

CHAPTER 4

GEOMETRIC DESIGN NORMS AND DESCRIPTION OF ALIGNMENT

4.0 GENERAL

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.

4.1 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 60 km/h shall be adopted. There are, however, exceptional situations where due to site constraints, use of sharper curves is unavoidable. Under such situations on this project, curves of 120 m radius (safe speed of 40 km/h) have been adopted. However in underground section desirable minimum radius of curve shall be 300 m with absolute minimum of 200 m.

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

Horizontal curves

Curve radius in mid section:			
Under Ground Section			
	Minimum	:	300 m
	Absolute Minimum	:	200 m
Elevated Section			
	Minimum	:	200 m
	Absolute minimum	:	120 m
Minimum curve radius at stations	:	:	1000 m
Maximum permissible cant (Ca)	:	:	125 mm
Maximum cant deficiency (Cd)	:	:	100 mm

Transition curves

Due to undulating terrain of Bangalore 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

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|--|---|
| Horizontal curves (m): | 0.44 times actual cant or cant deficiency (in mm), which ever is higher. |
| - Desirable | : 0.72 times actual cant or cant deficiency, (in mm) which ever is higher |
| - No overlap is allowed between transition curves and vertical curves. | |
| - Minimum straight between two Transition curves | : either 25 m or NIL. |
| - Minimum curve length between two transition curves | : 25 m |

VERTICAL ALIGNMENT

Elevated Sections

Track supporting structures on Elevated sections are to permit a vertical clearance of 5.5 m above road level. For meeting this requirement with the 'U' shaped structural design the rail level shall be at least 8.5 m above the road level. Similarly, the rail level for the stations on road locations (with concourse on sides on ground) shall be at least 10.5 m above the road level in the central portion and 9.5 m at ends. With elevated concourse the rail level at stations shall be 12 m. For the tracks carried on portals on roads, the minimum rail level shall be 9.5 m above the road level. An alternative structural section with pre-stressed box section is also designed which can be used with minimum rail level of 9.3 m above road level. The rail level at stations with elevated concourse will be 11.5 m and on portals the same shall be 9.9 m.

The track center on the elevated section is 3.7 m on straight stretches and increased on curves with a maximum of 4.0 m for curves with a radii of 120 m.

4.2.2 Underground sections

Rail level at midsection in tunnelling portion shall be kept at least 12.0 m below the ground level. At stations, the desirable depth of rail below ground level is 12.5 m, so that station concourse can be located above the platforms. This requirement has been kept in view while designing the vertical profile. At Majestic, the interchange station between the two corridors, the North - South corridor is proposed below the East - West corridor with the lowest rail level of about 20 m below ground level.

4.2.3 Gradients

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

- (i) Switch over ramp between underground and elevated sections where a grade upto 4% is adopted to minimise the length of ramp.

- (ii) Where existing road gradients are steeper than 2 % as the elevated section is kept parallel to road surface to minimise rail level (to reduce the pier heights).

- Maximum gradient at stations : 0.1 %
- Desirable gradient at stations : level
- Maximum gradient in mid section:
 - Normal : 2.0 %
 - Exceptional : 4.0 %

4.2.4 Vertical Curves

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

- Minimum radius of vertical curves:

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

4.3 DESIGN SPEED

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

Table 4.1
Cant, Permitted speed and Minimum Transition length for curves

Radius	Speed	Actual Cant	Cant Deficiency	Permitted Speed	Minimum Transition
(m)	(km/h)	(mm)	(mm)	(kmph)	(m)
3000	80	20	8.72	80	10
2000	80	30	13.09	80	15
1000	80	50	36.17	80	25
800	80	60	47.72	80	30
500	80	90	82.35	80	40
400	80	125	90.43	80	55
300	80	125	100	70	55
200	80	125	100	55	55
150	80	125	100	50	55
120	80	125	100	40	55

4.4 STATION LOCATIONS

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

made to propose station locations as uniform an inter station distance as feasible. The average spacing of stations is kept close to one km.

ROUTE ALIGNMENT: EAST-WEST CORRIDOR

4.5.1 General Description Of The Route

The alignment starts near Ring road junction on Mysore road with Mysore Road Terminal station on the North side of the road. The centre line of the station is taken as Zero chainage. The stabling facility beyond the station is provided on elevated section, which will also be used, for future extension to further west. Stabling facility for four rakes have been provided at this station so that rakes are stabled during the night and morning services can be started from this end on time. From this station the alignment runs eastward along Mysore Road up to the 'T' junction with Chord Road. At this junction the alignment turns to Chord Road with a left-hand curve. The Deepanjali Nagar station (Km.1.117) is located just after this curve so as to provide the station as close to the junction as possible. After the station the alignment crosses the Bangalore - Mysore railway line over the existing ROB. No serious difficulty is expected at this location for structural arrangement. Further the alignment moves from median of the road to East side at Km. 1.413 and comes back to median at Km. 1.700 due to continuous curves on the road. Thereafter the alignment runs all along this road up to the crossing of Chord road with Magadi Road at Tollgate junction. The length of alignment on the chord road is 3.750 km. Apart from the Deepanjali nagar station, three more stations namely Vijay Nagar (km 2.345), Hoshalli (km 3.444) and Tollgate (km 4.445) are located on this road.

From Tollgate junction, alignment turns into Magadi Road with a reverse curve of 150 m radius and passes over BWSSB area and some private properties. The alignment traverses along the central verge on Magadi road till the BWSSB tanks near the end of the Magadi road. The Magadi road station is located at km 5.600 on this stretch. The alignment is taken off the road near BWSSB tanks (km 6.300) to provide the switchover ramp in the Leprosy hospital area. The alignment is fully underground by the time it reaches the Junction of Magadi road with Tank Bund road.

