EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

0.1 INTRODUCTION

0.1.1 General

Nagpur is the third largest city of Maharashtra and also the winter capital of the state. With a population of approximately 25 lakhs. Nagpur Metropolitan Area is the 13th largest urban conglomeration in India. It has also recently been ranked as the cleanest city and the second greenest city of India. In addition to being the seat of annual winter session of Maharashtra state assembly "Vidhan Sabha", Nagpur is also a major commercial and political center of the Vidarbha region, It is also known as "Orange City" for being a major trade center of oranges that are cultivated in the region.

Nagpur lies precisely at the center of the country with the Zero Mile Marker indicating the geographical center of India. The city was founded by the Gonds but later became part of the Maratha Empire under the Bhonsles. The British East India Company took over Nagpur in the 19th century and made it the capital of the Central Provinces and Berar. After the first reorganisation of states, the city lost its capital status but according to the informal "Nagpur Pact" between political leaders, it was made the second capital of Maharashtra. **Nagpur** is also declared, "Tiger Capital of India " as it connects many Tiger Reserves in India to the world.

Nagpur lies on the Deccan plateau of the Indian Peninsula and has a mean altitude of 310 meters above sea level. The underlying rock strata are covered with alluvial deposits resulting from the flood plain of the Kanhan River. In some places these give rise to granular sandy soil. In low lying areas which are poorly drained, the soil is alluvial clay with poor permeability characteristics. In the eastern part of city crystalline metamorphic rocks such as gneiss, schist and granites are found, while in the northern part yellowish sand stones and clays of the lower Gondwana formations are found.

Nagpur city is dotted with natural and man-made lakes with Ambazari lake being the largest. Other natural lakes include Gorewada Lake and Telangkhedi lake. Sonegaon lake and Gandhisagar lake are man-made lakes created by the city's historical rulers. Nag river, Pilli nadi along with nallas form the natural drainage pattern for the city. Nagpur is known for its greenery, and was judged as the cleanest and second greenest in India. Recently, Government of India selected Nagpur as a Model City for *National Clean Air Mission* by allocating 25 crores for the plan. This project will be handled by Nagpur's own NEERI.

As it is located at centre of Indian peninsula far from the Bay of Bengal and the Arabian Sea, Nagpur has a tropical wet and dry climate with dry conditions prevailing for most of the year. It receives an annual rainfall of 1,205 mm (47.44 in) from monsoon rains during June to September. The highest recorded rainfall was 304 mm on 14 July 1994. Summers are extremely hot lasting from March to June, with maximum temperatures occurring in May. Winter lasts from November to January, during which temperatures can drop below 10 °C (50 °F). The highest ever recorded temperature in the city was 49°C, while the lowest was 3°C.

0.1.2 Study Area

In early 2012 Nagpur Improvement Trust (NIT) requested DMRC to provide Consultancy services for preparation of a Detailed Project Report for Metro Rail System in Nagpur, Maharashtra initially for 30 Km which was revised to 42 Km in July 2012. Thereafter, DMRC conducted Traffic Surveys, Topographical Surveys, Geotechnical Investigations and Environment Impact Assessment Survey.

The study area consisted of Nagpur Municipal Corporation Area. The study area totaled to approximately 217 sq km.

Based on the different types of surveys done by DMRC, metro alignments were finalized after repeated inspection of the road network, intersections, passenger traffic flow, traffic congestion, connectivity to important land uses. Alignment of routes proposed by DMRC were as follows

Table 0.1A: Alignments Proposed by DMRC (in July 2013)

Alignment (Proposed by DMRC)	Detail Route
Alignment-1 North-South Corridor (21.833 Km, 17 stations)	Automotive Square, along Kamptee Road, Wardha Road, Variety Square to Abhyankar Road, along Nag River alignment will fall on Humpyard Road, Rahate Colony Road, Wardha Road, Khamla Road, Airport, MIHAN Area
Alignment-2 East – West Corridor (18.266 Km, 19 stations)	From Prajapati Nagar, along Central Avenue Road, Railway Feeder Road, Munje Chowk, Jhansi Ranee Chowk, North Ambajhari Road, Hingna Road, Lokmanya Nagar

FINAL ALIGNMENT FOR NAGPUR METRO

On 03.08.2013, a meeting presided by Shri S K Lohia, JS-MoUD,GoI was held at Nagpur to discuss the DPR. In that meeting, JS-MoUD,GoI expressed that the FIRR of the project should be at least 8%. Recently, MoUD has also issued advisory that FIRR of Metro Project should not be below 8%.

On 1.10.2013, a presentation on the DPR was made by M/s NIT to The Chief Minister, Government of Maharashtra. He was of the opinion to avoid underground alignment in MIHAN and also construct Maintenance Depot in the land belonging to State Govt Land. Subsequently, on 21.10.2013, a joint inspection of the NS corridor was done by VC&MD-MADC, Chairman-NIT, and Director Business Development-DMRC.

The original alignment of Corridor-I proposed was passing through Khamla Road, Airport Area after Sahakar Nagar and finally was ending at MIHAN. The alignment up to Old Airport Station was elevated, then for a length of 3.30 km, it was underground with one underground station named as New Airport Station and again elevated in MIHAN Area. Since the cost of underground section of the alignment is much more than the elevated section or the section at grade, alternative alignment was suggested for cost reduction, enhancement in PHPDT and to increase FIRR so that project becomes financially and economically viable.

The new proposed alignment suggested in the above inspection, was to pass through a 24m wide road adjacent to London Street after Sehkar Nagar Junction and was proposed to be taken to the east along 24m wide road and London Street up to Wardha Road. From the intersection at Wardha road, the elevated alignment was proposed to be on the central divider on the Wardha Road. After crossing existing intersection point of Wardha Road & Airport Road, the alignment was to be shifted to the MIHAN area. Alignment in this portion was proposed to be at grade and to run parallel to Wardha road upto ROB and abuting railway line thereafter up-to proposed Car depot.

But, while working on this modification of alignment, it was noticed that a very large number of properties were falling along the alignment due to sharp curve at the junction of Sahakar Nagar & 24 m wide road and also at the junction of 24m wide road & Wardha Road. Acquiring of these properties will be very tough and may delay the whole project.

Hence to avoid all such situation, it has been decided to take the alignment on Wardha Road only without going on Khamla Road.

Finally, NS Corridor will pass through Wardha Road after Congress Nagar Metro Station. After crossing existing intersection point of Wardha Road & Airport Road, the alignment will be shifted to the MIHAN area. Alignment in this portion will be at grade and will run parallel to Wardha road upto ROB and parallel to railway line thereafter up-to proposed Car depot. 14m wide stretch of land between the railway boundary line and the road near

proposed Container Depot of Container Corporation of India Ltd. will be affected by this proposed alignment of the Metro Rail as the proposed alignment passes through this stretch of land. 73 Ha land is available on the west side of railway line and south of existing flyover near khapari station. Average width of this land is about 80m and is about 1800m long. This MADC land may be utilized for Car Depot. Similarly, Depot of EW Corridor has also been shifted to SRP Land near proposed Lokmanya Nagar Metro Station.

This has caused deletion of few earlier proposed metro stations on NS Corridor and addition of new stations on the same.

Final alignment for both the corridors is as below :

Table 0.1B
FINAL ALIGNMENT

Alignment	Detail Route
Alignment-1 North-South Corridor (19.658 km, 17 Stations)	Automotive Square, along Kamptee Road, Wardha Road, Variety Square to Abhyankar Road, along Nag River alignment will fall on Humpyard Road, Rahate Colony Road, Wardha Road, Parallel to Railway Line, Khapri Station and finally in MIHAN Area near concor depot
Alignment-2 East – West Corridor (18.557 km, 19 Stations)	From Prajapati Nagar, along Central Avenue Road, Railway Feeder Road, Munje Chowk, Jhansi Ranee Chowk, North Ambajhari Road, Hingna Road, Lokmanya Nagar

0.2 TRAFFIC DEMAND

0.2.1 Traffic Study and Ridership estimation are the first tasks in DPR which imply finalizing a feasible alignment plan of the proposed metro network and then locating normal and interchange metro stations (if any). After that, Ridership Estimation is done. Estimating daily and peak hour boarding and alighting from each station, daily link load and PHPDT link loads [all together is called Ridership Estimation] are estimated. These estimates are primary inputs to other important estimates such as station design, train operation plan, estimates of revenue collection, benefits of metro, rolling stock and many other estimates including EIRR and FIRR.

