevator	2	₹ 30,00,000	₹ 36,89,622	₹ 73,79,243	₹ 0.74
2		Escalator	4	₹ 90,00,000	₹ 90,00,000	₹ 3,60,00,000	₹ 3.60
As we have considered 2009 rates for **Lift** as basic, we are considering price escalation of 3% per annum till 2016 (07 Years). For Escalators, We have considered current rates only.							
						Total cost per stati	₹ 4.34

The rates adopted for various items are based on the last accepted rates of Bangalore Metro Phase I. Estimation cost inclusive of duties, taxes etc.

14.2.9 ROLLING STOCK

The cost has been estimated in the chapter on Train operation plan. This is estimated to be 120 coaches. Assuming the cost of each coach is Rs. 9.5 Cr and the total cost is coming to be Rs. 1140 Cr. Estimation cost inclusive of duties, taxes etc.

14.2.10 Signaling, Telecommunication, AFC, PSG Works

Since the Bangalore Metro Phase I project, there has been technology change in Signaling/Train Control System. Unlike Distance To Go (DTG), for the proposed new lone between K R Puram to Silk Board, CBTC Signalling is proposed. Considering the proposal for CBTC signaling system for this line, the cost of signaling system determined from the recently awarded works for similar project of CBTC systems of Kochi Metro (year 2014) is estimated in the DPR. As far as Telecom and AFC Systems are concerned, the technology will be more or less same and therefore, the updated cost of Phase I BMRCL project adopting current exchange rate of Euro and USD is estimated in the DPR.

a) Rate of INR 7.21 Cr. Per km has been considered for Signaling & Train Control System with CBTC technology.
b) Rate of INR 6.83 Cr. Per km has been considered for Telecom System.
c) Rate of INR 3.3 Cr. Per station has been considered for providing AFC System.
d) Rate of INR 6.6 Cr. Per stations has been considered for PSG

Estimated cost inclusive of duties, taxes etc. crores to Rs. 403 Cr.

14.2.11 Road Restorations

On this alignment it is expected that there would no major shifting of utilities involved. However, a provision of Rs 30.0 Cr has been kept.

14.2.12 Contingency, Consultancy and Miscellaneous expenses

In addition to the above capital cost there would be expenditure on Consultancies, contingencies, over heads and project offices. It is estimated that these expenses would be about 6% of the capital cost (Excluding Land cost). Since in accounting these expenses also are captialised therefore the provision for these expenses amounting to Rs 229.0 Cr is made and added back to the each item of capital cost and indicated in Table 14.4.

Table 14.4 Cost Estimate

Line:	Silk Board Junction to K R Puram		Depot:		WhiteField			
Length:	19.5 km		RSS:		WhiteField			
Stations:	13 nos.						Contingency, Conusltancy, etc	Total
Type:	Elevated							
Sl. No.	Particulars		Unit	Rate	Qty.	Amount		
1	**Land**			(Cr)	m2	in Cr.	in Cr.	INR CR.
	1.1	Land for alignment (kadubeesanahali						
	1.2	Land for stations		0.0001	15179	173.33		
	1.3	K R Puram to Tin Factory	LS					
	1.4	Land for Depot	LS	10				
		Sub Total (1)				**173.33**		**173.326**
2	**Alignment and Formation**							
	2.1	n including viaduct lengths in station (e	R.kM	42	19.5	819		
		Sub Total (2)				**819**	**49.1**	**868.1**
3	**Sation Buildings**							
	3.1	Elevated Stations	Per stn.	27	13	351		
	3.2	Architectural finish	Per stn.	5	13	65		
		Sub Total (3)				**416**	**25.0**	**441.0**
4	**Permanent-Way**							
	6.1	Ballast less Track for Elevated Sectic	R.kM	9	20.5	184.5		
	6.2	Ballasted Track for Sidings etc. In de	R.kM	2.5	9.5	24		
		Sub Total (4)				**208**	**12.5**	**220.7**
5	**Depot at Whitefield**							
	5.1	Civil Works	LS			140		
	5.2	E&M Works	LS			55		
	5.3	Machinery & Plant	LS			32		
	5.4	Remodelling of Biayappanahalli Depe	LS			5		
		Sub Total (5)				**232**	**13.9**	**245.9**
6	Miscellaneous							
	10.1	Misc. Utilities, Other Civil Works such	R.kM			10		
	10.2	Electrical Utilities	LS			80.5		
	10.3	Telecom Utilities	LS			0		
		Sub Total (6)				**90.5**	**5.4**	**95.9**
7	**Traction & Power Supply**							
	7.1	Traction & Power Supply including Third rail,ASS,TSS, RSS etc.	R.kM	14	19.5	273		
		Sub Total (7)				**273**	**16.4**	**289.4**
8	**E&M Works**							
	4.1	Elevated Stations	Per stn.	10.24	13	133		
	4.2	Escalators	Per stn.	3.6	13	47		
	4.3	Lifts	Per stn.	0.74	13	10		
		Sub Total (8)				**190**	**11.4**	**200.9**
9	**Rolling Stock (SG)**		Each	9.5	120	1140		
		Sub Total (9)				**1140**	**68.4**	**1208.4**
10	**Signalling and Telecom**							
	8.1	Signalling	R.kM	7.21	19.5	141		
	8.2	Telecom	R.kM	6.83	19.5	133		
	8.3	Automatic Fare collection	Per stn.	3.3	13.0	43		
	8.4	Platform Screen Gates (PSG) for Sta	Per stn.	6.6	13.0	86		
		Sub Total (10)				**403**	**24.2**	**426.7**
11	Road restoration etc.,		R.kM	2	15	30		
		Sub Total (11)				**30**	**1.8**	**31.8**
12		**Total of all items**				**3974**	**228.0**	**4202.2**

15 OPERATION AND MAINTENANCE COST

15.1 INTRODUCTION

The cost of operations includes the cost of running as well as maintaining the metro trains. These costs can be classified into fixed and variable costs.

15.1.1 Fixed cost

These costs are those which do not increase with the increase in volume of operations or in other words with the increase in train Kilometers

15.1.2 Variable cost

These are costs vary according to the quantum of operations or in other words according to the number of Train Kms.

These costs can be further sub classified into the following:

15.2 FIXED COSTS:

These include the cost of manpower for operation, maintenance and also the expenditure on outsourced staff. Basically all this can be clubbed into staff cost.

15.2.1 Staff Cost

The staff costs are basically the cost of human resources which are engaged to run the trains as well as to provide the different services for running the trains. This cost is a fixed cost and it will not vary with the quantum of operations. This includes, basically, the salary paid to the operations as well as maintenance staff and also the supervisory staff. It may be noted that the cost of maintenance staff is a fixed cost and therefore it is included as a part of the staff cost.

15.2.1.1 Staff cost – Permanent Employees

The staff costs for this line between Silk Board and KR Puram has been derived by making out the number of staff who would be engaged to run these train services. The staff cost has been estimated for the year 2020 as it is presumed that the line will be operational in the year 2020. The number of trains running on this 18 Kms stretch has been taken to be 20 trains for achieving three minutes headway. It is also estimated that the commercial speed of the trains on this stretch would be about 34 Kms. per hour. The number of staff of different categories required to be employed as well as the expenditure on their salaries is computed in Table No.15.1.

Thus the staff cost for the required number of people as indicated in Table-5.1 for one year at prices of 2016-17 is estimated at Rs. 32.27 Crores. Taking into consideration a yearly increment of 3% in basic and the increase in the DA component for the whole year at 12%, the gross increase year on year comes to about 9%. Hence, the staff cost for the year 2020 has been taken as 32.27 Crores X 1.094 (Rs. 45.55 Crores).

Table 15.1 Estimation of Salary and Cost to Company - O & M 2016-17 for KR Puram to Silk Board Junction line								
	Staff for 21 trains of 3 car set & 17 stns	Staff for 27 trains of 6 car set & 13 stns	Basic	DA 114.8%	HRA @30%	Super Anu.	Total (in Rs)	Per Annum (in Rs)
Director	1							
G.M	5							
Dy.GM	15	6	29100	33407	8730	5001	76237	5489089
Manager	7	3	24900	28585	7470	4279	65234	2348425
AM	44	19	20600	23649	6180	3540	53969	12304865
Total	72	28	74600	85641	22380	12819	195440	20142378
Section Eng	46	54	16000	18368	4800	2749	41917	27162501
Jr.Eng	106	158	14000	16072	4200	2406	36678	69541033
Maintainer	279	378	10170	11675	3051	1748	26644	120856153
Stn.Cont	65	50	14000	16072	4200	2406	36678	22006656
Train Op	102	128	14000	16072	4200	2406	36678	56337039
Asst.F/HR	18	18	10170	11675	3051	1748	26644	5755055
Total	616	786	78340	89934	23502	112810	304586	301658438
Grand Total	**688**	**814**	**152940**	**175575**	**45882**	**125629**	**500026**	**321800816**
				Conveyance p.a.		**942840**		**322743656**

15.2.1.2 Staff costs - Outsourced & Deployed personnel

The staff cost also includes the cost of Housekeeping, cost of Ticket Operating Machine personnel (TOM), and the security personnel costs. The House keeping staff will not be permanently employed by BMRCL but would be taken through a private outsourcing agency. Similarly the TOM Operators would also be outsourced through a private outsourcing agency.

15.2.1.2.1 Cost of Security Deployed Personnel

The security services would have two components – the first component would include the policemen provided by the State Government and the Homeguards whose expenditure would have to be borne by BMRCL, and the private security staff who would be used for crowd control and watch & ward duty who would again be taken from a private agency. The staff cost on account of security, operators and policemen has been estimated based on the actual expenditure which is incurred on these services in the East-West Corridor which is fully operational from May 2016. Currently for 5 stations in the East-West Corridor, the BMRCL is utilizing the services of 100 policemen (Karnataka State Industrial Security Force – KSISF). With these police personnel, the security cover for frisking and baggage scanning is provided to 5 metro stations. The approximate expenditure per year for the year 2016-17 for 100 KSISF personnel comes to Rs. 5.14 Crores per annum. As the line between KR Puram and CSB would have 13 stations, the cost of KSISF personnel for these stations has been arrived at Rs. 13.36 Crores per annum in the base year of 2016-17. For the year 2020 this cost will be estimated at Rs. 13.36 Crores X 1.094 which comes to Rs 18.86 Crores.

15.2.1.2.2 Cost of Outsourced Security Personnel

The cost of outsourced Security personnel in the East-West corridor for 17 stations is Rs. 261.37 lakhs per month in the year 2016-17 which comes to Rs. 31.36 Crores per annum for the year 2016-17 which includes the cost of rentals for security equipments. In order to arrive at the man power cost, 8% rental cost have been reduced because BMRCL will provide the equipments. The man power cost works out to 28.85 Crores for the year 2016-17. For the year 2020, the cost of security staff only would be Rs 40.72 Crores. This has been further adjusted as the number of stations in the reach between KR Puram and CS Board is only 13 stations. Therefore, the cost of outsourcing housekeeping for the year 2020 for the new line would be Rs 31.15 Crores.

15.2.1.2.3 Cost of outsourced Housekeeping personnel

The cost of Housekeeping in the East-West corridor for 17 stations is Rs. 56.67 lakhs per month in the year 2016-17 which comes to Rs. 6.80 Crores per annum for the year 2016-17. For the year 2020, the cost of Housekeeping staff would be Rs.9.60 Crores. This has been further adjusted as the number of stations in the reach between KR Puram and CS Board is only 13 stations. Therefore, the cost of Housekeeping for the year 2020 for the new line would be Rs 7.34 Crores per annum.

15.2.1.2.4 Cost of outsourced TOM Operators

The security cost and TOM Operators cost has been derived from the cost of TOM Operators in the East-West corridor. The cost of TOM Operators of 17 Stations of East-West Corridor is Rs. 34.77 lakhs per month or Rs. 4.17 Crores per annum for the base year 2016-17. For 13 stations this cost would be Rs 4.50 Crores in the year 2020.

Thus the total staff cost is Rs. 45.55 + 18.86 + 31.15 + 7.34 + 4.50 = 107.41 crore for the period of next 30 years the staff cost has been escalated at the rate of 10% per annum year on year on year basis.

15.3 MAINTENANCE COST

The maintenance cost basically includes the cost of spares, cost of repairs and consumables, cost of Insurance, civil and structural works, licensing fees for wireless etc. and administrative & contingency expenses (overheads). The maintenance cost has components of both fixed cost as well as variable cost. However, for the purpose of financial analysis, the maintenance cost has been worked out based on the actual expenditure of maintenance for the East-West Corridor. The maintenance cost for the year 2016-17 has been taken as Rs. 17.06 Crores per annum for the East West Corridor. For the year 2020, the maintenance cost has been adjusted by an annual increase of 5% year on year, after adjustments for 6 car train set in the proposed new line , thereby making the maintenance cost for 2020 to Rs 20.74 Crores. This cost also includes the maintenance cost for civil work.

15.4 ENERGY COST

The system consumes energy for the movement of trains as well as for auxiliary services at stations. While the energy cost for the trains is a variable factor, the energy cost of auxiliary power stations is

generally fixed. The energy cost for the new line is based on the actual energy consumption for the East-West corridor. On the East-West corridor which is having 116 round trips on a daily basis, but with a train which has only 3 cars, the energy consumption per train Km for movement of train is 8.17 Kwhr. For the new line, the energy consumption per train Km (6 car train set) would be 16.34 Kwhr, with a frequency of 3 minutes during peak hours (for 6 hours) and a frequency of 10 minutes for 12 hours. For 220 trips, the total train Kms would be 6912 Kms per day. The Energy consumed by trains is 1,12,942 Kwhr per day. The monthly consumption is 35,01,202 Kwhr. For the next 30 years the escalation of energy cost is taken at 5% per annum YoY basis.

