CHAPTER 6

STATION PLANNING

GENERAL

The proposed Metro for Bangalore comprises two corridors, namely *Mysore Road-Baiyappanahalli*, East-West corridor and *Yeshwantapur-RV Road*, North-South Corridor. The East-West corridor extending from *Baiyappanahalli* in the east to *Mysore Road* in the west covers for 18.10 kms from end to end while the North-South corridor extends from *Yeshwantapur* in the north to in the south covering 14.9 kms form end to end.

Stations on the Line

Eighteen stations have been planned along the proposed East-West corridor. Beginning from the East, the first station is a surface station followed by five elevated stations. Next four stations are underground stations while the remaining seven stations are elevated and last station is at-grade.

Fourteen stations are planned on the North-South corridor, of which the first five starting form North are elevated, followed by one surface station and three underground stations and then five elevated stations in the South.

The two corridors meet at Majestic under ground station. Average inter-station distance is 1.03 km approximately. This however varies from 0.62 km to 2.10 km, depending upon site, operational and traffic constraints.

Rail and Platform Levels

The alignment, for a large part, passes through the middle of roads. In order to keep the land acquisition to the minimum and rail levels as low as possible, a two level elevated station design has been proposed. The general rail levels are ~12 m above road and are governed by a ground clearance of 5.5 m. This in turn decides the level of the entire station structure in the elevated section of the alignment. In the underground section, utilities below the ground level become the governing criteria in fixing the station structure levels.

Platforms

Further, in the elevated section, to avoid the viaduct structure flaring in and out at stations thereby causing obstruction to the road traffic below, all stations have been planned with side platforms. On the other hand, from the consideration of bored tunnelling for underground section, island platforms are preferred in the underground section. It has been attempted to locate stations on straight alignment only. However in situations where other site constraints have become overpowering, a curve of minimum 1000 m radius has been accepted. The sequence of stations along with their respective chainages and locational characteristics and platform characteristics is presented in the **Table 6.1**.

Table 6.1
Locational Characteristics of stations on Bangalore Metro corridors

East-West corridor

Name of Station	Chainage (Km)	Distance from previous station in km	Rail Level (m) at CL	Height /depth of RL from adjacent ground	Platform type and Nos	Alignment Description	Remarks
1. Mysore Road Terminal	0.000	-	826.474	12.96	2, Side	Curve of rad. 1000m	Elevated
2. Deepanjali Nagar	1117.000	1117.000	861.974	12.126	2, Side	Straight alignment	Elevated
3. Vijaya Nagar	2345.000	1228.000	869.849	12.886	2, Side	Straight alignment	Elevated
4. Hoshalli	3446.000	1101.000	897.674	12.106	2, Side	Partly in transition 4 m	Elevated
5. Tollgate	4448.000	1002.000	881.299	14.01	2, Side	Partly in curve of rad. 1000m	Elevated
6. Magadi Road	5600.000	1152.000	877.387	13.02	2, Side	Partly in curve of rad. 4000m	Elevated
7. City Railway Station	6755.000	1155.000	886.762	8.26	1, Island	Curve of rad. 1500m	Underground
8. Majestic	7503.000	748.000	890.6366	8.43	1, Island	Curve of rad. 1000m	Underground
9. Central College	8697.000	1194.000	903.862	13.226	1, Island	Straight alignment	Underground
10. Vidhan Soudha	9318.000	621.000	896.612	12.226	1, Island	Curve of rad. 1000m	Underground
11. Cricket Stadium	10643.000	1325.000	921.987	7.61	2, Side	Straight alignment	Elevated
12. M G Road	11380.000	737.000	923.612	11.926	2, Side	Straight alignment	Elevated
13. Trinity Circle	12522.000	1142.000	918.662	12.196	2, Side	Straight alignment	Elevated
14. Ulsoor	13725.000	1203.000	899.624	11.64	2, Side	Partly in transition 5 m	Elevated
15. C M H Road	14610.000	885.000	897.724	12.276	2, Side	Straight alignment	Elevated

16. Indira Nagar	15537.000	927.000	912.424	12.316	2, Side	Straight alignment	Elevated
17. Old Madras Road	16419.000	882.000	912.474	9.24	2, Side	Straight alignment	Elevated
18. Baiyappa nahalli Terminal	17374.000	955.000	911.164	2.64	1 Island, 2 Side	Straight alignment	Surface

North South Corridor

Name of Station	Chainage (Km)	Distance from previous station in km	Rail Level (RL in m)	Height /depth of RL from adjacent ground	Platform type and Nos	Alignment Description	Remarks
19. Yesh wantapur	0.0		923.6	11.216	2, Side	Straight alignment	Elevated
20. Maha laxmi	2102.0	2102.0	930.68	13.146	2, Side	Partly in Curve of rad. 1200 m	Elevated
21. Rajaji Nagar	3069.0	967.0	930.066	12.76	2, Side	Partly in Curve of rad. 1200 m	Elevated
22. Kuve mpu Road	3975.0	906.0	908.68	14.39	2, Side	Curve of rad. 1000 m	Elevated
23. Malle swaram	4728.0	753.0	922.68	12.866	2, Side	Curve of rad. 1224 m	Elevated
24. Swas tik	5864.0	1136.0	902.68	7.06	2, Side	Straight alignment	Surface
25. Maje stic	7540.0	1676.0	882.624	21.14	1 Island	Straight alignment	Underground
26. Chick pete	86559.0	1019.0	886.164	8.636	1 Island	Partly in transition 20 m	Underground
27. City Market	9235.0	676.0	891.404	11.12	1 Island	Straight alignment	Underground

28. K R Road	10427.0	1192.0	916.164	14.766	2, Side	Partly in tangent 15 m	Elevated
29. Lalbagh	11431.0	1004.0	922.804	16.016	2, Side	Straight alignment	Elevated
30. South End Circle	12386.0	955.0	928.242	16.636	2, Side	Straight alignment	Elevated
31. Jayanagar	13288.0	902.0	933.492	13.916	2, Side	Straight alignment	Elevated
32. R V Road Terminal	14180.0	892.0	933.867	13.72	2, Side	Straight alignment	Elevated

STATION LOCATIONS

(A) East-West Corridor

6.2.1 Mysore Road Terminal (Km.0.00)

Mysore Road Terminal is the first station on the East West corridor and hence has a Chainage of 0.00. It is an elevated station and is located on the bifurcation of Mysore road and Chord Road. This station is about 13 meters above ground. Commuters from the surrounding areas like the B.H.E.L., Kavikanagar, Bapujinagar, Byatrayanapura, Timber Yard layout and Venkateshpuranagar would use the station.

The station is located in such a way that certain properties will have to be acquired; these properties include Vishnu Timbers, Poornima Timbers, Meenakshi Saw Mills. The location of this station will also cause the relocation of an 11 K.V. Sub Station. The station is also located at the street leading to Jothi Nagar. Opposite the station are the properties like Devatha Silk Mills and Rahmad Auto center and a few residences.

6.2.2 Deepanjali Nagar (Km. 1.117)

Deepanjali Nagar station is the second station on this corridor and is also an elevated station, which is around 12 meters above the ground. The station also touches Chord Road and is used by the commuters from Vijayanagar 2nd Stage, Binny Mills colony and Pre-university College, which are in close proximity.

The station requires the acquiring of the certain properties- Maruthi Enterprises, a few Shops, Akash Studio and a small temple. The station is ideally located and the passengers disperse via the roads- 1st Cross Street, 6th Cross Street, 7th Cross Street, 8th Cross Street and 9th Cross Street and II main Road.

6.2.3 Vijaya Nagar (Km. 2.345)

Vijaya Nagar station is an elevated station and is around 13 meters above the ground. The station is also located on the Chord Road and is patronised by people frequenting Subanna Garden, L.I.C. Colony, Marenahalli and Chikpet H.B.C.S.

Since this station is located right in the middle of the road and the road is also a wide one the acquisition of the properties on either side of the station is not required.

6.2.4 Hoshalli (Km. 3.446)

Hoshalli is also an elevated station. The station is 12 meters above the ground. The station users are mainly people from Hoshalli Extension, Cholurpalyanagar and Govindrajnagar.

The station is right in the middle of Chord Road and does not require the acquisition of properties around it. The local roads that feed into the station are many and are the 8th-14th Main roads of Vijaya Nagar. The station is located adjacent to the local bus terminal.