0.2.2 Station Loading (Daily and Peak)

Total daily boarding ridership in 2016 is estimated as 3.52 lakhs in which share of line 1 as 47% and line 2 as 53%. Average trip length is 6.41km. The daily and peak station

loads of the Metro System comprises of the following lines, are described as under in **Table 0.2.**

Table 0.2: Summary Output : Traffic

BOARDING/RIDERSHIP (DAY)	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**
ON LINE 1(AUTOMATIVE-KHAPRI)	168361	185531	203720	224316	248419	277704
ON LINE 2(PRAJAPATI-LOKMANYA)	184081	197908	215415	234577	260237	286031
TOTAL OF BOTH	352442	383439	419135	458893	508656	563735
AVERAGE TRIP LENGTH IN KM	6.419	6.453	6.494	6.533	6.521	6.522
MAXIMUM PHPDT ON LINE 1	10089	10936	11915	12934	14286	15729
MAXIMUM PHPDT ON LINE 2	7746	8460	9154	9906	10748	11882

0.3 SYSTEM SELECTION

The population growth in cities and urban centers has put a lot of pressure on the infrastructure of these cities. In rapidly developing countries like India the urban infrastructure is stretched to limit and requires very effective solutions. The rapid development in India is not unprecedented and such development earlier took place in several nations of Europe, America and in Japan. So several modes of urban mass transit are now available for solution to the problem of Urban Transit.

0.3.1 Benefits of Mass Transport System

The main benefits addressed by mass transport are the mobility and freedom. The sustainability of mass transport has greater potential and major benefits occur through immediate means of helping the environment and conserving energy. In developing countries, like India, benefit through mass transit systems extend to urban poor with affordable fare structure when compared with costs incurred by private transportation on fuels, parking, congestion etc. The supply of planned and integrated mass public transport is the only way to relieve traffic congestion and reduce hours of delay on major travel corridors. Moreover, supply of metro rail system in Nagpur will mean a lot in terms of sustainable means of transport that meets the mobility and accessibility needs of people.

0.3.2 Feasibility of Metro System:

From the 'Traffic Demand Forecast' it can be seen that peak hour peak direction trips (PHPDT) on the North South Corridor is 10089,10936,12934 and 15729 the year of 2016, 2021, 2031 and 2041 respectively. Similarly PHPDT on East West corridor in the year of 2016, 2021, 2031 and 2041 is 7746,8460,9906 and 11882 respectively.

Road-based systems can optimally carry up to a maximum of 8,000 PHPDT. Since the PHPDT assumed on the above corridors exceed 8,000, there can be two options namely 1) Mono Rail and 2) Light Capacity Metro. Mono rail can carry the PHPDT projected but this technology is not a tested one. The operation and maintenance cost is much higher that Light metro. The capital cost of Mono rail is also almost same as that of Light Metro with no experience of Mono rail in India. Even in the other countries, the Mono rail is being adopted only for small lengths and as feeder to Metro. Hence, keeping in view the above disadvantages, it is recommended to adopt an stable, tested and reliable Metro technology. However, for Nagpur it will be Light Capacity Metro System.

0.4 GEOMETRIC DESIGN NORMS

The geometrical design norms are based on international practices adopted for similar metro systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 85 kmph. Planning for any higher speed is not desirable as the average inter-station distance (37 stations in approx. 40 km) is about 1.10 km and trains will not be able to achieve higher speed.

0.4.1 GEOMETRIC DESIGN PARAMETERS

i) Horizontal Curves

Table 0.3: Horizontal Curve Parameters

Description	Underground Section	Elevated Section
Desirable Minimum radius	**300 m**	**200 m**
Absolute minimum radius	**200 m (only c/c)**	**120 m**
Minimum curve radius at stations	**1000 m**	**1000 m**
Maximum permissible cant (Ca)	**125 mm**	**125 mm**
Maximum desirable cant	**110 mm**	**110 mm**
Maximum cant deficiency (Cd)	**85 mm**	**85 mm**

ii) Transition Curves

- Length of Transitions of Horizontal curves (m)

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

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

- Overlap between transition curves and vertical curves not allowed.
- Minimum straight between two Transition curves (in case of reverse curves): either 25 m or Nil.
- Minimum straight between two Transition curves (in case of same flexure curves): either 25 m or both curves should be converted in to the compound curve by introducing single transition between the two circulars.
- Minimum curve length between two transition curves: 25 m

iii) Gradients

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

iv) 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.

v) Radius of vertical curves:

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

0.4.2 Route Alignment

Two Corridors have been identified for implementation in phase I of Nagpur Metro Rail Project network as per details given as under:-

- Corridor I: North-South Corridor : Automative Square to KHAPRI
- Corridor II: East West Corridor : Prajapati Nagar to Lokmanya Nagar

0.4.2.1 North-South Corridor : Automative Square to KHAPRI

This corridor originates from Automotive Square on Kamptee Road; move along Kamptee Road and reach the intersection point of Amravati Road and Vardha Road,

then after crossing Fly Over moves towards Munje Square, moves towards Dhantoli and along nala moves towards Empire/Dr Munje Marg, leads towards Congress Nagar T-Point, then on Rahate Colony Road and then falls on Wardha Road, leads towards NEERI, then moves along Wardha Road and then west of Railway Track in MIHAN area. And passes through 14m wide stretch of land between the railway boundary line and the road near proposed Container Depot.

Entire length (19.658 Km.) of this corridor is proposed as elevated except in 4.6 Km at grade after Airport Station and in MIHAN area near Khapri Railway StatioN.. There are 17 stations on this corridor of which 15 stations are elevated and 2 stations are at Grade. Sitaburdi Station is an Inter-change station.

0.4.2.2 East West Corridor : Prajapati Nagar to Lokmanya Nagar

This corridor originates from Prajapati Nagar and runs westwards, through Vaishnodevi Chowk, Ambedkar Chowk, Telephone Exchange, Chittar Oli Chowk, Agarsen Chowk, Doser Vaisya Chowk, Nagpur Railway Station, Sitaburdi, Jhansi Rani Square, Institute of Engineers, Shankar Nagar Square, Lad chowk, Dharmpeth College, Subhash Nagar, Rachna (Ring road Junction), Vasudev Nagar, Bansi Nagar to Lomanya Nagar. The entire corridor is elevated.

The total length of the corridor is 18.557 kilometer. There are 19 stations on this corridor. All stations are elevated stations and Sitaburdi station is an Interchange Station.

0.5 CIVIL ENGINEERING

0.5.1 Elevated Section - Choice of Superstructure

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

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

- Segmental construction is an efficient and economical method for a large range of span lengths and types of structures. Structures with sharp curves and variable super elevation can be easily accommodated.

- Segmental construction permits a reduction of construction time as segments may be manufactured while substructure work proceeds and assembled rapidly thereafter.

- Segmental construction protects the environment as only space required for foundation and sub-station is required at site. The superstructure is manufactured at a place away from busy areas and placement of superstructure is done with the system erected from piers at heights.

- Segments are easy to stack in the casting yard/stacking yard in more than one layer, thereby saving in requirement of space.

- It is easier to transport smaller segments by road trailers on city roads.

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

0.5.2 Types of Superstructures for Elevated Section

- Pre-cast segmental box girder using external unbounded tendon
- Pre-cast segmental U-Channel Superstructure with internal pre-stressing.

0.5.3 CONSTRUCTION METHODOLOGY

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

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

0.5.4 Utility Diversion

It is suggested that all utilities falling within excavation area are diverted away in advance to avoid damage to such utilities during the excavation/ construction phase. The cross utilities, however has to be kept supported. It is suggested that pressure water pipelines crossing the proposed cut area are provided with valves on both sides of the cut so that the cut area can be isolated in case of any leakage to the pipeline to avoid flooding of the cut/damage to the works.

0.5.5 Geo-Technical Investigations

0.5.5.1 Physiography

Nagpur is situated at 21° 09' N latitude and 79° 09' E longitude and a mean altitude of 310 meters above sea level. Being located far away from any major water body at the centre of the Indian peninsula, the Nagpur's climate is dry or mildly humid for most of the year except for the rainy season. The highest ever recorded temperature in the city was 49 °C, while the lowest was 3°C. The geology of the Nagpur region is famous for the metamorphic rocks, which occur in all the districts in the Nagpur region except Wardha and some part of Nagpur district. The other geological formation Deccan Traps occur in the Wardha and North and North-West part of Nagpur District

0.5.5.2 Objective of Geotechnical Investigation

The main objectives of Geo-Technical Investigation Services are:

- To determine the required strength characteristics of the underlying soil/rock strata to design the foundation of the structure proposed to be constructed at various locations.
- To determine the subsurface profile of the underlying strata.
- To decide the construction methodology.