For consumption of power at the stations, it is estimated that each station on an average would consume 1000 Kwhr per day. Thus, the total energy for 13 stations per month would be 4,03,000 Kwhr. In addition, the power consumption in the Depot control room and the electrical losses have been estimated at 3, 56,032 units per month. Thus the total energy cost per month for the new line would be Rs 34.35 Crs in the base year of 2016-17.

Table 15.2 Energy cost calculations

Energy usage	No of Trips/day	Train Kms / Month	KWHr / TKM	Kwhr / month	Cost per Kwhr In Rs	Cost per Month In Rs	Cost per annum In Rs
Train Energy Consumption	220	214272	16.34	3501204	6.72	23528094	282337129
Auxillary Energy for 13 stations- (1000 units / day/ station)				403000	6.72	2708160	32497920
Depot, OCC & Electrcial loss				356032	6.72	2392535	28710420
Total				4260236	6.72	28628789	343545470

The energy cost increase as notified by the Government on a year on year basis has been 4.5%, 4.34% 8.33% and 2.88% over the period 2011-12 to 2016-17. Thus the average year on year increase in the energy cost is around 5%. Therefore, the energy cost for the year 2020 for the new line would be Rs 41.75 Crores.

15.5 CONCLUSION

The total Operations and Maintenance cost for the year 2020 is Rs 169.90 Crore for the new line of 17 Kms with 13 stations and one depot, for running 6 coach train sets at a frequency of 4 minutes for 6 hours during peak hours and a frequency of 10 minutes during non-peak hours (12 hours). Thus the total Operation and Maintenance cost over the succeeding 30 years period is as given in the Table 15.3.

Table 15.3 Operation & Maintenance cost in Rs Crs				
Year	**Staff**	**Maintenance**	**Energy**	**Total**
2020	107.41	20.74	41.75	169.90
2021	117.07	21.77	43.84	182.69
2022	127.61	22.86	46.03	196.50
2023	139.10	24.01	48.33	211.43
2024	151.61	25.21	50.75	227.57
2025	165.26	26.47	53.29	245.01
2026	180.13	27.79	55.95	263.87
2027	196.34	29.18	58.75	284.27
2028	214.02	30.64	61.69	306.34
2029	233.28	32.17	64.77	330.22
2030	254.27	33.78	68.01	356.06
2031	277.16	35.47	71.41	384.03
2032	302.10	37.24	74.98	414.32
2033	329.29	39.10	78.73	447.12
2034	358.93	41.06	82.67	482.65
2035	391.23	43.11	86.80	521.14
2036	426.44	45.27	91.14	562.85
2037	464.82	47.53	95.70	608.05
2038	506.65	49.90	100.48	657.04
2039	552.25	52.40	105.51	710.16
2040	601.95	55.02	110.78	767.76
2041	656.13	57.77	116.32	830.22
2042	715.18	60.66	122.14	897.98
2043	779.55	63.69	128.24	971.49
2044	849.71	66.88	134.66	1051.24
2045	926.18	70.22	141.39	1137.79
2046	1009.54	73.73	148.46	1231.73
2047	1100.40	77.42	155.88	1333.70
2048	1199.43	81.29	163.68	1444.40
2049	1307.38	85.35	171.86	1564.59

16 DEPRECIATION COST AND INTEREST RATE

The Capital cost for the project has been arrived at in Chapter- 14. The break-up of these costs, into various components, is indicated in Table 14.4. Like any other asset, these assets also would depreciate over a period of time. Thus, depreciation cost is an important input in estimating both the FIRR and EIRR. The productive life of these assets like Civil Structures may be more than 100 years but in order to make the FIRR more realistic, we have not gone by the actual life of the asset but we have followed the norms which are followed for the purpose of accounting. Based on these norms, the following principles have been adopted:

i. Land: As per the accounting norms, no depreciation is factored for the land.

ii. Civil Structures: Civil structures have been depreciated presuming a productive life of only 30 years. The straight line method of depreciation has been adopted and therefore each year, the depreciation comes to 3.17%. The salvage value is taken as 5% of the current value of the asset .

iii. E&M Works: These include escalators, lifts and other electrical equipments. Though the life of these products ranges from 20 to 30 years, the accounting norms have been followed for these also. The Escalators and lifts have been presumed to have a life of 30 years and therefore the depreciation factor at 3.17% is applied per annum. The residual value is taken as 5% of the current value of the asset.

   In so far as the other electrical equipments are concerned, as prescribed by the Company Law, the life of the equipments is taken as 8 years and the salvage value at 5%. Therefore, the annual depreciation for these assets would be 11.88%.

iv. Plant & Machinery: The life of Plant & machinery at Depot, as per Company's Law, has been taken as 15 years. Therefore, the depreciation rate works out to 6.33% and the residual value is 5% of the current value.

v. Permanent Way: The track and its fixtures are presumed to have a life of 30 years and therefore the annual depreciation rate of 3.17% is applied and the residual value is 5% of the current value of the asset.

vi. Traction Power supply: The traction and power supply are considered to have a life of 8 years and therefore the annual depreciation rate of 11.88% is considered and the residual value at 5% of the asset value.

vii. Signaling and Telecommunication: The signaling and telecommunications are considered to have a life of 8 years and therefore the annual depreciation rate of 11.88% is considered and the residual value at 5% of the asset value.

viii. Miscellaneous: Comprising mainly shifting of electrical & telecommunication utilities and other civil works which are annually depreciated at 3.17% after considering the residual value of 5%.

ix. Rolling Stock: Rolling stock is presumed to have a life of 30 years and annually depreciated at 3.17% after considering the residual value of 5%.

x. Applying the above norms, the cost of depreciation over a period of 30 years is worked out to Rs. 3828 Crore as appended in Table No 14.1 & 14.2

16.1 COMPUTATION OF INTEREST COST & REPAYMENT OF PRINCIPAL:

The total project cost is estimated to be Rs. 4203 Crore. It is expected that the State share of taxes would be reimbursed. The State share of taxes on this amount excluding expenditure on land, consultancy & administration would be approximately 8% on an average and thereby the reimbursement expected by way of state taxes will be Rs. 336 Crore. Thus, the project cost excluding the state taxes is Rs. 3867 Crore. The drawl of the loan and repayment is assumed to be in the middle of the respective years. The interest during construction has been assumed to be zero and it is expected that the interest earned on the various cash inflows would offset the interest during construction.

In order to fund a total of Rs. 4203 Crore, it is expected that 50% of this will come through contribution and innovative financing and the balance would be from borrowings. It is also presumed that the expenditure during the three years of construction would be Rs.600 Crore, Rs.1800 Crore and Rs. 1803 Crore in the year 2017, 2018 and 2019 respectively. It is also presumed that each year the contribution from borrowings as well as from innovative financing and state funding would in equal proportions. Though, efforts will be made to borrow the funds on a long term basis say 20 years or more from Financing Institutions, for the purpose of computation of IRR, it is presumed that the borrowings would be made with a repayment period of 10 years and the rate of interest would be 9% per annum. The principal amount would be repaid in a period of ten years after the project commences i.e. the repayment would start from the year 2020. Based on these presumptions, the cash inflow and outflow on account of loans, repayment of loans and interest cost are tabulated below:

Table 16.1 Principal Drawal, Principal Repayment and Interest Repayment

Year	Principal Drawal	Principal Repayment	Interest Repayment
2017	300.00	-	27.00
2018	800.00	-	99.00
2019	1000.00	-	189.00
2020	-	210.00	179.55
2021	-	210.00	160.55
2022	-	210.00	141.75
2023	-	210.00	122.85
2024	-	210.00	103.95
2025	-	210.00	85.05
2026	-	210.00	66.15
2027	-	210.00	47.25
2028	-	210.00	28.35
2029	-	210.00	9.45
Total	**2,100.00**	**2,100.00**	**1,260.00**

Table 16.2 Cost Summary								
SL No	**Particulars**	**Amount in Rs**	**Consultancy and contingency (inc. Admin) Cost Rs**	**Total Incl. Contingency cost Rs**	**Rate of Depreciation**	**Residual Value 5% Rs**	**Annual Depreciation Rs**	**Total Depreciation 95% Rs**
1	Land	173.32		173.32				
2	Alignment And Formation- Vaiduct	819	49.14	868.14	3.17%	43.41	27.52	824.73
3	Station Buildings	416	24.96	440.96	3.17%	22.05	13.98	418.91
4	E&M works	190	11.4	201.4	11.88%	10.07	23.93	191.33
5 i	Civil Works	140	8.4	148.4	3.17%	7.42	4.7	140.98
ii	E&M works	60	3.6	63.6	11.88%	3.18	7.56	60.42
iii	Machinery & Plant	32	1.92	33.92	11.88%	1.7	4.03	32.22
6	Permanent Way Track Work	208	12.48	220.48	3.17%	11.02	6.99	209.46
7	Traction & Power Supply	273	16.38	289.38	11.88%	14.47	34.38	274.91
8	Signalling & Telecom	403	24.18	427.18	11.88%	21.36	50.75	405.82
9	Road restoration etc.,	30	1.8	31.8	19.00%	1.59	6.04	30.21
10	Miscellaneous	90.5	5.43	95.93	3.17%	4.8	3.04	91.13
11	Rolling Stock (SG)	1140	68.4	1208.4	3.17%	60.42	38.31	1147.98
Total		**3974.82**	**228.09**	**4202.91**		**201.48**	**221.22**	**3828.11**

Table 16.3 Calculation of Depreciation & Residual Value

Year of Depreciation	Land	Alignment And Formation - Vaiduct	Station Buildings	E&M works	Civil Works	E&M works	Machinery & Plant	Permanent Way Track Work	Traction & Power Supply	Signalling & Telecom	Road restoration etc.,	Misc.	Rolling Stock (SG)	Total
2020	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75	6.04	3.04	38.31	221.22
2021	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75	6.04	3.04	38.31	221.22
2022	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75	6.04	3.04	38.31	221.22
2023	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75	6.04	3.04	38.31	221.22
2024	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75	6.04	3.04	38.31	221.22
2025	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75		3.04	38.31	215.17
2026	0	27.52	13.98	23.93	4.70	7.56	4.03	6.99	34.38	50.75		3.04	38.31	215.17
2027	0	27.52	13.98	23.85	4.70	7.53	4.02	6.99	34.26	50.58		3.04	38.31	214.76
2028	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2029	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2030	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2031	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2032	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2033	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2034	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2035	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2036	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2037	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2038	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2039	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2040	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2041	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2042	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53

Table 16.3 Calculation of Depreciation & Residual Value														
Year of Depreciation	**Land**	**Alignment And Formation - Vaiduct**	**Station Buildings**	**E&M works**	**Civil Works**	**E&M works**	**Machinery & Plant**	**Permanent Way Track Work**	**Traction & Power Supply**	**Signalling & Telecom**	**Road restoration etc.,**	**Misc.**	**Rolling Stock (SG)**	**Total**
2043	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2044	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2045	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2046	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2047	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2048	0	27.52	13.98		4.70			6.99				3.04	38.31	94.53
2049	0	26.65	13.54		4.55			6.77				2.94	37.10	91.54
Total	**0**	**824.73**	**418.91**	**191.33**	**140.98**	**60.42**	**32.23**	**209.46**	**274.91**	**405.82**	**30.21**	**91.13**	**1147.98**	**3828.10**
5% residual Value	**0**	**43.41**	**22.05**	**10.07**	**7.42**	**3.18**	**1.70**	**11.02**	**14.47**	**21.36**	**1.59**	**4.80**	**60.42**	**201.48**
Grand Total		**868.14**	**440.96**	**201.4**	**148.4**	**63.6**	**33.92**	**220.48**	**289.38**	**427.18**	**31.80**	**95.93**	**1208.4**	**4029.58**

17 FARE BOX AND NON FARE BOX REVENUE

17.1 INTRODUCTION

The revenue earnings can be classified as Fare Box Revenue (FBR) and Non Fare Box Revenue (NFBR).