6.2.5 Tollgate (Km. 4.448)

Tollgate station is an elevated station and is around 14 meters above the ground. Also located in the Vijayanagar precinct, the station is one more of them, which do not need acquisition of private property for construction.

The station is immediately surrounded by the Sri Jagajyothi Basaveswara Kalyana Kendra, the K.V.V.N.S. hostel, Mandovi motors, the Sastry Memorial Hospital, the Sri Adi Chunchanagiri Community Hall and Temple.

6.2.6 Magadi Road (Km. 5.600)

Magadi Road is an elevated station. The station is around 13 meters above ground level. The surrounding precincts to this station include Manjunatha Nagar, Gopalpuram, the Minerva Mills, the Magadi Chord Rd Lyt and Agrahara Dasarahalli.

The station is located above the median needs the acquisition of a few sheds, a medical shop and the Canara Bank building. The immediate surroundings of this station include the Calama Industries Pvt. Limited, the Abhishoke Enterprises and Mandra motors.

6.2.7 City Railway Station (Km. 6.755)

City Railway station is located at a distance of 1.166 km from the previous station. The station is an underground one with rail level 8.26 m below road level and is a very important metro station as it attracts passengers from and to the Bangalore City Railway Station, and Subhash Nagar area.

6.2.8 Majestic (Km. 7.503)

Majestic station is a two level interchange station and is designed to handle passengers entering and exiting from both Metro corridors. The station is located at KSRTC Bus stand area, close to the city bus terminal.

The main roads leading to this station are the Subedar Chatram Road and the Kempegowda Road. The Majestic circle area is one where a number of picture houses are located viz. Majestic, Kalpana, Sagar, Spana, Tribuvan, Kailash, Himalaya, Triveni, Kapali and Aparna are located. Majestic Circle is also a Major commercial center in Banglore and requires special passenger dispersal methods.

6.2.9 Central College. (Km. 8.697)

Central College station is an underground station and is situated in an institutional area of Bangalore. The depth at which the station is located is 13 meters below the surface. It is at a chainage of 8697 meters. The precinct surrounding the station is the Central Jail, the Central College Grounds, the Central College, the University Visveswariah College of Engineering (UVCE), the Maharani's College and the S.J. Polytechnic.

6.2.10 Vidhan Saudha (Km. 9.318)

The last station on the underground segment at the East-West corridor of Bangalore Metro, the Vidhan Saudha station is around 12 meters below ground level. The station is also the shortest stop and is hardly 621 m distance from the Central College station.

Areas like Cubbon Park, the High Court, the Vidhan Soudha, the Government Press, the PMG's Office, The AG's office and the Century Club surround the station.

6.2.11 Cricket Stadium (Km. 10.643)

Cricket stadium station is the first station that emerges after the underground segment. Located opposite the Chinnaswamy Cricket stadium, the station is at a height of around 7.6 meters above ground level. The station is located on the Mahatma Gandhi Road and is patronised by the users of the Cubbon Park, St Mark's Cathedral and the Boring institute.

The station is at the junction of the Lavelle Road, Kasturba Road, Mahatma Gandhi Road, the Queens Road and the St. Marks Road. The position of the station is such that the entrance to the office of the Dy. Commissioner of Police will need to be realigned.

6.2.12 MG road (Km. 11.380)

MG Road station is an elevated station of around 12 meters above the road. Since the road has highly different edge characterstics with high rise commercial complexes on one side and the Manekshaw Parade ground on the other side. The station is placed towards the Manekshaw Parade ground; the other reason being the large number of cars parked in front of the Complexes makes it difficult to construct the station.

The station is also at the junction of MG Road, the Brigade Road and the K. Kamarajar Road all of which it serves along with Maciver Town and the Rajendra Singhji Institute.

6.2.13 Trinity Circle (Km. 12.522)

Trinity Circle station is in close proximity to the Oberoi Hotel, this landmark is one of the 100 best hotels in the World. Only the sidewalks are being acquired for the station as the properties in this area are of high value. The rail level at this station, which is also an elevated one, is around 12 meters above road level.

The station indirectly links up to the services of Richmond Road and the Defence area along with the Central Armed Reserve Police.

Ulsoor (Km. 13.725)

Ulsoor station as the name suggests is in Ulsoor area. The station is an elevated station at a height of around 11.6 meters. The station is off the road and requires complete acquisition of land. It services Swami Vivekanand Road, Ulsoor area and Nanjappa circle.

Acquisition includes properties like Upahar Hotel, Corporation Hospital, Komnathi Engineering Works, Adi Vinayagar Temple and the Police Quarters.

C M H Road (Km. 14.610)

C M H Road Station is an elevated road station and is located in the Indira Nagar Second Stage Layout. The C M H Road is a narrow one and in order to accommodate the station, the residences on either side have to be acquired and these include Sabhari Electric Company, Chandan Jewellers, a Recreation Club, Meena Jewellers, Rakshith Travels and a few residences.

The elevated station is at a height of 12.28 meters above the ground and a distance of 14609-chainage distances. The immediate areas surrounding this station are Lakshmipuram, Binnamangala 2nd stage, the Munniswamiappa Layout and the Jayaraj Nagar.

Indira Nagar (Km. 15.537)

Indira Nagar station is also an elevated station and is at a height of 12.3 meters above the ground level. Indira Nagar is predominantly residential but is being gentrified into commercial uses. The Metro will quicken this process. The last station and this one are what were the suburbs of Bangalore. The station is surrounded by areas like Binnamangala, H.A.L. 2nd stage, Defence colony and Lakshmipuram.

The station is to be constructed by the acquisition of a few houses in Indira Nagar and the other properties include NIHT computer education and State Bank of Hyderabad**.**

Old Madras Road. (Km. 16.419)

The Old Madras Road station serves the penultimate station on this corridor. The station is elevated, with rail level around 9.2 meters from the ground level.

Old Madras Station services the areas, namely Micheal Palya, Defence areas and parts of Binnamangala. The station is located in a precinct of Sawmills and the land needed to be acquired is all vacant land. The station is planned to provided integration with eastern suburabs through feeder buses.

Baiyappanahalli Terminal (Km. 17.374)

Baiyappanahalli terminal as the name suggests is the last station on this corridor and is a surface station. This is because the station leads into a depot at close proximity and allows for a smooth gradient for transition.

This station is to the extreme east of Bangalore and provides interchange with proposed commuter rail service. The station is adjacent to the depot.

B NORTH-SOUTH CORRIDOR

6.2.19 Yeshwantapur. (Km. 0.00)

This station is the first on the North South Corridor. Its Chainage is 0.0 and is an Elevated station at a height of around 11.2.meters. The purpose of this station is to connect the industrial areas to the rest of Banglore. The station is located opposite the recently developed terminal station by Indian Railway at Yeshwantapur and close to the industrial area. The areas around the, station are the Mathikere Layout, Mohan Kumar Nagar, the Central Manufacturing Technology Institute and the Defence Areas. It is located on the National Highway 4.

6.2.20 Mahalakshmi(Km. 2102)

Mahalakshmi station is the second of the Stations and is located near the Mahalaxmi temple on the Chord Road . The station is elevated at a height of 13 meters of the ground. It services the areas around Mahalakshmi Nagar, B K Nagar , Model City , the Railway Quarters and Goraguntepalya.

Rajaji Nagar. (Km. 3.069)

Rajaji Nagar station is an elevated station with a chainage of 3066 meters and a height of 12.75 Meters above the ground. The station is patronised by people from the Mahalakshmi Layout, West of Chord Road ,Sri Ram Nagar, Rajaji Nagar and located near the junction of Chord Road and Mahakavi Kuvempu Road.

Kuvempu Road. (Km. 3.975)

This station is also an elevated station, with rail level at about 14.4 m above ground. The station is oriented towards the East-West direction and serves the densly populated areas lying on either side of it. The areas include Rakesh Nagar, Gayatri Park, Gayathri Nagar and Mariappana Halli.

Malleswaram. (Km. 4.728)

This station is located on the Mahakavi Kuvempu Road and is in close proximity to the Malleswaram. The station is an elevated about 12 meters From the ground level and serves Malleswaram as the name suggests. Malleswaram is largely a residential area and hence justifies a station at this distance from the previous one. It also serves the areas like Sriram Puram, Nagappa Block and RBI colony.