0.5.5.3 Details of Bore Holes

Investigation Works

Geotechnical investigation work at site was carried out to determine the existing subsoil strata, proposed type & depth of foundations and safe bearing capacity of foundations required for the proposed two Metro Corridors in Nagpur based on the results of 80 boreholes. 41 bore holes were driven in AUTOMOTIVE SQUARE TO MIHAN alignment & 39 boreholes were driven in Lokmanya Nagar to Prajapati Nagar alignment. However, due to the site condition, depth of drilling work ranging from 10.50m to 25m was carried out at the proposed locations.

Table :0.4

SUMMARY OF BORE HOLES

N.S.CORRIDOR

BH No.	Location Details	Total depth	Soil	Soft Rock	Hard Rock	Water Table (m)
1	Automative Chowk	25.00	15.00	10.00	-	7.20
2	Go Gas Pump	16.50	6.50	10.00	-	7.10
3	kailly Automobiles	17.00	7.00	10.00	-	7.20
4	Lal godown chowk	15.50	5.50	10.00	-	6.00
5	New Indira Hindi School	16.00	6.00	10.00	-	6.90
6	Oppt. Jaswant Tuli Mall,	16.00	6.00	10.00	-	7.10

BH No.	Location Details	Total depth	Soil	Soft Rock	Hard Rock	Water Table (m)
7	Bharat Petrol Pump (10 No. Pulia)	14.50	4.50	10.00	-	5.40
8	Kadwii Chowk,	14.50	4.50	10.00	-	5.15
9	Gurudwara (Railway Line Near)	20.00	10.00	10.00	-	5.00
10	Gaddi Godown Chowk	12.00	2.00	10.00	-	4.25
11	L.I.C Chowk, AHM Church Campus	11.50	1.50	10.00	-	4.40
12	R.B.I Bank Chowk	12.00	2.00	10.00	-	4.00
13	Morrises Collage, T. Point	11.00	1.00	10.00	-	3.85
14	Sita Burdi Police Station	14.50	4.50	10.00	-	5.00
15	Ras Furniture, Oppt. Nangle Traders	16.00	6.00	10.00	-	4.70
16	Yaswant Stadium	17.00	7.00	10.00	-	4.60
17	Dhantoli P.S, Oppt. Green City Hotel	17.50	7.50	10.00	-	5.10
18	Madhukar Arts (M. Printers)	15.00	5.00	10.00	-	3.20
19	Asha Towers	14.50	4.50	10.00	-	3.90
20	Hardikar Chowk	14.00	4.00	10.00	-	3.40
21	Central Jail	15.00	5.00	10.00	-	3.60
22	Clock Tower Rajive Gandhi Chowk	11.50	1.50	10.00	-	3.25
23	Sanskar Vidhya Sagar School	12.50	2.50	10.00	-	4.00
24	Bharat Creations/Sanjay Traders	13.00	3.00	10.00	-	4.10
25	Sawarkar Chowk	12.50	2.50	10.00	-	2.90
26	Khamla Bus Stop	12.50	2.50	10.00	-	3.60
27	Baba Hardware/Vijay Trading	13.00	3.00	10.00	-	3.00
28	Arun Rao Purnakar Chowk (Puliya)	13.00	3.00	10.00	-	2.10
29	Park/Dence Forest Area (Airport)	14.00	4.00	10.00	-	2.90
30	Parking Airport	14.50	4.50	10.00	-	2.10
31	Airport Boundry	14.50	4.50	10.00	-	3.70

Table :0.5

SUMMARY OF BORE HOLES
E W CORRIDOR

BH No.	Location Details	Total depth	Soil	Soft Rock	Hard Rock	Water Table (m)
1	AIA Engineering Limited.	11.00	1.00	5.00	5.00	3.50
2	C.R.P.F Gate No.-1	11.00	1.00	6.00	4.00	4.20
3	Mahindra Company	11.50	1.50	6.00	4.00	4.30
4	Ambru Batti Chowk (Near Dharam kantta)	11.50	1.50	10.00	-	4.05
5	Toll Tax Naka	11.00	1.00	10.00	-	4.25
6	Super Enclave, Opp. Prashant Trading	11.50	1.50	10.00	-	5.30
7	Hingna T. Point	10.50	0.50	10.00	-	4.70
8	Karankutti Hotel	11.00	1.00	10.00	-	4.60
9	Pump House (G.C.C.R.P.F) Nagpur.	10.50	0.50	10.00	-	5.10
10	Subhash Nagar Chowk,	12.50	2.50	9.00	1.00	4.20
11	Nagpur Improvement Trust, Crazy Castle.	13.00	3.00	10.00	-	4.40
12	Tanveer Hotel	12.50	2.50	10.00	-	3.40
13	Leela house (Near Ambajhari T.Point)	12.00	2.00	8.50	1.50	3.60
14	L.A.D. Chowk	13.00	3.00	10.00	-	5.10
15	Shankar Nagar chowk	13.00	3.00	10.00	-	5.15
16	Adrash S.S High School	12.00	2.00	10.00	-	5.10
17	Dharampeeth Vidhyalay	14.00	4.00	10.00	-	4.90
18	A.M.I.E (Nagpur Local Center)	14.00	4.00	10.00	-	5.50

BH No.	Location Details	Total depth	Soil	Soft Rock	Hard Rock	Water Table (m)
19	M.J Collage	14.50	4.50	10.00	-	4.90
20	Jhansi Rani Chowk	14.00	4.00	10.00	-	5.10
21	Munje Chowk	14.00	4.00	10.00	-	5.70
22	Railway Push Box.	14.50	4.50	10.00	-	4.60
23	Nagpur Corporation octroi Naka - 13	14.00	4.00	10.00	-	4.20
24	Hazrat baba majar	14.00	4.00	10.00	-	5.30
25	Mayo Hospital	12.00	2.00	10.00	-	3.90
26	Sewa Sadan Chowk	13.00	3.00	10.00	-	4.50
27	Gandhi Bagh (Bus Stop)	12.50	2.50	10.00	-	4.35
28	Chittarawali Chowk	13.20	3.20	10.00	-	4.70
29	Darodkar Chowk	13.15	3.15	10.00	-	4.60
30	Rahate Hospital	14.50	4.50	10.00	-	4.75
31	Telephone Exchange	16.00	6.00	10.00	-	7.20
32	Chapro Nagar Chowk, Bharat Furniture	16.00	6.00	10.00	-	5.30
33	Ambedkar Chowk,	17.50	7.50	10.00	-	4.90
34	Ali Electrical, Vardhman Nagar Chowk	16.50	6.50	10.00	-	7.40
35	Near Mahalaxmi Collaction	18.50	8.50	10.00	-	6.40
36	Sapna Bar & Restorent	17.00	7.00	10.00	-	4.30
37	Radhe Krishan Hospital Chowk	17.50	7.50	10.00	-	7.30
38	Desi Wine Shop	21.00	10.00	10.00	-	7.60
39	Gomti Hotel, Near P & B Bank	25.00	10.00	10.00	-	7.30

TYPE OF FOUNDATION :NORTH – SOUTH CORRIDOR

A : Bored Cast in situ RCC Pile

Depending on the field and laboratory observations of subsoil strata, test results and the type of structures proposed at site, the most feasible soil-foundation system is recommended as normal bored cast in situ R.C.C. piles foundations of 0.80m & 1.0m diameter at different depths with cut-off level at 1.50m to 2.0m depth below existing Ground level. The safe load carrying capacities of these piles are given in following table.

Table 0.6 :RCC PILE DETAILS FOR NORTH – SOUTH CORRIDOR

Borehole Nos	Dia. of Pile	Cutoff level	Depth, m	Pile Capacity		
				Compression	Uplift	Lateral
1	0.80	1.50	19.00	185.0	90.0	9.0
	1.00	1.50	19.00	300.0	120.0	12.0
2, 3	0.80	1.50	11.00	170.0	40.0	9.0
	1.00	1.50	11.00	250.0	50.0	12.0
4,5,6	0.80	1.50	10.50	170.0	45.0	9.0

	1.00	1.50	10.50	250.0	50.0	12.0
7,8	0.80	1.50	10.00	150.0	35.0	9.0
	1.00	1.50	10.00	225.0	45.0	12.0
9	0.80	1.50	15.00	220.0	85.0	9.0
	1.00	1.50	15.00	320.0	100.0	12.0
14	0.80	1.50	10.00	150.0	35.0	9.0
	1.00	1.50	10.00	225.0	45.0	12.0
15,16	0.80	1.50	11.00	170.0	40.0	9.0
	1.00	1.50	11.00	250.0	50.0	12.0
17	0.80	1.50	12.00	180.0	45.0	9.0
	1.00	1.50	12.00	260.0	55.0	12.0
18 to 21	0.80	1.50	10.00	150.0	35.0	9.0
	1.00	1.50	10.00	225.0	45.0	12.0
23 to 28	0.80	1.50	10.00	140.0	33.0	9.0
	1.00	1.50	10.00	210.0	40.0	12.0
29 to 32	0.80	1.50	10.00	150.0	35.0	9.0
	1.00	1.50	10.00	225.0	45.0	12.0

B: Open square footing

Depending on the field and laboratory observations of subsoil strata, test results and the type of structures proposed at site, the types of foundations, depths and net safe bearing capacities recommended for design purposes are given in the following table. The net SBC/API in the following table are the lower of the values obtained from shear failure criterion as per IS: 6403 and settlement failure criterion as per IS: 8009, Part-I.