17.2 FARE BOX REVENUE

The main source of revenue for this line would be the fare box revenue. The fare box revenue is a function of the ridership (ridership is the number of passenger trip) as well as the notified fare. The traffic ridership figures for this line have been estimated in Chapter 3.0 and the total ridership as well as its station wise ridership is shown in Table 17.1 is reproduced below:

Table 17.1 Corridor - K R Puram to Silk Board along ORR

Station Name	Daily Board 2021		Peak Board 2021		Daily Board 2031		Peak Board 2031		Daily Board 2041		Peak Board 2041	
	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight	Board	Alight
K R Puram	31,016	30,916	8,317	8,256	35,237	34,834	9,189	9,405	40,973	40,481	10,789	10,648
Mahadevapura	13,068	13,199	3,625	3,573	15,479	15,808	4,903	4,837	17,352	17,930	5,422	5,417
DRDO Sports Complex	33,379	33,370	8,793	7,413	41,895	41,867	11,188	9,489	47,116	47,102	12,381	10,450
Doddanekundi	9,974	10,011	2,609	2,608	12,981	13,011	3,228	3,222	15,578	15,615	3,845	3,819
ISRO	24,259	24,366	4,831	6,039	32,180	32,298	6,886	8,452	38,155	38,287	8,598	10,402
Marathahalli	12,357	12,833	4,688	4,473	13,753	14,328	5,376	4,868	15,405	15,967	5,831	5,624
Kodibisanhalli	38,871	38,815	13,347	13,777	40,403	40,345	14,049	14,245	45,761	45,703	16,231	16,323
Kadubeesanahalli	21,261	21,261	3,872	4,405	36,374	36,374	6,421	7,083	51,577	51,577	8,802	9,603
Bellandur	42,024	42,010	13,526	13,799	66,483	66,464	20,123	20,538	94,108	94,083	27,918	28,450
Ibbalur	3,242	3,239	752	377	3,563	3,552	819	497	4,040	4,005	926	629
Agara Lake	2,250	2,404	837	829	2,797	2,957	1,011	996	3,299	3,438	1,140	1,131
HRS Layout	56,951	57,026	18,391	16,398	73,178	72,783	22,892	20,224	90,842	90,069	26,335	24,807
Slik Board	63,161	62,363	20,417	22,054	84,245	83,947	26,872	29,101	110,540	110,490	35,311	36,226

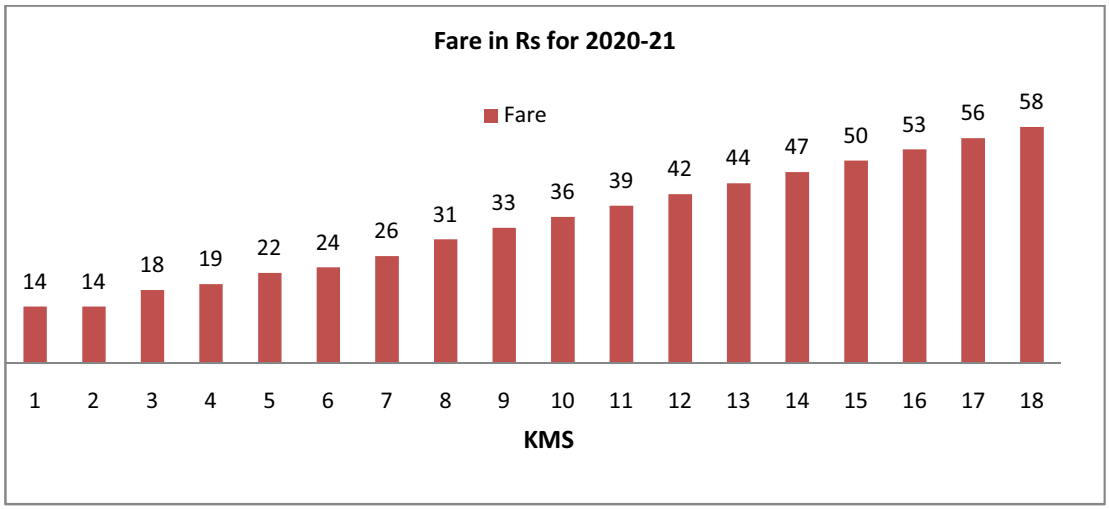
The daily ridership (no of passengers per day for 2020) is taken as 3.10 Lakhs.

The fares for this line have been extrapolated based on the existing fares of BMRCL. The existing fare table of BMRCL for the year 2016-17 is in Table17.2.

Table 17.2 BMRCL Fare Structure in 2016-17			
Distance in kms.	**Metro Fare (Rs.)**	**Distance in kms.**	**Metro Fare (Rs.)**
0-1	10.00	12-13	32.00
1-2	10.00	13-14	34.00
2-3	13.00	14-15	36.00
3-4	14.00	15-16	38.00
4-5	16.00	16-17	40.00
5-6	17.00	17-18	42.00
6-7	19.00	12-13	32.00
7-8	22.00	13-14	34.00
8-9	24.00	14-15	36.00
9-10	26.00	15-16	38.00
10-11	28.00	16-17	40.00
11-12	30.00	17-18	42.00

These are promotional fares which would be subject to revision once the entire network gets operational (a 20% increase would be reasonable) and thereafter these fares would be revised at periodical intervals as provided under law. It is estimated that the fares would go up by 10% over a block period of 2 years. Therefore, the fare table for the new line for the year 2020 has been derived and is shown in Figure 17.1.

Figure 17.1 Fares in Rs for Year 2020 to 2021



Continuing with the same presumption that the fares would increase by 10% over a block period of 2 years, the fares for the succeeding 30 years are shown the Table 17.3

Table 17.3: Fare for the Succeeding 30 Years (Amount in Rs.)															
KMs	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**	**2032**	**2034**	**2036**	**2038**	**2040**	**2042**	**2044**	**2046**	**2048**
1	14	15	17	18	20	22	25	27	30	33	36	40	44	48	53
2	14	15	17	18	20	22	25	27	30	33	36	40	44	48	53
3	18	20	22	24	26	29	32	35	39	43	47	52	57	62	69
4	19	21	24	26	28	31	34	38	42	46	50	55	61	67	74
5	22	24	27	30	33	36	39	43	48	52	58	63	70	77	84
6	24	26	29	31	35	38	42	46	51	56	61	67	74	82	90
7	26	29	32	35	39	43	47	51	57	62	68	75	83	91	100
8	31	34	37	41	45	49	54	60	66	72	79	87	96	106	116
9	33	37	40	44	49	54	59	65	71	79	86	95	105	115	127
10	36	40	44	48	53	58	64	70	77	85	94	103	113	125	137
11	39	43	47	52	57	63	69	76	83	92	101	111	122	134	148
12	42	46	50	55	61	67	74	81	89	98	108	119	131	144	158
13	44	49	54	59	65	72	79	87	95	105	115	127	140	153	169
14	47	52	57	63	69	76	84	92	101	111	123	135	148	163	179
15	50	55	61	67	73	81	89	97	107	118	130	143	157	173	190
16	53	58	64	70	77	85	94	103	113	124	137	151	166	182	200
17	56	61	67	74	81	89	98	108	119	131	144	159	174	192	211
18	58	64	71	78	85	94	103	114	125	138	151	166	183	201	222

The traffic ridership figures have been estimated in Chapter 3. This line on ORR would be a line connecting two trunk lines. It is assumed that people using this ORR line would travel on other lines and then reach and use this line. The average trip length in such case is presumed as 22 m with 50% being accounted on this line and the remaining 50% on the other part of Metro Network. The fare would be about Rs. 66.0 and half of this line is Rs. 33.0 can be credited to this line. Indeed, the opening of this Metro line would increase the ridership and viability of other lines but that has not been factored as we want the revenue figures to be conservative. The annual fare base revenue is shared in Table 17.4

Table 17.4 Details of Revenue and Ridership					
Year	Avg. Ridership p/day (no's)	Avg. Fare (amt. In rs)	Total ridership (no's)	Total fare box revenue per year	Amount (rs. In cr)
2020	3,10,000	33	105400000	3478200000	348
2021	3,23,506	33	109992133	3629740380	363
2022	3,37,013	37	114584265	4239617822	424
2023	3,50,519	37	119176398	4409526733	441
2024	3,64,025	40	123768531	4950741236	495
2025	3,77,531	40	128360664	5134426545	513
2026	3,91,038	44	132952796	5849923040	585
2027	4,04,544	44	137544929	6051976880	605
2028	4,18,050	49	142137062	6964716029	696
2029	4,31,556	49	146729195	7189730533	719
2030	4,45,063	54	151321327	8156219540	816
2031	4,58,569	54	155913460	8403735494	840
2032	4,70,187	59	159863459	9478304459	948
2033	4,81,804	59	163813457	9664993971	966
2034	4,93,422	65	167763456	10887848276	1089
2035	5,05,040	65	171713454	11161374529	1116
2036	5,16,657	71	175663453	12472105153	1247
2037	5,28,275	71	179613451	12752555051	1275
2038	5,39,893	79	183563450	14501512550	1450
2039	5,51,510	79	187513449	14813562437	1481
2040	5,63,128	86	191463447	16465856454	1647
2041	5,74,745	86	195413446	16805556331	1681
2042	5,91,988	95	201275849	19121205663	1912
2043	6,09,747	95	207314125	19694841833	1969
2044	6,28,040	105	213533548	22314255797	2231
2045	6,46,881	105	219939555	23093653248	2309
2046	6,66,287	115	226537741	26051840259	2605
2047	6,86,276	115	233333874	26833395467	2683
2048	7,06,864	127	240333890	30402237064	3040
2049	7,28,070	127	247543907	31438076130	3144

17.3 NON-FARE BOX REVENUE

In addition to fare box revenue, Metro system generates substantial amount of non-fare box revenue. This non-fare box revenue includes rentals from spaces at Metro stations, advertising income, income from property development, income from parking charges, and other sources like leasing of spare capacity of optical fiber etc. The non-fare box revenue for the year 2016-17 for the existing network of

about 33 kms is estimated to be about Rs.35 crores. At present, the network of 33 kms is not connected to each other thereby the true potential of the non-fare box revenue has not been captured so far. The new line passing through the IT hub of the city would have a better potential for non-fare box revenue as compared to the East-West line. Therefore, a conservative estimate of Rs.50 crores per annum has been taken for the year 2020. This revenue is expected to increase at a rate of 6% year on year. Thus, the non-fare box revenue for a 30 year cycle succeeding 2020 is tabulated in the table 17.5.

Table 17.5: Non Fare Box Revenue for 30 years (Rs. In Cr.)

Years	Non Fare Box Revenue	Years	Non Fare Box Revenue
2020	50	2035	120
2021	53	2036	127
2022	56	2037	135
2023	60	2038	143
2024	63	2039	151
2025	67	2040	160
2026	71	2041	170
2027	75	2042	180
2028	80	2043	191
2029	84	2044	202
2030	90	2045	215
2031	95	2046	227
2032	101	2047	241
2033	107	2048	256
2034	113	2049	271

The total revenue to be earned from fare box & the non fare box revenue for new line of 17 kms with 13 stations is as shown in the table 17.6.

Table 17.6 Details of Revenue (Rs. In Cr.)			
Year	**Fare Box**	**Non Fare Box**	**Total**
2020	348	50	398
2021	363	53	416
2022	424	56	480
2023	441	60	501
2024	495	63	558
2025	513	67	580
2026	585	71	656
2027	605	75	680
2028	696	80	776
2029	719	84	803
2030	816	90	906
2031	840	95	935
2032	948	101	1049
2033	966	107	1073
2034	1089	113	1202
2035	1116	120	1236
2036	1247	127	1374
2037	1275	135	1410
2038	1450	143	1593
2039	1481	151	1632
2040	1647	160	1807
2041	1681	170	1851
2042	1912	180	2092
2043	1969	191	2160
2044	2231	202	2433
2045	2309	215	2524
2046	2605	227	2832
2047	2683	241	2924
2048	3040	256	3296
2049	3144	271	3415

18 FINANCING OPTIONS – INNOVATIVE FINANCING

18.1 INTRODUCTION

In the Budget speech for the year 2016-17, the Hon'ble Chief Minister has emphasized the urgent need for decongesting traffic in Bangalore City and has stated that measures would be taken for providing Mass Rapid Transit System using Innovative Financing techniques. The Phase-1 of Bangalore Metro costing Rs 14405 Crores as well as the Phase-2 of Bangalore Metro costing Rs. 26,405 Crores have been funded jointly by the State Government and the Government of India. The contribution of the two Governments in Phase-2 of Namma Metro is given in the table below:

Table 18.1 Government Contribution in Phase 2

Funding Source & Type		Share in Project Cost (%)	Amount (INR IN CRORE)
GOI	Equity	14.65%	3868.35
	Sub-ordinate Debt	5.35%	1412.65
	Total GOI share	20.00%	5281.00
GOK	Equity	14.65%	3868.35
	Subordinate Debt	12.97%	3424.75
	Grant Contribution- GOK	6.40%	1689.90
	Total GOK share	34.02%	8983.00

From the table, it is evident that the Bangalore Metro has been funded primarily by the contributions from the State Government and the Central Government apart from borrowings from various domestic and foreign financial institutions. Funding of such large infrastructure projects puts a heavy pressure on the budgetary resources of the State Government as well as the Government of India. As a result, the pace at which the Metro network should expand, does not match the pace at which the demands for Metro network is growing and therefore, there is a need to explore other avenues for mobilization of funds for Metro systems.

18.2 INNOVATIVE FINANCING

18.2.1 Innovative Financing Instruments

A major advantage of the important transport infrastructure project is that apart from giving the impetus to economic activities it also leads to appreciation of the value of lands and buildings which lie in this vicinity. The experience of Bangalore Metro Rail Project Phase-1 has thrown up a very good lesson for innovative financing. It has been observed through anecdotal evidence that there has been a substantial increase in the values of properties abutting the Metro alignment. This observation would also hold true for several other transportation projects like Arterial Roads and Peripheral Ring Roads. The Peripheral Ring Road around Bengaluru, which is now proposed by BDA, would act as a

counter magnet to the Central Business District (CBD) and it would attract the economic activities near it. As a result, the part of activities of CBD would get relocated to the areas around the Peripheral Ring Road thus decongesting the heart of Bengaluru.

The issue of innovative financing has been examined in detail and it is found that the following mechanisms could be used as innovative financing instruments to fund the major transport infrastructure projects in Karnataka:

- Premium FSI / FAR (Floor Space index / Floor Area Ratio)
- Cess on approval of new layouts
- Construction and exploitation of commercial spaces near important infrastructure projects
- Generation of revenue through other sources like premium for roads developments etc.
- Betterment Tax

18.2.1.1 Premium FSI:

It is well established that wherever rail based mass transit system or an efficient transport system goes, the area falling in the vicinity of the line witness a tremendous appreciation in the value. Added to this is the concept of transit oriented development wherein cities need to be planned in such a manner where the density of population is increased along the corridors of mass transit systems. Combining the impact of above two principles, the concept of premium FSI has been evolved. As per this concept, the lands falling within the fixed distance of the mass transit corridor or transportation hubs, would be offered additional FSI over and above the existing FSI. This increased FSI is called the premium FSI for which the owners of the land would have to pay and buy the additional FSI. The proceeds would go to a Transport Development Fund or the Infrastructure Development Fund from which the construction of mass transit system could be funded. BDA or other Development Authorities should make suitable amendment to their Zoning Regulations.