Swastik (Km. 5.864)

This is a surface station with concourse at the ground and platforms above. Rail level is around 7.06 meters above the ground. It is the only station on the North- South corridor, which is on the surface. The segment of the Metro after this station runs Underground and passes through the more commercial districts of Bangalore city. The station helps serves its surrounding precincts like Seshadripuram, Swatantrapalovo and other parts of Srirampuram.

6.2.25 Majestic. (Km. 7.540)

This is the first of the underground stations and is double tiered. This is the interchange station with East-West corridor, with the rail level at 21.5 m below ground and about 13 below the rail level of EW corridor. The same has been done to accommodate a mezzanine floor between the platforms of the two corridors to facilitate interchange among the two. The city's main Inter State Bus Terminal and City Railway station being in the close proximity, this station is very important in terms of passenger traffic. The main areas that the station to serves are Subhash Nagar, the KSRTC, The BMTC, the Railway station and Gandhi Nagar, and Majestic.

6.2.26 Chickpete. (Km. 8.559)

Chickpete is also a major commercial area in Bangalore and is an underground station at a depth of 8.53 meters. Chickpete is an underground station, the main land-use of this area is commercial warehousing of cotton clothing, and hence the roads are used for bulk transit of the above-mentioned goods. The area is part of the old city and bustling with activities during the day.

The patronage of this station includes areas like Nagartepete, Cottonpete and Chickpete, and Sultanpete.

6.2.27 City market. (Chainage-9.235)

City Market Station is the last underground station on the North- south corridor. The interstation distance from Chickpete to this station is only 676 meters. The need for the station as the name suggests is that it is close to City market, which deals with both perishables and non-perishables.

The station is located at a depth of around 11 m below ground level. It serves areas like Chikkanna Gardens, Chamarajpet City Market and Seethapathi Agrahara. The Kalasipalayan Bus stand is close to the station. Vani Vilas and Victoria hospital are also close by.

6.2.28 K R Road. (Km. 10.427)

K.R. Road station is an elevated one and is around 14.7 m above the ground. The station is located on the Krishna Rajendra Road and is in a predominantly institutional zone and it serves institutes like the Bangalore Medical College, Tippu Sultans Palace, Fort High School. The other areas include Viswesvara Puram and Shankara puram.

6.2.29 Lal Bagh(Km. 11.431)

Lal Bagh station is the eleventh station on the North-South corridor and is an elevated station. This station is around 15 m above ground. The station is near Sajjan Rao Circle and the precincts in close proximity include the Vasavi temple Road, Lal Bagh and Mavalli.

6.2.30 South End Circle. (Km. 12.386)

South End Circle station is an important station. It is an elevated station at a height of 15.6 m above the ground. The station is located in a predominantly residential area and these areas include Siddapura, Basavangudi, Rajaramguptha layout, Sri Narasimharaja Colony Yediyur Nagasandra and Sakkamma Gdn.

Jayanagar. (Km. 13.288)

Jayanagar Station is the penultimate Station on this corridor and is an elevated one. The station is around 14m above ground. The Jayanagar station is like the previous station located in a predominantly residential area. The patronage of this station is from users frequenting areas like Yediyur Village, Yediyur, Kavisandra, Jayanagar and Banashankari Layout. Jayanagar market is also located nearby.

R V Road terminal. (Km. 14.180)

R.V Nagar terminal is the last station on the North South Corridor of the Bangalore Metro. It is located in R.V. Nagar the station is an elevated one at a height of 13.72 m above ground. The areas, which are serviced by this station, are J.P. Nagar, Ilyas Nagar, Kumaraswamy Layout and TMC Layout.

6.3 STATION PLANNING

Planning and Design Criteria for Stations

Stations have been planned following the norms and criteria being adopted by DMRC for Delhi Metro Project, currently under construction.

Salient features of a typical station are as follows:

- The station can be divided into public and non-public areas (those areas where access is restricted). The public areas can be further subdivided into paid and unpaid areas.
- Stations have, by and large, been designed around side platform configurations, taking into account the operational, spatial and structural constraints imposed by the frequent converging and diverging of tracks. Widths of platforms have been standardised as 4.0 m for side platforms for elevated stations and 10m for island platforms in underground stations.
- The platform level has adequate assembly space for passengers for both normal operating conditions and a recognised abnormal scenario.
- The platform level at elevated stations is determined by a critical clearance of 5.6 m under the platform structure above the road intersection, allowing 3.3 m clear height at concourse and about 1.6 m for the structures of the girder and cross over passage. Further the platforms are 1.09 m above the tracks. This would make the platforms in an elevated situation at least 12 m above road level.
- The concourse contains the automatic fare collection system in a manner that divides the concourse into distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates the passenger enters the 'paid area' which includes access to the platforms.
- The arrangement of the concourse is assessed on a station by station basis and is determined by site constraints and passenger access requirements. However it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs/ escalators. Ticket machines and AFC gates are positioned to minimise cross flows of passengers and provide adequate circulation space.
- Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.
- Station entrances are located with particular reference to passenger catchment points and physical site constraints within the right of way allocated to the Metro.
- Office accommodation, operational areas and plant room space is required in the non-public areas at each station. A list of areas are given below in Table 6.2

Table 6.2
Station Accommodation (non public area)

1. Station Control Room	2. Platform Supervisor’s Booth
3. Station Master’s Office	4. Traction Substation
5. Information & Enquiries	6. Signalling Room
7. Ticket Office	8. Communications Room

9. Ticket Hall Supervisor & Excess Fare Collection (Passenger Office)	10. Station Substation
11. Cash and Ticket Room	12. Fire Tank and Pump Room
13. Staff Area	14. UPS and Battery Room
15. Staff Toilets	16. Cleaner's Room
17. Refuse Store	18. Security Room
19. Miscellaneous Operations Room	20. First Aid Room

- The bore well pump houses, ground tank and pump houses would be located in one area in the ground floor on one side.
- The system is being designed to maximise its attraction to potential passengers and the following criteria have been observed:

(i) Minimum distance of travel to and from the platform and between platforms for transfer between lines
(ii) Adequate capacity for passenger movements.
(iii) Convenience, including good signage relating to circulation and orientation.
(iv) Safety and security, including a high level of protection against accidents.

- Following requirements of the operator have been taken into account:

(i) Minimum capital cost is incurred consistent with maximising passenger attraction
(ii) Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers
(iii) Flexibility of operation including the ability to adapt to different traffic conditions, changes in fare collection methods and provision for the continuity of operation during any extended maintenance or repair period, etc.
(iv) Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety.
(v) Provision of display of passenger information and advertising

- The numbers and sizes of the staircases are determined by checking the capacity against the Peak flow rates for both normal and emergency conditions.
- In order to transfer passengers efficiently from street to platforms and vice versa, station planning has been based on established principles of pedestrian flow and arranged to minimise unnecessary walking distances and cross-flows between incoming and outgoing passengers.
- Passenger handling facilities comprise the stairs/escalators, lifts and ticket gates required to process the peak traffic from street to platform and vice versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit).

6.3.2 Typical Elevated Station (Figures 6.1 & 6.2)

The station is generally located on the median of the road. Total length of the station is 136m. The stations are generally two level station. The concourse is concentrated in a width of about 80m in the middle of the station, with staircases leading to either side of the road. Passenger facilities like ticketing counters/automatic ticket vending machines, ticketing gates information etc. are provided at the concourse level. Uniform numbers of these facilities have been provided for system wide identity, although the requirement of the facilities actually varies from station to station. Typically, the concourse is divided into public and non-public zones. The non public zone or the restricted zone contains the station operational areas such as Station Control Room, Station Master's Office, UPS and Battery Room, Signalling Room, Security Room, Station Store Room staff toilets etc. The public zone is further divided into paid and unpaid area.

Since the station is in the middle of the road, minimum vertical clearance of 5.5 m has been provided under the station structure. Consequently the platforms are at a level of about 12 m from the road. To reduce the physical and visual impact of the elevated station, the stations have been made narrow towards the ends.