The alignment continues as underground below the Subhash Nagar colony, Railway quarters. The Bangalore city metro station is provided west of the Bangalore City railway station at km 6.755 with interchange facility with the proposed commuter corridors. The alignment passes below the Bangalore city railway station yard and reaches KSRTC bus stand where a combined station on both E - W and N- S corridors is provided. This station is named Majestic (Km.7.503) for both the corridors. From Majestic Bus stand the alignment goes under the K G Road till Mysore Bank crossing, after that it turns to left on to the Post Office road. The Central College Station (km 8.697) is located just after the curve below the road. It goes further after crossing K R Circle on the Ambedker Road. The Vidhan Soudha under-ground station (km 9.318) is located on this road. The station is close to the Vidhan Soudha and the High Court. After this station the alignment turns into the Cubbon Park with a right hand curve, still underground, and the switch over ramp is provided to come to the surface between the fountain and Bal Bhawan (Jawahar Lal Bhawan). The switch over

ramp is located in such a manner that minimum number of trees are affected in the Cubbon park area. The ramp structure and the landscaping around it will further beautify this area and will not in anyway spoil the picturesque surroundings. The artistic view of the ramp is shown in **picture 1**.

The alignment is fully elevated before reaching the Queen's circle. An elevated station is provided in the park adjacent to the Chinnaswamy cricket stadium (km 10.643). From Queen's Circle, the alignment runs on the left edge of the M G Road adjacent to the elevated walkway and continues till Brigade road. The M G Road station (km 11.380) is provided opposite Plaza cinema. After the Brigade road the alignment is brought to the central verge of road and continues till Trinity Circle. The Trinity circle station (elevated) is provided at km 12.522. The artistic view of the elevated corridor is shown in **picture 2**.

From Trinity circle the alignment moves on the Swami Vivekanand Road. This road has ROW of 12 to 18 m only and has many curves. It is proposed to keep the alignment in the middle of road on Portals so that the road traffic is not affected after construction is complete. Ulsoor station is located at km 13.725 on this road on the land now occupied by the police quarters.

From Swamy Vivekanand road the alignment turns into CMH road with a sharp right hand curve of 120 m radius. On C M H Road it runs on the middle of the road till B M Circle where it turns left with a curve of 120 m radius on to the 100 ft. road on the median. At both ends of CMH road private properties on the corner are affected due to sharp bend in road alignment. CMH road station is provided at km 14.610. Another station Indira Nagar is proposed at km 15.537 on 100ft. road.

From 100 ft road the alignment turns right on to the old Madras road and runs on the eastern edge of the road where it crosses the BEML railway siding and turns into the Vacant land belonging to NGEF and ends opposite Baiyappanahalli railway station. The alignment is brought to surface after crossing the railway siding with a gradient of 3%. Old Madras road station is proposed at km 16.419 which is an "off the road" station. The Baiyappanahalli metro station is at km 17.374 on the surface. The terminal station is located adjacent to Indian railway's Baiyappanahalli station so as to have convenient passenger integration facilities. A full fledged maintenance and stabling depot is being proposed at this location. Provision is kept for extending the corridor further east in future. The index plan of proposed alignment is shown in **Fig. 4.1**.

4.5.2 Terminal Stations

West terminal :

Mysore road terminal station will be the western terminal on East - West corridor and will have provision for future extension towards Bangalore University. This terminal station is located at the proposed site due to following reasons:

- Station has been proposed on the side of the road with the provision of further extension towards Mysore side to link Bangalore University.

- This station provides integration with ring road junction on Mysore road and can be integrated with feeder bus services from colonies on outskirts of the city on Western side.
- Vacant land is available near this station for utilizing for integration with Bus facility surrounding the Kwaliti biscuit factory.

East Terminal :

On the Eastern side the existing Indian Railway station of Baiyappanahalli provides integration with the proposed commuter service. The existing Baiyappanahalli station is on important route connecting Bangalore with Chennai.

A site suitable for the Depot is also available near the station. This facility avoids the idle running of trains at the beginning/ending of services during Morning and late night. Accordingly, the terminal station is proposed just at the depot area.

4.5.3 Major Roads along the Route

The dead end on the western end at Km (-) 0.400 is located just near main Junction of Ring Road with Mysore Road. This is the lowest point of the whole east-west alignment. The gradients on the Mysore road are very steep and at some locations exceeds four percent. The Alignment is on the Mysore road from Km (-) 0.400 to Km 0.874. From here the alignment turns into the Chord road and remains on Chord road till km 4.735. Most of the stretches on chord road is having park on either side and widening of road is possible because it is main road used for linking Tumkur Road & Mysore Road. From the junction of Magadi road and Chord road at Km 4.735 the alignment goes on the Magadi road. In the beginning the Magadi road is very wide having median but after crossing the T junction with Dr. Rajkumar road at Km 5.246 the road becomes narrow and without any median. The minimum Right of Way is only 12.60 m. The ramp from elevated to underground corridor is provided at the end of this road.

The underground corridor passes below the Bangalore city railway station and KSRTC bus stand with stations at both locations. After KSRTC bus stand the underground alignment goes deep below the K.G. Road and Post office road and crosses the K.R. Circle. At Km 9.200 it goes under the Cubbon park after taking Right hand curve of Radius 150m.

After the switch over ramp in Cubbon Park the elevated corridor crosses the queens road and moves on the side of MG road. On M G road it crosses the St. Marks road / Anil Kumble circle at Km 10.830 and Brigade road (Km 11.521). After crossing the Brigade road it comes to the median and continues till Trinity Junction, Further the alignment crosses the Residency road at Km 11.900 and Dickenson road at Km 12.176 and moves to Swami Vivekanand road. Swami Vivekanand Road is having plenty of curves, beside ROW is also very less (13m) average. In this stretch it crosses Cambridge road at Km 13.500 and after crossing A.Nanjappa circle Km 13.854 the ROW is 25m average. At km 14.03 the alignment turns to CMH road upto BM Circle (Km 15.300). Further it traces 100 ft road and moves on to the old Madras road till it reaches the terminal station.