18.2.1.2 Cess on approval of new layouts:

While the premium FSI as well as the Betterment Levy would be confined to the impact zone i.e. in the areas in the vicinity mass transit corridor, the levy of cess has no such restriction. The cess would be levied within entire area of the jurisdiction of BDA. The levy of cess and surcharge is governed by Section 18A of the Karnataka Town and Country Planning Act, 1961. The Section reads as follows:-

Section 18-A. Levy and collection of cess and surcharge:

1. Notwithstanding anything contained in this Act, the Planning Authority may while granting permission for development of land or building levy and collect from the owner of such land or building:
    - A cess for the purpose of carrying out any water supply scheme;
    - A surcharge for the purpose of formation or ring roads;
    - A cess for the purpose of improving slums; and
    - A surcharge for the purpose of establishing Mass Rapid Transport system.

2. At such rates but all the above levies together not exceeding one-tenth of the market value of the land or building as may be prescribed.
3. The cess and surcharge levied under Sub-Section (1) shall be assessed and collected in such manner as may be prescribed.
4. Any person aggrieved by the levy, assessment and collection of cess or surcharge under this section may within thirty days from the date of the order appeal to the prescribed authority whose decision shall be final.
5. The prescribed authority may after giving a reasonable opportunity of being heard to the appellant and the planning Authority pass such order as it deems fit.
6. The State Government may exempt any Board Authority or Body constituted by or under any law and owned or controlled by the State Government or the Central Government or an infrastructure Project promoted or implemented by any company or person and approved by the State Government or Central Government from the payment of cess or surcharge leviable under Sub-section (1).

The Cess is levied at the time of granting approval for development of land or buildings.

18.2.1.3 Construction And Exploitation Of Commercial Spaces Near Important Infrastructure Projects

The appreciation in land value immediately next to the transport infrastructure project is substantially high. Therefore, it would make economic sense to acquire lands and then later on these could be exploited for generation of commercial revenue either by leasing of lands or through Public Private Partnerships. Some of the infrastructure projects also lend themselves for exploitation of air space above the infrastructure projects. For example, the air space over the Metro Station or above the major transportation hub can be commercially exploited for mobilization of resources.

18.2.1.4 Generation Of Revenue Through Other Sources

The major transport infrastructure projects have a tendency to attract the commercial activities around it. This holds true for major roads, Metro Rail projects, transportation and logistics hubs etc. It is possible to mobilize resources through various commercial activities like advertising, providing access, business development, naming rights for stations, etc.

18.2.1.5 Generation of Revenue Through Levying Of Fees For Change Of Land Use In The Vicinity Of Infrastructure Projects

The nature of activities in the areas around the major new Infrastructure projects such as Ring Road etc. are likely to undergo significant change from Agriculture or Residential to Commercial. It would be prudent to facilitate easy change of land use under Section 18 of KTCP Act as it will yield a better income to the owner by levying a fee as provided in Section 18 of KTCP Act. The new Infrastructure project will be able to sustain the additional burden of the enhanced activities and the land owners will not have the time consuming process for change of land use individually. It could provide an important additional source of revenue to finance the Infrastructure projects.

18.2.1.6 Betterment Levy

As stated earlier, the land values in the vicinity of mass transit system would go uip once the mass transit system becomes operational. In order to capture the appreciation in the value of land, there is a concept of betterment levy. The concept of betterment levy differs from the premium FSI concept because while the premium FSI concept is voluntary, the betterment levy is mandatory. The concept of betterment tax find the place in the Bangalore Development Act, 1976. Section 20 of the Act reads as follows:-

"Levy of betterment tax: (1) Where as a consequence of execution of any development scheme, the market value of any land in the area comprised in the scheme which is not required for the execution thereof has in the opinion of the Authority, increased or will increase, the authority shall be entitled to levey on the owner of the land or any person having an interest therein, a betterment tax in respect of the increase in value of the land resulting from the execution of such scheme.

(2) Such increase in value shall be the amount by which the value of the land, on the completion of the execution of the scheme, estimated as if the land were clear of buildings exceeds the value of the land prior to the execution of the scheme estimated in like manner, and the betterment tax shall be one-third of such increase in value."

It is proposed that this tax may be levied only on a case to case basis on certain categories of properties and on the land holdings, the size of which exceeds a minimum threshold. It may also be stipulated that the betterment levy should be imposed in impact areas only and the impact areas should be defined as the areas, which fall within a fixed distance, say one Km. of the Urban transport corridor.

The concept of Betterment levy also finds a mention under the Karnataka Municipalities Act. However, this provision for levy of betterment tax need to be recast in view of the recent important developments in the major infrastructure projects. It is, therefore, proposed to bring a comprehensive self contained amendment to the Karnataka Town and Country Planning Act so that a mechanism of betterment tax could be levied all over the State by the concerned Planning Authority.

A conservative estimate of revenue on above innovative financing instruments is tabulated below:

Table: 18.2 Estimate Of Revenue On Innovative Financing Instruments

Source	Estimated upfront yield
Premium floor area ratio (far)	INR 600 CR
Additional cess on approval of new projects / developments	INR 50 CR
Construction and Exploitation of Commercial space near Infra project	INR 100 CR
Other Sources - Naming rights / advertising	INR 250 CR
Premium access ways / ramps / naming rights	INR 300 CR
Change of land use fees	INR 25 CR
Betterment levy	INR 50 CR
Total	INR 1375 CR

18.3 FINANCING OPTIONS

Although the efforts will be made to mobilize funds through innovative financing to start the project and also to indicate a firm commitment of the State Government, the project would require some contribution from the State budget / Central budget. In addition, the BMRCL has in possession some land parcels which were acquired for Phase-1 and Phase-2, which could be offered for commercial development. The BMRCL would also be in a position to mobilize revenues through long term lease of these land parcels. It is estimated that the BMRCL would be able to mobilize a sum of Rs.500 Crores through long term lease of the lands which has in its possession. In addition, it is also porposed that the State Government can give a contribution of Rs. 500 Crores over three years of project execution period.

18.3.1 Different scenarios for innovative financing

Since the innovative financing is being tried for the first time, it will be difficult to accurately forecast the actual amount which could be mobilized through this technique. Therefore, for the purpose of financing analysis, three different scenarios have been used – (a) Pessimistic, (b) Optimistic and (c) Most likely.

In the Pessimistic scenario, it is being presumed that there would be no mobilization through innovative financing and such being the case, the project would be funded by the contribution from the State Government / Government of India / BMRCL and from borrowings. Since the contribution of the State Government and the BMRCL has been pegged at Rs. 1000 Crores, the balance amount of Rs. 3,200 Crores would be mobilized through borrowings.

In the Optimistic scenario, it is estimated that the BMRCL would be able to mobilize a sum of Rs. 2100 Crores by way of innovative financing. If this happens, the borrowings would reduce to Rs. 1100 Crores and the contribution of the State Government and the BMRCL would be Rs. 1000 Crores.

In the Most Likely scenario, it is estimated that the fund mobilization through Innovative financing would be about Rs. 1100 Crores thus restricting the borrowing to about Rs.2100 Crores. The primary contribution would continue to be Rs. 1000 Crores.

The three scenarios have been described in details in the table below:

Table: 18.3 Scenario analysis for funding options (RUPEES IN CRORE)

S. no.	Funding Source	Scenario 1 Pessimistic	Scenario 2 Most likely	Scenario 3 Optimistic
1	Central Govt / State Govt contribution (equity / sub debt)	500.00	500.00	500.00
2	Internal generation by BMRCL through leasing of surplus land	500.00	500.00	500.00
3	Innovative financing	0	1100.00	2100.00
4	Borrowing @ 9% P A.	3200.00	2100.00	1100.00
	Grand total	4200.00	4200.00	4200.00

18.4 TAX REIMBURSEMENT

Both during Phase-1 and Phase-2, all the taxes which accrued to the State Government because of various levies on the project, were reimbursed to BMRCL. The same arrangement should be continued for this ORR line also. The total amount on tax reimbursement would be Rs. 336 Crores at an average rate of 8% of the project cost.

19 FINANCIAL ANALYSIS FIRR

19.1 INTRODUCTION

Financial analysis is done based on revenue and cost figures as estimated in the projected cash inflow and outflow for each year as tabulated in Table 19.1

Table 19.1 Capital Cost of Project

Sl.No	Particulars	Amount in Crores
1	Land	173
2	Alignment and Formation	868
3	Sation Buildings	441
4	Permanent-Way	220
5	Depot at Whitefield	246
6	Miscellaneous	96
7	Traction & Power Supply	290
8	E&M Works	201
9	Rolling Stock (SG)	1209
10	Signalling and Telecom	427
11	Road restoration etc.,	32
	Total	**4203**

19.2 FACTORING IN INNOVATIVE FINANCING:

In the above analysis the component of innovative financing has been taken as zero. But as mentioned in Chapter 18 on innovative financing substantial amount would be contributed through innovative financing. Therefore, 3 different scenarios for innovative financing have been considered as under:

1. Pessimistic
2. Optimistic
3. Most likely

19.3 ASSUMPTIONS:

The primary assumptions are:

1. Promoters contribution would be Rs.1000 crore
   a) Central Government/State Government would contribute Rs.500 Crore.
   b) Internal generation by BMRC through leasing of surplus land Rs.500 crore
2. Borrowing & innovative financing would be interchanged based on the estimate for each of the scenarios.
3. State Government would reimburse taxes of Rs.336 crore approximately.

BMRCLwould not be liable to pay Income Tax due to accumulated depreciation & losses from Phase I & Phase II operations.

19.3.1 Scenario-1: Pessimistic

In the pessimistic scenario, it is assumed that nothing would be mobilised through innovative financing. With this presumption, the FIRR is worked out as in Table 19.2

Table 19.2: PESSIMISTIC SCENARIO - FIRR (INR IN CRORE)

	SNAP SHOT - INFLOW OWNERS FUNDS - 952 INNOVATIVE FIN - 0 BORROWINGS - 3199 TAX REIMB - 336 TOTAL INFLOW - 4487				OUTFLOW CAPEX 4200 IDC 287 TOAL 4487			CASH FLOW PROJECTIONS FROM OPERATIONS							
Year	CAPITAL							REVENUE							FIRR
	INFLOW				OUTFLOW			INFLOW		OUTFLOW					
	OWNERS FUNDS	INNOVATIVE FINANCING	TAX REIMB	BORROWING	CAPEX	INT DURING CONST	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	Staff Costs	Maintenance Costs	Energy Consumption Costs	Interest	Depreciation	Net cash flow
								Refer to Table No							
								17.6	17.6	15.3	15.3	15.3		16.3	
2017	136	0	48	457	-600	-41									-136
2018	408	0	144	1371	-1800	-123									-408
2019	408	0	144	1371	-1800	-123									-408
2020							-320	348	50	107	21	42	-274	-221	-365
2021							-320	363	53	117	22	44	-245	-221	-331
2022							-320	424	56	128	23	46	-216	-221	-252
2023							-320	441	60	139	24	48	-187	-221	-218
2024							-320	495	63	152	25	51	-158	-221	-148
2025							-320	513	67	165	26	53	-130	-215	-115
2026							-320	585	71	180	28	56	-101	-215	-29
2027							-320	605	75	196	29	59	-72	-215	4
2028							-320	696	80	214	31	62	-43	-95	106
2029							-320	719	84	233	32	65	-14	-95	139
2030								816	90	254	34	68		-95	549
2031								840	95	277	35	71		-95	551
2032								948	101	302	37	75		-95	634
2033								966	107	329	39	79		-95	626
2034								1089	113	359	41	83		-95	719
2035								1116	120	391	43	87		-95	715
2036								1247	127	426	45	91		-95	811
2037								1275	135	465	48	96		-95	802
2038								1450	143	507	50	100		-95	936
2039								1481	151	552	52	106		-95	922
2040								1647	160	602	55	111		-95	1040
2041								1681	170	656	58	116		-95	1021
2042								1912	180	715	61	122		-95	1194
2043								1969	191	779	64	128		-95	1189
2044								2231	202	850	67	135		-95	1382
2045								2309	215	926	70	141		-95	1386
2046								2605	227	1009	74	148		-95	1601
	952	0	336	3199	-4200	(288)	-3200	30771	3185.29	-11032	-1133.8	-2282.44	-1440	-3547.9	13915
														FIRR	11.35%

19.3.2 Scenario-2: Optimistic

In the optimistic scenario, it is assumed that a sum of Rs.1,968 crores only would be mobilised through innovative financing in the first 3 years (spread equally). With this presumption, the FIRR is worked out as in Table below:

Table 19.3 : OPTIIMISTIC SCENARIO - FIRR (INR IN CRORE)

	SNAP SHOT - INR IN CR INFLOW OWNERS FUNDS - 962 INNOVATIVE FIN - 1968 BORROWINGS - 1038 TAX REIMB - 336 TOTAL - 4304				OUTFLOW CAPEX 4200 IDC 104 TOTAL 4304			CASH FLOW PROJECTIONS FROM OPERATIONS							
	CAPITAL							REVENUE							FIRR
	INFLOW				OUTFLOW			INFLOW		OUTFLOW					
Year	OWNERS FUNDS	INNOVATIVE FINANCING	TAX REIMB	BORROWING	CAPEX	INT DURING CONST	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	Staff Costs	Maintenance Costs	Energy Consumption Costs	Interest	Depreciation	Net cash flow
								Refer to Table No							
								17.6	17.6	15.3	15.3	15.3		16.3	
2017	130	288	48	148	-600	-16									-132
2018	419	840	144	445	-1800	-44									-415
2019	413	840	144	445	-1800	-44									-415
2020							-103	348	50	107	21	42	-94	-221	31
2021							-103	363	53	117	22	44	-84	-221	46
2022							-103	424	56	128	23	46	-74	-221	106
2023							-103	441	60	139	24	48	-64	-221	122
2024							-103	495	63	152	25	51	-54	-221	173
2025							-103	513	67	165	26	53	-45	-215	187
2026							-103	585	71	180	28	56	-35	-215	254
2027							-103	605	75	196	29	59	-25	-215	268
2028							-103	696	80	214	31	62	-15	-95	352
2029							-103	719	84	233	32	65	-5	-95	365
2030								816	90	254	34	68		-95	549
2031								840	95	277	35	71		-95	551
2032								948	101	302	37	75		-95	634
2033								966	107	329	39	79		-95	626
2034								1089	113	359	41	83		-95	719
2035								1116	120	391	43	87		-95	715
2036								1247	127	426	45	91		-95	811
2037								1275	135	465	48	96		-95	802
2038								1450	143	507	50	100		-95	936
2039								1481	151	552	52	106		-95	922
2040								1647	160	602	55	111		-95	1040
2041								1681	170	656	58	116		-95	1021
2042								1912	180	715	61	122		-95	1194
2043								1969	191	779	64	128		-95	1189
2044								2231	202	850	67	135		-95	1382
2045								2309	215	926	70	141		-95	1386
2046								2605	227	1009	74	148		-95	1601
	962	1968	336	1038	-4200	(104.00)	-1030	30771	3185	-11032	-1134	-2282	-495	-3548	17021
														FIRR	20.27%