Table 0.7 : OPEN FOUNDATION DETAILS FOR NORTH – SOUTH CORRIDOR

For Permissible settlement = 40.0 mm

Type of Foundation	Depth of Foundation (m)	Size of Foundation (m)	Net Safe Bearing Capacity/ Allowable Pressure Intensity (t/m^2)
For Bore Hole Nos : 10 to 13, 22 & 33 to 41 :			
Square footing	2.50 to 3.0	5.0 to 6.0	20.00

Note: For design purpose water table shall be considered at foundation level.

TYPE OF FOUNDATION : EAST - WEST CORRIDOR

A : Bored Cast in situ RCC Pile

Depending on the field and laboratory observations of subsoil strata, test results and the type of structures proposed at site, the most feasible soil-foundation system is recommended as normal bored cast in situ R.C.C. piles foundations of 0.80m & 1.0m diameter at different depths with cut-off level at 1.50m to 2.0m depth below existing Ground level. The safe load carrying capacities of these piles are given in following table.

Table 0.8 :RCC PILE DETAILS FOR EAST - WEST CORRIDOR

Borehole Nos	Dia. of Pile	Cutoff level	Depth, m	Pile Capacity		
				Compression	Uplift	Lateral
11	0.80	1.50	12.00	400.0	60.0	9.0
	1.00	1.50	12.00	600.0	90.0	12.0
17 – 22	0.80	1.50	14.00	155.0	50.0	9.0
	1.00	1.50	14.00	240.0	70.0	12.0
23 – 24	0.80	1.50	14.00	180.0	60.0	9.0
	1.00	1.50	14.00	250.0	75.0	12.0
25 – 29	0.80	1.50	12.00	150.0	40.0	9.0
	1.00	1.50	12.00	220.0	50.0	12.0
30 – 31	0.80	1.50	14.00	170.0	50.0	9.0
	1.00	1.50	14.00	240.0	70.0	12.0
32	0.80	1.50	12.00	170.0	40.0	9.0
	1.00	1.50	12.00	250.0	50.0	12.0
33 – 34	0.80	1.50	15.00	200.0	80.0	9.0
	1.00	1.50	15.00	300.0	100.0	12.0
35 – 37	0.80	1.50	15.00	190.0	75.0	9.0
	1.00	1.50	15.00	300.0	100.0	12.0
38	0.80	1.50	15.00	180.0	80.0	9.0
	1.00	1.50	15.00	250.0	100.0	12.0
39	0.80	1.50	20.00	200.0	80.0	9.0
	1.00	1.50	20.00	300.0	100.0	12.0

Note:

1. For design purpose, water table shall be considered at cut off level.
2. For design purpose, effective overburden pressure at pile tip should correspond to pile length equal to 15 times the diameter.
3. The above values should be confirmed through pile load tests in the field before adopting these values for design purposes.

B : Open square footing

Depending on the field and laboratory observations of subsoil strata, test results and the type of structures proposed at site, the types of foundations, depths and net safe bearing capacities recommended for design purposes are given in the following table. The net SBC/API in the following table are the lower of the values obtained from shear failure criterion as per IS: 6403 and settlement failure criterion as per IS: 8009, Part-I.

Table :0.9: OPEN FOUNDATION DETAILS FOR EAST-WEST CORRIDOR
For Permissible settlement = 40.0 mm

Type of Foundation	B/Hole No	Depth of Foundation (m)	Size of Foundation (m)	Net Safe Bearing Capacity/ Allowable Pressure Intensity (t/m^2)
Square footing	1 – 9	2.50 - 3.0	5.0 to 6.0	25.00
	10 & 12	3.0	5.0 to 6.0	20.00
	12 – 13	3.0	5.0 to 6.0	20.00
	14 – 15	3.00 - 4.00	5.0 to 6.0	25.00
	16	3.0	5.0 to 6.0	20.00

Note: For design purpose water table shall be considered at foundation level.

0.5.6 LAND

Land Requirement for following Major Components

- MRTS Structure (including Route Alignment), Station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities, Depots, etc.
- Receiving/Traction Sub-stations
- Radio Towers
- Temporary Construction Depots and work sites.
- Staff quarters, office complex and operation control centre(OCC)

Table 0.10: Summary of Permanent Land Requirement *

LAND DETAILS	EAST-WEST CORRIDOR PRAJAPATI NAGAR TO LOKMANYA NAGAR		NORTH-SOUTH CORRIDOR AUTOMATIVE SQUARE TO KHAPRI DEPOT	
	GOVT. LAND (in sqm)	PVT. LAND (in sqm)	GOVT. LAND (in sqm)	PVT. LAND (in sqm)
STATIONS EXIT/ENTRY	3644.80	7769.40	7525.30	13812.50
RUNNING SECTION	3255.30	5680.80	101882.00	19025.90
DEPOT AREA	258973.00		339000.00	
TRAFFIC INTEGRATION/PARKING	8779.10	1465.70	53759.80	5179.20
TOTAL	**274652.20**	**14915.90**	**502167.10**	**38017.60**
TOTAL GOVT LAND	**776819.30**	**SAY 77.68 HECTARES**		
TOTAL PVT LAND	**52933.50**	**SAY 5.3 HECTARES**		

*Apart from this the State Government should provide 20 hectare land free of cost for PD activity. Also for construction depots, temporary land @2 hectares per 10 km. will be required on Temporary Basis.

0.6 STATION PLANNING

Line -1 (North-South Corridor) Automative Square to KHAPRI Depot

A total of 17 Stations have been planned along the proposed NS Corridor. This corridor originates starts from Automotive square and runs southwards on NH-7 through Nari Road, Indora chowk, Gaddi Godam Square, Kastrurchand Park, Zero Mile, Sitaburdi, Congress Nagar, Rahate colony, Ajn Sqre Station, Chhatrapati Sqr Station, Jaiprakash Nagar, Ujjawal Nagar, Airport Station, New Airport Station and Khapri Station. The Corridor is partly elevated and partly at grade. Total Length of the corridor is 19.658 Km of which approximately 15.058 is elevated and 4.6 km is at grade. There are 17 stations on this corridor of which 15 stations are elevated and 2 stations are at grade. Sitaburdi Station is an Inter-change station. Average inter-station distance is 1.20km approximately varying from 0.54km to 2.4km depending upon the site, operational and traffic requirements. The sequence of stations with their respective chainages and locational and platform characteristics is presented in **Table 0.11A.**

Table 0.11A: NS Corridor :
Sequence of Stations with Chainages and Locational & Platform Characteristics

Name of Station		Chainage (in m)	Distance from previous station (in m)	Rail level (in m)	Platform type	Alignment
	Dead End	-145.0				
1.	AUTOMOTIVE SQRE	0.0	408.2	303.900	Side	Elevated
2.	NARI ROAD	975.8	975.8	308.900	Side	Elevated
3.	INDORA CHOWK	2139.7	1163.9	314.100	Side	Elevated
4.	KADVI CHOWK	3181.2	1041.5	318.400	Side	Elevated
5.	GADDI GODAM SQRE	4399.0	1217.8	323.200	Side	Elevated
6.	KASTURCHAND PARK	5148.6	749.6	326.300	Side	Elevated
7.	ZERO MILE	6175.5	1026.9	319.600	Side	Elevated
8.	SITABURDI	6709.2	533.7	310.900	Side	Elevated
9.	CONGRESS NAGAR	7897.2	1188.0	317.900	Side	Elevated
10.	RAHATE COLONY	8682.6	785.4	321.500	Side	Elevated
11.	AJNI SQUARE	10104.7	1422.1	315.300	Side	Elevated
12.	CHHATRAPATI SQUARE	11146.3	1041.6	319.500	Side	Elevated
13.	JAIPRAKASH NAGAR	11811.5	665.2	320.000	Side	Elevated
14.	UJWAL NAGAR	12846.6	1035.1	311.000	Side	Elevated