The major roads along and across the alignment are given in the **Table 4.2**.

TABLE 4.2
MAJOR ROADS ALONG/ACROSS the E - W ALIGNMENT

Road	Chainage (m)	Name of Road across the alignment	ROW (m)
Elevated Stretch			
Mysore Road			29.2
	(-) 88	Old Madras Road (Ring Road)	30
	1100	Chord Road & Mysore Road junction	34
Chord Road			52
	2276	Chandra Layout	21
	2986	Ramco 5th main road	25
	3317.5	Club Road/20th main road	19
	3677	Vijaynagar 5th main road/MC layout 8th main road	18
	4355	Vijaynagar 3rd cross street	16
	4736	Sri Krishna Dev Arayar road	13
Magadi Road			29
	4900	Cholurpalya Cross	15
	5245	Dr. Rajkumar road	24
	6600	Magadi road end / junction	17
Underground Section			
	7300	Gubbi Thotadappa road	46
	7700	Dhanyandhri road	35
K. G. Road			24
	7850	Subedar chatram road	22
	7968	W. H. Hammanthappa road	23
	8109	Kalidas Marg / BVK Iyeangar road	21
	8500	Palace road	18
District Office Road			21
	9200	K. R. Circle	45
Elevated Section			
	10540	Queens Circle	
M. G. Road			39
	10830	St. Marks Road / Anil Kumble Circle	26
	11519	Brigade Road / K. Kamraj road	16
	11900	Field Marshal Kariappa road/Residency road	11
	12178	Dickenson road	24
	12800	Trinity Church Junction	
	12857	Kensington road	20
Swamy Vivekananda Road			18
	13123	Gowthampuram road	14
	13500	Cambridge road	16
	13845	A. Nanjappa circle	

C M H Road			20
	14033	Old Madras road	17
	14900	Double road	18.5
	15300	100ft Road/BM Circle	
Old Madras Road (NH-4)			28
	16419	80ft road	25
	16755	Surendar Dass road	28

4.5.4 VERTICAL PROFILE

Mysore road, Chord road and magadi road are located on the western side of the city with rolling gradients and sharp curves. The level difference from lowest point on Mysore road to highest point on Magadi road is 87 mts. The Mysore Road stretch of 1100 m is continuously rising whereas Chord road and Magadi road have many rise and fall with steep gradients. L-section of E-W Corridor is shown in **Fig 4.2**. The road gradients in this stretch are given in the **Table 4.3**.

TABLE 4.3
ROAD GRADIENTS

S.No.	Chainages (Km)	Grade (%)	Road Levels(avg.)
1	0-850	3.46 (Rise)	824.802
2	850-975	2.95 (Fall)	837.654
3	975-1075	Level	835.606
4	1075-1375	1.92 (Rise)	838.289
5	1375-1537	3.64 (Rise)	844.124
6	1537-1675	1.95 (Rise)	848.49
7	1675-1975	3.81 (Rise)	855.472
8	1975-2075	Level	861.244
9	2075-2450	1.41 (Fall)	858.674
10	2450-3125	3.44 (Rise)	867.635
11	3125-3900	1.15 (Rise)	883.677
12	3900-4715	2.92 (Fall)	876.231
13	4715-5075	2.88 (Rise)	869.523
14	5075-5325	1.43 (Fall)	872.923
15	5325-5550	3.52 (Fall)	867.178
16	5550-5800	0.89 (Rise)	864.324
17	5800-6700	3.52 (Rise)	881.282

After Magadi Road the road gradient does not vary much. The K.R.Circle is the lowest point between District Office road and Dr. B.R. Ambedker Road. The gradient on MG road, Swami Vivekanand road and CMH road has mild gradients.

The vertical profile adopted along the alignment are shown in the **Table 4.4**.

TABLE 4.4
VERTICAL PROFILE

GRADE TABLE			
FROM CHAINAGE	TO CHAINAGE	GRADE	RISE/FALL
-160	82	0	LEVEL
82	615	4	RISE
615	990	1.2	RISE
990	1240	0	LEVEL
1240	1815	3.4	RISE
1815	2015	-1.25	FALL
2015	2290	0.3	RISE
2290	2415	0	LEVEL
2415	2990	3.5	RISE
2990	3340	2.2	RISE
3340	3590	0	LEVEL
3590	3690	1	RISE
3690	3940	-1	FALL
3940	4353	-3.5	FALL
4353	4515	0	LEVEL
4515	4765	-0.5	FALL
4765	4940	2.25	RISE
4940	5490	-1.2	FALL
5490	5690	0	LEVEL
5690	6315	3.3	RISE
6315	6660	-3.5	FALL
6660	6915	0	LEVEL
6915	6940	1.1	RISE
6940	7390	1	RISE
7390	7640	0	LEVEL
7640	7865	-0.3	FALL
7865	8565	2	RISE
8565	8790	0	LEVEL
8790	8865	-1	FALL
8865	9240	-2	FALL
9240	9465	0	LEVEL
9465	9740	2	RISE
9740	9990	1	RISE
9990	10515	3.5	RISE
10515	10690	0	LEVEL
10690	10865	0.3	RISE
10865	11040	-1	FALL
11040	11315	1	RISE
11315	11490	0	LEVEL
11490	12090	-1	FALL
12090	12440	0.3	RISE
12440	12615	0	LEVEL
12615	13240	-1.5	FALL
13240	13665	-2.25	FALL
13665	13840	0	LEVEL

13840	13965	-2	FALL
13965	14165	-1	FALL
14165	14365	1	RISE
14365	14515	0.4	RISE
14515	14715	0	LEVEL
14715	15415	2.1	RISE
15415	15640	0	LEVEL
15640	15790	-1	FALL
15790	16040	0.8	RISE
16040	16190	-0.3	FALL
16190	16340	0	LEVEL
16340	17065	1	RISE
17065	17340	-3	FALL

4.5.5 Curvature

Due to rolling terrain there are many sharp turns and curves along the roads. This necessitates provision of curves for metro alignment also to keep the same at the median of the roads. The curves are also provided to turn at various intersections. The radius of curves at intersections is kept as low as 120 m to reduce the property acquisition. 44.43 % of the length of the alignment is on curves. The details of curves on East - West Corridor is given Table 4.5.