19.3.3 Scenario-3: Most likely

In the most likely scenario, it is assumed that a sum of Rs.1,067 crores only would be mobilised through innovative financing in the first 3 years (spread equally). With this presumption, the FIRR is worked out as in Table below:

Table 19.4 : MOST LIKELY SCENARIO - FIRR (INR IN CRORE)

SNAP SHOT - INR IN CR		OUTFLOW	CASH FLOW PROJECTIONS FROM OPERATIONS
INFLOW	OWNERS	CAPEX 4200	
FUNDS -	958	IDC 189	
INNOVATIVE FIN -	1067	TOTAL 4389	
BORROWINGS -	2028		
TAX REIMB -	336		
TOTAL -	4389		

Year	CAPITAL							REVENUE							FIRR
	INFLOW				OUTFLOW			INFLOW		OUTFLOW					
	OWNERS FUNDS	INNOVATIVE FINANCING	TAX REIMB	BORROWING	CAPEX	INTDURING CONST	LOAN REPAYMENT	Fare Box Revenue	Non Fare Box Revenue	Staff Costs	Maintenance Costs	Energy Consumption Costs	Interest	Depreciation	Net cash flow
								Refer to Table No							
								17.6	17.6	15.3	15.3	15.3		16.3	
2017	132	157	48	290	-600	-27									-132
2018	413	455	144	869	-1800	-81									-413
2019	413	455	144	869	-1800	-81									-413
2020							-202	348	50	107	21	42	-179.6	-221	-153
2021							-202	363	53	117	22	44	-160.7	-221	-129
2022							-202	424	56	128	23	46	-141.8	-221	-60
2023							-202	441	60	139	24	48	-122.9	-221	-36
2024							-202	495	63	152	25	51	-104	-221	25
2025							-202	513	67	165	26	53	-85.05	-215	48
2026							-202	585	71	180	28	56	-66.15	-215	124
2027							-202	605	75	196	29	59	-47.25	-215	147
2028							-202	696	80	214	31	62	-28.35	-95	239
2029							-210	719	84	233	32	65	-9.45	-95	254
2030								816	90	254	34	68		-95	549
2031								840	95	277	35	71		-95	551
2032								948	101	302	37	75		-95	634
2033								966	107	329	39	79		-95	626
2034								1089	113	359	41	83		-95	719
2035								1116	120	391	43	87		-95	715
2036								1247	127	426	45	91		-95	811
2037								1275	135	465	48	96		-95	802
2038								1450	143	507	50	100		-95	936
2039								1481	151	552	52	106		-95	922
2040								1647	160	602	55	111		-95	1040
2041								1681	170	656	58	116		-95	1021
2042								1912	180	715	61	122		-95	1194
2043								1969	191	779	64	128		-95	1189
2044								2231	202	850	67	135		-95	1382
2045								2309	215	926	70	141		-95	1386
2046								2605	227	1009	74	148		-95	1601
	958	1067	336	2028	-4200	-189	-2,028	30,771	3,185	-11,032	-1,134	-2,282	-945	-3,548	15,577
														FIRR	15.27%

19.4 CONCLUSION

As seen from the above, the project is financially viable even in pessimistic scenario as FIRR (11.35%) is more than the hurdle rate (9%) and that too without any contribution from innovative financing. This is predominantly due to the following reasons:

1. Cost of construction on this line will be less as compared to other corridors because there is no tunnel and even the height of the viaduct is being optimized. Added to this, there is no significant land acquisition cost for the viaduct.
2. The ridership is expected to be more than other lines because of high concentration of IT companies along this corridor and rapid transport facility is the need of the hour.

Thus there is enough justification to take up this project.

20 ECONOMIC ANALYSIS

20.1 INTRODUCTION

The objective of the cost- benefit analysis is to identify and quantify the economic benefits and costs associated with the project (implementation of 17 kms of metro corridor: K. R. Puram – Silk Board 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 %) for the proposed investments linked with the project.

20.2 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.

20.3 ANALYSIS PERIOD

The analysis period of the project is taken as 30 years from the base year 2017 as follows:

- Base Year - 2016
- Construction period – 2017 to 2019 (3 years)
- Project opening for traffic – 2020
- End of the analysis period –2046
- No. of operating years, considered for economic analysis – 30 years

20.4 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 capital cost for economic analysis is taken as Rs. 4200 Crores. The Operation & Maintenance Cost (O & M cost) is as worked out in the respective Chapter.

20.5 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 could be 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.

1. Savings in time of commuters using the metro over the existing transport modes because of faster speed of metro.
2. Savings in cost of externalities due to reduction in emissions.
3. Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads
4. 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.

20.6 ESTIMATION OF MONEY VALUE OF TIME SAVED

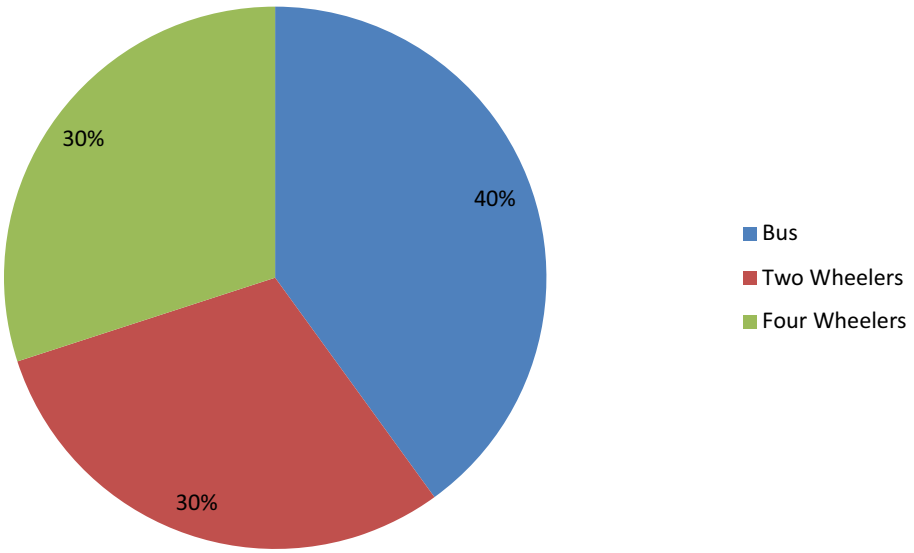
One of the major advantages of having a metro system would be saving in the time for people using this corridor. It is estimated that everyday there would be 3.1 lakhs passenger trips on this corridor though the passengers would be coming on the metro would be arriving from far away distance and for the purpose of present analysis, we have confined the benefit accruing out of this stretch. On an average passengers would be travelling a length of about 17 kms in this corridor resulting in saving of 15 minutes per day per person per trip. This estimation is on the conservative side. Furthermore, the factors like value of comfort, value of certainty of travel and value of safety would be a further add on. However, for the purpose of present analysis, the benefit which has been quantified is only the money value of the travel time saved. The total travel time saved per day for all the passengers put together would be 77,500 hours. Assuming a salary of Rs.200 per hour (which is again on the conservative side), the total money value for time saved would be Rs.1.55 crores (77,500 x 200) per day. For the entire year, this saving would translate into Rs.388 crores. For every subsequent year, this figures has been escalated by 10% year on year.

20.7 ESTIMATING THE SAVING IN COST OF EMISSIONS

It is estimated that in the year 2020, there would be 3.1 lakh passenger trip per day on this corridor. In effect, emissions with these many trips by other modes would come down as passengers would shift from other modes and adopt the metro. The daily passenger trips of 3.1 lakhs would be a switch over from 2 wheelers, 4 wheelers and buses in the following ratio.

a. Buses 40%
b. 2 Wheelers 30%
c. 4 wheelers 30%

Figure 20.1 Mode-wise Share of Traffic



Applying the above modal shift shown in the figure above, the vehicle kms (VKM) saved in different modes is estimated as follows:

a) Buses 31,886 vkm
b) 2 Wheelers 5,97,857 vkm
c) 4 wheelers 3,34,800 vkm

The marginal external cost for each one of these modes has been taken from a study – Estimating marginal external cost of transport in Delhi (Akshaya Kumar Sen , GeetamT iwari, Vrajaindra Upadhyay) 2009. This study had arrived at the following marginal external cost of urban transport as shown in Table below.

Table20.1 : Total Marginal Cost of Urban Transport (Rs/VKM)*						
Vehicle Type	**Congestion**	**Air pollution**	**Accidents**	**Noise**	**Total**	**Total(USD/VKM)**
Petrol Car						
Peak small	4.91	0.28	0.067	0.05	5.307	0.118
Peak big	4.91	0.31	0.067	0.05	5.337	0.119
Off-peak small	0.32	0.27	0.067	0.13	0.787	0.017
Off-peak big	0.32	0.30	0.067	0.13	0.817	0.018
Diesel Car						
Peak small	4.913	1.674	0.067	0.05	6.704	0.149
Peak big	4.913	2.736	0.067	0.05	7.766	0.173
Off-peak small	0.361	1.030	0.067	0.13	1.543	0.034
Off-peak big	0.316	1.665	0.067	0.13	2.178	0.048
Bus						
Peak	9.826	14.14	1.771	0.49	26.227	0.583
Off-peak	0.632	9.106	1.771	1.28	12.788	0.284

* Aksaya Kumar Sen, Geetam Tiwari, Vrajaindraa Upadhayay 2009, “Estimating marginal external cost of transport in Delhi”, Transport Policy, 17 Page:27-37.

Based on above Table, the marginal external cost for the year 2016 has been estimated as follows:

a. Buses : Rs.52 per km
b. 2 Wheelers : Rs.13 per km
c. 4 wheelers : Rs.3.6 per km

Applying the above marginal cost, the saving on account of switch over from other modes of transport to Metro for this corridor is estimated as follows:

Table 20.2: Savings on Account on Emission (Rs. Lakhs per Day)	
Buses	16.58
2 Wheelers	21.52
4 wheelers	43.52
Total	**81.62**

These costs are for the year 2016. We have not escalated this cost for 2016 even for 2020. However, after 2020, these costs would escalated at 5%. The annual escalation has been kept on

the lower side presuming that vehicular technology would improve and would mitigate the emission costs to some extent.

Scenario analysis by factoring in innovative financing for project funding:

As discussed in the chapter on Financing Options and Financial Analysis, there are three scenarios and analysis thereof are as under: :

1. Pessimistic
2. Optimistic
3. Most likely

Table 20.3: Scenario analysis for funding options (RUPEES IN CRORE)

S no	Funding Source	Scenario 1 Pessimistic	Scenario 2 Most likely	Scenario 3 Optimistic
1	Central Govt / State Govt contribution (equity / sub debt)	500.00	500.00	500.00
2	Internal generation by BMRCL through leasing of surplus land	500.00	500.00	500.00
3	Innovative financing	0	1100.00	2100.00
4	Borrowing @ 9% P A.	3200.00	2100.00	1100.00
	Grand total	4200.00	4200.00	4200.00

EIRR under above scenarios is worked out as discussed below

Scenario-1: Pessimistic

In the pessimistic scenario, it is assumed that minimum promoters contribution would be Rs.1,000 crores and nothing would be mobilised through innovative financing. Hence the balance amount of Rs 3200 crore would need to be borrowed.. With this presumption, the EIRR is worked out as in Table 19.4.

Scenario-2: Most Likely

In the most likely scenario, it is assumed that a sum of Rs. 1,000 crore would be contributed by promoters (as in scenario 1) and Rs 1,100 crores would be mobilised through innovative financing in the first 3 years (spread equally), while borrowing would be to the tune of Rs 2100 crore. With this presumption, the EIRR is worked out as in Table 20.5.