Name of Station		Chainage (in m)	Distance from previous station (in m)	Rail level (in m)	Platform type	Alignment
15.	AIRPORT	13784.9	938.3	313.300	Side	Elevated
16.	NEW AIRPORT	16184.4	2399.5	299.000	Side	At-Grade
17.	KHAPARI	18460.6	2276.2	308.700	Side	At-Grade
	Dead End	19250.0				

Line -2 (East-West Corridor) Prajapati Nagar to Lokmanya Nagar

A total of 19 Stations have been planned along the proposed EW Corridor This corridor originates from Prajapati Nagar and runs westwards, through Vaishnodevi Chowk, Ambedkar Chowk, Telephone Exchange, Chittar Oli Chowk, Agrasen Chowk, Doser Vaisya Chowk, Nagpur Railway Station, Sitaburdi, Jhansi Rani Square, Institute of Engineers, Shankar Nagar Square, LAD chowk, Dharmpeth College, Subhash Nagar, Rachna (Ring road Junction), Vasudev Nagar, Bansi Nagar to Lomanya Nagar. The entire corridor is elevated. The total length of the corridor is 18.266 kilometer. All stations are elevated stations and Sitaburdi station is an Interchange Station. Average inter-station distance is 1.00km approximately varying from 0.65km to 1.29km depending upon the site, operational and traffic requirements. The sequence of stations with their respective chainages and locational and platform characteristics is presented in **Table 0.11B**

Table 0.11 B: EW Corridor :
Sequence of Stations with Chainages and Locational & Platform Characteristics

Name of Station		Chainage (in m)	Distance from previous station (in m)	Rail level (in m)	Platform type	Alignment
	Dead End	-392.0				
1	Prajapati Nagar	0.0	392.0	301.0	Side	Elevated
2	Vaishno Devi Chowk	1229.3	1229.3	305.3	Side	Elevated
3	Ambedkar Chowk	1947.9	718.6	308.3	Side	Elevated
4	Telephone Exchange	3137.4	1189.5	311.6	Side	Elevated
5	Chittar Oli Chowk	3950.2	812.8	311.5	Side	Elevated
6	Agarsen Chowk	4759.8	809.6	319.5	Side	Elevated
7	Dosar Vaisya Chowk	5590.4	830.6	321.9	Side	Elevated
8	Nagpur Railway station	6464.4	874.0	319.7	Side	Elevated
9	Sitaburdi (Interchange)	7707.7	1243.3	320.1	Side	Elevated
10	Jhansi Rani Square	8354.0	646.3	313.9	Side	Elevated

Name of Station		Chainage (in m)	Distance from previous station (in m)	Rail level (in m)	Platform type	Alignment
11	Institute Of Engineers	9117.2	763.2	315.4	Side	Elevated
12	Shankar Nagar Square	10074.9	957.7	316.9	Side	Elevated
13	Lad Chowk	10873.1	798.2	319.1	Side	Elevated
14	Dharmpeth College	12020.7	1147.6	329.5	Side	Elevated
15	Subhash Nagar	12947.1	926.4	336.0	Side	Elevated
16	Rachna Ring Road Jn.	14201.1	1254.0	338.8	Side	Elevated
17	Vasdev Nagar	15173.9	972.8	345.2	Side	Elevated
18	Bansi Nagar	16131.6	957.7	336.3	Side	Elevated
19	Lokmanya Nagar	17792.6	1661.0	330.4	Side	Elevated
	Dead end	18165.0	372.4			

Site specific plans for the stations were prepared and put up in the respective chapter.

0.7 TRAIN OPERATION PLAN

0.7.1 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.
- A short train consists of 3 coaches.
- Multi-tasking of train operation and maintenance staff.

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0.7.2 Train Operation Plan

0.7.2.1 Salient Features

- Running of services for 19 hours of the day (5 AM to Midnight) with a station dwell time of 30 seconds, No services are proposed between 00.00 hrs to 5.00 hrs, which are reserved for maintenance of infrastructure and rolling stock.
- Make up time of 5-10% with 8-12% coasting.
- Scheduled speed for these corridors has been assumed as:

  Line-1: North – South Corridor

  - 'Automotive Sqre to Congress Nagar' section: 32 kmph
  - 'Congress Nagar to Depot Station' section: 36 kmph

Line-2: East-West Corridor

- 'Prajapati Nagar to Lokmanya Nagar' section: 30 kmph
- 'Agrasen Chowk to Subhash Nagar' section: 29 kmph

0.7.2.2 Train formation

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

Composition

DMC : Driving Motor Car

TC : Trailer Car

Capacity (@ 6 passengers per square meter of standee area)

Driving Motor Car (DMC) - 247 (43 seated + 204 standing)
Trailer Car (TC) - 270 (50 seated + 220 standing)
3 Car Train - 764 (136 seated + 628 standing)

0.7.2.3 PHPDT capacity provided

Table 0.12: PHPDT capacity provided

Description	YEAR			
	2016	2021	2031	2041
North – South Corridor				
Cars/trains	3	3	3	3
Head way (Minutes)	6.0/12	5/10	4/8	3/6
Max. PHPDT Demand	10089	10936	12934	15729
PHPDT Capacity Available	7640 (9730*)	9168 (1676*)	11460 (14595*)	15280 (19460*)
East – West Corridor				
Cars/trains	3	3	3	3
Head way (Minutes)	6.5/13	6/12	4.5/9	3.5/7
Max. PHPDT Demand	7746	8460	9906	11882
PHPDT Capacity Available	7052 (8982*)	7640 (9730*)	10187 (12973*)	13097 (16680)*

* @ 8 persons per square meter of standee area

0.7.2.4 Year wise rake requirement

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

Table 0.13 : Year wise rake requirement

Corridor	Year	No. of Rakes	Rake Consist	No. of cars
North – South Corridor	2016	11	3 car	33
	2021	12	3 car	39
	2031	16	3 car	51
	2041	20	3 car	63
East – West Corridor	2016	12	3 car	36
	2021	13	3 car	39
	2031	17	3 car	51
	2041	20	3 car	60

0.8 ROLLING STOCK

The required transport demand forecast is the governing factor for the choice of the Rolling Stock. The forecasted Peak Hour Peak Direction Traffic calls for a Light Capacity Metro System (MRTS).

0.8.1 Coach Size

The following optimum size of the coach has been chosen for this corridor as mentioned in **Table 0.14**

Table 0.14: Size of the coach

	Length*	Width	Height
Driving Motor Car (DMC)	21.64 m	2.9 m	3.9 m
Trailer car (TC)/Motor Car (MC)	21.34 m	2.9 m	3.9 m

Maximum length of coach over couplers/buffers = 22.6 m

0.8.2 Passenger Carrying Capacity

In order to maximize the passenger carrying capacity, longitudinal seating arrangement shall be adopted. The whole train shall be vestibuled to distribute the passenger evenly in all the coaches. Criteria for the calculation of standing passengers are 3 persons per square meter of standing floor area in normal state and 6 persons in crush state of peak hour.

Therefore, for the Medium Rail Vehicles (MRV) with 2.9 m maximum width and longitudinal seat arrangement, conceptually the crush capacity of 43 seated, 204 standing thus a total of 247 passengers for a Driving motor car, and 50 seated, 220

standing thus a total of 270 for a trailer/motor car is envisaged. Following train composition is recommended:

3-car Train: DMC + TC + DMC

Table 0.15: Carrying Capacity of Medium Rail Vehicles

3 car Train Composition	: DMC +TC +DMC
Train Carrying Capacity of 3 Car Train (@6 passengers per square meter of standee area)	: 764 passengers @6 standee/sqm

NORMAL- 3 Person/sq. m of standee area, CRUSH - 6 Person/sq. m of standee area

0.9 SYSTEM OF TRACTION AND POWER TARIFF

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

(i) Specific energy consumption of rolling stock – 75KWh/1000 GTKM
(ii) Regeneration by rolling stock – 30%
(iii) Elevated station load – initially 200KW, which will increase to 400 KW in the year 2041
(iv) Underground Station load – initially 2000 kW, which will increase to 2500 kW in the year 2041
(v) Depot auxiliary load - initially 1500 KW, which will increase to 2500 KW in the year 2041