TABLE 4.5
DETAILS of CURVES

CHAINAGE							
TP1	TP2	TP3	TP4	RADIUS	TRANSITION	CURVE LENGTH	STRAIGHT BETWEEN TWO CURVES
-1150.00	START OF ALIGNMENT						
-964.947	-924.947	-889.012	-849.012	600	40	35.94	286.47
-562.539	-542.539	138.6	158.6	1000	20	681.14	310.57
469.167	524.167	554.535	609.535	350	55	30.37	28.20
637.737	692.737	723.38	778.38	400	55	30.64	40.73
819.11	874.11	985.581	1040.581	150	55	111.47	143.09
1183.671	1238.671	1266.085	1321.085	160	55	27.41	47.64
1368.72	1413.72	1556.379	1601.379	400	45	142.66	43.21
1644.585	1654.585	1836.344	1846.344	3000	10	181.76	178.88
2025.222	2080.222	2183.605	2238.605	200	55	103.38	305.01
2543.614	2563.614	2590.349	2610.349	1500	20	26.74	424.53
3034.881	3054.881	3112.725	3132.725	1000	20	57.84	378.69
3511.419	3566.419	3713.773	3768.773	200	55	147.35	391.21
4159.985	4179.985	4383.913	4403.913	1000	20	203.93	125.62
4529.528	4584.528	4624.833	4679.833	325.1	55	40.30	0.00
4679.837	4734.837	4813.112	4868.112	151.375	55	78.27	0.00
4868.112	4923.112	5062.827	5117.827	151.375	55	139.72	140.57
5258.397	5318.397	5354.18	5414.18	150	60	35.78	40.52
5454.697	5474.697	5522.196	5542.196	3000	20	47.50	79.74

5621.94	5641.94	5749.481	5769.481	4000	20	107.54	136.67
5906.15	5946.15	6020.972	6060.972	1200	40	74.82	103.00
6163.969	6213.969	6245.847	6295.847	684.2	50	31.88	0.00
6295.848	6345.848	6371.086	6421.086	300	50	25.24	240.65
6661.738	6681.738	6941.839	6961.839	1500	20	260.10	204.33
7166.173	7186.173	7269.02	7289.02	1000	20	82.85	229.84
7518.86	7543.86	7619.903	7644.903	1000	25	76.04	81.77
7726.677	7781.677	7830.698	7885.698	300	55	49.02	502.86
8388.562	8443.562	8536.34	8591.34	150	55	92.78	261.95
8853.289	8873.289	8982.169	9002.169	1000	20	108.88	214.75
9216.919	9236.919	9270.712	9290.712	1000	20	33.79	120.67
9411.384	9466.384	9574.114	9629.114	166.605	55	107.73	0.00
9629.117	9674.117	9700.096	9745.096	165	45	25.98	57.84
9802.934	9842.934	9914.575	9954.575	450	40	71.64	156.06
10110.639	10130.64	10170.8	10190.8	1500	20	40.16	92.14
10282.935	10327.94	10388.04	10433.04	450	45	60.10	328.59
10761.625	10801.63	10848.48	10888.48	600	40	46.85	613.82
11502.296	11527.3	11558.02	11583.02	1000	25	30.73	28.91
11611.928	11636.93	11665.21	11690.21	1000	25	28.28	440.25
12130.464	12150.46	12189.46	12209.46	5000	20	39.00	458.20
12667.662	12727.66	12782.63	12842.63	400	60	54.97	49.98
12892.612	12952.61	13041.29	13101.29	300	60	88.68	416.57
13517.863	13572.86	13609.15	13664.15	200	55	36.29	79.51
13743.656	13798.66	13866.31	13921.31	300	55	67.65	55.82
13977.124	14032.12	14082.12	14137.12	150	55	50.00	269.39
14406.513	14446.51	14485.83	14525.83	600	40	39.32	643.94
15169.772	15224.77	15407.81	15462.81	150	55	183.04	347.59
15810.397	15865.4	15958.94	16013.94	120	55	93.54	678.82
16692.763	16747.76	16824.94	16879.94	150	55	77.18	75.63
16955.566	17010.57	17142.19	17197.19	200	55	131.62	351.32
17548.51							

4.5.6 Switch Over Ramps

Switch over ramp is required for transitioning the alignment from Elevated corridor to Underground or vice versa. On East - West corridor two such ramps are to be provided. The location of ramp is selected so as to minimise the obstruction on surface but at the same time keep the length of underground corridors to bare minimum.

Ramp on Magadi Road

On east west corridor the eastern ramp is located at the end of Magadi road by diverting the alignment on southern side of the road in vacant land belonging to BWSSB and Hospital. Only some temporary structures are affected. The road at this location needs widening for which vacant land is available.

RAMP on Cubbon Park/MG Road

The Western ramp can be located at three different locations. These locations are

- (a) Inside Cubbon Park - opposite children park
- (b) Between St Marks road and Brigade road on MG road
- (c) Between Brigade road and Residency road on MG road.