Scenario-3: Optimistic

In the optimistic scenario, it is assumed that a sum of Rs 1000 crore would be contributed by the promoters, Rs.2,100 Crore would be mobilized through innovative financing in the first 3 years (spread equally) whereas balance Rs 1100 crore would be through borrowing. With this presumption, the EIRR is worked out as in Table 20.6

Table 20.4: Case 1: PESSIMISTIC SCENARIO (INR IN CRORE)

	SNAP SHOT - INR IN CR INFLOW OWNERS FUNDS - 952 INNOVATIVE FIN - 0 BORROWINGS - 3199 TAX REIMB - 336 TOTAL INFLOW - 4487				OUTFLOW CAPEX 4200 IDC 287 TOAL 4487			CASH FLOW PROJECTIONS FROM OPERATIONS										
Year	CAPITAL							REVENUE							FIRR	ECONOMIC		EIRR
	INFLOW				OUTFLOW			INFLOW		OUTFLOW					Net cash flow	Time Saving Costs	Emmission Saving Costs	Net ECONOMIC BENEFIT
	OWNERS FUNDS	INNOVATIVE FINANCING	TAX REIMB	BORROWING	CAPEX	INT DURING CONST	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	Staff Costs	Maintenance Costs	Energy Consumption Costs	Interest	Depreciation				
								Refer to Table No										
								17.6	17.6	15.3	15.3	15.3		16.3			20.2	
2017	136	0	48	457	-600	-41									-136			-136
2018	408	0	144	1371	-1800	-123									-408			-408
2019	408	0	144	1371	-1800	-123									-408			-408
2020							-320	348	50	107	21	42	-274	-221	-365	388	298	320
2021							-320	363	53	117	22	44	-245	-221	-331	445	311	424
2022							-320	424	56	128	23	46	-216	-221	-252	510	324	581
2023							-320	441	60	139	24	48	-187	-221	-218	583	337	702
2024							-320	495	63	152	25	51	-158	-221	-148	666	350	868
2025							-320	513	67	165	26	53	-130	-215	-115	760	363	1008
2026							-320	585	71	180	28	56	-101	-215	-29	866	376	1213
2027							-320	605	75	196	29	59	-72	-215	4	985	389	1378
2028							-320	696	80	214	31	62	-43	-95	106	1120	402	1628
2029							-320	719	84	233	32	65	-14	-95	139	1272	415	1826
2030								816	90	254	34	68		-95	549	1443	428	2420
2031								840	95	277	35	71		-95	551	1635	441	2627
2032								948	101	302	37	75		-95	634	1845	452	2931
2033								966	107	329	39	79		-95	626	2079	463	3168
2034								1089	113	359	41	83		-95	719	2342	474	3536
2035								1116	120	391	43	87		-95	715	2637	485	3837
2036								1247	127	426	45	91		-95	811	2968	497	4275
2037								1275	135	465	48	96		-95	802	3338	508	4647
2038								1450	143	507	50	100		-95	936	3752	519	5207
2039								1481	151	552	52	106		-95	922	4216	530	5668
2040								1647	160	602	55	111		-95	1040	4736	541	6316
2041								1681	170	656	58	116		-95	1021	5317	552	6890
2042								1912	180	715	61	122		-95	1194	6024	569	7787
2043								1969	191	779	64	128		-95	1189	6825	586	8599
2044								2231	202	850	67	135		-95	1382	7733	604	9718
2045								2309	215	926	70	141		-95	1386	8761	622	10769
2046								2605	227	1009	74	148		-95	1601	9926	640	12167
	952	0	336	3199	-4200	(287.86)	-3200	30771	3185.288284	-11032.4647	-1133.83768	-2282.436029	-1440	-3547.88132	13915	83170	12474.09712	109559
	Note: Income tax is considered as zero for all these years due to depreciatio and carry forward lossess of BMRCL as a whole.														11.35%			47.80%

EIRR in this case comes to 47.08%.

Table 20.5 Scenario 2: MOST LIKELY SCENARIO - EIRR (INR IN CRORE)

	SNAP SHOT - INR IN CR INFLOW OWNERS FUNDS - 958 INNOVATIVE FIN - 1067 BORROWINGS - 2028 TAX REIMB - 336 TOTAL - 4389				OUTFLOW CAPEX 4200 IDC 189 TOTAL 4389			CASH FLOW PROJECTIONS FROM OPERATIONS									
Year	CAPITAL							REVENUE							FIRR		EIRR	
	INFLOW				OUTFLOW			INFLOW		OUTFLOW					Net cash flow	Time Saving Costs	Emmission Saving Costs	Net ECONOMIC BENEFIT
	OWNERS FUNDS	INNOVATIVE FINANCING	TAX REIMB	BORROWING	CAPEX	INT DURING CONST	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	Staff Costs	Maintenance Costs	Energy Consumption Costs	Interest	Depreciation				
								Refer to Table No										
								17.6	17.6	15.3	15.3	15.3		16.3			20.2	
2017	132	157	48	290	-600	-27									-132			-132
2018	413	455	144	869	-1800	-81									-413			-413
2019	413	455	144	869	-1800	-81									-413			-413
2020							-202	348	50	107	21	42	-179.55	-221	-153	388	298	532
2021							-202	363	53	117	22	44	-160.65	-221	-129	445	311	626
2022							-202	424	56	128	23	46	-141.75	-221	-60	510	324	774
2023							-202	441	60	139	24	48	-122.85	-221	-36	583	337	884
2024							-202	495	63	152	25	51	-103.95	-221	25	666	350	1041
2025							-202	513	67	165	26	53	-85.05	-215	48	760	363	1171
2026							-202	585	71	180	28	56	-66.15	-215	124	866	376	1366
2027							-202	605	75	196	29	59	-47.25	-215	147	985	389	1521
2028							-202	696	80	214	31	62	-28.35	-95	239	1120	402	1761
2029							-210	719	84	233	32	65	-9.45	-95	254	1272	415	1941
2030								816	90	254	34	68		-95	549	1443	428	2420
2031								840	95	277	35	71		-95	551	1635	441	2627
2032								948	101	302	37	75		-95	634	1845	452	2931
2033								966	107	329	39	79		-95	626	2079	463	3168
2034								1089	113	359	41	83		-95	719	2342	474	3536
2035								1116	120	391	43	87		-95	715	2637	485	3837
2036								1247	127	426	45	91		-95	811	2968	497	4275
2037								1275	135	465	48	96		-95	802	3338	508	4647
2038								1450	143	507	50	100		-95	936	3752	519	5207
2039								1481	151	552	52	106		-95	922	4216	530	5668
2040								1647	160	602	55	111		-95	1040	4736	541	6316
2041								1681	170	656	58	116		-95	1021	5317	552	6890
2042								1912	180	715	61	122		-95	1194	6024	569	7787
2043								1969	191	779	64	128		-95	1189	6825	586	8599
2044								2231	202	850	67	135		-95	1382	7733	604	9718
2045								2309	215	926	70	141		-95	1386	8761	622	10769
2046								2605	227	1009	74	148		-95	1601	9926	640	12167
	958	1067	336	2028	-4200	(189.00)										83170		
															15.27%			55.69%
Note: Income tax is considered as zero for all these years due to depreciatio and carry forward lossess of BMRCL as a whole.																		

EIRR in this case comes to 55.69%.

Table 20.6 Scenario 3: OPTIMISTIC - EIRR (INR IN CRORE)

	SNAP SHOT - INR IN CR INFLOW OWNERS FUNDS - 962 INNOVATIVE FIN - 1968 BORROWINGS - 1038 TAX REIMB - 336 TOTAL - 4304				OUTFLOW CAPEX 4200 IDC 104 TOTAL 4304			CASH FLOW PROJECTIONS FROM OPERATIONS									
Year	CAPITAL							REVENUE							FIRR		EIRR	
	INFLOW				OUTFLOW			INFLOW		OUTFLOW								
	OWNERS FUNDS	INNOVATIVE FINANCING	TAX REIMB	BORROWING	CAPEX	INT DURING CONST	LOAN REPAYMENT	Fare Box Revenue	Non FareBox Revenue	Staff Costs	Maintenance Costs	Energy Consumption Costs	Interest	Depreciation	Net cash flow	Time Saving Costs	Emmission Saving Costs	Net ECONOMIC BENEFIT
								Refer to Table No										
								17.6	17.6	15.3	15.3	15.3		16.3			20.2	
2017	130	288	48	148	-600	-16									-132			-132
2018	419	840	144	445	-1800	-44									-415			-415
2019	413	840	144	445	-1800	-44									-415			-415
2020							-103	348	50	107	21	42	-94	-221	31	388	298	717
2021							-103	363	53	117	22	44	-84	-221	46	445	311	802
2022							-103	424	56	128	23	46	-74	-221	106	510	324	940
2023							-103	441	60	139	24	48	-64	-221	122	583	337	1042
2024							-103	495	63	152	25	51	-54	-221	173	666	350	1189
2025							-103	513	67	165	26	53	-45	-215	187	760	363	1310
2026							-103	585	71	180	28	56	-35	-215	254	866	376	1496
2027							-103	605	75	196	29	59	-25	-215	268	985	389	1642
2028							-103	696	80	214	31	62	-15	-95	352	1120	402	1873
2029							-103	719	84	233	32	65	-5	-95	365	1272	415	2052
2030								816	90	254	34	68		-95	549	1443	428	2420
2031								840	95	277	35	71		-95	551	1635	441	2627
2032								948	101	302	37	75		-95	634	1845	452	2931
2033								966	107	329	39	79		-95	626	2079	463	3168
2034								1089	113	359	41	83		-95	719	2342	474	3536
2035								1116	120	391	43	87		-95	715	2637	485	3837
2036								1247	127	426	45	91		-95	811	2968	497	4275
2037								1275	135	465	48	96		-95	802	3338	508	4647
2038								1450	143	507	50	100		-95	936	3752	519	5207
2039								1481	151	552	52	106		-95	922	4216	530	5668
2040								1647	160	602	55	111		-95	1040	4736	541	6316
2041								1681	170	656	58	116		-95	1021	5317	552	6890
2042								1912	180	715	61	122		-95	1194	6024	569	7787
2043								1969	191	779	64	128		-95	1189	6825	586	8599
2044								2231	202	850	67	135		-95	1382	7733	604	9718
2045								2309	215	926	70	141		-95	1386	8761	622	10769
2046								2605	227	1009	74	148		-95	1601	9926	640	12167
	962	1968	336	1038	-4200	(104.00)	-1030	30771	3185	-11032	-1134	-2282	-495	-3548	17021	83170	12474	112665
Note: Income tax is considered as zero for all these years due to depreciatio and carry forward lossess of BMRCL as a whole.														FIRR	20.27 %		EIRR	62.78%

EIRR in this case comes to 62.78%

20.8 CONCLUSION

From the above analysis, it is clear that the project gives very large quantum of Economic benefits. In the most pessimistic scenario, i.e. where there is no innovative financing contribution, in that case also, the EIRR, works out to 47.80%

Even this EIRR, is conservative estimate. As from out of the several benefits which accrue to travelers as well as citizens, only two factors – value of travel time saved, and saving in external cost due to emissions, have been reckoned. The other savings have not been factored in. Had they also been factored in, the EIRR would have been much greater.

21 IMPLEMENTATION PLAN

21.1 BACKGROUND

As mentioned earlier in the DPR, the area around this corridor is a fast growing area with very heavy vehicular traffic on the existing roads. The construction of Metro on this line would involve blocking of about 9 meters in the middle of the road which would in effect mean that the availability of the road for the traffic would be reduced from 3 lanes to 2 lanes each way. Although there are service roads on both sides throughout the alignment and these service roads would be merged with the main carriage way at several locations. In spite of these modifications to the road, the vehicular traffic would be adversely affected during the construction phase. Therefore, efforts have been made to ensure that the project completion time is brought down to minimum.

There are several factors which favor quick construction of metro line over this alignment. Firstly, no major land acquisition is involved specially in the viaduct portion. The grade separators could have posed a major problem, but all the grade separators have been so designed such that there are split flyovers and even for underpasses there is enough space between the two main Carriageways on either side, where the viaduct could be accommodated without any major problem.

Another factor in favor of this alignment is that there would be no sharp horizontal or vertical curves as the construction of the ORR has ensured that sharp curves on the roads are totally eliminated. Moreover, there is no underground portion or tunneling which needs to be done in this stretch. The actual construction work can commence immediately after award of tender as no land acquisition is involved for viaduct portion. Even for the station portions, the work can be commenced and the land requirement is only for the entry structure on either side, which will not affect the construction of the station structures.

Because of the above factors, it is targeted to complete the entire project within a period of 36 months.

21.2 IMPLEMENTATION PLAN

It is envisaged to complete the entire project within duration of 36 months. Activities with their completion time is given in table 21.1 below

Table 21.1 Implementation Plan				
Sl. No.	**Activities**	**Start**	**End**	**Duration**
1	Mobilization of equipment rigs casting yard etc	0	3	3
2	Land acquisition in station duration	0	6	6
3	Mobilization and commissioning of launching girders	1	8	7
4	Completion of pile and pile cap works	3	15	12
5	Completion of pier and pier cap work	6	22	16
6	Erection of segments	10	26	16
7	Completion of station work	2	26	24
8	Completion of parapet	24	30	6
9	Erection of tracks and fittings	26	32	6
10	Architectural finishing	26	32	6
11	Traction, E&M and Signaling works	26	36	10

The Bar Chart showing the same is shown in the Figure 21.1.

Many of the activities may be over lapping the entire work will be completed in 36 months from the date of award of the work.