Keeping in view of the train operation plan and demand of auxiliary and traction power requirements projected for the year 2016, 2021, 2031 and 2041 are summarized in **Table 0.16**:-

Table 0.16: Power Demand Estimation (MVA)

Corridor		Year			
		2016	2021	2031	2041
North-South Corridor – 1 Automotive Sqre to KHAPRI. [19.658 kms ; 15 elevated Stations & 2 at Grade Station].	Traction	4.32	5.01	5.84	7.16
	Auxiliary	7.72	7.84	9.14	11.49
	Total	12.04	12.85	14.98	18.65
East-West Corridor – 2 Prajapati Nagar to Lokmanya Nagar [18,557 kms ; 19 Elevated Stations].	Traction	4.24	4.57	5.73	7.01
	Auxiliary	8.34	8.46	9.88	12.48
	Total	12.58	13.03	15.61	19.49

0.10 MAINTENANCE DEPOT

0.10.1 Depot-cum-Workshop

It is proposed to establish one depot- cum- workshop near Khapri Station in MADC Land for North South Corridor and one depot- cum- workshop in the land belonging to SRP near Lokmanya Nagar for East West Corridor with following functions:

a) Depot- cum- workshop for North South Corridor (Line 1)

(i) Major overhauls of all the trains of Line 1.
(ii) All minor schedules and repairs of Line 1.
(iii) Lifting for replacement of heavy equipment and testing thereafter of Line 1.
(iv) Repair of heavy equipments of Line 1.

b) Depot- cum- workshop for East West Corridor (Line 2)

(i) Major overhauls of all the trains of Line 2.
(ii) All minor schedules and repairs of Line 2.
(iii) Lifting for replacement of heavy equipment and testing thereafter of Line 2.
(iv) Repair of heavy equipments of Line 2.

0.10.2 The Depot planning near Khapri Station for North South Corridor and near Lokmanya Nagar for East West Corridor is based on following assumptions:

(i) Enough space should be available near Khapri Station for North South Corridor and near Lokmanya Nagar for East West Corridor for establishment of a Depot- Cum-workshop
(ii) All inspection, workshop lines and stabling lines are designed to accommodate two trainsets of 3- car each.
(iii) All stabling lines are planned in the proposed depot-cum-workshop assuming adequate space availability. In case of space constraints, if any, stabling facilities may need to be created at terminal stations or elsewhere to cater to the required stability facilities.
(iv) Provision of transfer line from one corridor to another corridor.

In broad terms, based on the planned Rolling Stock requirements, this chapter covers conceptual design on following aspects and will work as a guide for detailed design later:

- Layout of Stabling-shed, Inspection-shed, minor repairs and heavy repair overhauling workshop and cleaning of Rolling Stock.
- Operational and functional safety requirements.
- Ancillary buildings for other maintenance facilities.
- Electrical & Mechanical Services, power supply and distribution system.
- Water Supplies, Drainage & Sewerage.

0.11 SIGNALLING

The signaling system shall provide the means for an efficient train control, ensuring safety in train movements. It assists in optimization of metro infrastructure investment and running of efficient train services on the network.

0.11.1 Standards

The following standards will be adopted with regard to the Signalling system.

Table 0.17: Standards of Signalling System

Description	Standards
▪ Interlocking	Computer based Interlocking adopted for station having switches and crossing. All related equipment as far as possible will be centralised in the equipment room at the station. The depot shall be interlocked except for lines mainly used for workshop lines, inspection shed lines etc.
▪ Operation of Points	With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.
▪ Track Circuit (if used)	Audio frequency Track circuits on running section, test track and in depot.
▪ Signals at Stations with point & crossings	Line Side signals to protect the points (switches). LED type signals for reliability and reduced maintenance cost.
▪ UPS (uninterrupted power at stations as well as for OCC)	For Signalling and Telecommunications

Description	Standards
▪ Train protection system	Automatic Train Protection system (CBDT based). The system architecture shall provide for redundancy.
▪ 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 Operational Control Centre and at the SCR. Remote control of stations from the OCC. 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 signal application.
▪ Immunity to External Interface.	All data transmission on telecom cables/OFC/Radio. All Signalling and telecom cables will be separated from power cables. CENELEC standards to be implemented for EMC.
▪ Train Working under emergency	Running on site with line side signal with speed automatically restricted between 15-25 kmph.
▪ Environmental Conditions	Air-conditioners for all equipment rooms.
▪ Maintenance philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling equipments shall be followed. Card / module / sub-system level replacement shall be done in the field and repairs under taken in the central laboratory/ manufacturer's premises.

0.12 TELECOMUNICATION AND AUTOMATIC FARE COLLECTION

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

0.12.1 Technology

The Technologies proposed to be adopted for telecommunication systems are shown in **Table 0.18** below:-

Table 0.18: Technologies Proposed for Telecommunication Systems

System	Standards
• Transmission Media	Optical Fibre system as the main bearer for bulk of the telecommunication network
• Telephone Exchange	EPABX of minimum 30 ports is to be provided at all Stations, an Exchange of 60 Ports to be provided at Terminal Station . Larger exchange is required at OCC/Depot depending upon the actual users
• Train Radio System	Digital Train radio (TETRA) communication between motorman of moving cars, stations, maintenance personnel and central control.
• Train Destination Indicator System	LED/LCD based boards with adequate visibility to be provided at convenient location at all stations to provide bilingual visual indication of the status of the running trains, and also special messages in emergencies.
• Centralized clock system	Accurate display of time through a synchronisation system of slave clocks driven from a master clock at the OCC and sub – master clock in station. This shall also be used for synchronisation other systems.
• Passenger Announcement System	Passenger Announcement System covering all platform and concourse areas with local as well as Central Announcement.
• Redundancy (Major System)	Redundancy on Radio's in the Base Stations, Path Redundancy for Optical Fibre Cable by provisioning in ring configuration.
• Environmental Conditions	All equipment rooms to be air-conditioned.
• Maintenance Philosophy	System to have, as far as possible, automatic switching facility to alternate routes/circuits in the event of failure. Philosophy of preventive checks of maintenance to be followed. System networked with NMS for diagnosing faults and co-ordination. Card/module level replacement shall be done in the field and repairs undertaken in the central laboratory/manufacture's premises.

0.12.2 Automatic Fare Collection

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.

0.12.3 Automatic fare collection systems have the following advantages:

1. Less number of staff required.
2. Less possibility of leakage of revenue due to automatic ticket check by control gates.
3. Recycling of ticket fraudulently by staff avoided.
4. Efficient and easy to operate, faster evacuation both in normal and emergency.
5. System is amenable for quick fare changes.
6. Management information reports generation easy.
7. System has multi-operator capabilities. Same Smart Card can be used for other applications also, including in other lines of the Metro.
8. AFC systems are the worldwide accepted systems for LRT/Metro environment.

0.12.4 Technology

The technology proposed for AFC systems are as given under in **Table 0.19**:

Table 0.19: Technologies Proposed for AFC Systems

Standards	Description
• Fare media	a) Contactless smart card – For multiple journeys. b) Single Journey : Contactless Token
• Gates	Computer controlled retractable flap type automatic gates at entry and exit. There will be following types of gates: • Entry • Exit • Reversible (if required as per final station layout) – can be set to entry or exit • Reversible Handicapped Gate -gate for disabled people.

Standards	Description
• Station computer, Central computer and AFC Net work	All the fare collection equipment shall be connected in a local area network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control centre through the optic fibre communication channels. The centralised control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc.
• Ticket office machine (TOM/EFO)	Manned Ticket office machine shall be installed in the stations for selling tickets to the passengers. Also POM's shall be provided for Automatic Ticket Vending.
• Ticket reader/Add value Machine and portable ticket decoder.	Ticket reader shall be installed near EFO for passengers to check information stored in the ticket. .This shall also be used as a Add Value Machine to allow passeneger to tap and add value to his card which has been topped up through internet.
• UPS (uninterrupted power at stations as well as for OCC).	**Common UPS of S&T system will be utilised.**

0.13 DISABLED FRIENDLY FEATURES

The objective of making this chapter is to create a user-friendly mass transport system in India which can ensure accessibility to persons with disabilities, people travelling with small children or are carrying luggage, as well as people with temporary mobility problems (e.g. a leg in plaster) and the elderly persons.

The design standards for universal access to Public Transport Infrastructure including related facilities and services, information, etc. would benefit people using public transport.