The ramp can be adjusted at any of the above locations. However the merits and demerits of each case has been studied in detail. The three cases are compared as below:

S. No	Description	Option-I Ramp in Cubbon Park	Option-II Ramp between St. Marks Road and Brigade Road	Option-III Ramp between Brigade Road & Residency Road
1.	Length of under-ground section	3.9 Km	4.7 Km	5.2 Km
2.	Number of under-ground stations	4	5	6
3.	Cost difference	----	Rs. 110 cr. Higher than option I	Rs. 200 cr. Higher than option I
4.	Traffic diversion during construction on MG Road (2 to 2 ½ yrs)	Not required	Cut & Cover work will require partial diversion of traffic	Cut & Cover work will require partial diversion of traffic
5.	Environment consideration	Require removal / replantation of 40 trees in Cubbon park	Require removal / replantation of 15 trees on the side of Road	No effect
6.	Aesthetic	Landscaping of ramp is proposed	Ramp Visible on side of M. G. Road	Visible in middle of M. G. Road
7.	Parade ground security matters	Screens to be erected.	Screens to be erected	Not affected

From the above comparison it is clear that construction of the ramp in Cubbon park is preferable even aesthetically while environmentally also the mitigation measures can be taken. Hence It is proposed that the cut and cover stretch and surface ramp is located in Cubbon park in such a manner that minimum number of trees will be affected. The surface ramp can be landscaped and merged with surroundings. Two artists views of this are appended.

NORTH SOUTH CORRIDOR

The North - South corridor starts from the Tumkur Road, near the existing Yeshwantapur railway station. There is sufficient space for locating a depot in the area as land can be acquired from Mafatlal & Suryodaya mills, both of which are closed⁰⁰. The terminal station Yeshwantapur is opposite the Indian Railway Yeshwantapur station with zero chainage at the centre of station. This station is off

the road and thereafter the alignment moves on the median of Chord Road. Further the alignment is taken over the ramp of the ROB and will cross with double elevation at the junction of Tumkur Road and Chord Road. The alignment moves on Chord Road along the edge of the circle at the junction with Dr. Rajkumar road and continues on the median up to short of Mahakavi Kuvempu Road junction. On Chord Road, two stations Mahalaxmi (Km 2.102) & Rajaji Nagar (Km 3.069) are proposed. From Chord Road, the alignment turns to Mahakavi Kuvempu Road with a radius of 120 m and continues in the middle of road up to the approach ramp of ROB over Bangalore City - Tumkur railway line. Two stations namely Kuvempu (Km 3.975) and Malleswaram (Km 4.728) are proposed on this road. To cross the railway line the alignment is taken along south side of the ramp of ROB and turns parallel to Railway track on the 8th Main Road. A few properties are affected at this location and are to be relocated. After crossing the road across railway line (Near RUB - Km 5.449') the alignment turns in to open area of Binny mill and moves along the boundary of the Binny Mill. There after the alignment starts coming to the surface through Bhima Nagar and Binny Mill to reach the Swastik, station. The station itself is located in the Binny Mill area. After Swastik station the alignment is taken underground through a ramp. The ramp is located on the side of the existing stadium (part acquisition is required) and in the vacant land along the Platform Road and in front of Krishna Floor Mill. The alignment will be fully underground before the junction of Platform Road and Lower Road and continues to be so below the railway land and Railway tracks and reaches KSRTC Bus stand at Majestic. Majestic station (KM. 7.540) of the North - South corridor is proposed below the Majestic station of East - West corridor at right angles.

From Majestic the alignment continues to be underground and passes below the busiest area of Chikpet and Balepet and crosses the BVK Iyenger Road, City Market, Mysore Road flyover, etc. In this stretch two underground stations Chikpet (Km. 8.559) & City Market station (Km. 9.235) are proposed. Both these station are adjacent to the roads and hence can be constructed by cut and cover method.

The alignment after the City Market station (in the Vanivilas hospital area) comes below the junction of Albert Victor Road and K R Road and runs at the middle of the K R Road. A ramp is provided for transition of corridor from underground to elevated. The alignment starts coming up at Km 9.850 and it will be completely elevated before the K R Road station at Km 10.427. After this station the alignment turns to the Vani Vilas Road with the radius of 120 m. At Vani Villas Circle a fly over is proposed along the Vani Vilas Road which needs to be integrated with the metro alignment. Due to this reason a few properties on the North of Vani Vilas Road are affected.

From Vani Vilas Road, the alignment runs on the centre of the road and turns to R V road at the H. Siddiah circle with the radius of 120 m. On R.V.Road also the alignment runs on the median all along the road till the last station, i.e. R.V.Road Terminal at Km 14.180. The other stations located on this stretch are Lal Bagh (Km 11.431), South end Circle (Km 12.386) and Jayanagar (Km 13.288). The terminal station location provides possibility for future extension either to Kanakpura Road or Hosur Road for the link with Electronic city whenever the same is required

4.6.1 Terminal Stations:

North Terminal:

On Tumkur road, Yeshwantapur station is the Northern terminal on this corridor and in future the corridor can be extended to Tumkur Road side covering Peenya Industrial area. The location of this station has been chosen with following reasons.

- Station has been located just adjacent to the existing Yeshwantapur Railway Station which provides passenger integration for long distance passengers of Indian Railways as well as the commuters from proposed commuter service for Bangalore.
- Sufficient vacant area is available for a maintenance depot and stabling facilities adjacent to the station location
- Future extension is possible to further North of the city.

Southern Terminal:

R.V.Road terminal station is located at the end of the R.V. Road at elevated position with following considerations.

- This alignment can be extended in future either to the Kanakpura Road or Hosur Road for further link to the Electronic city.
- Sufficient space is available on both side of the road for making the terminal facilities like stabling line etc. Without affecting the properties.

4.6.2 Major Roads along the Route:

The alignment starts on Tumkur Road, where terminal station and depot are located. The alignment has been kept generally along the center verge of important roads when elevated. The major roads with Right of Way (ROW) of these roads along and across the alignment are listed in **Table 4.6**.