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

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

Typical Underground Station (Figure 6.3)

Typical underground station is under the road. This is a two level station with the platforms at the lower level and concourse on the upper level. The upper level has, in addition to the concourse, all the passenger amenities, ECS plant rooms, electrical and S&T equipment rooms, station operation areas such as Station Control Room, Station Master's Office, Security Room, Station Store Room, Staff Toilets etc. the lower level has platforms, tracks, seepage sump and pump room and similar ancillary spaces beyond the platforms on either side.

Ventilation shafts, equipment hatch, entrances and chiller plants for ECS plant are above ground structures associated with the underground station. Four entrances have been provided to the station, two at each end (one each from either side of the road). One lift has also been provided, which has access to the unpaid area. Other above-ground structures are suitably located near the station.

Structure of the underground station is essentially a concrete box 20m wide, 13.7m high and 230m long with an intermediate slab. Sides of the box are made of 1.2m thick RCC.

Interchange station at Majestic (Figure 6.4)

The interchange station at (Majestic) is an underground station where the two underground segments of East West and North South alignments intersect each other approximately at 90^0. The station is designed around island platform configuration of 10m width each. The two platforms are separated by a mezzanine in between to facilitate the interchange of passengers from upper platform to lower platform and vice versa within the paid area without having to cross the ticket gates.

Through the entry structure at ground level, the passengers proceed to the paid area of the concourse after passing through the gates. From this level the passengers can go directly to the upper and lower platforms directly. The ticket vending facilities are located at this level in the unpaid area.

Over the station box, office accommodation in eight storied structures have been planned with its longitudinal axis parallel to the N-S direction, to facilitate natural lighting into the station at upper platform level and mezzanine level. The station layout and the tunnels carrying the tracks between the stations have governed the rail levels, which are 8mts for the E-W corridor and 20mts for NS corridor.

6.3.5 Passenger Amenities

Passenger amenities such as ticketing counters/ automatic ticket vending machines, ticketing gates etc are provided in the concourse. Uniform numbers of these facilities have been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station. The same applies to provision of platform widths and staircase/ escalators. Maximum capacity required at any station by the year 2021 for normal operation has been adopted for all stations. For this purpose, *peak minute traffic* is assumed to be 2% of the *peak hour traffic*.

6.3.5.1Concourse

Concourse forms the interface between the street and the platforms. In the underground stations it is directly above the platforms. In the elevated stations in the middle of road, the concourse is directly below the platforms. This concourse is contained in a length of about 80m in the middle of the station. The concourse contains the automatic fare collection system in a manner that divides the concourse into distinct *paid* and *unpaid* areas. The *'unpaid area'* is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates the passenger enters the *'paid area'* which includes access to the platforms. The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimise cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow has been allowed in front of the ticketing gates.

6.3.5.2Ticketing Gates

Ticketing gates' requirement has been calculated taking the gate capacity as 30 persons per minute per gate. Passenger forecast for the horizon year 2021 has been used to compute the maximum design capacity. Although the actual requirement of gates may be less at certain stations, minimum two gates for entry and two gates for exit have been provided. In addition one gate for disabled has been provided at each station.

6.3.5.3Ticket Counters and Ticket Issuing Machines

It is proposed to deploy manual ticket issuing in the beginning of the operation of the line in 2007. At a later stage, automatic machines would be used, for which space provision has been made in the concourse. Capacity of manual ticket vending counters is taken to be 10 passengers per minute and that of the automatic machines as 6 persons per minute. It is assumed that only 40 percent of the commuters would purchase tickets at the stations while performing the journey. The rest are expected to buy season tickets or prepaid card etc. accordingly the requirement of ticket counters has been calculated and the same provided for in the plans.

6.3.5.4Platforms

A uniform platform width of 4m has been has been followed for side platforms system wide. For underground station, island platforms,10 m wide, are proposed. The platform level has sufficient assembly space for passengers for both normal and recognisable abnormal scenario.

6.3.5.5Stairs, Escalators and Lifts

Since the rise from road to platforms (in case of elevated stations) is about six m to the concourse, it is proposed to provide escalators in addition to stairs for vertical movement of passengers from street to concourse. However, escalators may be provided in the future.

Provision has been made for escalators in the paid area i.e. from concourse to platforms. On each platform, one meter wide escalator has been proposed. In addition two staircases with combined width of 7.2 m is provided on each platform connecting to the concourse. These stairs and escalator together provide an escape capacity adequate to evacuate passengers in emergency from platforms to concourse in 6.6 minutes. While calculating the waiting passengers on the platform in emergency 2 missed headways are assumed and the train arriving is assumed to be carrying peak section load.

While calculating the staircase requirements, peak boarding in peak direction has been considered for stations with side platforms. For island platforms combined boarding +alighting traffic has been considered for calculation of staircases.

6.3.5.6 Emergency Evacuation

Additional staircases have been provided for fire escape at two stations where the stairs mentioned above are not enough to evacuate passengers in the required time. These are *City Railway Station* and *Majestic* . Two staircases at the end of each platform have been provided. At these stations.

6.3.5.7 Passenger information Kiosks and commercial kiosks

Passenger information Kiosks and, wherever space permits, commercial kiosks are provided in the unpaid and paid areas of the concourse respectively

6.3.5.8 Summary of passenger amenities

Summary of passenger amenities required and proposed at stations based on projected traffic for the year 2021 is given in the following table:

Table 6.3
Passenger traffic and requirement of amenities in stations (projections for year 2021)

	daily boarding	peak minute boarding	Total peak minute traffic including alighting	Ticketing Gates provided	Ticket Counters	Stairs provided on each platform	Additional emergency stairs	Lifts provided at each station		Escalators provided at each station	
East-West Corridor								G to C	P to C	G to C	P to C
1. Mysore Road Terminal	14240	28	31	6	2	7.2	nil	1	2	1	2
2. Deepanjali Nagar	34838	70	87	6	3	7.2	nil	1	2	1	2
3. Vijaya Nagar	69060	138	173	6	6	7.2	nil	1	2	1	2
4. Hoshalli	92010	184	230	6	8	7.2	nil	1	2	1	2
5. Tollgate	44284	89	111	6	4	7.2	nil	1	2	1	2
6. Magadi Road	62161	124	166	6	6	7.2	nil	1	2	1	2
7. City Railway Station	63979	128	179	9	6	7.2	3.00	1	1	1	2
8. Majestic	76938	162	213	9	7	7.2	3.00	1	1	1	2
9. Central College	27633	66	77	9	3	7.2	nil	1	1	1	2
10. Vidhan Saudha	42820	86	120	9	4	7.2	nil	1	1	1	2
11. Cricket Stadium	24000	48	67	6	2	7.2	nil	-	2	1	2
12. M G Road	37631	76	106	6	4	7.2	nil	1	2	1	2
13. Trinity Circle	22621	46	63	6	2	7.2	nil	1	2	1	2
14. Ulsoor	21841	44	61	6	2	7.2	nil	1	2	1	2
15. C.M.H Road	36990	74	92	6	3	7.2	nil	1	2	1	2
16. Indira Nagar	27826	66	70	6	3	7.2	nil	1	2	1	2
17. Old Madras Road	32129	64	80	6	3	7.2	nil	1	2	1	2
18. Baiyappanahalli	46400	91	100	6	4	7.2	nil	-	2	0	2
North –South Corridor											
19. Yeshwantapur	61600	123	136	6	6	7.2	nil	1	2	1	2
20. Mahalaxmi	28800	68	72	6	3	7.2	nil	1	2	1	2
21. Rajaji Nagar	66607	131	164	6	6	7.2	nil	1	2	1	2
22. Kuvempu road	68400	137	171	6	6	7.2	nil	1	2	1	2
23. Malleswaram	76906	162	190	6	7	7.2	nil	1	2	1	2
24. Swastik	74177	148	89	6	6	7.2	nil	-	2	1	2
25. Majestic	89799	180	108	9	8	7.2	nil	-	-	2	2
26. Chickpete	47200	94	67	9	4	7.2	nil	1	1	1	2
27. City Market	36064	72	43	9	3	7.2	nil	1	2	1	2
28. K R Road	29682	69	74	6	3	7.2	nil	1	2	1	2
29. Lal Bagh	36386	71	88	6	3	7.2	nil	1	2	1	2
30. South End Circle	38326	77	96	6	4	7.2	nil	1	2	1	2
31. Jayanagar	66468	131	164	6	6	7.2	nil	1	2	1	2
32. R V Road Terminal	118698	237	261	8	10	7.2	nil	1	2	1	2

6.3.5.9 Salient features of lifts and escalators

Lifts

Stations shall be provided with lifts specifically designed for handicapped and disabled persons. Machine-room-less lifts with gearless drive are proposed which are highly energy efficient and merge well with station aesthetics. Lifts shall comply with international standards (EN-81) and Indian Standards (IS-14665). The salient features of the proposed lifts are as under:-

- ❖ Car size : 1600x1400 mm
- ❖ Capacity : 8 persons, 630 kg.
- ❖ Speed : 1m/s
- ❖ Automatic rescue devices for landing in case of power failure
- ❖ 3-D infra red curtain type door safety device
- ❖ Specific features for disabled persons : Brail buttons, handrail, buttons at lower height, audio announcement, intercom with Station Master etc.