The access standards given here are extracted from Indian Roads Congress Code, IRC 103: 2012, Guidelines for Pedestrian Facilities; Model Building Bye-Laws, 2011 and National Building Code, 2005. Central Public Works Department's (CPWD) "Space Standards for Barrier Free Built Environment for Disabled and Elderly Persons", 1998 and 2013 edition (under revision by MoUD), and international best practices / standards

Further, it has also been attempted to provide guidelines/ standards for alighting and boarding area, approach to station, car parking area, drop-off and pick-up areas, taxi/auto rickshaw stand, bus stand/stop, footpath (sidewalk), kerb ramp, road intersection, median/pedestrian refuge, traffic signals, subway and foot over bridge etc. to achieve a seamless development around metro

0.14 ENVIRONMENT IMPACT ASSESSMENT

0.14.1 Environmental Impacts

A total of 101 structures (74 in EW Corridor and 27 in NS Corridor) of various dimensions shall be affected by the proposed project. Majority of the structures are privately owned.

According to the results of the present study, it is found that about 337 trees are likely to be lost due to the project. Four trees have to be planted for each tree cut. Hence 1348 trees to be planted. These trees would have occupied about 96 ha in the forest. No no-forest land is available, hence 96 ha have to be re-afforested in degraded forests in or around Nagpur

Utility/Drainage Problems: The alignment will cross drains/nallahs large number of sub-surface, surface and utility services, viz. sewer, water mains, storm water drains, telephone cables, overhead electrical transmission lines, electric pipes, traffic signals etc. These utilities/ 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.

0.14.2 Positive Environmental Impacts

Employment Opportunities: Manpower will be needed in various activities during construction. In operation, about 45 persons per kilo meter length of the corridor, ie (approx. 1,700 persons) will be employed for operation and maintenance of the proposed system. Thus the project would provide substantial direct employment; besides, more people would be indirectly employed in allied activities and trades.

Enhancement of Economy: The construction of Nagpur Metro will facilitate the population to move from one end of the city to another. The proposed transport facility will facilitate rural population to move quickly towards urban centres and return there from. With the development of Nagpur Metro, it is likely that more people will be involved in trade, commerce and allied services.

Mobility: Metro lines will facilitate people to move quickly towards urban centres and return from there. Any reduction in number of private vehicles will results in reduction of accidents which will involve savings from damage to vehicles and savings towards medical and insurance expenses to persons involved in accidents.

Less Fuel Consumption: On implementation of the project both petrol and diesel consumption will get reduced due to shift of passengers from road to rail and also due to decongestion on road.

Less Air Pollution: With the construction of metro, there will be less vehicular traffic by road, and consequently less air pollution, and hence the air quality will improve.

Reduction in Traffic Congestion: Metro will reduce the congestion and journey time on roads because of diversion of some traffic to Metro. Reduction in traffic congestion will save the necessary capital investment and vehicle operating cost as well as increase in time saving per vehicle.

Environmental Management Plan: The project will provide higher living standard, better quality of life, less travel time, better connectivity and transport facilities. The management plans are essential to ensure that stress/ loads on the systems are within carrying capacity. The management plan aims at maintaining the environmental quality of project area minimal in pre-project stage. An environmental management strategy/ plans were developed to mitigate the adverse impacts

0.15 SECURITY MEASURES FOR A METRO SYSTEM

Metro is emerging as the most favoured mode of urban transportation system. The inherent characteristics of metro system make it an ideal target for terrorists and miscreants. Metro systems are typically open and dynamic systems which carry thousands of commuters. Moreover the high cost of infrastructure, its economic impotence, being the life line of city high news value, fear & panic and man casual ties poses greater threat to its security. Security is a relatively new challenge in the context of public transport. It addresses problems caused intentionally. Security differs from safety which addresses problems caused accidentally. Security problems or threats are caused by people whose actions aim to undermine or disturb the public transport system and/or to harm passengers or staff. These threats range from daily operational security problems such as disorder, vandalism and assault to the terrorist threat.

0.15.1 Necessity of Security

It is well known that public transportation is increasingly important for urban areas to prosper in the face of challenges such as reducing congestion and pollution. Therefore, security places an important role in helping public transport system to become the mode of choice. Therefore, excellence in security is a prerequisite for Metro system for increasing its market share. Metro railway administration must ensure that security model must keep pace rapid expansion of the metro and changing security scenario.

0.15.2 Three Pillars of Security

Security means protection of physical. Human and intellectual assets either from criminal interference, removal of destruction by terrorists or criminals or incidental to technological failures or natural hazardous events. There are three important pillars of security as mentioned under:

(i) The human factor;
(ii) Procedures; and
(iii) Technology

0.16 DISASTER MANAGEMENT PLAN FOR A METRO RAIL SYSTEM

A disaster is a tragic event, be it natural or manmade, which brings sudden and immense agony to humanity and disrupts normal life. It causes large scale human suffering due to loss of life, loss of livelihood, damages to property and persons and also brings untold hardships. It may also cause destruction to infrastructure, buildings, communication channels essential services, etc.

0.16.1 Need for Disaster Management Measures

The effect of any disaster spread over in operational area of Delhi Metro is likely to be substantial as DMRC deals with thousands of passengers daily in underground tunnels, viaducts and stations. Disaster brings about sudden and immense misery to humanity and disrupts normal human life in its established social and economic patterns. It has the potential to cause large scale human suffering due to loss of life, loss of livelihood, damage to property, injury and hardship. It may also cause destruction or damage to infrastructure, buildings and communication channels of Metro. Therefore there is an urgent need to provide for an efficient disaster management plan.

0.16.2 Objectives:

The main objectives of this Disaster Management Measures are as follows:

- Save life and alleviate suffering.
- Provide help to stranded passengers and arrange their prompt evacuation.
- Instill a sense of security amongst all concerned by providing accurate information.
- Protect Metro Rail property.
- Expedite restoration of train operation.
- Lay down the actions required to be taken by staff in the event of a disaster in

- Delhi Metro Rail Corporation in order to ensure handling of crisis situation in coordinated manner.

To ensure that all officials who are responsible to deal with the situation are thoroughly conversant with their duties and responsibilities in advance. It is important that these officials and workers are adequately trained in anticipation to avoid any kind of confusion and chaos at the time of the actual situation and to enable them to discharge their responsibilities with alertness and promptness

0.17 MULTI MODAL TRANSPORT INTEGRATION

The Metro Transport Network in Nagpur will cover a length of approximately 39 kms. It will be augmented through enhanced flexibility of criss-cross interchanges to other modes and reduce the travel time of commuters. While Metro provides a high capacity corridor to carry the passengers, the need for integration of with other secondary/intermediate transport modes is getting highlighted more than ever to ensure a seamless transfer. This concept is to provide at least last mile or half mile connectivity to the commuters with in their places of stay. Accordingly top priority to this issue, MoUD has laid down policy guidelines to include the need and provisioning of all public, IPT and private modes in the DPRs for the Metro Systems. (Ref: MoUD (Urban Transport Wing) Advisory Circular no. K-14011/1/2007-UT-IV dated 30.08.2013)

The share of various modes of secondary/ intermediary modes of travel is complex and debatable issue which is dependent on a large number of variables like available road width, penetration in the residential areas, Road condition, distance from the existing Metro Stations, availability of parking and lay out and availability of circulating areas at the Metro Stations, Business centre or markets & existing traffic densities. These factors relate with each other and evolve with development of new modal mix of transport, infrastructure and changes with the passage of time . Even though for a given urban transport scenario, optimal mode share may be determined from computer based models but actual optimal mode share is never achievable on the road due to dynamic nature of demand and supply of transport modes

0.18 COST ESTIMATES

Cost estimates have been prepared based on the rates accepted for Delhi Metro duly escalated up to June 2012 level.

Corridor - 1: NORTH-SOUTH CORRIDOR (AUTOMOTIVE SQUARE TO KHAPRI)

The overall capital cost for Corridor 1: at June 2012 price level, works out to Rs. 3015 Crore, excluding taxes and duties, but including general charges & design charges @ 5% on all items except land and 3% contingencies on all items. Estimated total taxes & duties are Rs. 420Crore.

Corridor-2: EAST-WEST CORRIDOR (LOKMANYA NAGAR TO PRAJAPATI NAGAR)

The overall capital cost for Corridor-2: at June 2012 price level, works out to Rs. 2984 Crore excluding taxes and duties, but including general charges & design charges @ 5% on all items except land and 3% contingencies on all items. Estimated total taxes & duties are Rs. 443Crore.