TABLE 4.6
List of Roads along/across the alignment

S. No.	Chainage (Km)	Road Name	ROW (m.)
1.	0.15-0.954	Tumkur Road	50
2.	0.980	Tumkur Road & Chord Road junction	46
3.	0.980-3.20	Chord Road	34
4.	1.20	Road bifurcation left to Majestic	23.5
5.	1.870	Mahalaxmi layout road	40
6.	2.156	Srinivasa Temple road	26
7.	2.563	Rajaji Nagar 1 st Block circle	
8.	3.25	Chord Road & Kuvempu Road junction	47
9.	3.30-4.874	Mahakavi Kuvempu Road	20
10.	3.310	19 th Main 1 st Block Rajaji Nagar	17.5
11.	3.536	Navarang Circle	22
12.	4.010	13 th Main Road D'Block, Rajaji Nagar	9.5

13.	4.752	Malleshwaram Rly. Stn. Road	9.5
14.	5.078-5.444	Side road of Rly. Line Malleshwaram	19
15.	6.470	Krishna floor mill junction	50
16.	7.000	Upper road to Majestic	22
17.	7.10	Lower Road to Majestic	22
18.	7.653	Tank Bund Road	36
19.	8.170	Chikpet Road	9.8
20.	8.435	B.V.K Iyenger Road	17.2
21.	8.80	Mysore Road flyover	24
22.	9.351	Albert Victor Road crossing	24.3
23.	9.351-10.547	K. R. Road	23
24.	9.642	Shiv Shankar Circle	
25.	10.100	S.S.Temple street	13
26.	10.610	Vani Vilas Circle	
27.	10.682-11.178	Vani Vilas Road	28
28.	10.924	Vasovi Temple Road	23
29.	11.244	H. Siddiah Circle	
30.	11.312-14.451	R. V. Road	29.5
31.	11.738	Asoka Piller Road	29
32.	12.069	Mosque Road	12.5
33.	12.200	Khazi street / 9 th cross	14
34.	12.500	South end circle	
35.	13.155	27 th Cross Road	23
36.	13.549	Diagonal Road/32 nd cross	22
37.	13.970	36 th Cross Road	23
38.	14.154	38 th Cross Road	17
39.	14.361	40 th Cross Road	23

4.6.3 Vertical Alignment

Undulating:

As the city has rolling terrain, the gradient on roads are steep with ups and downs at short intervals. This feature is more common on Chord Road and Mahakavi Kuvempu Road. Again from km 12.1 to end of section the terrain is undulating and the gradients are steep. L-section of N-S Corridor is shown in **Fig 4.3**. The road gradient on these two roads are shown in **Table 4.7**.

TABLE 4.7
Road Gradients

S.No.	Chainages (Km)	Grade	Road Levels(avg.)
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1	1.0-1.350	0.69 % (Fall)	918.582
2	1.35-1.600	2.5 % (Fall)	913.338
3	1.60-1.875	2.0 % (Rise)	912.419
4	1.875-2.275	0.94 % (Rise)	918.535
5	2.275-2.650	3.44 % (Fall)	915.153
6	2.65-2.900	2.80 % (Rise)	913.025
7	2.90-3.200	Level	917.180
8	3.20-3.775	2.89 % (Fall)	905.806
9	3.775-3.950	Level	894.199
10	3.950-4.200	1.20 % (Rise)	896.675
11	4.20-4.425	1.30 % (Fall)	897.094
12	4.425-4.4775	2.29 % (Rise)	903.035
13	4.775-4.900	Level	909.734
14	11.30 – 12.150	0.10 % (Fall)	907.495
15	12.150-12.60	1.92 % (Rise)	912.269
16	12.60-12.875	2.00 % (Fall)	913.820
17	12.875-13.350	1.66 % (Rise)	915.495
18	13.550-13.750	1.70 % (Fall)	916.001
19	13.750-14.50	1.00 % (Rise)	916.600

Due to these reasons the gradient along the proposed alignment also varies and at many locations exceeds 2%. The gradient at ramp locations is planned as 2.5 % and 2.75%. The list of gradients is given in **Table 4.8**.

TABLE 4.8
VERTICAL PROFILE

FROM CHAINAGE	TO CHAINAGE	GRADE %	RISE/FALL
0	150		
150	225	0.75	(RISE)
225	725	0.5	(RISE)
725	1025	1.9	(FALL)
1025	1425	1.1	(RISE)
1425	1575	3.1	(FALL)
1575	2025	1.6	(FALL)
2025	2175	0	LEVEL
2175	2250	1.2	(RISE)
2250	2375	0.5	(RISE)
2375	2675	3.5	(FALL)
2675	3000	3	(FALL)
3000	3235	0	(RISE)
3235	3700	4	(FALL)
3700	3825	2.5	(FALL)
3825	4075	0	LEVEL
4075	4200	0.5	(RISE)
4200	4425	1	(RISE)
4425	4650	4	(FALL)

4650	4825	0	LEVEL
4825	5275	0.5	(RISE)
5275	5525	2.5	(FALL)
5525	5800	4	(FALL)
5800	5975	0	LEVEL
5975	6535	2.5	(FALL)
6535	7035	0.3	(RISE)
7035	7450	1	(RISE)
7450	7675	0	LEVEL
7675	7781	1.5	(RISE)
7781	8315	0.3	(FALL)
8315	8675	0	LEVEL
8675	8825	0.5	(FALL)
8825	9125	1.5	(RISE)
9125	9350	0	LEVEL
9350	9525	1	(RISE)
9525	10325	2.75	(RISE)
10325	10525	0	LEVEL
10525	10675	0.5	(RISE)
10675	11375	1.2	(RISE)
11375	11538	0	LEVEL
11538	11800	1.5	(RISE)
11800	12325	1.75	(FALL)
12325	12500	0	LEVEL
12500	12675	1	(RISE)
12675	12925	1	(FALL)
12925	13225	2.3	(FALL)
13225	13400	0	LEVEL
13400	13725	1.5	(RISE)
13725	13875	1	(FALL)
13875	14125	1.75	(RISE)
14125	14787	0	LEVEL

4.6.4 Curvature

Due to rolling terrain there are many sharp turns and curves along the roads. This necessitates provision of curves for the metro alignment also to keep the same on the median of the roads. Curves are also provided to turn at various intersections. The radius of curves at intersections is kept as low as 120 m to reduce property acquisition. The list of curves along the alignment is enclosed in **Table 4.9**. Nearly 39.70 % of the length of the alignment is on curves.