IMPLIMENTATION PLAN			
Activity	START	END	Duration
activity 1	0	3	3
activity 2	0	6	6
activity 3	1	8	7
activity 4	3	15	12
activity 5	6	22	16
activity 6	10	26	16
activity 7	2	26	24
activity 8	24	30	6
activity 9	26	32	6
activity 10	26	32	6
activity 11	26	36	10

activity 1 Mobilisation of equipment rigs casting yard etc
activity 2 Land acquisition in station duration
activity 3 Mobilisation and commissioning of launching girders
activity 4 Completion of pile and pile cap works
activity 5 Completion of pier and pier cap work
activity 6 Erection of segments
activity 7 Completion of station work
activity 8 Completion of parapet
activity 9 Erection of tracks and fittings
activity 10 Architectural finishing
activity 11 E&M and Signalling Works

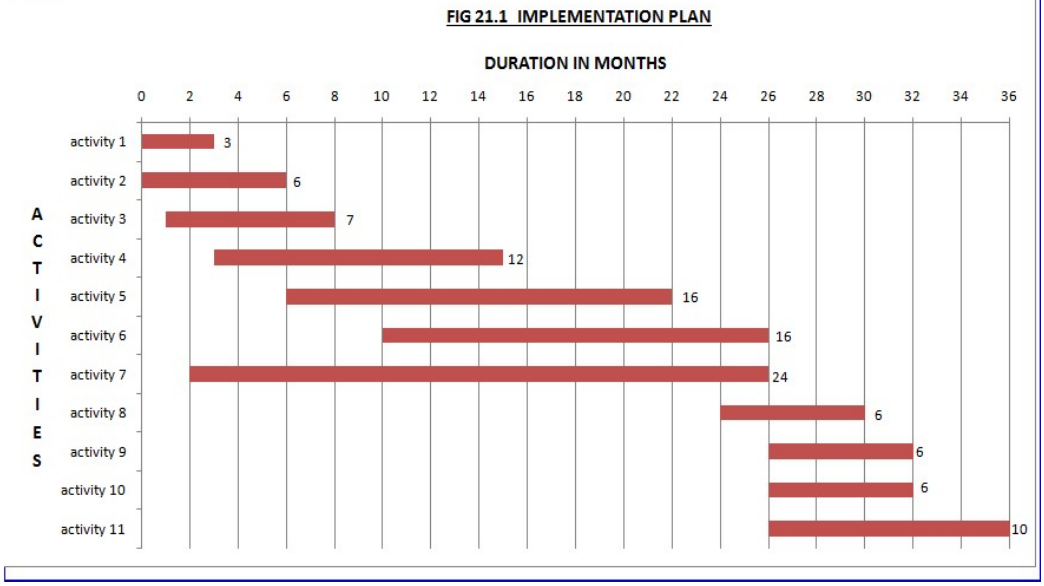


FIG 21.1 IMPLEMENTATION PLAN

22 FUTURE EXTENSION

Preamble

22.1 BACKGROUND

The present DPR has proposed the construction of metro line from Central Silk Board to K.R.Puram, which is about 18 km in length. This line has to be serviced by a depot. Non-availability of land on this corridor necessitates that from K.R.Puram the line is extended to existing Baiyappanahalli depot which is about 2½ km away. Thus the Baiyappanahalli depot would be servicing this line. Since the Baiyappanahalli depot was constructed in Phase-1 primarily to service the East-West line, a new depot at Whitefield would have to be constructed to service the East-West line. The construction of depot at Whitefield has therefore been included as a part of this DPR.

22.2 FUTURE EXTENSION

As per the Feasibility Report prepared by M/s.RITES, it has been recommended that the entire corridor from Central Silk Board via K.R.Puram upto Hebbal and even beyond gets covered by a metro line. Thus, ultimately this line from K.R.Puram would have to be extended all along the ORR at least till Hebbal. The alignment showing stations of this line beyond K.R.Puram and upto Hebbal is given in Figure 22.1. The distance between K.R.Puram to Hebbal is about 12 km and about 11 stations can b e planned to be constructed in this alignment. The proposed location of the stations is as follows:

List of Stations is as under:

i. TIN Factory Bus Stand
ii. Kasturi Nagar Bus Stand
iii. Vijaya Bank Colony
iv. Babusa Palya
v. Kalyan Nagar
vi. HBR Layout
vii. Nagawara
viii. Manyata Tech Park
ix. Jogappa Layout
x. Kariyana Layout
xi. Hebbal

The current DPR deals with Metro line from Silk Board to K.R. Puram, which is about 18 kms in length from K.R.Puram this line is connected to Byappanahalli Depot which is about 2½ km from K.R. Puram. Thus there will be four lines running between K.R. Puram to Byappanahalli as the part of East-West corridor line from Byappanahalli to White Field in Figure 22.2

22.3 STABLING LINES

Ideally speaking, a depot at both the ends on this line from Central Silk Board to Hebbal would have been desirable. But, the non-availability of big chunk of open space along this alignment makes locating this depot at the two extremities extremely difficult. Therefore, the capacity at Baiyappanahalli depot can be increased to hold another 10 trains and at the Hebbal end there is open land available and also there is air space over the BMTC depot which can be used for stabling 8 to 10 trains.

22.4 INTERCHANGE STATION

Near Hennur road the alignment will swing towards the right side of the carriage way to form an interchange station with Nagawara underground phase-2 Metro station and the alignment will continue on right hand service road to reach the stabling lines. In future this will provide connection to the Airport.

Figure 22.1

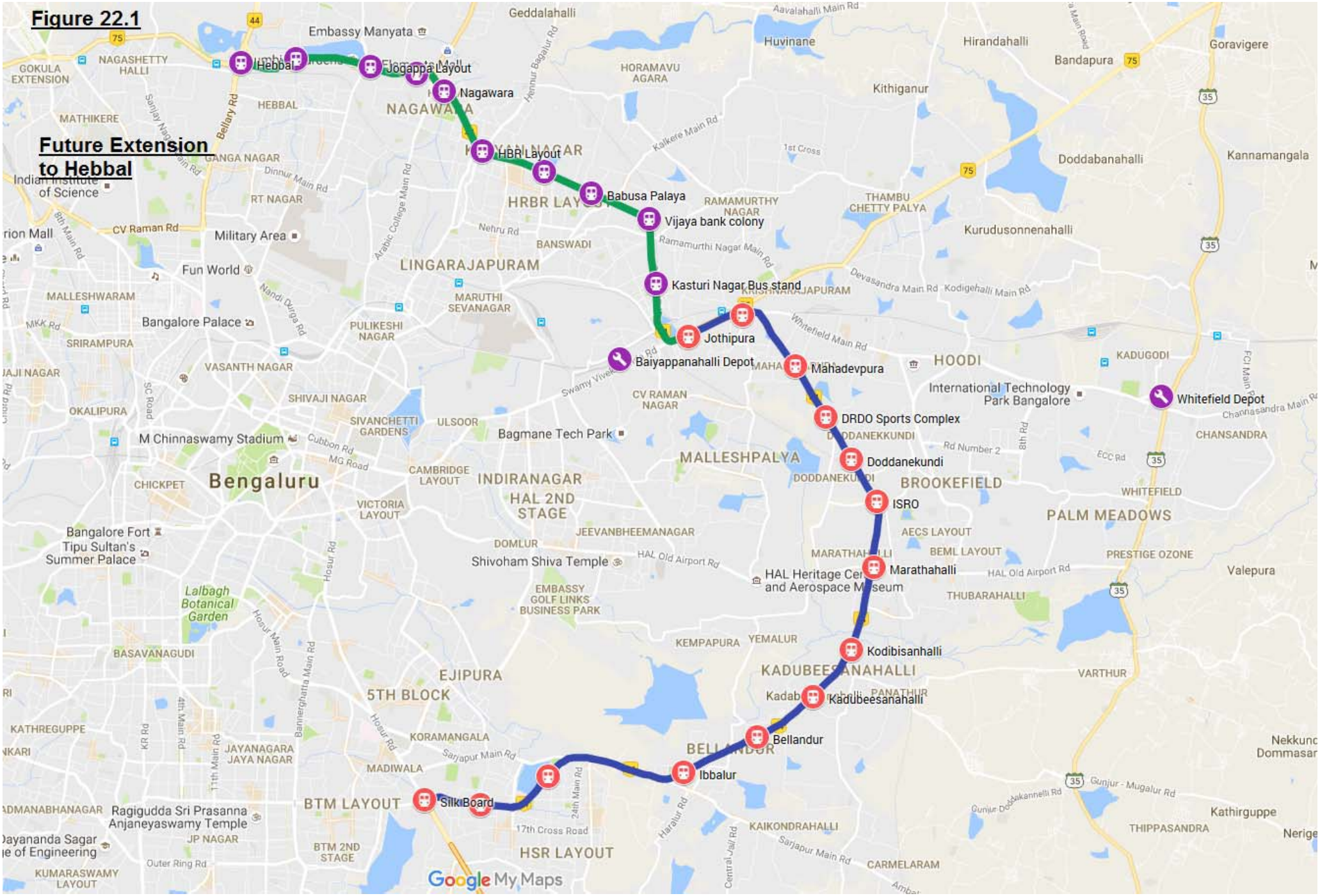
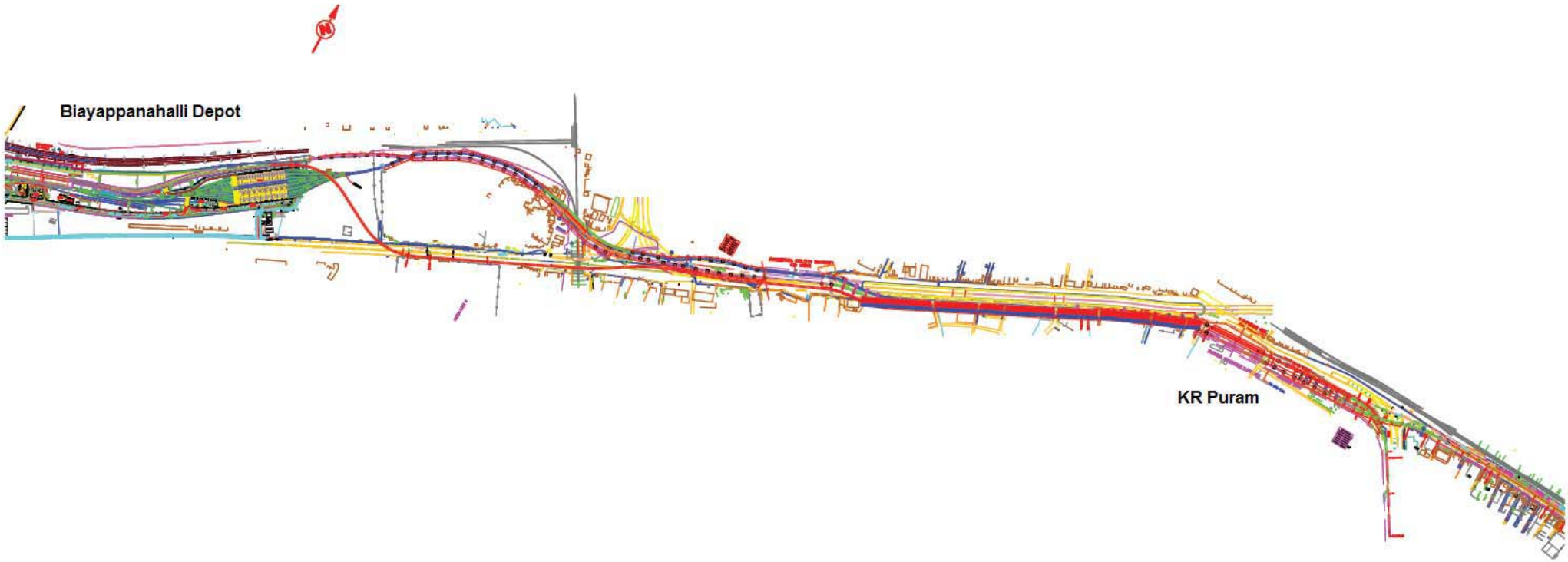

Future Extension to Hebbal
Hebbal
Embassy Manyata
Jogappa Layout
Nagawara
HBR Layout
Babusa Palaya
Vijaya bank colony
Kasturi Nagar Bus stand
Jothipura
Baiyappanahalli Depot
Mahadevpura
DRDO Sports Complex
Doddanekundi
ISRO
Marathahalli
Kodibisanhalli
Kadubeesanahalli
Bellandur
Ibbalur
Silk Board
Whitefield Depot
Bengaluru
Bangalore Palace
Fun World
Military Area
M Chinnaswamy Stadium
Bagmane Tech Park
Shivoham Shiva Temple
Lalbagh Botanical Garden
Bangalore Fort
Tipu Sultan's Summer Palace
Ragigudda Sri Prasanna Anjaneyaswamy Temple
Indian Institute of Science
International Technology Park Bangalore
Google My Maps

Figure 22.2 KR Puram to Biayappanahalli Depot



23 RISK FACTORS AND THEIR MITIGATION

This project has a high rate of return but there are several risks associated with the implementation of this project. These risks along with the mitigation measures which would be taken up are enumerated below:

1. **Engineering challenges:** The work of construction of viaduct will have to be carried out in the middle of a congested road. This would pose challenges during construction as there would be limitations of movement of heavy equipments. In addition, there are several underpasses which would cross the viaduct. The viaducts would have to be built over these underpasses necessitating very long spans.
   Mitigation measures: Though the road is highly congested, it has got service roads of adequate width on both the sides. During the construction, the central portion of about 9 meters width would be blocked but additional traffic space can be provided by merging the service roads with the main carriageway on several locations. Thus, there may not be a big issue on traffic diversion. As far as the long spans are concerned, it is estimated that the longest span which is required to be constructed would be about 60 meters in length. The BMRCL in Phase-1 has already used spans exceeding 65 meters. Therefore this challenge also can be handled by BMRCL.

2. **Viability Challenges:** The success of this project would depend upon the financial viability and this hinges around the ridership figures. The ridership of 3.1 lakhs passengers per day has been assumed in the very first year. In case this ridership is not achieved, the entire viability of the project would be adversely affected.
   Mitigation measures: The ridership of 3.1 lakhs passenger trips per day is very much on the lower side. With the working population of about one million along this corridor, expecting the ridership of only 3.1 lakhs passenger trips per day is a highly conservative estimation. Therefore it can be safely presumed that the passenger trips will not fall below 3.1 lakhs per day.

3. **Mobilization of Capital challenges:** It has been presumed that the funds would be mobilized through innovative financing and the State Government's contribution to the extent of Rs.500 Crores over a period of three years and also BMRCL is expected to contribute a sum of Rs. 500 Crores mobilized through long term lease of surplus lands in its possession. The innovative financing is expected to contribute somewhere around Rs.1,000 Crores. The mobilization both by BMRCL as well as through innovative financing has certain degree of uncertainty and if these funds are not mobilized, the project could get affected adversely.
   Mitigation measures: Even though the project is viable with high internal rate of return, it is necessary that the BMRCL contributes significantly and also substantial funds are mobilized

through Innovative financing. A condition may be imposed that the ground-breaking for the project should not be done unless the BMRCL and the innovative financing are able to mobilize at least Rs.250 Crores each.