0.19 FINANCING OPTIONS, FARE STRUCTURE AND FINANCIAL VIABILITY

0.19.1 The Nagpur Metro project- North South corridor (Automative Square to KHAPRI) and East West corridor (Prajapati Nagar to Lokmanya Nagar), covering a total route length of 38.215 Kms is proposed to be constructed with an estimated cost as per details are shown in **Table 0.20** below:-

Table 0.20: Completion Cost

(Rs./Crore)

Corridor No	Name of Corridor	Distance (KMs)	Estimated Cost without Central taxes at June-2012 Price Level	Estimated Cost with Central taxes at June-2012 Price Level	Completion Cost
I	North-South Corridor	19.658	3015.00	3435.00	**8680**
II	East-West Corridor	18.557	2984.00	3427.00	
Total		**38.215**	**5999.00**	**6862.00**	

The estimated cost at June-2012 price level also includes an amount of Rs.40 Crore as one-time charges of security personal towards cost of weapons, barricades, and hand held and door detector machine etc. However, the recurring cost towards salary and allowances of security personal have not taken in to account in FIRR calculation

0.19.2 Financial Internal Rate of Return (FIRR)

The Financial Internal Rate of Return (FIRR) and costs for 30 years business model including construction period is **10.35%.**

0.19.3 Funding Pattern

The funding pattern has been worked out under two models viz., SPV model and BOT Model.

a) The proposed funding with Central Taxes assumed under the SPV model is placed in Table 0.21 as under: -

Table 0.21: Funding pattern under SPV model

(Rs/Crore)

Particulars	With Taxes & Duties	
	Amount (Rs/Crore)	% of contribution
Equity by GOI	1114.00	12.83%
Equity by GOM	1114.00	12.83%
SD by GOM to central Taxes (50%)	441.00	5.08%
SD by GOI for Central Taxes (50%)	441.00	5.08%
SD by GOM to StateTaxes	259.00	2.98%
SD by GOM for Land	644.00	7.42%
Nagpur Improvement Trust Contribution	421.00	4.85%
Nagpur Municipal Corporation Contribution	421.00	4.85%
JICA Loan @ 1.40% PA/Market Borrowing @12%	3825.00	44.08%
Total	8680.00	100%

b) The proposed funding with Central Taxes assumed under the BOT model is placed in Table 0.22 as under: -

Table 0.22 Funding pattern under BOT model (with central taxes)

Particulars	Amount (Rs/Crore)	% of contribution
VGF by GOI	1555.40	20.00%
VGF by GOM	524.60	6.75%
Equity by Concessionaire	1899.00	24.42%
Concessionaire's debt @12% PA	3798.00	48.83%
Total	**7777.00**	**100.00%**
Land Free by GOM	644.00	
State Taxes by GOM	259.00	
IDC	445.00	
Total including IDC	**9125.00**	

0.19.4 Cost Investment Break Up

It is assumed that commercial operation shall start from April-2018. The Revenue Opening Date (ROD) has been assumed as 01.04.2018. The total completion costs duly escalated is shown in Finance Chapter, which has been taken as the initial investment. The cash flow of investments based on completion cost is in **Table 0.23** as below:

Table 0.23: Year wise Investment-With Central Taxes

Financial Year	Cost at June 2012 Price Level	Completion Cost
2013-14	447.00	452.00
2014-15	944.00	1021.00
2015-16	1555.00	1874.00
2016-17	1865.00	2412.00
2017-18	1430.00	1983.00
2018-19	497.00	740.00
2019-20	124.00	198.00
Total	**6862.00**	**8680.00**

0.20 ECONOMIC ANALYSIS

0.20.1 The sources from where economic savings occur are identified first. Although there are many kinds of primary, secondary and tertiary benefits, only the quantifiable components can be taken to measure the benefits. These components are quantified by linking with the number of passengers shifted and the passenger km saved by the trips which are shifted from road/rail based modes to metro. It may be observed that first four benefit components given in Table 0.24 are direct benefits due to shifting of trips to metro, but other benefit components are due to decongestion effect on the road. Benefit components were first estimated applying market values then were converted into respective Economic values by using separate economic factors which are also given in **Table 0.24.** Depending upon methodology of estimation, economic factors are assumed. Overall economic value of benefit components is 90% of the market value. Similarly economic value of the cost components are 80% of the market cost.

Table 0.24: **Benefit Components due to Metro**

	Benefit Components	Economic Factors
1	Construction Cost	80%
2	Maintenance Cost	80%
3	Annual Time Cost Saved by Metro Passengers	90%
4	Annual Fuel Cost Saved by Metro Passengers	90%

	Benefit Components	Economic Factors
5	Annual Vehicle Operating Cost Saved saved by Metro Passengers	90%
6	Emission Saving Cost	100%
7	Accident Cost	100%
8	Annual Time Cost Saved by Road Passengers	90%
9	Annual Fuel Cost Saved by Road Passengers	90%
10	Annual Infra Structure Maintenance Cost	90%
11	Overall economic factor for the benefit components	93%

The project cost comprises capital cost, operation and maintenance cost including:

- Capital cost of infrastructure (civil engineering, land, track, power supply, traction system, signaling and telecommunications, etc.) and rolling stock.
- Operating cost of metro

The benefit stream that has been evaluated and quantified includes:

- Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing bus system and private vehicles in case metro project is not taken up.
- Savings in operating costs of all buses and other vehicles due to de-congestion including those that would continue to use the existing transport network even after the metro is introduced.
- Savings in time of commuters using the metro over the existing transport modes because of faster speed of metro.
- Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of accidents and pollution with introduction of metro.
- Savings in road infrastructure and development costs that would be required to cater to increase in traffic, in case metro is not introduced.
- 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.

The Economic Internal Rate of Return (EIRR) in worked out as 17.70% for this project.

0.21 IMPLEMENTATION STRATEGY AND PROJECT IMPLEMENTATION

0.21.1 To ensure that the project is implemented as targeted in this report it has to get the visible positive support from Nagpur Administration, GoM and GoI. To enable Nagpur metro project to be implemented without any loss of time and cost over-run, effective institutional arrangements would need to be set up. Presently, Nagpur Improvement Trust (NIT) is dealing with this Project but there is need to have an SPV responsible entirely for this project.

0.21.2 Special Purpose Vehicle

Special Purpose Vehicle (SPV) is a legal entity established for implementation of specific projects and is used to isolate the governing authority / stakeholder company from operational and financial risk. SPV has a management dedicated to the accomplishment of the specific objective. The SPV also allows securitization of assets without disturbing the managerial relationship. Under the arrangement, any predictable income stream generated by secure assets can be securitized. Three models have been analyzed and summarized below:-

a) Implementation through Government

Under this model, the entire project development, implementation and operation is undertaken and financed by the government authority. Some recent examples of metro rail projects implemented directly through Government agencies are as under.

- Delhi
- Bangalore
- Chennai
- Jaipur
- Kolkata

b) Implementation through BOT model

BOT approach assumes that the metro is given to a private partner (Concessionaire) to develop and operate over the concession period. The private partner brings requisite funds and the efficiency of private sector management in the implementation as well as operation of the project. NMRC's role in this option is limited to that of a regulatory authority. Thus NMRC would monitor the implementation of the project such as laying down the passengers fares, targets for the minimum number of services to be run by the private partner, frequency, punctuality and reliability of these services, etc. There are only two projects namely Hyderabad and Mumbai being implemented through BOT model. The success of this model in India is still to be known.

c) Implementation through PPP model

Under this mode, the government entity undertakes all civil works and the associated station work, while all other works like rolling stock, signaling and telecom, track laying work are undertaken by the private partner along with management of the metro service over the concession period. This enables the client to monitor and adhere to quality and construction timelines for the project in a better way. Implementation of airport express line in Delhi is the only example of this model in India.

d) Proposed Implementation Model

Due to very low FIRR and uncertainties of getting the agencies for taking up this work on BOT/PPP model, it is proposed that implementation of Nagpur Metro should be done on DMRC/BMRC model.

0.19 CONCLUSIONS AND RECOMMENDATIONS

i) It has been established that a Light Capacity Metro System (MRTS) with carrying capacity of about 25,000 PHPDT would be adequate to meet not only the present traffic demand but also cater to the demand for the next 30 years.

ii) After examining the various options for execution of Nagpur Metro Rail Project, it is recommended that the project be implemented through government funding, Implementing through an SPV namely " Nagpur Metro Rail Corporation (NMRC)" registered under the Companies Act, 1956. This SPV should be a PSU of GoM and GoI. After the approval of State Government, DPR to be sent to the Secretary, Ministry of Urban Development, Government of India, advising GOI of the State Government's intention to take up the Project on government funding basis and requesting for the latter's "In Principle" clearance to go ahead with the Project.

Key plan of Nagpur Metro is shown in Fig-0.1

FIG : 0.1