TABLE 4.9
CURVE DETAILS

CHAINAGE				
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TP1	TP2	TP3	TP4	RADIUS	TRANSITION	STRAIGHT BETWEEN TWO CURVES	CURVE LENGTH
-925	START OF ALIGNMENT						
-832.436	-792.436	-717.127	-677.127	550	40	29.958	75.309
-647.169	-607.169	-518.258	-478.258	550	40	544.467	88.911
66.209	121.209	230.34	285.34	300	55	222.344	109.131
507.684	562.684	589.293	644.293	375	55	190.617	26.609
834.91	874.91	949.846	989.846	600	40	174.332	74.936
1164.178	1219.178	1338.214	1393.214	150	55	218.94	119.036
1612.154	1667.154	1741.999	1796.999	344.86	55	0.004	74.845
1797.003	1842.003	1864.529	1909.529	476.71	45	0.001	22.526
1909.53	1964.53	1994.906	2049.906	200	55	117.596	30.376
2167.502	2222.502	2250.154	2305.154	255	55	242.181	27.652
2547.335	2557.335	2583.692	2593.692	2400	10	418.37	26.357
3012.062	3032.062	3060.137	3080.137	1500	20	51.326	28.075
3131.463	3186.463	3323.487	3378.487	120	55	139.659	137.024
3518.146	3528.146	3557.026	3567.026	3000	10	159.559	28.88
3726.585	3781.585	3843.853	3898.853	323.85	55	0.002	62.268
3898.855	3923.855	4116.064	4141.064	1000	25	143.878	192.209
4284.942	4309.942	4370.812	4395.812	1000	25	48.672	60.87
4444.484	4499.484	4529.346	4584.346	225	55	25.038	29.862
4609.384	4629.384	4770.886	4790.886	1223.5	20	0.004	141.502
4790.89	4845.89	4877.48	4932.48	200	55	0.003	31.59
4932.483	4987.483	5085.112	5140.112	126.04	55	168.343	97.629
5308.455	5333.455	5372.683	5397.683	1500	25	535.36	39.228
5933.043	5988.043	6097.942	6152.942	300	55	269.814	109.899
6422.756	6462.756	6502.617	6542.617	600	40	286.514	39.861
6829.131	6884.131	6971.218	7026.218	300	55	97.423	87.087
7123.641	7178.641	7252.467	7307.467	300	55	340.53	73.826
7647.997	7702.997	7863.187	7918.187	300	55	34.549	160.19
7952.736	8007.736	8170.208	8225.208	300	55	380.337	162.472
8605.545	8625.545	8735.458	8755.458	1000	20	229.689	109.913
8985.147	9040.147	9075.045	9130.045	310	55	206.346	34.898
9336.391	9376.391	9429.683	9469.683	600	40	95.071	53.292
9564.754	9619.754	9670.34	9725.34	300	55	477.161	50.586
10202.5	10212.5	10280.3	10290.3	6000	10	185.428	67.799
10475.73	10530.73	10652.12	10707.12	120	55	72.453	121.388
10779.57	10819.57	10872.7	10912.7	800	40	194.211	53.134
11106.91	11161.91	11296.75	11351.75	120	55	660.876	134.833
12012.62	12022.62	12089.25	12099.25	12000	10	2335.985	66.627
14435.24	14490.24	14731.96	14786.96	200	55	0.358	241.728
14787.32	END OF ALIGNMENT						

4.6.5 Switch-Over Ramps

Near Swastik station:

Swastik station is provided with concourse at ground level with rail level as 6.00 m above ground level. Immediately after the station a falling gradient of 2.5% is

provided to for ramping in the alignment which goes 9 m below the ground level before platform road junction. The alignment of the ramp is kept off the road so that no road is affected either during construction or later on.

Implications of the Switch-Over Ramp (SWR)

Following are the notable implications on the proposed SWR:

1. The entrance to the Stadium needs to be relocated. Also the size of the Stadium will be reduced marginally.
2. The front of Krishna floor mill will be slightly affected due to the ramp.
3. The approach of the residential areas/ slum, which are located between the Bangalore railway line & Platform Road, will need to be modified.

Southern Switch over Ramp

Just after crossing the Shiv Shankar circle, the alignment has to come up on the surface. A gradient of 2.75 % is proposed for switch over ramp. The ramp will cover about 11 m of road width from chainage 9750 to 10200 where the section is completely elevated. In this stretch, one cross road S. S. Temple Street/ Mahila Sanoja Road at KM 10.10 will be blocked due to the ramp.

Both sides of this road have enough space for widening, without affecting any structure. However about 5 m in front of Vittal Mallaya Scientific Research Foundation, the Theosophical Society, KIMS C.T. Scan Centre, Bangalore Gayana Samaj, Bangalore Institute of College, Sri Madhwa Yuvaka Sangha, C. B. Bhandari Jain college & Visvesvarepuram College have to be taken for widening of road. The existing centre verge is 1.10 m wide & Carriageway 8 m wide left side & 7 m wide right side. The ROW is about 25 m average.