Escalators

Escalators shall be provided at elevated and underground stations for passenger transportation. Heavy-duty public service escalators are proposed complying with international standards (EN-115) and Indian standards. The salient features of the proposed escalators are as under:-

- ❖ Step width : 1000mm
- ❖ Flat step : 4 at top and bottom landing
- ❖ Speed : 0.65m/s, 0.5m/s (optional) and 0.13m/s (idling)
- ❖ Carrying capacity : 195 passenger/Min.
- ❖ Safety devices as per international and national standards

6.4 TRAFFIC INTEGRATION

6.4.1 Concept of Traffic Integration

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

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

- Suitable linkages are proposed so that various corridors of Metro are integrated within themselves, with existing rail services and with road based modes.
- Parking and circulation area requirement is worked out for each station and the areas are planned on the basis of prevailing norms.
- Facilities needed at various stations are planned in conformity with the type of linkages planned there.
- Traffic and transport integration facilities are provided for three different types of linkages;
- Interchange links to provide integration of various Metro corridors
- Feeder links to provide integration between various Metro corridors and road based transport modes i.e. public, hired, and private vehicles.
- Walk links to provide access to the pedestrians.

Mode wise Parking Requirement at Stations

The mode wise parking requirements at stations are based on the station loads. It has been assumed that 70% of the passengers will come to station by walk at all the integration stations. Of the vehicular feeder trips, 80% of the trips are performed by buses and the remaining trips are performed by cars, Two wheelers and cycles. It is further assumed that private vehicles parking is provided only in the stations where integration facilities are available. The **Table 6.4** shows summary of station wise traffic integration requirements.

Table 6.4
Mode wise parking/halting requirement at stations

Station name	No. of parking bays				Area Required in m^2 (for all vehicles other than buses)			
	Bus	scooter	car	Cycle	scooter	car	Cycle	Total
East-West Corridor								
1. Mysore Road Terminal	1	85	17	11	214	256	17	487
2. Deepanjali Nagar	3	0	0	0	0	0	0	0
3. Vijaya Nagar	7	50	10	25	125	150	38	313
4. Hoshalli	9	50	10	25	125	150	38	313
5. Tollgate	4	0	0	0	0	0	0	0
6. Magadi Road	6	0	0	0	0	0	0	0
7. City Railway Station	6	0	0	0	0	0	0	0
8. Majestic	7	60	25	50	150	375	75	600
9. Central College	3	40	20	22	100	300	33	433
10. Vidhan Saudha	4	0	0	0	0	0	0	0
11. Cricket Stadium	2	0	0	0	0	0	0	0
12. M G Road	4	0	0	0	0	0	0	0
13. Trinity Circle	2	0	0	0	0	0	0	0
14. Ulsoor	2	0	0	0	0	0	0	0
15. C.M.H Road	4	0	0	0	0	0	0	0
16. Indira Nagar	3	0	0	0	0	0	0	0
17. Old Madras Road	3	50	25	26	125	375	39	539
18. Baiyappanahalli	4	75	40	36	188	600	54	842
North –South Corridor								
19. Yeshwantapur	6	75	30	49	188	450	74	711
20. Mahalaxmi	3	30	10	23	75	150	35	260
21. Rajaji Nagar	6	0	0	0	0	0	0	0
22. Kuvempu road	7	0	0	0	0	0	0	0
23. Malleswaram	7	0	0	0	0	0	0	0
24. Swastik	7	25	10	25	63	150	38	250
25. Majestic	9	40	10	25	100	150	38	288
26. Chickpete	5	0	0	0	0	0	0	0
27. City Market	3	0	0	0	0	0	0	0
28. K R Road	3	25	10	24	63	150	36	248
29. Lal Bagh	3	0	0	0	0	0	0	0
30. South End Circle	4	0	0	0	0	0	0	0
31. Jayanagar	6	25	10	25	63	150	38	250
32. R V Road Terminal	11	25	10	30	63	150	45	258

Approach adopted in Planning Traffic Integration Facilities

The integration facilities at Metro stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate parking areas for various modes likely to come to important stations including feeder buses/minibuses. The provisions have been made for peak hour demand. Traffic integration facilities were identified on the basis of location of station and its proximity to other existing / proposed activity generating or attracting land uses such as the District Centre/ CBD, Rail / Bus stations and originating and terminating nodes of the Metro corridor. These facilities have been provided directly under the stations/ adjacent area in the Metro corridor. Further, the area planning ensures that dispersal of large volumes of pedestrians is adequately provided for. Wherever required, grade separated pedestrian access has been planned to avoid a clash between vehicular and pedestrian traffic.

6.5 VENTILATION AND AIR-CONDITIONING

6.5.1 Introduction:

This section covers the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed Bangalore Metro alignment. It includes the following:

- Station Air-conditioning System
- Ventilation System for station plant rooms (ancillary spaces)
- Station Smoke Management System
- Tunnel Ventilation System

6.5.2 ALIGNMENT

The proposed alignment has two corridors viz. east-west and north-south lines. The two lines have about 3.4 km and 3.3 km of underground sections respectively. This would include 4 underground stations on east west line and 3 underground stations on north south line (including an underground interchange station namely Majestic circle). There shall also be a provision of an underground link line connecting two corridors having a length of about 300 m.

The Metro alignment passes through heart of the city. The underground section runs below highly dense areas near the Anand Rao circle, Majestic circle, Kempe Gowda circle, KSRTC bus stand and City Rly. Station. For each line the underground section is switched over to the elevated track via ramp sections.

6.5.3 Need for Ventilation and Air Conditioning

The underground stations of the Metro Corridor are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from outside and do not have natural ventilation. It is therefore, essential to provide forced ventilation in the stations and inside the tunnel (termed as subway area) for the purpose of:

- Supplying fresh air for the biological needs of passengers and the staff;
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the sub-way;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.;
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Escalators, Fare Gates etc. working in the stations;

- Removing heat from air conditioning plant and sub-station and other equipment if provided inside the underground station.

This large quantity of heat generated in M.R.T. underground stations cannot be extracted by simple ventilation, especially when the outdoor air temperature is high. It is, therefore, essential to cool the outdoor air before circulating in the station so as to remove the heat to the maximum extent and to provide fair degree of comfort (or avoid discomfort) to passengers in the station. Although, in winter months it may not be necessary to cool the ventilating air. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered appropriate.

6.5.4 External Environment Conditions and Weather data

The weather data from the meteorological department has been received for Bangalore city for the last few years. The analysis of a representative year suggests that the summer season for Bangalore is generally between March to May. The maximum dry bulb temperatures are seen to have reached upto 37 deg C during end of April. It is also observed from the relative humidity data that moisture content during the summer months is low. The winter months can be assumed from November to January when the maximum temperatures are around 26 deg C. The rest of the months generally have temperate conditions. A chart showing variation in average maximum and minimum temperatures for the year 2000 is at Fig. 1.

Another important feature of Bangalore weather data is the ‘diurnal variation’, which is the change in temperature during 24 hours. The peak values are between 2.00 pm to 4.00 pm, but the temperature falls rapidly with night temperatures around 22 deg. C in summer and around 12 deg in winters. The hourly weather data collected have been analysed and its interpretation would be useful during the detail design stage.

The high air pollution of Bangalore throughout the year adds a new dimension and there is a critical need for maintaining desired Air – Quality (Environmental control) in public places like MRT stations. High content of suspended particles, Carbon Mono-oxide, Sulphur Dioxide etc. discharged in the air from moving traffic, industries, etc requires consideration of appropriate measures for air -pollution control in Metro stations, while designing the VAC system.