4. **Land challenges:** There would be no land acquisition involved for the construction of viaduct. The construction of viaduct will not have any land related issues but the land would be required for landings wherever the stations are planned. Substantial amount of land would be required at the Silk Board junction where this line would meet the Electronic city line of Phase-2. In addition, land measuring about 50 acres would be required for a depot at Whitefield. In addition, the land acquisition would also be required for running the viaduct from KR Puram to Jyothipuram station and in this case the viaduct would be running over the built-up area. This built up land is required as the trains have to be fed on this line from Baiyyappanahally Depot.

   Mitigation measures: As far as the land for depot at Whitefield is concerned, there is about 400 acres of Govt. land available at Whitefield and it should be possible for the Government to grant 30 acres of land for construction of Depot. As far as the land at Silk Board is concerned, the design and construction of the Silk Board Metro Station as well as the roads at the intersections are a part of the Phase-2 and it is expected that the Central Silk Board would be in a position to spare the requisite land. As far as the land for viaduct between KR Puram and Jyothipuram is concerned, this viaduct would run alongside the Reach-1 viaduct of Phase-2 for which the land is already being acquired. Therefore, what is required is acquisition of additional strip of about 7 to 8 meters to accommodate one more viaduct on this stretch.

5. **Environmental Issues:** On the ORR all along the median, trees have been planted by the BDA in the recent years and these trees are growing. The number of trees coming on the median is about 1200.

   Mitigation measures: A survey has been done for all these trees and it is noted that all these trees are small in size with girth less than 12". BMRCL will have to ensure that not all trees are uprooted but only those trees are removed where foundations are coming. Other trees can be allowed to grow under the viaduct. In addition, efforts have to be made to transplant some of these trees as these trees are not very big and it can be possible to transplant such trees.

6. **Delays in execution:** There is a risk of the project in getting completed within the scheduled time of 36 months. The Phase-1 has been considerably delayed and the fear is that the implementation of this project may also get delayed.

   Mitigation measures: The reasons which were responsible for delay in implementing Phase-1, were mainly due to non-availability of land and tunneling in the difficult geographical terrain of the Bangalore city. Both these factors are absent for this project. Moreover, the BMRCL

has gained considerable experience during the implementation of Phase-1 and Phase-2 and therefore it can be expected that this project can be completed within a period of 36 months.

7. **Price escalation:** There is risk of the total cost of the project getting escalated as it happened in Phase-1. If this happens, the viability of the project would get reduced.
   Mitigation measures: The escalation of the cost of Phase-1 was closely associated with the delay in implementation because of various factors like non-availability of land and difficult in tunneling. For this reach, the land availability is not a constraint and also there is no underground section in this reach. With proper monitoring and supervision and with the experience gained in Phase-1 and Phase-2, the BMRCL will be able to complete the project within the estimated amount.

24 CONCLUSION

24.1 INTRODUCTION

The analysis in this Detailed Project Report (DPR) establishes not only the financial viability and desirability of this project but also brings out that construction of a Metro line on this corridor is inevitable.

The cost of construction of this Metro line measuring about 17 Kms. would be Rs.4200 Crores. It is proposed to be funded by contributions from the State Government, Government of India and the BMRCL. In addition, it is expected that the innovative financing model would contribute significantly for this project.

The work of execution of this project has to be entrusted to a Special Purpose Vehicle (SPV) which has the technical and managerial components to execute it. The Bangalore Metro Rail Corporation Ltd. (BMRCL) is the right agency for execution of this project. It may be noted that the financial structure of this project would be different from that of Phase-1 and Phase-2. In both Phase-1 and Phase-2, the Government of India as well as the State Government were equal shareholders and 50% of the cost of the project came from these two Governments (the contribution of the State Government was much larger than that of Government of India). However, in this case, the contributions from the Government of India may not be expected to be as much as what it was in Phase-1. Also from the State Government, the contribution cannot be expected to be of the same order as it was in the earlier two Phases. That is why recourse have been made to Innovative Financing and greater component of borrowings.

24.2 FINANCING OF THE PROJECT

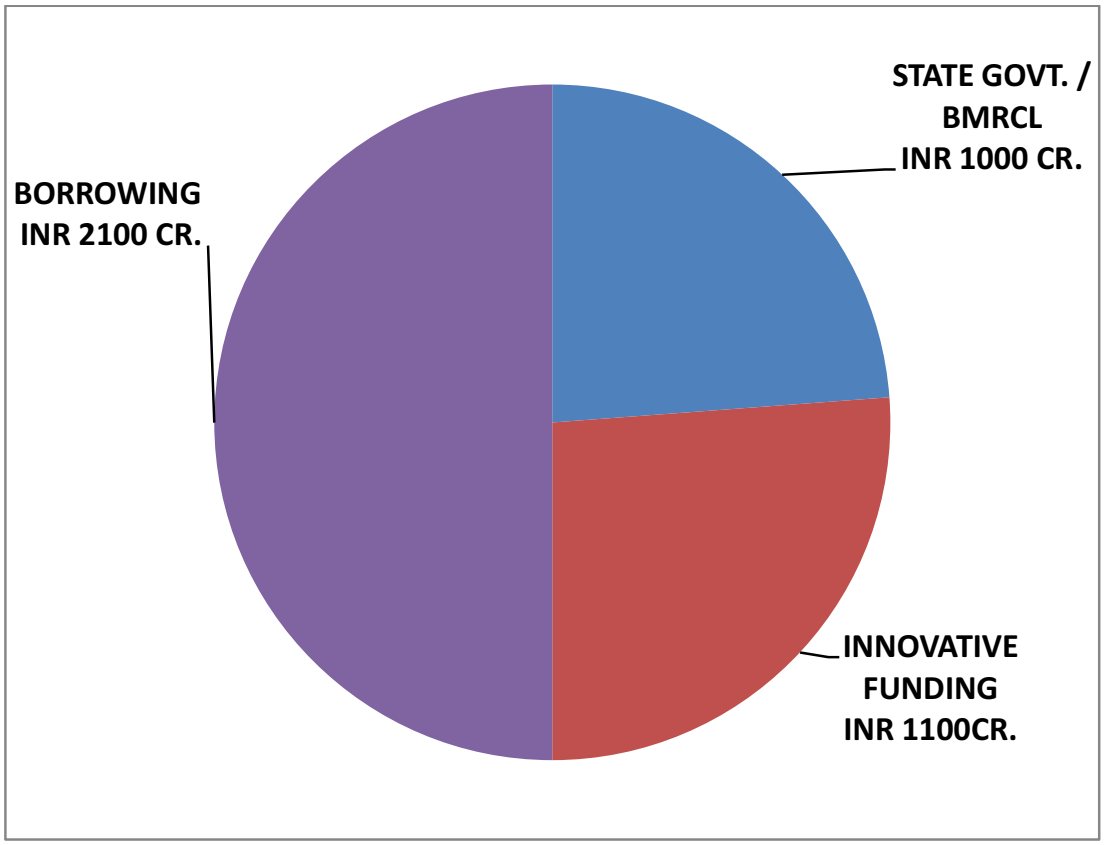
It is suggested that the State Government may contribute a sum of Rs. 500 Crores over the next three years period and the BMRCL would also mobilize a sum of Rs.500 Crores by long term lease of its lands which have commercial potential. In addition, the Innovative Financing is expected to yield about Rs.1100 Crores. The balance Rs. 2100 Crores would be borrowed. The above situation may change in case the contribution from the Innovative Financing is not on the expected lines. In such cases, the gap would have to be filled up by increasing the borrowings. In the most likely scenario, the funding pattern for this line would be as in Figure 24.1.

24.3 APPROVALS REQUIRED FROM THE STATE GOVERNMENT

Apart from providing finances to the tune of Rs. 500 Crores over the next three years, the following approvals would be required from the State Government:

1. Tax Reimbursement: Both in Phase-1 and Phase-2, all the taxes which were paid to the State Government on account of the project, were reimbursed by the State Government back to BMRCL. For this line also, the same facility may be extended to BMRCL. The total quantum of tax reimbursement is estimated to be Rs. 336 Crores.

Figure 24.1 Most Likely - Capital funds inflow



2. Making Government land available at Kadugodi (Whitefield): As there is no big chunk of land available adjacent to the ORR, the depot for this line will have to be located at Baiyyappanahally and the depot facilities at Baiyyappanahally which are meant for the East-West corridor would have to be provided by construction of a new Depot at Kadugodi (Whitefield). There is a big chunk of Government land measuring about 400 acres available at Kadugodi. It is expected that an extent of 50 acres of land would be allotted to BMRCL
3. Cash Support Agreement: In Phase-1 and Phase-2, the State Government has provided a Cash Support Agreement as per which the operational losses of the BMRCL, if any, would be funded by the State Government. The same facility may be extended for this project also. Such a Cash Support agreement would enable BMRCL to borrow money at competitive rates.
4. Implementation of this project: Since BMRCL has got all the required technical and managerial facilities, the implementation of this project should be entrusted to BMRCL only.

24.4 APPROVALS FROM THE GOVERNMENT OF INDIA

1. In Phase-1 and Phase-2, the Government of India has contributed equal amount as has been done by the State Government. The State Government should request the Government of India to extend the same facility for this project also. In case the Government of India finds it difficult to concede to this request, the Government of India should at least provide funds to

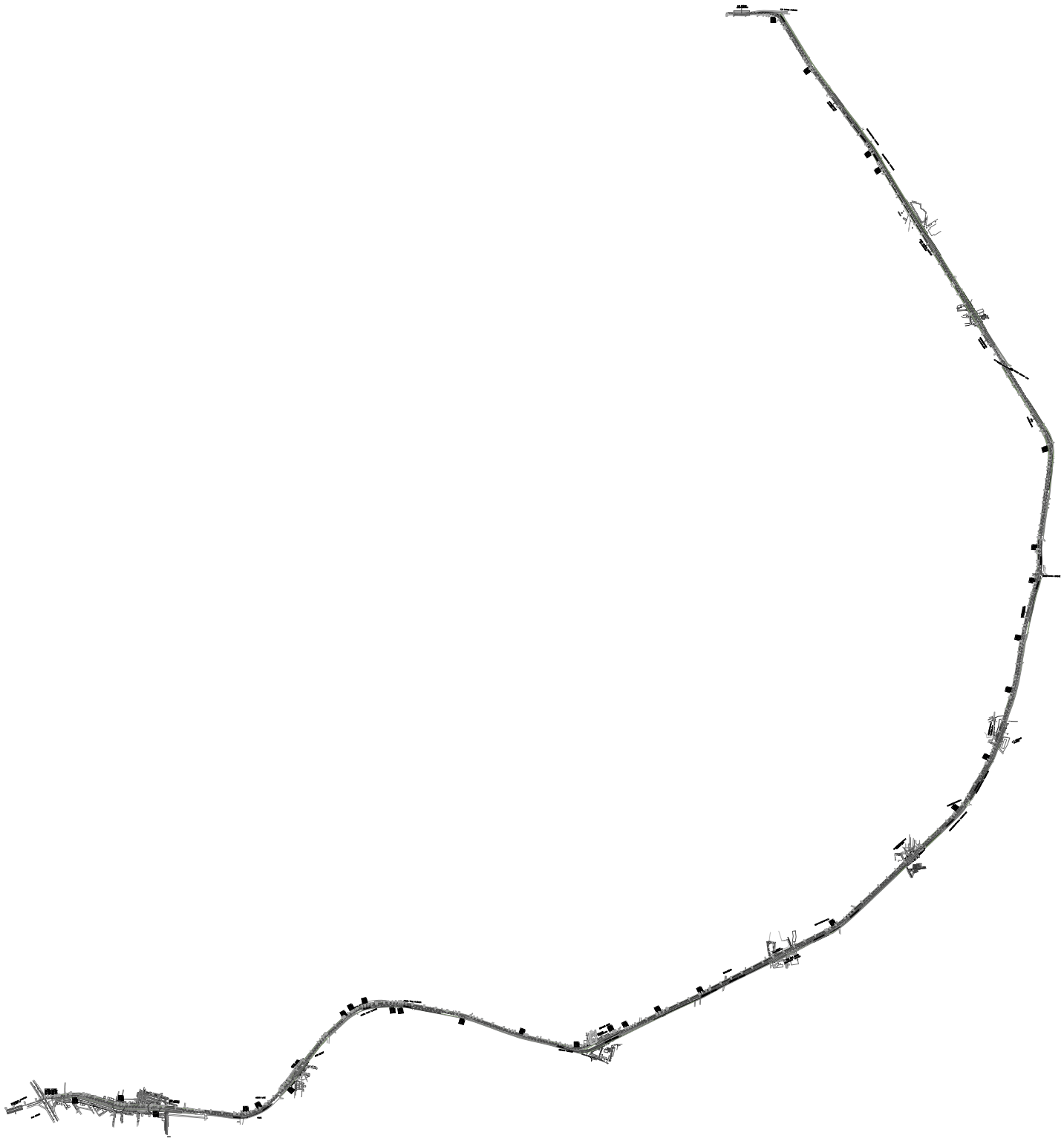
the extent of taxes which would be paid on account of this project to Government of India. This amount may be approximately Rs. 300 Crores.

2. The Government of India should support the project in helping the BMRCL to pose this before the International Financial Institutions so that the borrowings from them could be made as has been done in Phase-1 and Phase-2 i.e. by way of Soverign loans which are then passed on directly to BMRCL and the BMRCL takes the responsibility of repaying the loans with the State Government providing a back-up facility for repayment of such loans in case the BMRCL finds it difficult.

24.5 INNOVATIVE FINANCING

As Innovative Financing is a hall-mark of this project but at the same time it is being explored for the first time. It would be better to prescribe a figure so that once a particular level of any Innovative Financing is reached only then should the project be taken up. A reasonable figure could be mobilization or at least a firm commitment to the tune of Rs.250 Crores through Innovative Financing and another Rs. 250 Crores mobilization by BMRCL through long term loans of its commercially viable lands.

The DPR has also highlighted various risks the project is likely to face but has also suggested mitigation measures by which these risks could easily be handled.



Metro Alignment from KR Puram to Silk Board