There is no shop/residence both side of the road, only front of college, school etc. are affected.

4.7 ALTERNATIVE ALIGNMENT

Following alignment options were considered while carrying out the study for the DPR. These options were studied in detail and the best option have been recommended due to the reasons explained herein.

East - West Corridor

- (i) M G Road - Options of locating the alignment on the median or on North edge of the road
- (ii) MG Road to Old Madras Road - Through Murphy Road or Swami Vivekanand Road/CMH Road
- (iii) Swami Vivekanand Road - Options of locating the alignment on the median, or on South edge of the road
- (iv) CMH Road to Old Madras Road - via 80' Road, through ADE or through 100' Road

North - South Corridor

- (i) R V Road to J P Nagar via Jaya Nagar (11th Main Road)

Alignment on M G Road: Once it was decided to provide elevated corridor on M G Road, further studies were made to work out the location of the piers on M G Road. It is observed that on MG Road from Queens Circle to Brigade Road all the commercial complexes are located on the south side while on the north side raised walkway exists. From Brigade Road to Trinity Circle many structures on the north side of the road also exist. Hence it has been recommended to finalise the alignment on the northern edge of the road from Queens Circle to Brigade Road and on the median of the road from Brigade Road to Trinity so that no permanent structure is affected. However this arrangement will require construction of 4 portals near the Brigade Road to shift the alignment.

It is, however, possible to continue the alignment on the northern edge of the road through the areas presently used for parking of vehicles on the roadside, without affecting permanent structures except the electric substation near Dickenson Road and Defence quarters. This alternative avoids all the portals, a visual intrusion, near the Brigade Road. The shifting of the transformer on the busy M G Road may not be easy as an alternative location is required nearby. The shifting may affect the electric supply to a number of commercial centers on the M G Road. However the proposed alignment is marked and can be seen in Drg no. MRTS-BANG/E-W/01.

MG Road to Old Madras Road - Through Murphy Road or Swami Vivekanand Road/CMH Road: Three options were considered for taking the alignment from MG Road to Baiyappanahalli Depot. These are (i) MG Road to Murphy Road/Old Madras Road; (ii) MG Road to Swami Vivekanand Road to Old Madras Road and (iii) MG Road to Swami Vivekanand Road - CMH Road - Old Madras Road. These alternative alignments can be seen in Drg.no.MRTS BANG/E-W/02.

The first option is the same as earlier proposed ELRTS alignment. This alignment is not recommended due to (a) minimum ridership of the three alternatives as the alignment passes through open areas and (b) even with a curve of 120 m radius a part of the Taj Residency Hotel on the corner of MG Road is affected.

In the 2nd option also the ridership is lower than the third option as almost 2 km length of the corridor passes through sparsely habitated areas.

The third option gives the maximum ridership as it passes through the heavily populated area and serves important colony (Indira Nagar) and adjoining areas in the West.

Swami Vivekanand Road: The right-of-way on Swami Vivekanand Road varies from 12 m to 21 m. The Road width is only 12 m. The alignment is taken through this road as the traffic projection through this route is higher as compared to the route via Murphy Road.

Due to right-of-way constraint the alignment was originally proposed on the south footpath of the road. However acquisition of about 15 -20 m width of land from the

Defence workshop would have been required for this option including part dismantling of the existing workshop building. This would have been a time consuming process. All attempts to carry out survey inside the premises failed as permission was not granted due to security reasons.

Thus the alignment is planned on the middle of road. This can be done either by providing portals or a central pier. In case of portals the height of rail level will be about 1 m extra and additional cost of substructure is also involved. The extra cost involved is of the order of Rs.15 crores. In case of central pier 4 wheeler traffic during construction is to be diverted to Murphy Road.

CMH Road - Three options were studied to continue the alignment from CMH Road to Old Madras Road. These are through - (a) 100' Road (b) 80' Road and (c) ADE. The radius of curves required for turning either on 80' Road or 100' Road is 120m. In case of the alignment moving on 80' Road, it will result in taking the alignment over the temple area which is not desirable. The number of properties (and area for acquisition) affected in either case is same. The other alternative of continuing the alignment through ADE has following problems :

- (i) Permission to acquire 20 m corridor in the Defence land which is time consuming process
- (ii) The elevated guideway being close to the explosives storage which may not be agreed by Commissioner of Metro Railway Safety (CMRS).
- (iii) Crossing of Old Madras Road near the BEML railway siding to reach Baiyappanhalli. There is a proposal to utilise the existing siding for commuter rail service in future with provision of laying one more line along with electrification of these lines. This will necessitate a road over bridge or underpass on Old Madras Road across the railway lines with provision for permitting traffic movement on Suranjandas Road. Construction of Road over-bridge will clash with the elevated structure of Metro system while underpass may not provide full traffic movement on Suranjandas Road.

Thus the 1st option of taking the alignment through 100' Road has been recommended as it has following advantages

- Station is located in busy residential area on important road.
- No controversy regarding acquisition of land from important temple.
- No delay in construction and implementation.
- No conflict with future ROB over BEML siding.

North - South Corridor

R V Road to J P Nagar via Jaya Nagar (11th Main Road): Two alternatives were considered for alignment beyond the Southend Circle (a) South end Circle to Jayanagr (11th Main Road) to J P Nagar phase VI and, (b) Southend Circle to R V Road terminal. Alignments in both the alternatives are parallel about 1.75 km apart. The ridership on the corridors is also more or less similar. However the alignment in J P Nagar comes to an dead end with no possibility for its extension in future. Also enough space for stabling of rakes in J P Nagar area is not available.

The alignment on R V Road is straight with sufficient land on both sides, of the road for stations, integration areas, receiving substation and stabling of rakes. The corridor can be extended further south through a turn in either direction for going to Kanakpura or Hosur Road/Electronics City.