6.5.5 Sub Soil Temperature

The temperature conditions of sub-soil play a vital role in the system design of the underground stations and in order to have the knowledge of sub-soil temperature, probes have been inserted at 2 locations and reading for the same has been planned for monitoring. Sub soil temperature measurements for the full year at three different depths are being taken. For the concept design purpose it is possible to arrive at approximate value of sub-soil temperature. This can be assessed from Fig.1, which indicates average max. and min. temperature plots. The average temperature in a year is thus 24 deg. C and can be assumed as the likely sub-soil temperature value.

6.5.6 Internal Design conditions in Underground Stations

The comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat is given out by the process of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin and this is promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The 'Effective Temperature' criterion was used in selecting the comfort conditions in earlier Metros. In this criteria comfort is defined as the function of temperature and the air velocity experienced by a person. More recently a new index named RWI (Relative Warmth Index) has been adopted for Metro designs worldwide. This index depends upon the transient conditions of the metabolic rate and is evaluated based on the changes to the surrounding ambient of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a subway system where the train headway is expected to be six minutes or less, then RWI is the preferred criterion.

6.5.7 Design parameters for VAC system

Based on the reasons stated in the previous sections. The following VAC system design parameters are assumed in the present report.

(1) Outside ambient conditions:

This is based upon ASHRAE recommended design conditions for 2% and 1% criteria.

	2% Criteria	1% Criteria
Summer	: 32.8 DB, 19.5 WB; (55.39 kJ/Kg)	33.6 DB, 19.4 WB;(55.37 kJ/Kg)
Monsoon	: 27.4 DB, 22.4 WB; (65.97 kJ/Kg)	28.0 DB, 22.8 WB;(67.45 kJ/Kg)

For Bangalore Metro it is suggested to use 2% criteria, which is defined as the conditions, when the temperatures are likely to exceed for only 2% of the total time in a year.

(2) Inside design conditions:

Platform areas - 27 deg. C at 55 % RH
Concourse - 28 deg. C at 60% RH

(3) Tunnel design conditions

Normal conditions – max. DB 40 deg. C
Congested conditions -- Max. DB 45 deg. C

(4) Minimum fresh air - 10 % or 18 cmh / person
(in station public areas).

6.5.8 Design Concepts for VAC system

There are various VAC design concepts feasible in a subway system that can provide and maintain acceptable subway environment conditions. These are: Open type; Closed type; Mid - Tunnel Cooling; Semi Transverse Ventilation; Use of jet fans; use of mid-shafts; platform screen doors etc. An overview of VAC systems in other Metros like Jubilee line extension, Bangkok etc. that have similar climatic behavior and ambient conditions have provided valuable information in deciding VAC concept for Bangalore Metro.

It is observed that with open shaft system the piston effects can be sufficient to maintain acceptable conditions inside the tunnel. The stations can be equipped with air-conditioning during the summer months to provide acceptable environment for patrons. There shall be provision of Trackway Exhaust System (TES) by which platform air can be re-circulated. The train cars reject substantial heat inside subway. When the trains dwell at the stations TES would capture a portion of heat released by the trains, before it is mixed with the platform environment.

The train heat generated inside the tunnel sections would be removed by the train piston action. It is envisaged that for the design outside conditions, it may not be necessary to provide forced ventilation using Tunnel Ventilations Fans for normal operating conditions. The number of shafts required would be two or three depending on the inter station distances. The two shafts would be at the end of the stations and the third shaft, if required, can be at the mid-tunnel section. These end-shafts at the stations also serve as Blast Shafts i.e. the piston pressure is relieved to the atmosphere before the air-blast reaches the station. All these shafts are connected to the tunnels through dampers. The dampers are kept open when the exchange of air with the atmosphere is permitted (Open system). For the closed system the dampers can be in closed mode. The typical scheme for the proposed Tunnel Ventilation system for Bangalore Metro is shown in Fig.2.

Generally each tunnel ventilation shaft has a fan room in which there are two fully reversible tunnel ventilation fans (TVF) with isolation dampers. These dampers are closed when the fan is not in operation. There is a bypass duct around the fan room, which acts as a pressure relief shaft when open during normal conditions, and enables the flow of air to bypass the TV fans, allowing air exchange with flows generated by train movements. Dampers are also used to close the connections to tunnels and nozzles when required by operating modes. The details for the shaft sizes, airflow exchange with the atmosphere, fan capacities can be estimated in more accurate manner with the help of Computer Simulations during the detailed design stage.

6.5.9 Trackway Exhaust System (TES)

The TES is to be installed in the trainways of each station to directly capture heat rejected by the vehicle propulsion, braking, auxiliary and air conditioning systems as the train dwells in the station. The TES includes both an under platform exhaust (UPE) duct and an Over-trackway (OTE) exhaust duct. The TES uses concrete ducts formed in the under platform void and over the trackway. Exhaust intakes are to be located to coincide with the train-borne heat sources.

6.5.10Tunnel Ventilation Systems (TVS)

The TVS is provided in a Subway system essentially to carry out the following functions:

a) Heat removal during normal, congested and emergency conditions.
b) Ventilation during maintenance periods,
c) Train Pressure relief during normal operation.
d) Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies.
e) Removal of smoke during emergency conditions.

There are various operating modes for the Tunnel Ventilation system. These are described as under:

6.5.11Normal Condition

Normal condition is when the trains are operating to timetable throughout the system, at prescribed headways and dwell times, within given tolerances. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system and, in some cases, the trackway exhaust system. It is envisaged that there will be several normal operating conditions due to the variability of the climate in Bangalore.

During summer and the monsoon season, the system will be essentially with the station air conditioning operating. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements. The platform air captured by the trackway exhaust system shall be cooled and recirculated. For less severe (i.e. cool) environmental conditions (or in the event of an AC system failure), station air conditioning will not be used and ventilation shafts will be open to atmosphere (open system) with the trackway exhaust system operating. For cold conditions, the closed system or open system mode may be used, but without any station air conditioning. System heating is achieved via train heat rejection.

6.5.12Congested Condition

Congested conditions occur when delays cause disruption in the movement of trains. It is possible that the delays may result in the idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures may result, causing reduced performance of coach air conditioners that may lead to passenger discomfort.

During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The open system congested ventilation shall be via a 'push-pull' effect where tunnel vent fans behind the train are operated in supply and tunnel vent fans ahead of the trains are operated in exhaust. Nozzle fans or booster (jet) fans will be used to direct air into the desired tunnel, if required.

6.5.13Emergency Condition

Emergency conditions are where, for any of a variety of reasons, smoke is generated in the tunnel or station trackway. In emergency conditions, the tunnel ventilation system would be set to operate to control the movement of smoke and provide a smoke-free path for passenger evacuation and for fire fighting purposes. The method of controlling the smoke is the same as for the open system congested mode. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction.

6.5.14Pressure Transient

The movement of trains within the underground system induces unsteady air motion in the tunnels and stations. Together with changes in cross section, this motion of air results in changes in air pressure within trains and for wayside locations. These changes in pressure or 'pressure transients' can be a source of passenger discomfort and can also be harmful to the wayside equipment and structures. Two types of transient phenomenon are generally examined:

a) Portal Entry and Exit Pressure Transients

As a train enters a portal, passengers will experience a rise in pressure from when the nose enters until the tail enters. After the tail enters the pressure drops. Similarly, as the nose exits a portal, pressure changes are experienced in the train.

b) Wayside Pressure Transients

As trains travel through the system they will pass structures, equipment and patrons on platforms. Equipment would include cross passage doors, lights, dampers, walkways etc. Pressures are positive for the approaching train and negative for retreating trains. Most rapid changes occur with the passage of the train nose and tail. The repetitive nature of these pressures may need to be considered when considering fatigue in the design of equipment.

In the proposed routes there are four portal locations where the alignment changes from underground section to the above surface section. The detail analysis to assess the effect of pressure transients will have to be done during the design stage. For the portal entry/exits the effect of higher train speed may pose discomfort to the passengers. Although, based on the recent studies, it is assumed that a design train speed of 80 kmph would not be of major concern. The estimation of Way-side transients during design stage would be necessary to select design mechanical strength of the trackside components and fixtures.

6.5.15Ventilation and Air Conditioning of Ancillary Spaces

Ancillary spaces such as staff room, equipment plant room, will be mechanically ventilated and air conditioned in accordance with the desired air change rates and temperatures/humidity.

All ancillary areas that require 24-hour air conditioning will be served by fan-coil units connected to the chilled water system. Standby cooling for critical areas will be achieved by using a separate package unit connected such that it will commence operation immediately in the event of a failure of the initial system. Return air grilles will be fitted with washable air filters.

Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filter, common to a group of ancillary areas. The fresh air unit will be located in the VAC plant room and will be time switch controlled with local override. Temperature control will include an alarm setting, which is activated on high temperature.

6.5.16Station Smoke Management System

The Trackway Exhaust and Concourse smoke extract fans will be provided for smoke extract purposes from the public areas and will operate in various modes depending on the location of the fire. The associated supply air-handling units will provide support, to assist in smoke control in the event of a fire in the station where appropriate. The control of this system in fire mode will be hard-wired and fail-safe. These exhaust fans will be provided with “essential” power supplies, with automatic changeover on loss of supply.

Downstand fins will be provided underneath the ceiling around floor openings for stairs and escalators, such that a smoke reservoir is formed on the lower floor. The basic concept for the control of smoke is that it will be contained in this reservoir at ceiling level and exhausted to atmosphere. By controlling smoke in this manner, it is possible to maintain a relatively smoke clear layer above head height and to protect the escape route, giving sufficient time for evacuation. The stations will be designed to provide the full smoke exhaust volumes and thus prevent the reservoir from completely filling with smoke. To provide an additional barrier against smoke migration, the overall smoke management system would be designed to provide a stream of fresh air downward through entrances and escape routes, to assist in protecting those routes from smoke.

6.5.17System Components for VAC

The various components and equipment used in the VAC system are described in the following sections:

6.5.18Station Air Conditioning

The platform and concourse areas will be air-conditioned using supply air handling units located in air-handling plant rooms throughout the station. Each platform will be served by at least two separate air handling units (AHU's) with the distribution systems combined along each platform to ensure coverage of all areas in the event of single equipment failure. Based on the initial estimation about 6 units (2 for concourse and 4 for the platform) each having 15 cum/s air-flow would be needed for the full system capacity.

These air conditioning systems mix return air with a variable quantity of outside air. The outside air is based on occupancy, with a minimum of 5 liters per second per person or 10% of circulated air volume, whichever is the greater. The provision of free cooling by a simple two-position economizer control system will be included, with the use of enthalpy sensors to determine the benefits of using return air or outside air. This will signal the control system to operate dampers between minimum and full fresh air, so as to minimise the enthalpy reduction needed to be achieved by the cooling coil. This mixture of outside and return air is then filtered by means of automatic roll filters and then cooled by a cooling coil before being distributed as supply air via high level insulated ductwork to diffusers, discharging the air into the serviced space in a controlled way to minimise draughts. Return air to the platform areas is extracted via the trackway exhaust system and either returned to the AHU'S or exhausted as required. The air-conditioning system scheme is shown in Fig. 3 & 4.

Air-cooled chiller units will be provided at each station. These units can be installed in a chiller plant room at surface level. Based on the initial concept design the estimated capacity for a typical station would be around 500 TR, hence about three units of 250TR (including one stand-bye) may be required for full system capacity (i.e. 40,000 PHPDT). For the inter change station at Majestic Circle the plant capacity may be higher (approx. 750 TR). During the design stage this estimated capacity might get changed for individual station depending on the heat loads. It is recommended that initially two units of 250 / 200 TR may be installed with the provision of third unit be kept in terms of space.

In view of the temperate outdoor conditions, generally, it is possible to utilize air-cooled chiller units, which can save large amount of water requirement. The air-cooled chillers should be equipped with screw compressors so that they can be operated at a very less load with high efficiency. These units also eliminate requirement of condenser water circuits including pumps, cooling towers and make up water plants.

6.5.19Tunnel Ventilation System

As described earlier tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be two fans in a fan room at each end of the station. The initial fan capacity estimated is about 60cum/sec. If necessary nozzle type structures made up of concrete or steel may be constructed to achieve desired airflow and air velocity in the tunnel sections. Alternatively booster fans (jet fans) may be installed to direct the flow in the desired direction.

These fans may also be used for emergency ventilation at crossovers locations and for the link line.

The trackway exhaust system will have two fans of each 20 cum/sec. for each platform. The connections to tunnels and shafts will be through damper units that may be either electrically or pneumatic actuated.

A comprehensive remote control and monitoring system for operation and control of tunnel ventilation system will be installed. The alarm and status signals from the equipment will be transmitted to operations control centers (OCC) through SCADA. The activation command for a group of equipment will be initiated from OCC by the controller. There shall be mode table defining sequence of equipment operation for each event or scenario.

6.5.20Space Requirement for VAC System

The station air conditioning and tunnel ventilation equipment plant room are normally located at each end of the concourse for the two level stations. The approximate area for air handling equipment room would be 400 sq. m and for tunnel ventilation fan room would be 600 sq. m. respectively at each end of the station. The tunnel vent shafts of approximately 20 sq. m. area will be constructed at each end of the stations. There shall be supply shaft and exhaust shafts at the stations of similar dimensions. The air-cooled chiller units can be installed in chiller plant room at surface level. For the underground stations with large inter station distances there may be necessity of constructing mid tunnel shaft.

6.5.21Control and monitoring Facilities

For the underground stations the control and monitoring of station specific systems such as station air-conditioning, ventilation to plant rooms, lighting, pumping systems, lifts & Escalators, etc shall be performed at Station Control Room (SCR). However, the operation and control of Tunnel Ventilation as well as Smoke Management system will normally be done through OCC. All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at stations shall be transmitted to the OCC via communication network (such as FOTS).

There shall be an Auxiliary Power Controller at OCC who will be monitoring these systems. The command signals will be initiated at OCC and relayed upto the relevant equipment for operation. The feedback signal is received through SCADA if the command is implemented or not. The control from OCC is generally performed using 'Mode Tables' for each system. This table defines the sequence of the desired equipments that need to be operated based on the event. The abnormal conditions such as train congestion, emergency, fire in subway would be detected by various components and the emergency response there to will be activated based on the mode tables. In the event that remote control is not possible due to any reason, the local control via SCR would be performed. The OCC will also be used for logging the alarm status, fault occurrences, and other maintenance related data for the above systems.

6.5.22Codes and Standards

The concept VAC design is guided by the following codes and standards:

(b) SEDH – Subway Environment Design Handbook
(c) ASHRAE – Handbook, current series.
(d) CIBSE – relevant document.
(e) NFPA – 130, 2000 edition.

List of attachments

The following annexures are attached to this report.
Annexure – I: Concept design calculations for VAC system (typical).
Annexure – II: Equipment data sheet for VAC system on tentative basis.

Annexure I

VAC Calculations for Bangalore Metro typical subway station
(Concept Design)

1 Assumptions

1.	Headway	-	3 min.
2.	PHPDT	-	40,000
3.	Inter station distance	-	900 m (typical)
4.	PF length	-	130 m
5.	Bored tunnel dia	-	5.2 m
6.	Max. Speed	-	80 kmph
7.	Train frontal area	≈	2.88 x 3.8 = 10.9 m^2
8.	Train wt (empty)	=	36 Ton (DMC)
9.	Passenger/Car	=	322 (DMC)
10.	Acceleration	-	1.0 m/s/s
11.	Braking	-	1.1 m/s/s
12.	Traction Motor rating	-	200 kW
13.	No. of cars / train	-	6
14.	Car length	-	20.6 m
15.	Sub-Soil temperature	-	24°C

Analysed Data

1.	Total weight of each car	=	322 x 65 + 3600
	(DMC)	=	56.9 Ton ≈ 57 Ton
2.	No. of trains in either direction	=	60/3 = 20 trains
3.	Bored tunnel cross section area	=	20.15 m^2 (discounting 5% for invert)
4.	Blockage Ratio	=	10.9 m^2/20.15 m^2 ≈ 54%
5.	Equivalent wt. of each car	=	57 x 1.08
	(Adding 8% Rotational Inertia)	=	61.5 Ton
6.	Max. Train speed	=	$\frac{80 \times 1000}{60 \times 0.3048}$ = 4375 fpm.

7. Design Outside Conditions
(From ASHRAE 2% Criteria)
Summer 32.8 DB, 19.5 WB; (55.39 kJ/Kg)
Monsoon 27.4 DB, 22.4 WB; (65.97 kJ/Kg)

2 ESTIMATION OF COOLING REQUIREMENT

C.1Total heat rejected in a Subway station module

Kinetic Energy to be dissipated per hr would be,

K.E. = $11.1 \times 10^{-6}.W_eNnU^2$, (Ref. SEDH, Vol.I, Part 3)

Where, K.E. - Kinetic Energy in BTH.
W_e – W_e – equivalent Wt./car, ton

N – No. of cars/trains
n – no. of trains through module / hr.
U – max. train speed / fpm.

For Bangalore Metro
W_e = 61.5 Ton, N = 6,
U = 4375 fpm, n = 40 (both directions)
Hence,
K.E. = $11.1 \times 10^{-6} \times 61.5 \times 6 \times 40 \times (4375)^2$.
= 313, 592 BTH
= 918 KW

Total System heat to be removed in a station module
= 2 x K.E.
= 2 x 918 = 1836 kW

C.2Total Heat in a station module – Spatial Distribution

Total Heat	=	1836 kW
Heat rejected in approach tunnel	=	367 kW (20%)
Heat rejected in departure tunnel	=	367 kW (20%)
Heat generated in the station box	=	1102 kW (60%)

C.3 Tunnel Heat Loads (from different sources)

1.	Braking + accessories	≈	50%	≈	918kW
	(Reduction due to regen braking)	≈	20%	≈	184 kW
	Net Heat due to braking			≈	734 kW
2.	Acceleration + propulsion acc.	≈	12%	≈	220kW
3.	Train A/c Units	≈	30%	≈	550kW
4.	Others – Tunnel lighting + Third rail + station area heat	≈	8%	≈	148kW

Total heat generated in a subway module = 148 + 550 + 220 + 734
= 1652 kW

Now total Heat to be removed by the station ECS
= Subway heat @ station box (60%)
+ Tunnel heat convective (20%)
+ other steady state heat (concourse + pax)

C.4Heat load in concourse area

(a) Area of Concourse = 20 m (width) x 130 m (length)
= 2600 m^2.
Total load @ 40 W/m^2 (eqpt. + lighting + Esca. + lift)
= 2600 x 40
= 104 kW (on higher side)

(b) Pass. heat released at concourse
= 140 W/person
No. of avg. pass. = (Waiting time + Moving time) x peak min. load
= (1/2 x headway + 90 sec) x <u>40,000</u>

60

= 3min x 666

= 2000 pax

Pass. heat load = 2000 x 140

= 280 kW

Hence total steady state heat = 280 + 104 = 384 kW

Total heat load for station ECS = 384 + 1652 x 0.8 kW

= 1705 kW

= 487 TR

Hence, initial capacity proposed = 2 x 250 TR = 500 TR

Later addition = 1 x 250 TR = 250 TR (in future)

For interchange station

Initial Capacity = 3 x 250 TR

Later addition = 1 x 250 TR

Annexure II

EQUIPMENT DATA SHEET FOR A TYPICAL STATION

The tentative requirement of VAC Equipment for a typical station is estimated as under:

1.	Tunnel Vent Fans	:	4 Nos x 60 cum/s (Two on each end).
2.	Trackway extract fans	:	4 Nos. x 20 cum/s (Two on each end).
3.	Smoke extract fans (concourse)	:	2 Nos. x 12.0 cum/s(one on each end).
4.	Plantroom vent fans	:	4 Nos.x 7.5 cum/s (Two on each end).
5.	Tunnel Booster fans	:	As per requirement at crossovers.
6.	Chiller units	:	2 x 250 TR plus 1 x 250 stand bye (to be added later)
7.	Air Handling units (Platform)	:	4 x 15 cum/s (Two on each end).
	(Concourse)	:	2 x 15 cum/s (Two on each end).
8.	Automatic roll filters for AHU's	:	As per requirement
9.	Ducting and pipe works.	:	As per requirement
10.	Dampers	:	As per requirement.
11.	Power supply and accessories.	:	As per requirement.
12	Control and monitoring system	:	As per requirement.

Note: For the interchange station the number of TV equipment will be twice and the VAC plant capacity would be based on the cooling requirement.

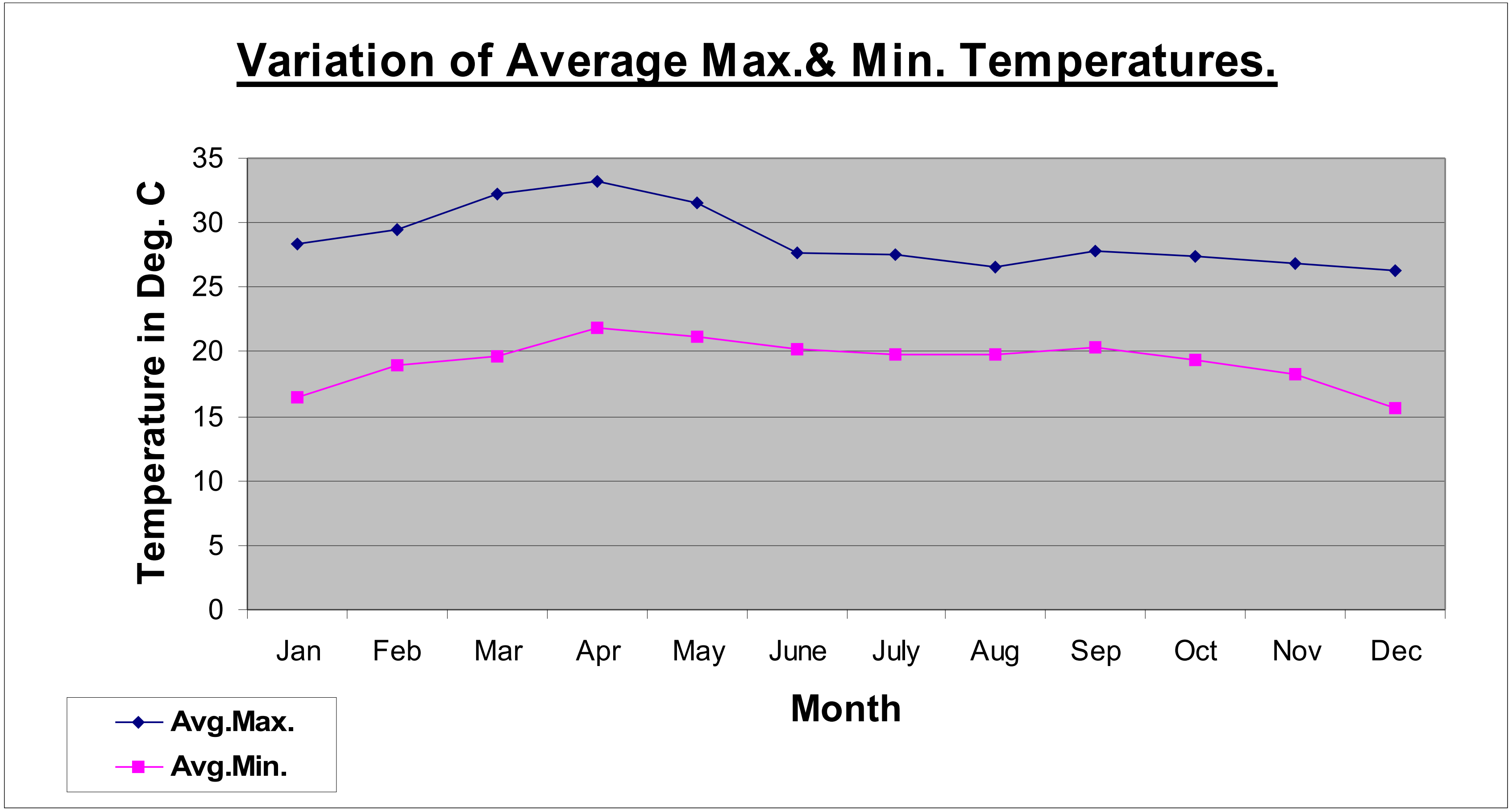

Fig.1 – Bangalore City – Variation of Temperature in a year.

FIG.2 TUNNEL VENTILATION SCHEME FOR BANGLORE MRTS